FLOOD INUNDATION MAPPING OF MAJOR RIVERS OF BANGLADESH USING HEC-RAS 2D

Md. Mukdiul Islam*[1] and Md. Ataur Rahman[2]

[1]Lecturer, Chittagong University of Engineering & Technology, Bangladesh, e-mail: mukdiul1808@gmail.com
[2]Professor, Bangladesh University of Engineering & Technology, Bangladesh, e-mail: mataur@wre.buet.ac.bd

***Corresponding Author**

ABSTRACT

Bangladesh lies at the downstream of GBM basin which is susceptible to large amount of precipitation resulting large amount of water to be drained out through Bangladesh each year. This draining water along with various other reasons causes frequent flooding with severe damage all over Bangladesh. Therefore, a mathematical model has been developed under this study, which is capable of simulating flood inundation area of the major rivers of Bangladesh and their associated flood plains. The study area has been selected based on the major rivers such as Ganges, Jamuna, Padma and Meghna of Bangladesh with the associated flood plains. For the analysis, two-dimensional hydrodynamic model software HEC-RAS 2D has been used. Bathymetry grid has been prepared using bathymetry data of the rivers collected from Institute of Water Modelling (IWM). DEM of the floodplain with resolution 30.87 m has been collected from USGS. Hydrographic data has been collected from BWDB. Combined bathymetry and topography grid have been prepared using ArcMap software. HEC-RAS 2D model has been set up based on the combined bathymetry and topography grid data of the study area and necessary boundary conditions. The calibration and validation of the model have been done against measured water level at Sengram (Ganges), Sirajganj (Jamuna), Mawa (Padma) and against measured discharge at Mawa (Padma). A flood inundation map for August 2, 2016, has been prepared based on the model simulation results and compared quantitively with the flood inundation map of that day prepared by Flood Forecasting and Warning Center (FFWC) of Bangladesh based on actual inundation data. The comparison shows good agreement of model simulated flood inundation area with that prepared by FFWC. Different flood parameters such as depth, arrival time etc. have been analyzed for the year of 2014 using the model simulated results. Manikganj district was the most flood affected district based on area of inundation with a percent of inundation 47.73 on 27 August 2014 is obtained from the inundation map prepared by model simulation.

Keywords: *Flood, HEC-RAS 2D, Inundation map.*

1. INTRODUCTION

Bangladesh is prone to flooding due to its location at the downstream of the GBM (Ganges-Brahmaputra-Meghna) river basin. The Ganges-Brahmaputra-Meghna (GBM) basin is approximately 1.6 million km2 and crosses five national boundaries: India, China, Nepal, Bhutan, and Bangladesh. The combined discharge of the GBM basin drains through Ganges, Brahmaputra and Meghna rivers and finally reaches the Bay of Benga (Curtis et al., 2017). Again heavy rainfall in the monsoon period is also responsible for floods in Bangladesh. Bangladesh is blessed with rivers. Padma, Meghna, and Jamuna are the major rivers of Bangladesh. The country Bangladesh is occupied with a network of about 405 rivers mostly alluvial in nature, spreading all over the country out of which 57 are transboundary (Pal et al., 2017). This low-lying country is an alluvial delta, and therefore, is extremely prone to flooding. It is one of the most susceptible countries to flood disasters. Flood occurs mainly during the monsoon season from June to September. The main causes of floods in Bangladesh are heavy rainfall in monsoon, snowmelt from the Himalayas, enormous upstream discharge and siltation of the river.

Flood Inundation Mapping is an important tool for engineers, planners, and the government agencies used for emergency action plans, flood risk assessment (economic, environmental, social, cultural and mankind). Flood inundation mapping provides important information like depth, and spatial extent of flooded zones, required by the authorities to inform the citizens about the major flood-prone areas and to adopt appropriate flood management strategies.

The Hydrologic Engineering Centre's River Analysis System (HEC-RAS) is a software package that is of great use for developing flood inundation map. An HEC-RAS model can be used for both steady and unsteady flows and supercritical flow regimes. Flood inundation mapping and analysis using HEC-RAS (2D) provides effective and standard results and saves time and resources.

