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Preparation of Flood Inundation Map in Ganga River at Farakka Bridge, Malda, West Bengal, India

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Abstract: *This paper presents a case study on preparation of flood inundation mapformaximum monthly floodmagnitude in Ganga River at Farakka Bridge using HEC RAS 4.1 and Google Earth online tool. The 21 year flow data have been analyzed to arrive on best fit distribution. The Log Pearson type III distribution has been selected on the basis of ranking given by goodness of fit tests (GOF). The results indicated that the location at Farakka Bridge is prone to flood for return period (T) from 200 to 2 years. The area left to river bank (in the direction of flow) is susceptible to more flood than area right of river bank. The Floodwall/Levee has been proposed on both side of river to save the population and property from flood hazards. The following study can be used as a base for further detailed study of Ganga River basin at Farakka Bridge.*

Keywords: Ganga River, Log Pearson Type III, HEC RAS 4.1, Flood map.

1. Introduction

India has a large network of rivers which are spread out over the country. They are a great source of prosperity and energy if properly harnessed. The Ganges alsoGanga is a Tran's boundary river of India and Bangladesh. The 2,525 km (1,569 miles) 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. It is the third largest river in the World by discharge. The Ganges is the most sacred river to Hindusand is also a lifeline to millions of Indians who live along its course and depend on it for their daily needs.The river Ganga is one of the three great rivers of the sub-continent, the other two being the Brahmaputra and the Indus. Floods represent a natural risk with a very high frequency, which yearly produce important material and human losses. Therefore, developing some detailed maps regarding floods vulnerability imposes[1]. Flood maps play an increasingly prominent role in government strategies for flood risk management. Maps are instruments not just for defining and communicating flood risks, but also for regulating them and for rationalizing the inevitable limits and failures of those controls. Planning is the most sustainable method to manage flood risk in that not only can it provide for risk management, it can also avoid or even reduce risk by influenceing factors such as the location, type, design, and function, of development. To accomplish thisprevention or reduction of losses, accurate prediction of the floodinundation area and dissemination of information on the inundationareas to emergency managers, city planners, and the generalpublic is necessary. Accurate prediction of the flood inundationarea is also required for developing and quantifying flood insurancerates. Flood inundation modeling involves hydrologic modelingto estimate peak flows from storm events, hydraulicmodeling to estimate water surface elevations, and terrain analysisto estimate the inundation area [2][3]. Since data for low-frequency events e.g., precipitation, water surface elevation, river discharge areusually unavailable, flood inundation is simulated by using hydrologicand hydraulic models calibrated against gauged low flows[4][5][6][7]. In most cases, the result from flood inundationmodeling is a single deterministic prediction of the flood area forthe peak flow.The Hydrologic EngineeringCenter's River Analysis System (HEC-RAS) is a softwarepackage that is well-suited for developing flood inundationmaps for a variety of applications. An HEC-RAS modelcan be used for both steady and unsteady flow, and sub andsupercritical flow regimes. With its companion utility, HEC-GeoRAS and ArcView©, seamless integration withGIS makes both the construction of the model geometryand the post-processing of the output very easy. This paperpresents a case study while addressing the steps taken toconstruct and HEC-RAS model and to resolve the outputinto flood inundation maps. In this paper, we will focus on preparation of flood inundation map by using Google Earth tool and HEC RAS 4.1 software. Floodwall/Levees will be proposed to save population from flood hazards.

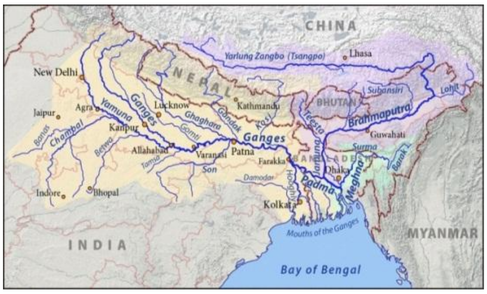
2. Materials and Methods

2.1. Study Area Description

The Ganges River, also called Ganga, is a river located in northern India that flows toward the border with Bangladesh (map). It is the longest river in India and flows for around 1,569 miles (2,525 km) from the Himalayan Mountains to the Bay of Bengal. The river has the second greatest water discharge in the world and its basin is the most heavily populated in the world with over 400 million people living in the basin [8]. The location, tributaries and catchments of Ganga River have been shown in Figure 1.

