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Flood Inundation Mapping In Belsiri River Basin Linking HEC-RAS and HEC-GeoRAS Model and Flood Frequency Analysis

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Abstract

Flood is basically a natural phenomenon which has its obvious impacts on floodplain environment. It is a high magnitude episodic discharge of river, which, in turn brings about significant changes in the adjacent floodplains. In this paper an attempt is made to map the flood inundation areas of Belsiri river basin in HEC-GeoRAS model integrating the empirical methods of flood frequency analysis. For mapping the flood inundation areas, covering the period 1991-2011, the calculated design floods with 5, 10, 20, 50, 100 and 200 years return periods are integrated in HEC-GeoRAS and the resultant inundation areas are estimated, mapped and demarcated using the model the design floods of 126,139,147,158,163 and 168 m^3s^{-1} with return periods of 5, 10, 20, 50, 100 and 200 years estimated following Log Pearson Type III method correspond to inundation areas of 22.704, 22.946, 23.138, 23.303, 23.394 and 23.442 km^2 respectively. These data are similar to flood inundation data estimated using HEC-GeoRAS. It is evident in the flood inundation map prepared in HEC-GeoRAS that the extents of flood inundation are increasing.

Keywords: HEC-RAS, HEC-GeoRAS, flood, flood frequency

INTRODUCTION

Flood is a fluvio-geomorphic event of a river or stream that overflows the banks causing notable changes in floodplain morphology. Flood is a period of high discharge of a river caused by high rainfall, rapid snow melt, or the breaching of a barrier (Goudie, 2014) and it may exceed a channel's capacity and lead to inundation of adjacent low-lying land (Goudie, 2014). In many big and small river basins of the world this powerful geomorphic event creates havoc and misery to the people. Therefore, it is extremely important to study and interpret the pattern and impact of flood events for rational use and management of natural resources. In this paper an attempt has been made to link flood frequency analysis with HEC-RAS and HEC-GeoRAS in order to map the inundation areas of Belsiri river basin.

Study area

Located in northeastern India, the Belsiri River is a right-bank tributary of the Brahmaputra River. Its basin stretches from 26°36/N lat. to $27^0$05/N lat. and from 92°20/E long. To $92^0$40/E long (Figure 1). The West Kameng district of Arunachal Pradesh and the western portion of the Sonitpur District of Assam, India, are traversed by the Belsiri River. The Belsiri basin covers 496 km^2, of which 154 km^2 (31%) and 342 km^2 (69%) are located in the states of Assam and Arunachal Pradesh, respectively.

When compared to other river basins in India, such as the Ganges, Brahmaputra, Godavari, and Krishna Rivers, the Belsiri River basin is very small. It is mostly classified as a middle-class river among the Brahmaputra river system's tributaries. The basin perimeter measures 158 km with a maximum length and width of 57 km and 15 km respectively.

