USE OF MATHEMATICAL MODEL AS A TOOL FOR MITIGATION OF FLOOD: CASE STUDY SURMA RIVER SYSTEM IN BANGLADESH

Wahiduzzaman PhDEng*, Abu Saleh Khan MScEng**, Faruq Ahmed Mohiuddin MEng***, Kazi Emran Bashar BScEng****

*Senior Specialist, Institute of Water Modelling(IWM), H # 476, R # 32, New DOHS, Dhaka, Bangladesh, E-mail: waz@iwmbd.org, Tel: 880-2-8824590, Fax: 880-2-8827901

**Principal Specialist, ***Associate Specialist, ****Junior Specialist

Abstract

Flood during pre-monsoon and monsoon is the main cause for damaging crops and housing settlement inside the study area. Flood occurs mainly due to heavy rainfall locally and in the hilly region of Indian border. A one-dimensional mathematical model is applied to simulate the variations in water level and discharge with and without project in the Surma River system. The results show the potential of computer-based simulation model for assessment of the hydraulic behaviour of the river system. The model is also simulated the performance of the system giving input data like topography, boundary conditions etc. Such a mathematical simulation model constitutes a useful computational tool for the development, assessment, control and utilization of water resources.

Keywords

Drainage, discharge, flood, siltation, topography, water level

INTRODUCTION

Bangladesh experiences colossal damages frequently due to disastrous floods and cyclones. To mitigate flood damage embankments have been constructed over the years along riverbanks. These engineering works and developments have been beneficial in reducing damages of properties and intensification of agricultural food production but gave rise to adverse impacts on the environment, such as (i) reduction of flood plain area, (ii) consequent increase in flood flow and water level within the embanked flood channel, (iii) change in sediment movement regime because of changed channel hydraulics, (iv) drainage congestion etc. Computer based mathematical models are being increasingly used by engineers and planners in the country for water resources system planning, management and design, as well as to study the impact of various existing and proposed projects.

In the field of river engineering, one of the aspects is to improve the river or river system for its changes caused by natural or human interferences. Before any interference takes place it is always desirable to predict the consequences of the anticipated designed works, which can be performed by mathematical modelling.

This paper deals with the development, calibration and application of a one-dimensional simulation model to study the impact on hydraulic condition of a river system with and without project situation. The present study concerns the Surma River system that is originally bifurcated from Barak river of India and fall into the Meghna River in Bangladesh. The plan view of the river system is shown in Figure 1. The main objective of the study is to understand the complex behaviour of rivers and khals in and around the study area and to find out optimum solution for reducing damages (crops, housing settlement etc) due to flood in the urbanized area, along the river system.

STUDY AREA

The study area is located in an area bounded in the south and east by the right bank of the Surma River and the right bank of the Lubha River to Bangladesh border. The western border is the Sylhet to Sarighat road and the northern border is the Lain nadi (see Figure 1).