2.2. Hydrology of Study Area

The hydrology of the Ganges River is very complicated, especially in the Ganges Delta region. One result is different ways to determine the river's length, its discharge, and the size of its basin.The hydrologic cycle in the Ganges basin is governed by the Southwest Monsoon. About 84% of the total rainfall occurs in the monsoon from June toSeptember. Consequently, stream flow in the Ganges



http://en.wikipedia.org/wiki/File:Ganges-Brahmaputra-Meghna_basins.jpg

Figure1. *Location of study area*

is highly seasonal. The average dry season to monsoon discharge ratio is about 1:6, as measured at Hardinge Bridge [9]. This strong seasonal variation underlies many problems of land and water resource development in the region.The seasonality of flow is so acute it can cause both drought and floods. Bangladesh, in particular, frequently experiences drought during the dry season and regularly suffers extreme floods during the monsoon.

2.3. Data collection

2.3.1. Flow data

The data has been collected with courtesy from Centre for Sustainability and Global Environment web site. The discharge site is Farakka Bridge which is located at Malda, West Bengal (24° 48′16″N, 87 ° 55′59″E) and has been shown in Figure 2.

http://en.wikipedia.org/wiki/File:India_West_Bengal_location_map.svg

Figure2. *Stream gage location*

The flood flow data has been shown in Figure 3.

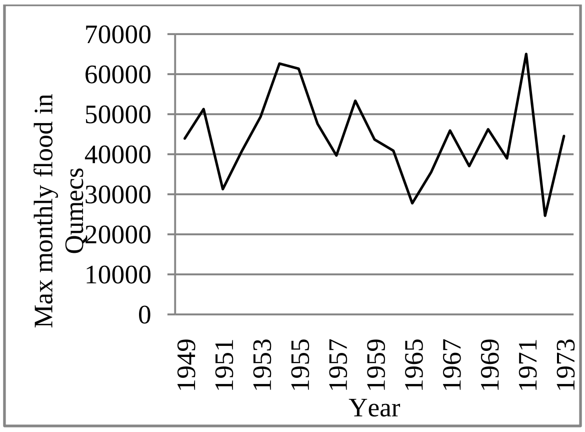


Figure3. *Flood flow data at Farakka Bridge*

2.3.2. River geometry data

The river bed elevation was extracted using "Elevation profile" tool present in Google Earth software and plotted in excel. The manning's valuewas considered 0.020 though flood plan manning value varies from0.025 to 0.080 [10]. The river bed shows no resistance to flow when the river bank overflows. Also lower manning value will help to account any future urban development on floodplain. The manning value considered constant throughout the river reach for simplicity in calculation and due to unavailability of such data. The value has been plotted in Figure 7.

3. MODELING MAXIMUM MONTHLY FLOOD AT FARAKKA BRIDGE

Models of flood flow amount are described as follows with their probability density functions and cumulative distribution functions. Note that X is the random variable representing the Maximum monthly flood magnitude. The maximum monthly flood at Farraka Bridge has been shown in Figure 3.

3.1. Estimation of Parameters

Many methods are available for parameter estimations, which include the method of moments (MM), maximum likelihood estimation (MLE), the least squares method (LS), L-moments and generalized probability weighted moments (GPWM).The MLE method is considered in this study because it provides the smallest variance as compared to other methods. The idea of this method is to find a set of parameters that will maximize the likelihood function. The parameters are obtained by differentiating the log likelihood function with respect to the parameters of the distribution. The all parameters was estimated by creating formulas in Microsoft excel 2010 and have been shown in Table 1.

4. GOODNESS-OF-FIT TESTS (GOF)

Three different mostly used GOF tests have been used in this study to identify the best fit models. The chosen distribution that best fits the maximum monthly flood is based on the minimum error indicate by all these seven tests. The description of all tests can be found in any basic statistics books. The results have been shown in Table 2.

5. RESULTS AND DISCUSSIONS

The excel sheet was developed for calculation of all statistics and result were prepared.The results and calculations were verified by using Easyfit software. The results have been summarized in Table 4. The Goodness of fit test was done for all distribution using three methods. The rank has been given on the basis of minimum value of error given by GOF test.

First, we will proceed to give comments on the results of fitting distributions that are based on GOF criteria. Finally the remarks on the estimated parameters for the best model will be made.

5.1. Descriptive Statistics

The frequency analysis was performed on21 years of flood record. The flood data was missing in-between 1961 to 1964 which were omitted from calculation. The basic parameters of flood record have been shown in Table 3. The maximum flood value obtained is 65,073 cumecs from observation.