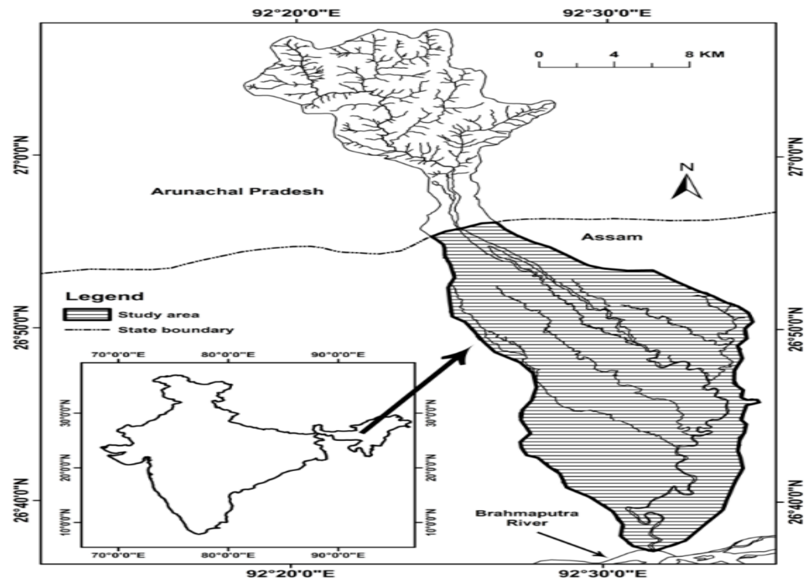


Figure 1: Location of the study area

DATABASE AND METHODOLOGY

Discharge data used in this study are collected from the Water Resource Department, Government of Assam. Daily discharge data are for available the period from 1991 to 2011. All these hydrological data were observed at Thelamara (North Trunk Road-52 crossing point). The basin is delineated using Survey of India topographical maps of 1: 50,000 scale and Landsat-8 satellite imageries and Google maps. The flood inundated areas are mapped using HEC-RAS model integrating the flood frequency analysis results.

RESULTS AND DISCUSSIONS

For estimation of flood inundation, design floods are calculated using Log-Pearson Type-III distribution and plotted in normal probability paper along with observed data presented in Figure 2. It is observed in the figure that the Log-Pearson Type-III distribution curve has appeared best with the observed line graph. It is interpolated from the Log-Pearson Type-III distribution curve that the probability of occurrence of minimum flood flow of 40 m^3s^{-1} is 95% while the maximum and mean annual flood flow of 171 m^3s^{-1} and 100 m^3s^{-1} have probability 4 % and 54% respectively.

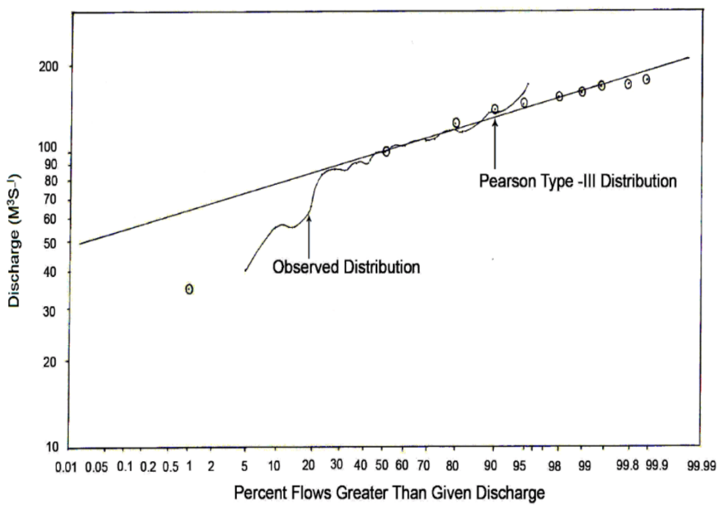


Figure 2: Log-Pearson Type-III distribution of flood flows of the Belsiri River at N.T. Road crossing point near Thelamara, 1991-2011

Table 1: Design flood of selected return periods using 'k' factor methods

Method	Return Period (Year)								
	1	2	5	10	20	50	100	200	500
Log Pearson's Type-III distribution	94	100	126	139	147	158	163	168	171

It is to be admitted that HEC-RAS and HEC-GeoRAS has been used worldwide for inundation mapping, such as in Europe (Dragan, et al. 2009, Panagoulia, et al. 2013, Getahun and Gebre, 2015), in USA (Brunner, 2013; Keren, et al. 2008) and also in Africa and in Asia. Dimension of flood in Belsiri river is examined using Hydrologic Engineer Centre's River Analysis System Software (HEC-RAS) developed by US Army Corps of Engineers. The HEC-RAS facilitates to perform one dimensional floodplain modelling and sediment transport characteristics. In this study, floodway approach is adopted to create a smooth boundary around the river centreline that maintains the floodway top width at each cross section as modelled by HEC-RAS.