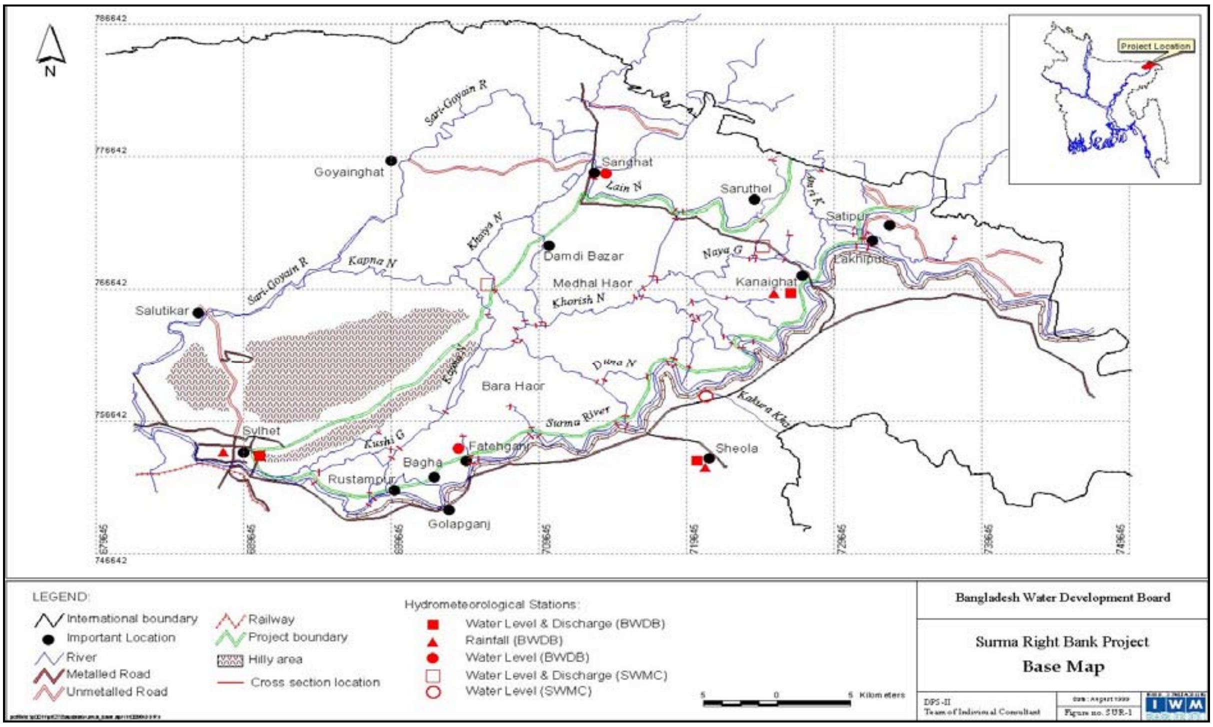


Figure 1: Study Area Map

Topography

The topography of the study area consists of low ridges (maximum elevation 60m PWD) to the north and southwest, apparently associated with echelon faulting along the base of the Shillong Plateau escarpment. The rest of the area is gently undulating with levels ranging from about 6 to 15m (PWD), with the highest elevations located along the Surma River bank and along the Sarighat-Kanaighat road in the north. The land generally slopes from north to south and east to west into the saucer-shaped central depression; this drains through the Sylhet-Jaintiapur road bridges to the west and through Kushi Gang to the south and then into the Surma River (see Figure1).

Hydrology

The study area is located in one of the highest rainfall areas in Bangladesh. The men annual Rainfall over the study area is approximately 5000mm. About 95% of the total annual rainfall fals during the April-October period. Maximum temperatures vary from about 28 C to over 40 C with highest temperature experienced during April and may. Minimum temperature range from 6C to 25C.

The principal water courses governing the study area's hydrology are the Sarigoyain, Lubha, and Surma Rivers. These rivers mainly spill to the study area through the Lain nadi, Pora

Khal, Kushi Gang, Amri khal, Kapna Nadi. All the principal water courses are flashy and flash peaks can occur many times during pre-monsoon and monsoon seasons. The recorded minimum and maximum discharge for Surma River is varies from 2.2m3/s to 2730m3/s.The study area is subjected to both pre-monsoon flash flood and monsoon flooding from the Surma, Lubha and Sarigoyain rivers (Flood Action Plan, 1993). Flash flood occur in late April or early May and damage standing boro crops – often just before harvest. Monsoon flooding generally occurs during July or August.

Flood damages

Both pre-monsoon and monsoon floods damages many things inside the study area. Settlements within the study area are mainly in the form of villages along the levees of the rivers and along various road sides. Exceptions are Sylhet town and along the hills of the Sylhet-Khadimnagar-Haripur area (see Figure 1).The portion of the Sylhet town which falls within the study area is densely settled, while in the hills, settlements are mainly scattered along the foot of the hills.

Nowadays it is observed that observed that many villages, especially along the Sarighat-Kanaighat road are reporting damage to homestead as a result of flashy pre-monsoon, monsoon floods. The damage mainly occurs when the embankment of Lan Nadi is overtopped. Sometimes the villages along Kapna, Kushi Gang and the Khorish Rivers are also affected by pre-monsoon and monsoon floods.

Flooding both pre-monsoon and monsoon is the major in the study area. This floding mainly damages rice crops, housing settlements etc. Bore rice is affected by pre-monsoon flooding every year. Flash flood enters through the Pabijuri, Khorish, Kushi Gang and Amir Khal into the study area and damage crops, housing etc.

APPROACH AND METHODOLOGY

Modelling Approach

In the normal process mathematical modelling starts with the collection and processing of historical and recent data. Then the development and calibration of a base model takes place in different steps. For the present study the model developed by Surface Water Modelling Centre for river systems of North East Region of Bangladesh (see Figure 2) has been applied to generate boundaries for the study area model (BWDB, 2002).