Sumaiya (2017) developed a two-dimensional hydrodynamic model using HEC-RAS 5.0.3 of Jamuna River. Mozumder (2017) developed a 1D-2D coupled hydrodynamic model using HEC-RAS 5.0.3 of the Teesta River.

1.1 Study Area

A map of the study area focusing the flood plain of the major rivers system (Ganges, Jamuna, Padma, upper Meghna and lower Meghna) of Bangladesh is shown in Figure 1.

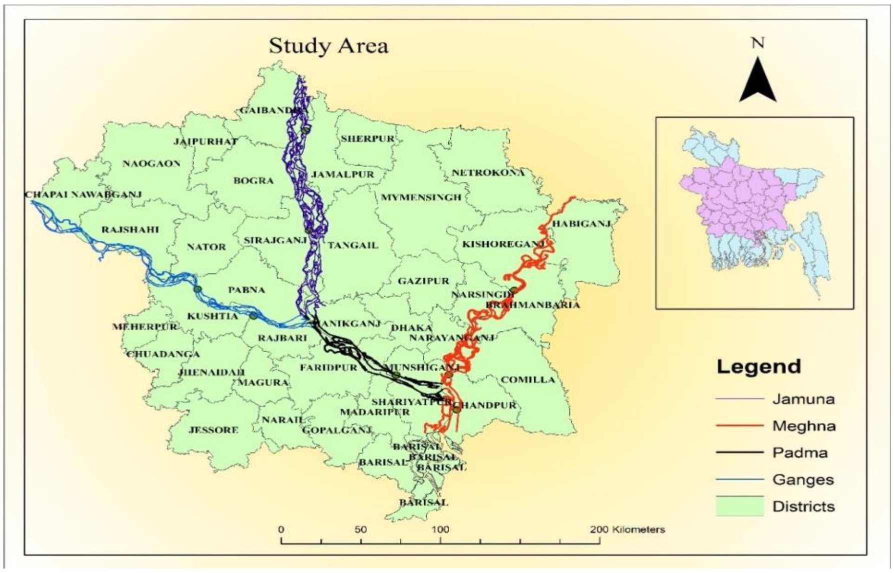

Figure 1: Map of the study area.

The Ganges is a transboundary river with a total length of 2,525 km (Mujiburrehman, 2015). The river rises in the western Himalaya basin the Indian state of Uttarakhand and flows south and east through the Gangetic Plain of North India into Bangladesh, where it empties into the Bay of Bengal. The Padma is the main distributary of the Ganges. It starts from the confluence of Jamuna and Ganges river and flows for 120 km. From the confluence of upper Meghna and Padma near Chandpur the river lower Meghna starts. The Brahmaputra-Jamuna is originated in the Himalayas, flowing through China, India and entering Bangladesh through the northern boundary. The Brahmaputra-Jamuna river has a basin area of approximately 1330 km^2 within Bangladesh (Rahman, 2015).

1.2 Data Collection

The collected data includes geometric data like river bathymetry, hydrologic data like discharge, water level and digital elevation model (DEM) as land topographic data. These data are collected from different sources. Table 1 represents the data collected for this study with their source and period.

Table 1: Collected data for this study with their source and period.

Data Type	Location	Data Source	BWDB Station Id	Period
DEM	Bangladesh	USGS	-	2014
Bathymetry Data at Rivers (x,y,z)	Ganges	IWM	-	2017
	Padma	IWM	-	2017
	Jamuna	IWM	-	2017
	Upper Meghna	IWM	-	2017
Discharge	Hardinge Bridge (Pakshi)	BWDB	SW90	2000-2017
	Bahadurabad	BWDB	SW46.9L	2000-2017
	Mawa	BWDB	SW93.5L	2000-2012
	Bhairabbazar	BWDB	SW273	2000-2017
Water Level	Chandpur	BWDB	SW277	2000-2017
	Sengram	BWDB	SW91.1	2000-2012
	Mawa	BWDB	SW93.5L	2000-2012
	Sirajganj	BWDB	SW49	2000-2012
	Badyar Bazar	BWDB	SW275	2000-2012
Flood Map	Bangladesh	FFWC	-	-

2. METHODOLOGY

Figure 2 represents a schematic diagram of the overall steps in the methodology of this study.