Table 2: Manning's n values for channels (Chow, 1959) is used to calculate cross sectional average velocity flow in open channel

Floodplains	Minimum	Normal	Maximum
a. Pasture, no brush			
1.short grass	0.025	0.030	0.035
2. high grass	0.030	0.035	0.050
b. cultivated areas			
1. no crop	0.020	0.030	0.040
2. mature row crops	0.025	0.035	0.045
3. mature field crops	0.030	0.040	0.050
c. Brush			
1. scattered brush, heavy weeds	0.035	0.050	0.070
2. light brush and trees, in winter	0.035	0.050	0.060

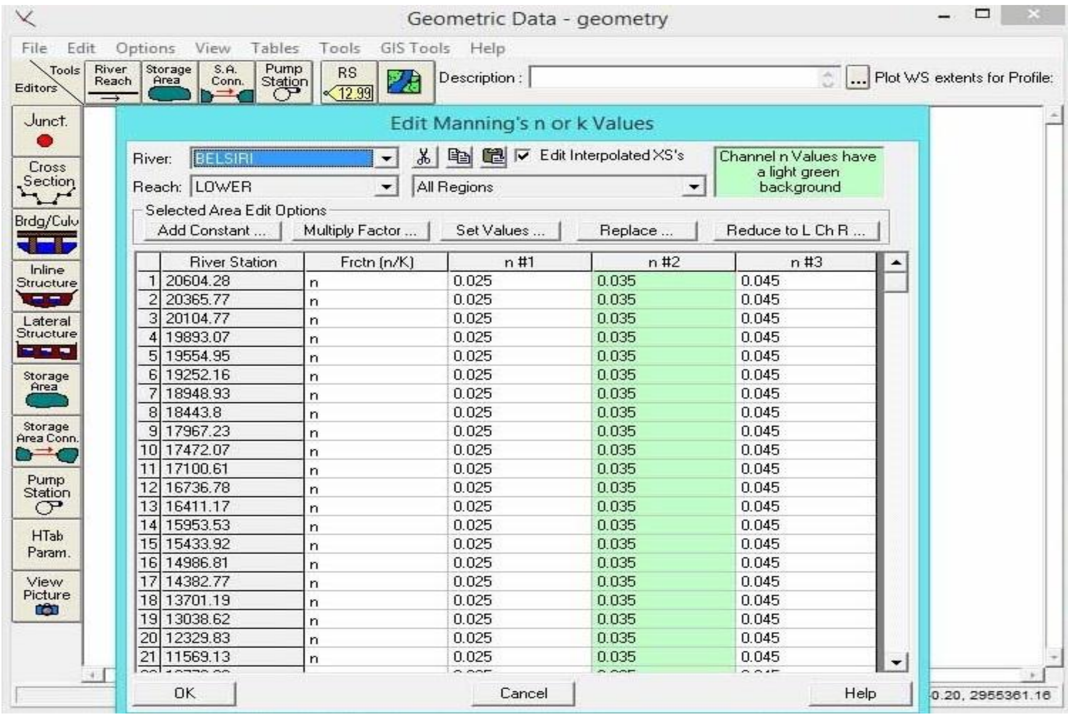


Figure 3: Manning’s ‘n’ values in HEC RAS software

To estimate and map the inundation area for floods with 5, 10, 20, 50, 100 and 200 years return period using the HEC-RAS incorporating GIS and flood frequency analysis methods are integrated for probabilistic flood inundation mapping in HEC-RAS software. Here, the HEC-RAS and DEM data are combined to develop a three-dimensional terrain model. The added advantage of HEC-GeoRAS is that it is an ArcGIS extension suitably used to prepare the river geometry of a particular river and help create necessary files which can be processed in HEC-RAS to create the inundated maps. The river geometry files are nothing but the stream centreline, bank lines, flow path centerline, and cross-section cut lines (figure 4). These are stored in Geodatabase file of HEC-GeoRAS (Botes, 2010). The river and the cross section data layers are created with predefined attribute tables that are manually computed in the case of river and reach names, while all other attributes are automatically calculated by the HEC-GeoRAS (Botes, 2010). The interface extracts the geometric data in an .xml format that is imported into HEC RAS (Getahun and Gebre, 2015).