Methodology

MIKE11 mathematical modelling technique developed in the Danish Hydraulic Institute (DHI) has been used in the study. The MIKE11 software is based on an implicit finite difference scheme solution of the Saint Venant equations (MIKE11 user's guide, 1988; Saint-Venant, B. De, 1949; Abbott, M. B. and Ionescu, F,1967). For hydrodynamic model the following equations are used:

$$b\frac{dh}{dt} + \frac{dQ}{dx} = q$$

$$\frac{dQ}{dt}+\frac{d}{dx}\left(\beta\frac{Q^2}{A}\right)+gA\frac{dh}{dx}+\frac{gn^2\,|Q^2|}{AR^{3/4}}=0$$

where A the flow area, b is the width of channel, h is the stage, Q is the discharge, R is the hydraulic radius , n is the roughness coefficient, ß is the momentum distribution coefficient, q is the lateral inflow rate per unit length.

MODEL DEVELOPMENT FOR THE STUDY AREA

A model comprising networks of rivers in and around the study area has been developed from the North East Regional Model (NERM) of Bangladesh. The results of this updated North East Regional model provided boundaries to the study area model. Figure 1 shows the layout of the study area model. The study area model has been calibrated with the observed data. The important rivers in the study area model are Surma, Sarigwain, Lain Nadi etc.

The Figure 3 shows a good agreement between measured and simulated water level and discharge, indicating the god performance of the mathematical models of the river systems of the study area.

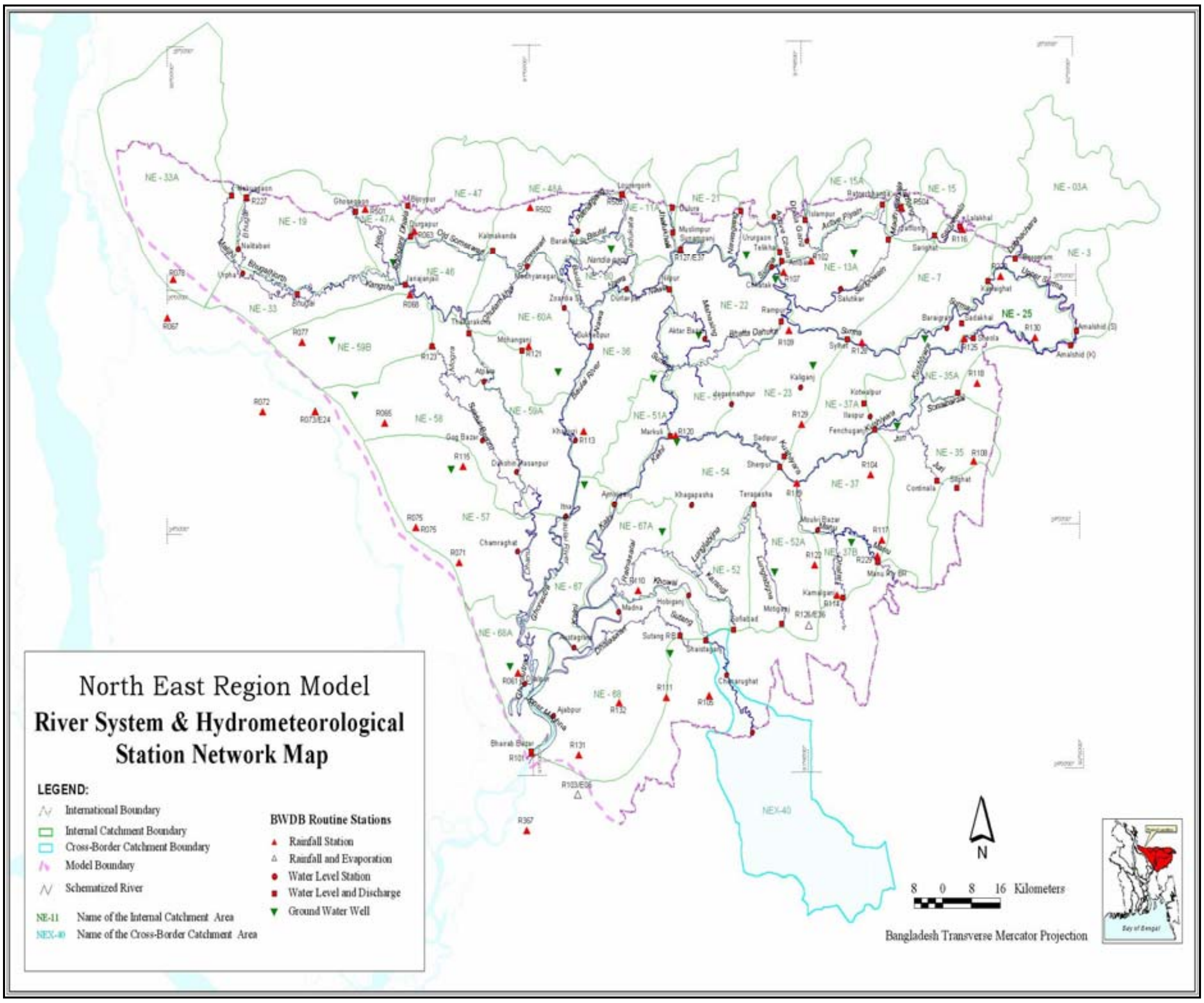
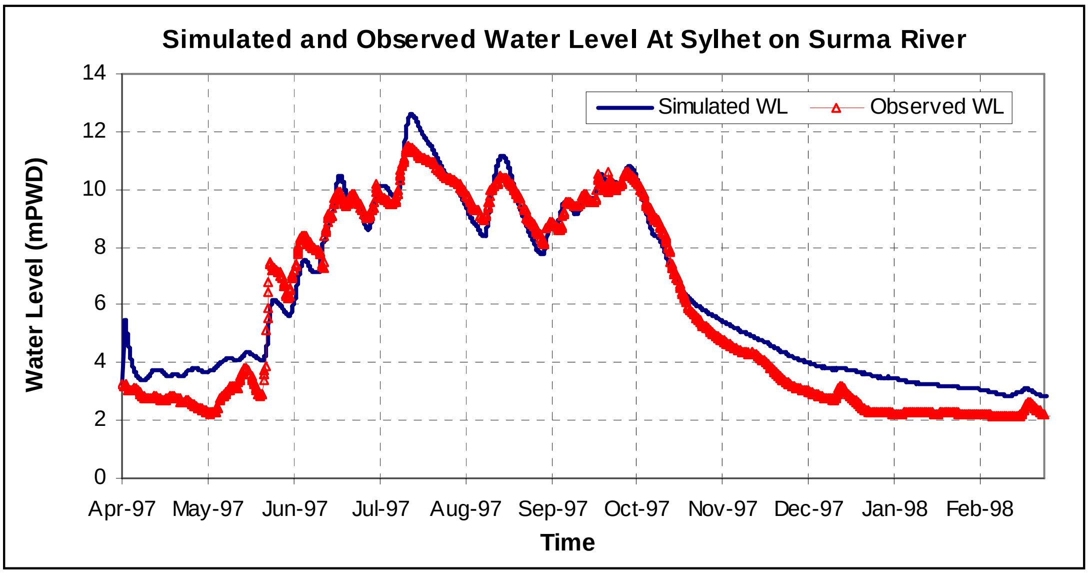