The flood value is almost symmetrical which indicated that it will be fit well for methods based on symmetrical distribution. The low value of kurtosis indicates non peakedness of flood. The average value

5.2. Fitting Distribution Based on GOF Criteria

The values of three goodness-of-fit criteria have been calculated and the best distribution was chosen based on the minimum error of GOF tests. The distributions were then ranked in ascending order based on those values. Unfortunately, when many criteria are used to identify the best distribution, it is more difficult to for the same data may be different for different analysis. In this study, we chose the best fitting distribution based on the majority of the tests, since we did not investigate which is the most effective test. Based on the results, Log Pearson Type III distribution was found to be best fitting curve for Maximum Monthly flood data at Farakka Bridge.

Table1.*Parameters of selected distributions*

SR NO	Distributions	Parameters				
		μ	σ	α	β	ϒ
1	Normal	44399	10635	--	--	--
2	Lognormal	0.2426	10.67	--	--	--
4	Gumbell maximum value	396130	8292	--	--	--
6	Log Pearson Type III	--	--	21.4	0.053	11.8

Table2.*GOF value for selected probability distributions*

SR NO	Distributions	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
		Statistic	Rank	Statistic	Rank	Statistic	Rank
1	Log Pearson Type III	0.08349	1	0.22026	1	0.62635	4
2	Normal	0.09714	2	0.24768	2	0.54671	3
3	Lognormal	0.09993	3	0.25641	3	0.43531	2
4	Gumbell maximum value	0.11499	4	0.4368	4	0.26238	1

Table3. *Basic Parameters for flood record*

Parameters	Symbol	Values
Average	X^{--}	44399.19
Standard Deviation	s	10635.05
Variance	s^2	113104293.36
Skew	C_s	0.24
Kurtosis	C_k	-0.06
Maximum	X_{max}	65072.00
Minimum	X_{min}	24693.00

5.3. Estimation of Flood Magnitude for Various Design Return Period

The Log Pearson Type III method was adopted for frequency analysis of flood data. The procedure given in flood flow frequency, Bulletin 17B has been adopted. The result in have been shown in Figure 4 for design return periods of 200, 100, 50, 25, 10, 5, 2, and 1.25 years so that its value can be used in different applications.

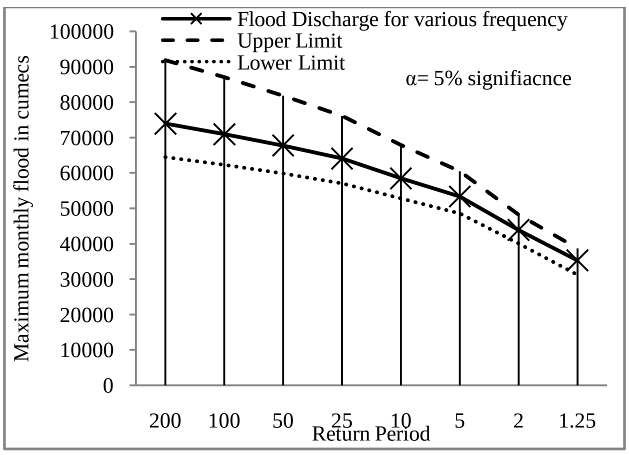


Figure4.*Flood magnitude for various design return period*

5.4. Preparation of Flood Inundation Map

5.4.1. Calculation of water depth

The methodology developed by HEC RAS 4.1 was used for estimating water depth at Farakka Bridge. Itis assume that flow is steady at the time of peak flow.

The effect of Farakka Bridge was not considered inwater depth calculation. The model was prepared in HEC RAS 4.1 and run for mixed flow condition due to presence of bridge piers. The flow depth and velocity at Farakka Bridge have been summarized in Table 4.

Table4. *Basic Parameters for flood record*

Recurrence Year	Percent chance	Peak Discharge	WSE in m	Velocity in m/s
200	0.5	74000	28.71	6.9
100	1	71000	28.53	6.81
50	2	67800	28.34	6.69
25	4	64100	28.11	6.57
10	10	58500	27.75	6.39
5	20	53400	27.41	6.19
2	50	43900	26.73	5.81
1.25	80	35300	26.05	5.41

5.4.2. Preparation of flood map

The basic and simple methods have been use for flood preparation map at Farraka Bridge. The calculated water depth for various return periods was merged in Google Earth to check the condition of Inundation. The obstruction in flow due to presence of tree, natural pond, swamp etc. was completely neglected. The area was marked in Google Earth using editing tool where the water surface elevation (WSE) is more than ground elevation. The Flood maps prepared for return period of 200, 50 and 2 years and have been shown in Figurer 5, 6 and 7.