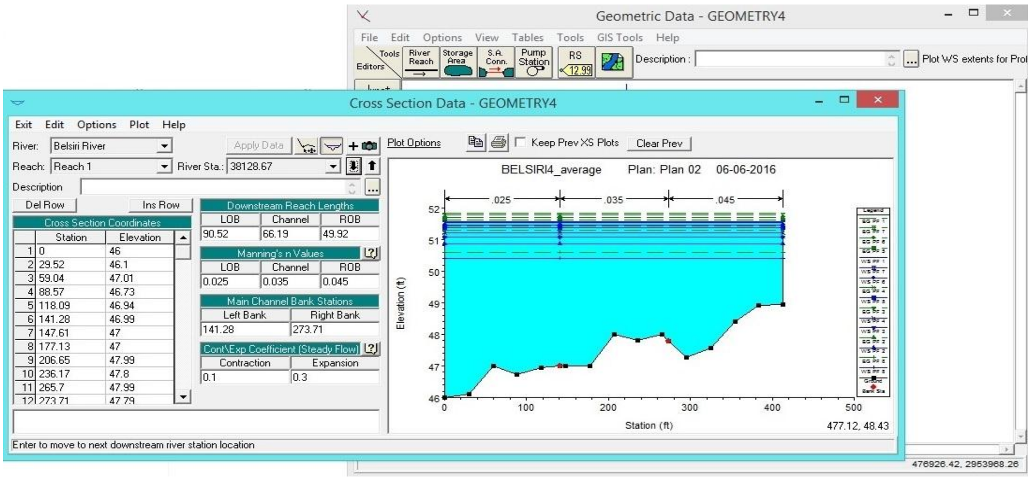


Figure 4: Geometry data preparation

The results of HECRAS model simulation are entered into a GIS environment and further analysis needs to be performed using HEC-GeoRAS tool (Getahun and Gebre, 2015). River geometry files are prepared using the DEM, TIN and land use data. After the creation of river geometry files, the stream flow data are entered in HEC-RAS to generate water surface levels along the river.

In the study, floodway approach is adopted to create a smooth boundary around the river centreline that maintains these floodway top widths at each cross section as modelled by HEC-RAS. Flood inundation areas are mapped and estimated in the HEC-RAS integrating GIS and flood frequency analysis method, i.e. Log-Pearson Type-III method for the design floods with 5, 10, 20, 50, 100 and 200 years return periods. Here a combine HEC-RAS and DEM data is used to develop a three-dimensional terrain model. It is estimated that 5, 10, 20, 50,100 and 200 years return period floods corresponds with 22.704 km^2, 22.946 km^2, 23.138 km^2, 23.303 km^2, 23.394 km^2 and 23.442 km^2 of inundation areas.

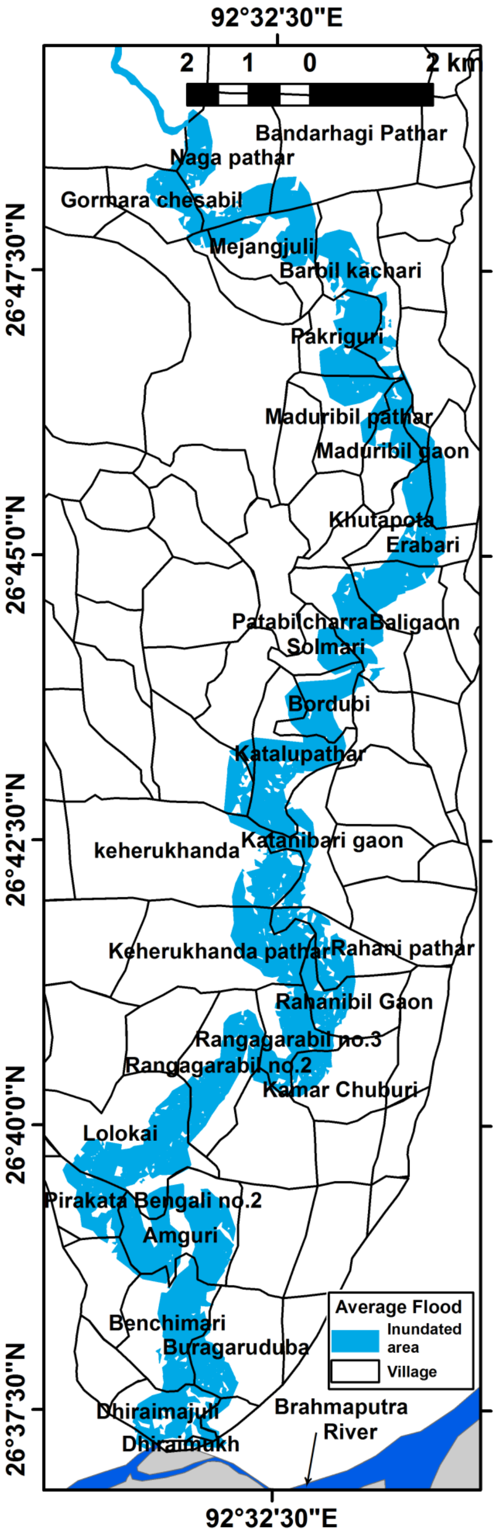
The magnitudes of flood inundation are considered to be significant as because the flooded areas are intensively populated and occupied by agricultural lands represents the backbone of economy. Data on flood inundation area in the Belsiri basin collected from government sources and presented in table 3 during 1998-1999, 2000-2001, and 2001-2002 are 7.31km^2 (731 ha), 14.27 km^2 (1427 ha), and 15.91 km^2 (1591 ha) respectively.