Figure 2: Map of North East region

Model Application

Mathematical models are very useful tools for development of different post project scenarios to simulate the impact of different interventions on the project and its surroundings. So, the planners and decision-makers are able to select the appropriate option for development. Once the model is developed and calibrated, it can be used to see the impacts of different development scenarios t achieve controlled drainage, controlled flooding in the project and its surroundings. The scenario models were tested for selected event of five-year, ten-year and twenty-year return period of pre monsoon, monsoon and post monsoon.



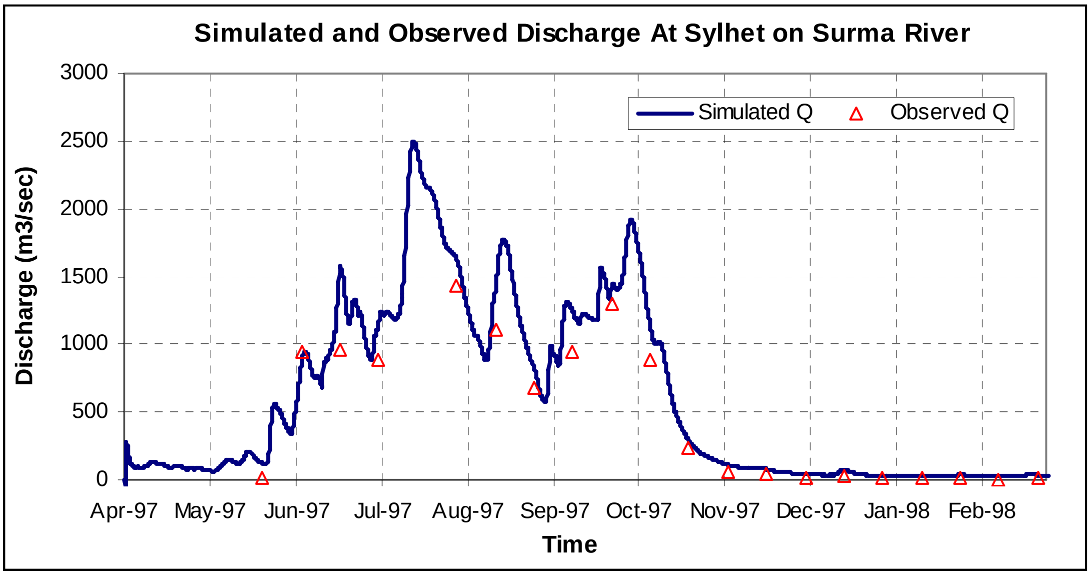


Figure 3: Calibration Results

Option Studies

To reduce crop and housing settlement damages due to flash flood, there are three options have been analysed. The description of options is given in Table 1. The options are developed mainly based on existing topography and hydraulic condition of the study area.

Table 1: List of options analysed using mathematical model

Option	Description			Remarks
Base Option	Existing condition of the project area			Figure 1
Option-1	**Broad Crest Weir:**			Figure 1
	River Name	Chinage (km)	Sill Level (m)	
	Birdhali Khal (re-excavated)	6.00	13.50	
	Dhal Beel (re-excavated)	5.90	13.00	
	Chatrapur K (re-excavated)	2.50	12.50	
	Khorish N (re-excavated)	25.7	12.50	
	Dura Khal (re-excavated)	2.20	12.50	
	Basbari K (re-excavated)	2.50	12.25	
	Amri Khal	9.60	15.00	
	Bharkula K	2.70	11.50	
	Lamapur	0.80	12.00	
	Parkul Khal	1.70	12.00	
	Kushi Gang (re-excavated)	25.40	10.00	
	Kachua (re-excavated)	-	-	
	Naya Gang (re-excavated)	-	-	
	Khepa Gang (re-excavated)	-	-	
Option-2	**Broad Crest Weir:**			Figure 1
	River Name	Chinage (km)	Sill Level (m)	
	Birdhali Khal	6.00	13.50	
	Dhal Beel	5.90	13.00	
	Chatrapur K	2.50	12.50	
	Khorish N	25.7	12.50	
	Dura Khal	2.20	12.50	
	Amri Khal	9.60	15.00	
	Kushi Gang	25.4	10.00	
	Embankment:			
	River Name	Chinage (km)	Sill Level (m)	
	Dhal Beel	0-7.6		
	Khorish N	6-22		
	Kushi Gang	0-26		
	Kachua Gang	0-9.8		
	Naya Gang	3-5		
	Bara Gang	4-15		
	Pabijuri	6.5-8		
	Dura N	0-2.7		
Option-3	i) Same as option-1 ii) Dredging of Surma River (0-5 Km)			Figure 1

Result of Option Runs and discussion

From the options results it has been clearly seen that flood free land (dry land) has been increased significantly by option-1 (see Table2), which means that flood damages could be reduced by implementing the option-1.

Table 2: Impact of different options

Inundation depth	Area (Sq.Km)			
	Base Option	Option-1	Option-2	Option-3
Dry Land	567.24	685.24	642.4	627.56
0-30 cm	73.64	60.40	68.48	57.84
30 cm-90 cm	134.24	110.52	120.84	117.12
90cm-180cm	164.46	102.40	116.36	137.36
> 180cm	99.20	80.4	90.52	99.08

CONCLUSION

Flash flood is the main cause of damage crops and damage crops and homestead in the study area both in pre-monsoon and monsoon seasons. Flash flood mainly occurred due to heavy local rainfall and high discharge from Indian hilly region. To investigate the impact of man made intervention (options) in the study area the simulation of water level and discharge has been performed by a one-dimensional mathematical model. The result shows the potential of computer based simulation model for evaluating the impact of interferences on the flow regime of rivers inside the study area. The controlling of flash flood inside the study area can be achieved by dredging the Surma and others river, that is implementing the option-1

REFERENCES

Abbott, M. B. and Ionescu, F., On the numerical computation of nearly horizontal flows, Journal Hydraulic Research, 5(2), pp 97-117, 1967.

BWDB, Updating and Validation of General Model & Six Regional Models, 2002

Flood Action Plan (FAP6), Surma Right Bank Project, 1993

MIKE11 user's guide, Horsholm, Danish Hydraulic Institute, Denmark 1988

Saint-Venant, B. De. Theory of unsteady water flow, with application to river floods and propagation of tides in river channels, Coputes Rendus Acad. Sci. , Paris, 73, PP 148-154, 871 (Translated into English by US Corps of Engineers, No.49 Waterways Experiment Station, Vicksburg, Mississipi, 1949.