Study Area Selection: Ganges, Jamuna, Padma and Meghna River System

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Background Study and Literature Review

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Collection of Data: River Bathymerty DEM,Water Level, Discgarge, Flood Map

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Processing of DEM in ArcMap 10.2.2

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Export Processed DEM in HEC-RAS 5.0.3(2D) and Creation of Terrain in RAS Mapper

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Setup Model for Study Area in HEC-RAS 5.0.3(2D)

⇩

Calibration of Model (Water Level, Discharge)

⇩

Validation of Model (Water Level, Discharge)

⇩

Simulation of Model for Generating Flood Scenario

⇩

Compare the Model Generated Flood Map with the Previous Real Field Flood Map

⇩

Simulation of Flood Mapping for the Study Area and analyzing different flood parameter.

Figure 2: Schematic diagram of the overall steps in the methodology

To develop flood inundation map, the bathymetry data of the Ganges, Jamuna, Padma, Upper Meghna & Lower Meghna are processed in ArcMap. The processed bathymetry data are superimposed on the Digital Elevation Model of the study area to create a combined bathymetry & topography model. This model is exported to Ras-Mapper of HEC-RAS, the grid size is selected as 500m×500m. Assigning the boundary condition the model is simulated for unsteady flow. Flow hydrograph has been used as boundary condition at Hardinge Bridge(The Ganges), Bahadurabd (The Jamuna) & Badyarbazar (The upper Meghna). Stage hydrograph has been used as boundary condition at Chandpur (The lower Meghna). The model is then calibrated and validated at different locations against both discharge and water level. Finally, the calibrated and validated model is used to prepare flood inundation map using both HEC-RAS & ArcMap. Different flood parameters have been analyzed then using ArcMap.

3. ANALYSIS & RESULTS

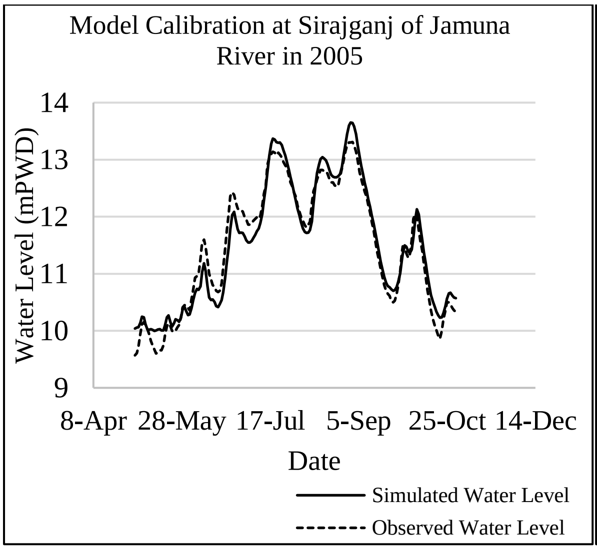
3.1 Calibration & Validation of the model

The model has been calibrated against water level for the year of 2005 at different stations such as Sengram at the Ganges, Sirajganj at the Jamuna, Mawa at the Padma and Badyar Bazar at the Meghna. Table 2 represents the values of manning's roughness values at different river channels used for calibration and validation of the model.

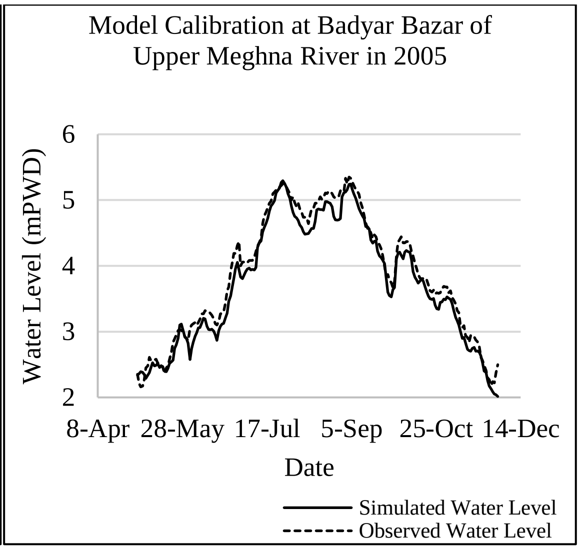
Table 2: Calibrated values of manning's roughness value at different rivers.