Table 3: Flood damage caused by the Belsiri River during 1998-2002

Parameters	Spatial unit	1998-1999	1999-2000	2000-2001	2001-2002
Area inundated (ha)	Sonitpur District	49628 (9.39 %)	No flood	12999 (2.46 %)	39201 (7.42 %)
	Belsiri sub basin	731 (1.47 %)	No flood	1427 (2.88%)	1591 (3.21 %)
No. of affected village	Sonitpur District	505	No flood	130	368
	Belsiri sub basin	11	No flood	16	14
Population affected (Persons)	Sonitpur District	40688	No flood	11295	37281
	Belsiri sub basin	536	No flood	1247	1367
Cropped area affected (ha)	Sonitpur District	18299	No flood	13036	14205
	Belsiri sub basin	129	No flood	900	1235
Crop loss (Rs. in lakh)	Sonitpur District	12772	No flood	8994	9801
	Belsiri sub basin	90	No flood	621	852
Total value of property loss (Rs. in crore)	Sonitpur District	6.68	No flood	6.11	6.66
	Belsiri sub basin	0.06	No flood	0.42	0.57

Source: Belsiri Master Plan 2008, Brahmaputra Board, Government of India

The flood inundation data estimated using HEC-RAS are compared with the secondary data presented in table 3 and it has been found that the data is almost confined with each other. Thus, the flood inundation areas examined in this study are found to be authentic and significant. Besides, the flood inundation area map for average flood of 100 m^{3}s^{-1} and the highest flood of 171 m^{3}s^{-1} prepared in HEC-RAS is presented in Fig.5 and Fig.6. It is evident in the flood inundation maps prepared in HEC-RAS for average flood and highest flood data (Fig.5 and Fig.6) that there are very less difference in extent of flood inundation area. However, it is observed in the flood inundation areas that there are some white spots which are non-inundated areas. These non-inundation areas are the high elevation areas scatterdly present within the flood inundated areas. Non-inundated areas in the average flood inundation map (Fig.5) are higher than the flood inundation map of highest flood (Fig.6). It is estimated from the flood inundation map prepared in HEC-RAS (Fig.6) for the highest flood of 171 m^{3}s^{-1} that flood spilled to a maximum distance of 1.27 km at Keherukhanda Pathar village and an average distance of 0.78 km. It is also evident in flood inundation maps prepared for design flood of 126 for 5 yearsf return period (Fig.7) and design flood of 168 for 200 year return period (Fig.8) that extent of inundation is similar but non-inundation area within the inundated areas is more in 5 years return period (R.P.) map. This is mainly because of siltation in the floodplain, bed aggradation which raises the flood level and its corresponding effects are reflected in the longer return period inundation maps.