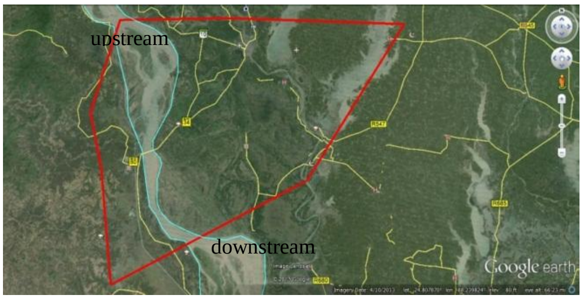


Figure5. *Inundation area (T=200, 2400 sq km)*

Figure6.*Inundation area (T=200, 1060 sq km)*

Figure7. *Inundation area (T=200, 550sq km)*

5.5. Proposal of Flood Wall or Levee

Floodwall or Levee has been proposed at the bank of Ganga River to save the populated area from flood of about 200 Years. The proposed flood wall and its height on both side of River have been shown in Figure 8.

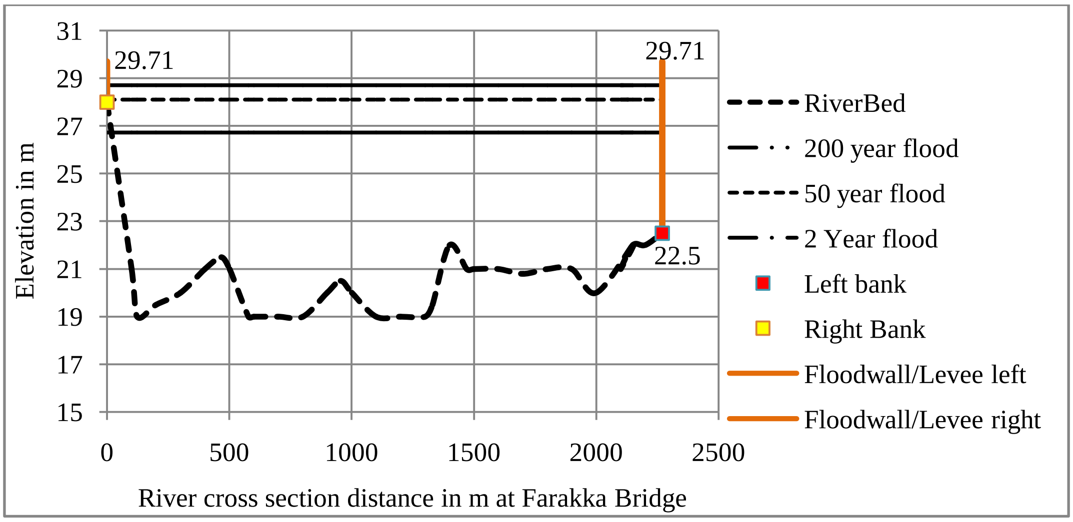


Figure8.*water surface elevation (WSE) for various return period and position of Floodwall/Levee*

6. Conclusions

The study was performed to prepare the flood inundation map around Farakka Bridge, Ganga River. Flood flow data analysis confirmed thatthe Log Pearson Type III distribution is best fit. The magnitudes of floods have been estimated for 200,100, 50, 25, 10, 5, 2 and 1.5 years. The calculated value is well in-between the 95% confidence interval.HEC RAS 4.1 has been used to calculate the water depth for various magnitudes of floods. The study shows that area at right bed of river is more prone to flood than area to left bank of river. The 200 years. Flood has been found to affecting residential, Industrial, Commercial areas, school, colleges and Airport etc. If such flood occurs then huge loss of life and property is endangered. However proposals of Floodwall/levee will require more detail technical study and cost benefit analysis.

This study should be further extended and accurate detail should be obtained by site visits and survey. The effect of bridge pier on water surface elevation should also be studied. The detention effect of natural pond, swamps, and trees should come into study.However uncertainties in flood inundation mapping are generated by uncertainty in the design flow, terrain elevations, water surface elevations, and accuracy of the techniques used for mapping the inundation area.

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