River Name	Manning's roughness value
Jamuna	0.03
Ganges	0.027
Padma	0.025
Upper Meghna	0.03

Figure 3(a) and (b) show the calibration curve against water level at Sirajganj of Jamuna river & Badyar Bazar of Upper Meghna River respectively.



(a)



(b)

Figure 3: (a) Model calibration at Sirajganj & (b) Model calibration at Badyar Bazar

The model has been also calibrated against discharge in Mawa at the Padma for the year of 2005. Figure 4 shows the calibration of the model against discharge at Mawa of Padma river in 2005.

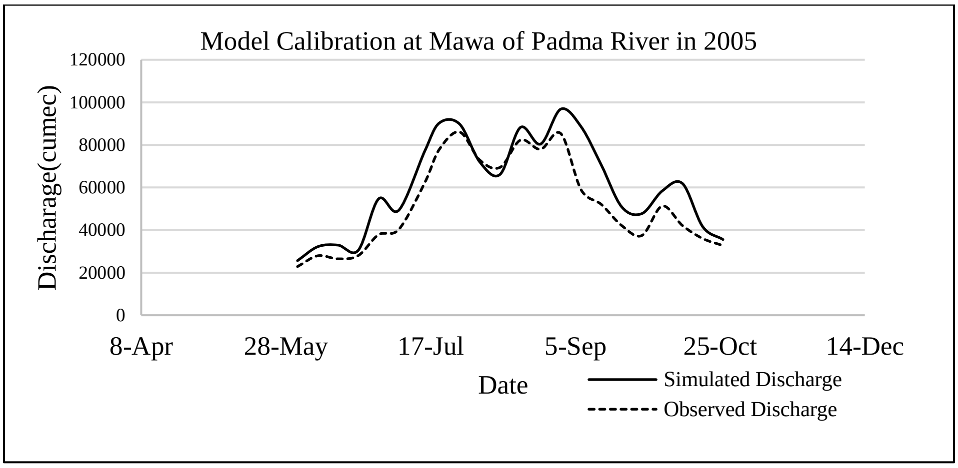
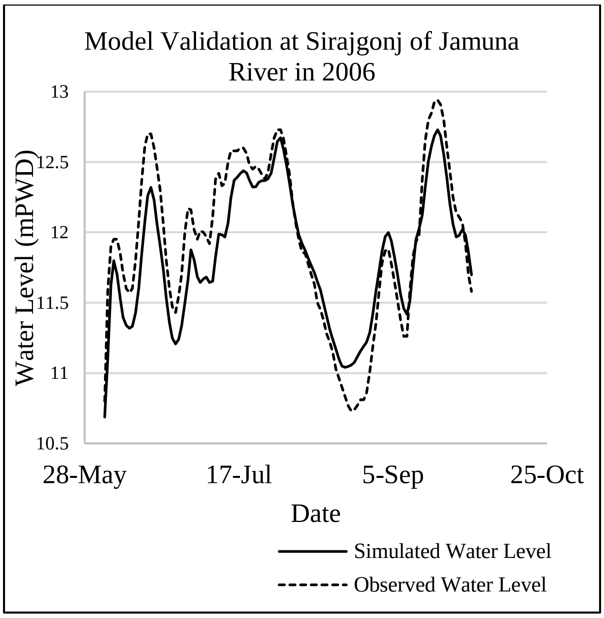
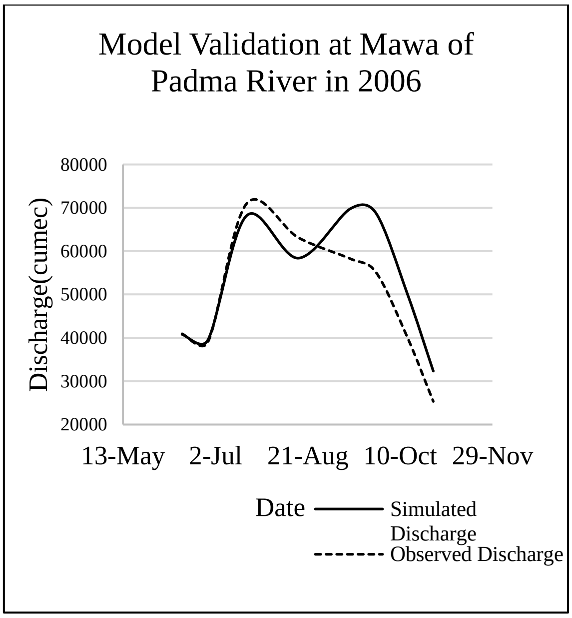