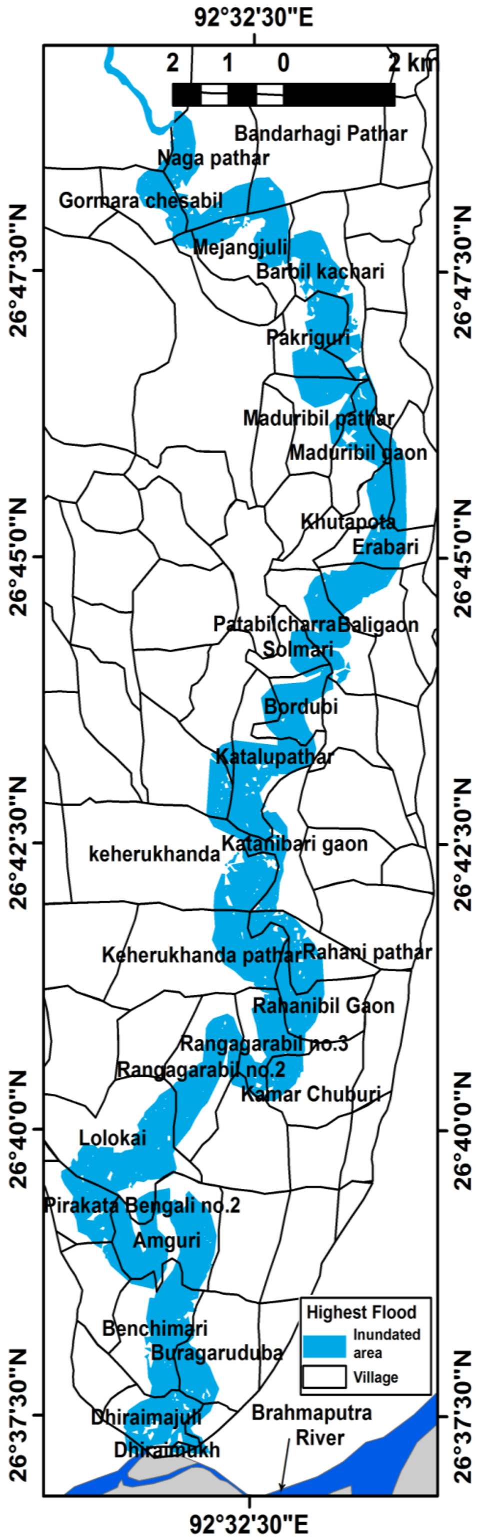


Figure 5: Flood inundation area for average flood (100m^{3}s^{-1}), 1991-2015	**Figure 6:** Flood inundation area for highest flood (171m^{3}s^{-1}), 1991-2015