Figure 4: Calibration of the model against discharge at Mawa of the Padma river in 2005.

Figure 5 (a) & (b) represent the validation of the model against water level at Sirajganj of the Jamuna river in 2006 and against discharge at Mawa of the Padma river in 2006 respectively.



(a)



(b)

Figure 5: (a) Model validation at sirajganj & (b) Model validation at Mawa.

3.2 Model Performance Evaluation for Calibration

Figure 6 (a) & (b) represent model generated water level vs observed water level at Sengram of the Ganges river in 2005 & model generated water level vs observed water level at Badyar bazar of Upper Meghna river in 2005. The correlation coefficient is obtained as 0.952 & 0.993 respectively.

3.3 Inundation Map

Inundation map gives an idea about which area are most vulnerable to flooding. Inundation maps are generated using both HEC-RAS and ArcMap. In this study inundation maps have been created for the year of 2014 & 2016.

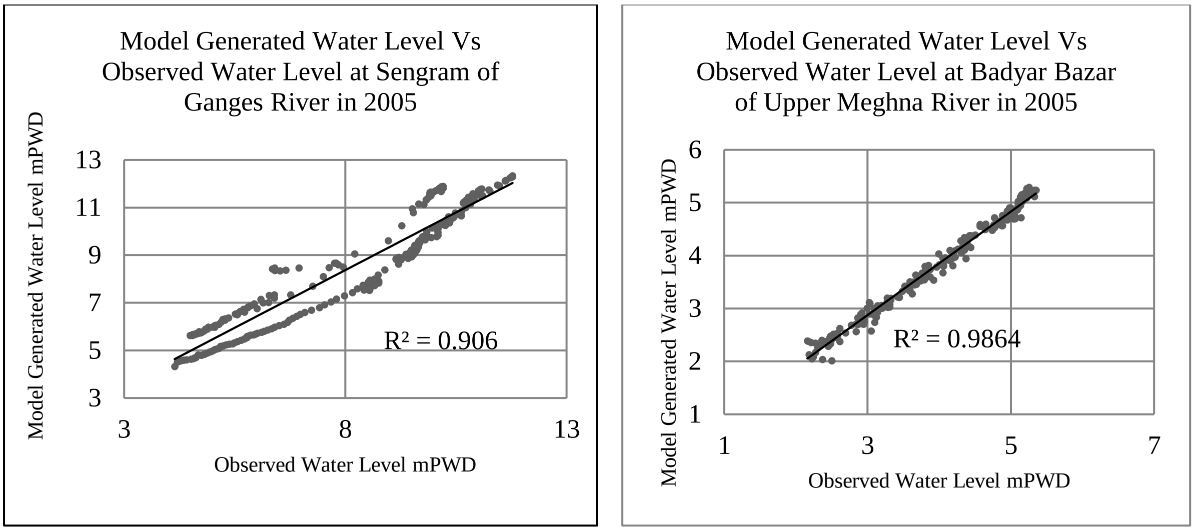
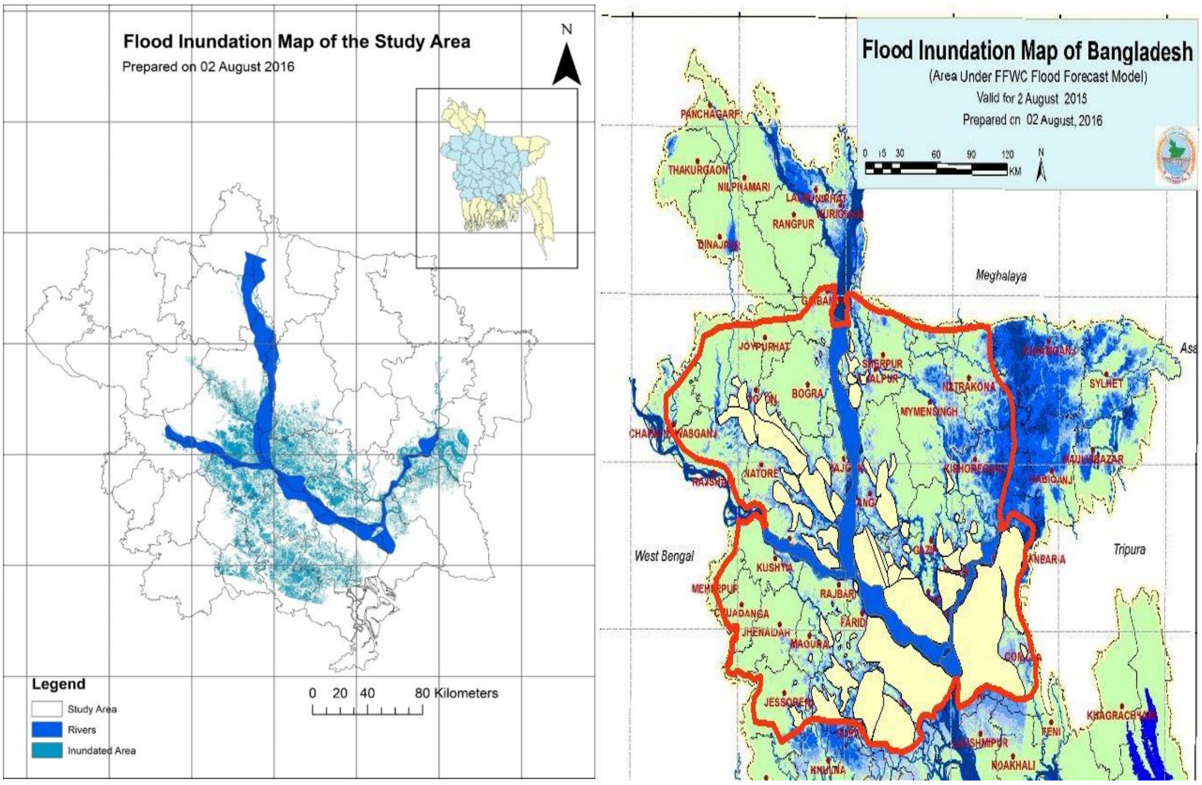


Figure 6: (a) Correlation at Sengram in 2005 & (b) Correlation at Badyar bazar in 2005.

Figure 7 (a) & (b) represent model generated flood inundation map and flood inundation map prepared by FFWC on 2 August,2016.



(a) (b)

Figure7: (a) Model generated flood inundation map & (b) FFWC flood inundation map.

Flood inundation map prepared by FFWC has been digitized to compare on the basis of inundated area with the model generated flood inundation map. Figure 8 represents the comparison on the basis of inundated area between the inundation map prepared by FFWC and model generated inundation map.

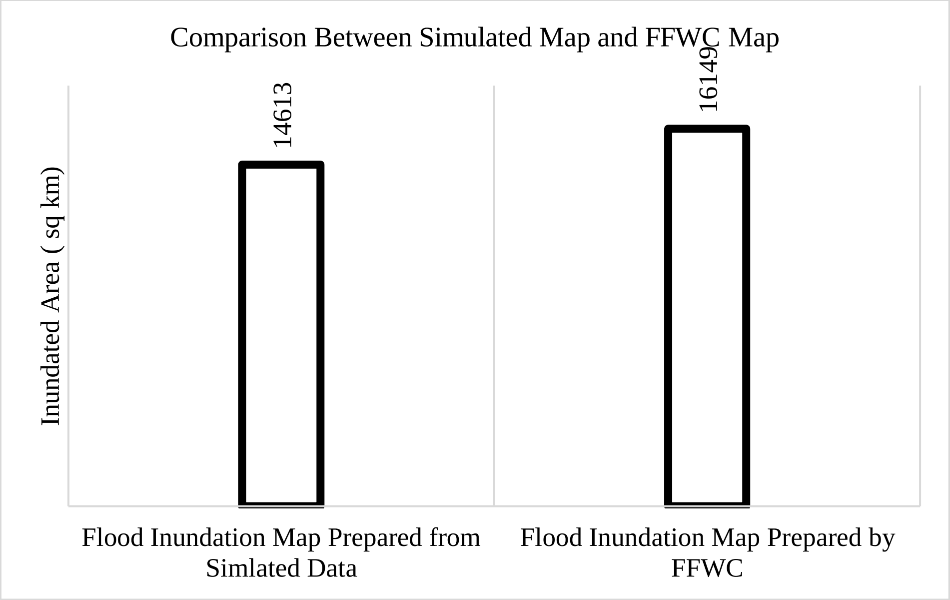


Figure 8: Comparison between simulated map & FFWC map on the basis of area of inundation.

3.4 Analysis of Different Flood Parameters for the Flood of 2014

3.4.1 Flood Arrival Time

Arrival time indicates the time required for the flood water to rise above threshold depth (0.1m) from the beginning of the simulation. Figure 9 represents the flood arrival time map for the year of 2014.

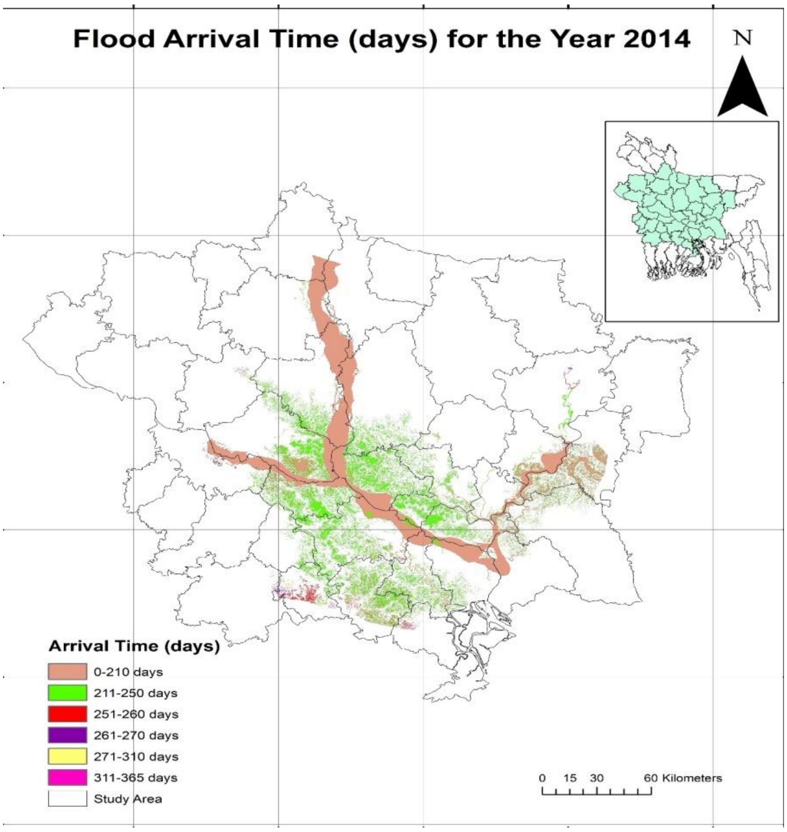


Figure 9: Flood arrival time (days) map for the year 2014.