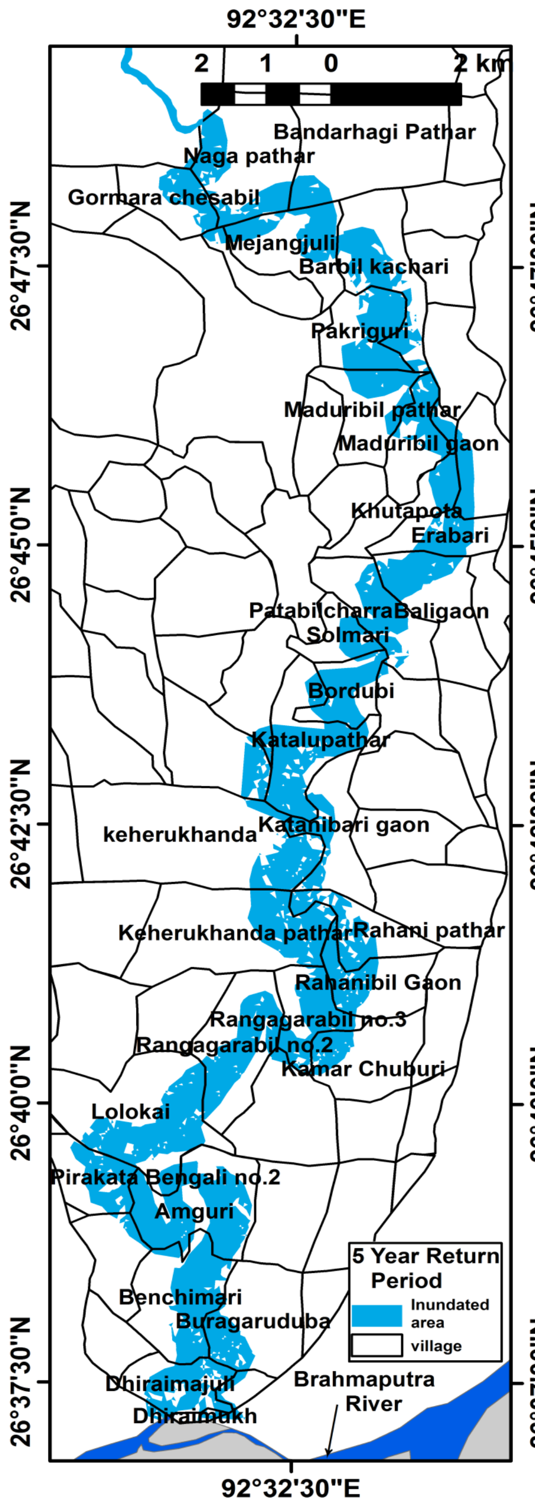


Figure 7: Flood inundation area for design flood of 126 m^3s^{-1} for 5 years R.P.,1991-2015

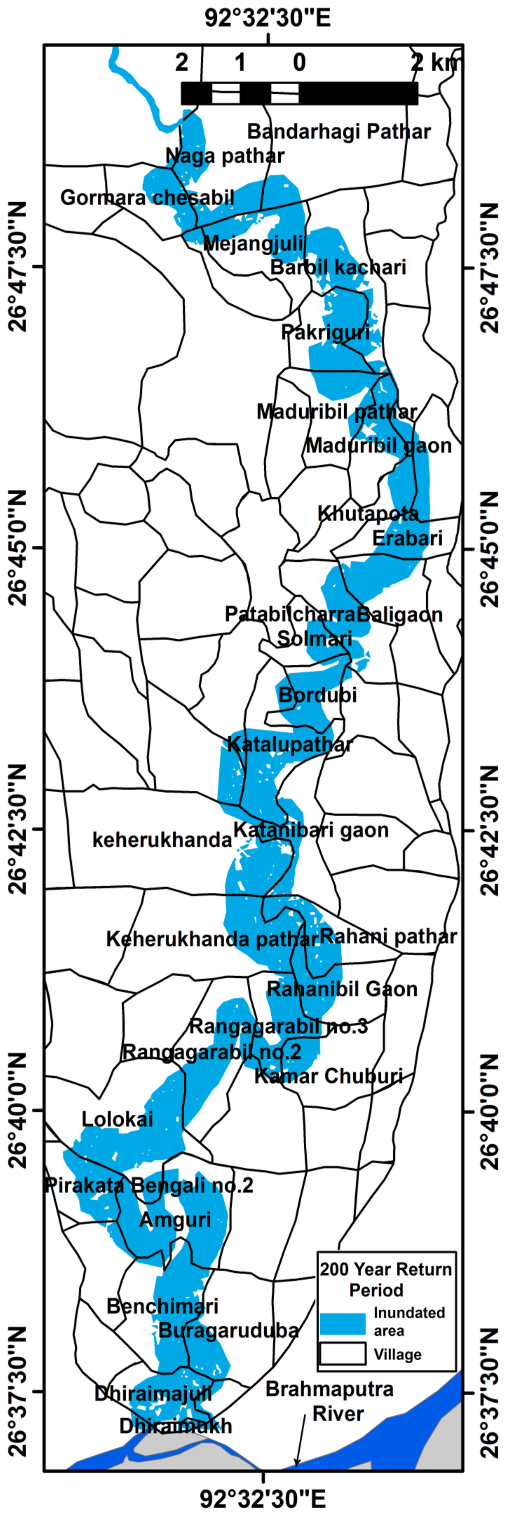


Figure 8: Flood inundation area for design flood of 168 m^3s^{-1} for 200 years R.P., 1991-2015

CONCLUSION

It is estimated in the model that 5, 10, 20, 50,100 and 200 years return period corresponds and 22.704, 22.946, 23.138, 23.303, 23.394 and 23.442 km^2 area inundation. It is also evident in the flood inundation map prepared in HEC-GeoRAS that the extents of flood inundation are increasing at a very low rate. Due to increased estimated stream flow data in the 200 year return period, the inundated area was a little high relative to other return period. It is noted that the floodplain results are highly dependent on the characteristics of the terrain of the basin area. In case of steep terrain, it is hard to find any difference between floodplain lines.

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