It is seen that flood arrival time for most part of the study area is about 211-250 days, which means that the time required to rise the flood depth above the threshold depth (0.1m) is 211-250 days. So flood water will enter most part of the study area during 30th July to 7th September.

3.4.2 Date-wise Inundated Area

Table 3 represents date-wise total inundated area.

Table 3: Date-wise inundated area.

Date	Inundated Area (sq km)
16 June 2014	3176.124
27 August 2014	6149.132
17 September 2014	5486.849

3.4.3 District-wise Inundated Area & Percentage of Inundation

Table 4 represents district-wise inundated area and percentage of inundation.

Table 4: District-wise inundated area and percentage of inundation.

District Name	Inundated Area (sq km)	Percent Inundation
Narayanganj	89.58	11.49
Narshingdi	235.44	20.24
Pabna	717.38	29.76
Sirajganj	750.08	30.85
Tangail	345.81	10.03
Bogra	280.21	9.64
Brahmanbaria	359.07	18.75
Comilla	108.51	3.46
Munshiganj	271.44	29.13
Manikganj	655.99	47.73
Madaripur	250.46	22.46
Kushtia	317.28	18.83
Faridpur	396.52	19.19
Dhaka	223.54	14.71

The study shows that the Manikganj district was mostly affected by the flood of 2014 according to the percentage of inundation.

3.4.4 Area of Inundation Based on Depth of Manikganj District.

Figure 10 represents area of inundation based on depth of Manikganj district on 27 August,2014. It is seen that about 332.06 km^2 area of the Manikganj district had a flood depth above 3.6m & about 733.514 km^2 area had a flood depth below 0.1m.

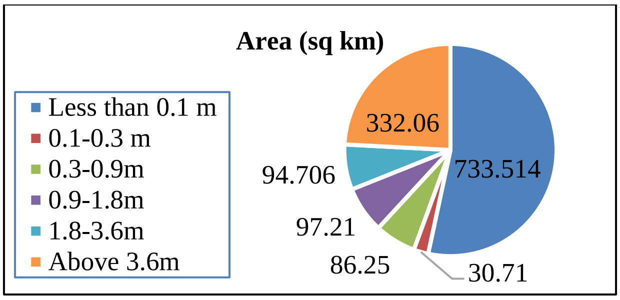


Figure 10: Area of inundation based on depth of Manikganj district on 27 August 2014.

4. CONCLUSIONS

In this study, HEC-RAS 2D has been used to prepare flood inundation maps of major rivers of Bangladesh including the Ganges, Padma, Jamuna, upper Meghna & lower Meghna rivers. Discharge and water level has been taken as the boundary condition. The model has been calibrated and validated with the help of iterating the calibration parameter Manning's roughness value 'n'. The verified model has been used to prepare flood inundation map of 02 August 2016 and has been compared with the flood inundation map prepared by Flood Forecasting and Warning Centre (FFWC). This comparison shows, the simulated flood map represents 90.4% of the inundated area represents in the map prepared by FFWC. Different flood parameters such as area of inundation, depth of inundation, arrival time etc. for the flood of 2016 has been analyzed. Area of inundation of the study area on 16 June 2014, 27 August 2014 and 17 September 2014 has been found as 3176.124 km^2, 6149.132 km^2, and 5486.849 km^2 respectively. On 02 August 2016 it has been found that the Manikjanj district was most affected according to area of inundation. A flood depth hazard map has been prepared for the Manikganj district and it has been found that almost 94.706 km^2 area had a water depth between 1.8m-3.6m.

This study shows the utility and effectiveness of using HEC-RAS 2D for the preparation of flood inundation map, identify the probable locations most affected by floodwater, depth of floodwater at different location and the time taken for flood water to rise above a threshold value which is of great use to reduce damage by flood to life and property.

ACKNOWLEDGEMENTS

Authors are gratefully acknowledging the deepest gratitude to Bangladesh Water development board (BWDB) and Institute of Water Modelling (IWM) for providing with the necessary data for conducting the study.-

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