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Magnitude of Floods and its Consequences in Puthimari River Basin of Assam, India

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Abstract:

The main aim of the present study is to analyse the magnitude and consequences of floods in the Puthimari River Basin of Assam, particularly from the second half of the 20th century to the 1st decade of the 21st century. An attempt has been made to study floods from 1958 to 2008. The hydrological data such as water level and water discharge have been collected from two different sources depending on its availability. The stage hydrographs have been prepared using maximum and minimum water level. The magnitude of floods has been identified by comparing the maximum stage hydrograph and danger level specified by Central Water Commission. The stage of 21 floods has been found to be more than 2m in height from DL and one flood has been reported with more than 3m in height within a span of 51years from 1958 to 2008. The flood damage data such as flood affected area, affected cropped area, number of affected villages and affected population have been collected for the same period as in the case of hydrological data. The same data set has been used as indices to find out flood magnitude and their overall socio-economic

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consequences. The individual scores of these indices have been put in a separate rank table and total scores have been calculated by adding individual scores of each index for the study period. Finally, the magnitude of floods has been compared with its consequences. The most consequences have been found in the floods of 2007,2004,1988,1993 showing the highest magnitude flood for the 2nd half of 20th Century and 1st decade of 21st Century.

Key words: flood magnitude, flood hazard, hydrological data, rank and socio-economic consequences.

1. Introduction

Inundation of smaller or larger area for few hours to several days by water is called flood. Illustrated Oxford Dictionary defines flood as “an overflowing of water beyond its normal confines, especially over land”. A flood is synonymous with discharge greater than bankfull channel capacity although many people refer to any high discharge as a flood. In all cases, it has been seen that floods occur when the river exceeds its normal condition or threshold limit. Before that input must be much more to exceed the channel flow capacity. It implies that supply of water must be plenty in the form of precipitation or by breaking of big dams. After all, flood is an event or phenomenon which may be natural or anthropogenic in origin relating to availability of water in the drainage basin on the earth surface.

In India, a river is said to be in flood when its water level crosses the danger level (DL) at that particular site. Central Water Commission (CWC), New Delhi, which is the nodal agency in India for the development of water resources, has fixed DLs at important gauge discharge (G/D) sites on most of the rivers in consultation with State Government Engineers. As such, when water level in a river touches or exceeds the DL at a particular G/D site, the river at that site is said to be in flood. Major floods are those when water level is 1 m or more above the DL and if it is 5 m or more above the DL, that flood is said to be catastrophic (Nandargi and Dhar 1998, pp. 1-25).

Rivers in the alluvial plains normally spill over their banks several times in a year causing floods. It is a common feature and also essential for the river to accommodate its water flowing in excess to its carrying capacity during high storm period on its flood plain. However, it is the extreme flood, which occurs rarely causing misery to the people and is responsible for losses of many types. Hence, it is necessary to assess the post flood scenario and study the anthropogenic consequences of floods. This paper has been prepared considering the fundamental aim to high light the floods in the Puthimari River Basin (PRB) of Assam in India.

2. Relevant Literature

There is a growing demand for the quantification of flood magnitudes or flood frequencies (Benson 1968; Nandargi and Dhar 1998; Nandargi and Dhar 2000; Weiler et al. 2000; Ahearn 2004; Herold and Mouton 2006; Roland and Stuckey 2007; Griffis and Stedinger 2009)and the estimation of the socio-economic consequences (Bora 2003; Papp 2000) although, the identification of flood magnitude from socio-economic consequences or hazard perspectives is rarely used in current practice. An exact treatment of the problem has failed to produce a widely accepted interpretation in the case of floods, though the basic mathematical equation of flood magnitude analysis is well known.

On the other hand, a socio-economic assessment of its consequences will denote a flood as extreme if it has caused extremely high losses, regardless of the meteorological or hydrological conditions which have triggered it. In quantifying extremeness of floods caused by natural hydrological situations, it is advisable to take each of the three --- quantifying or defining flood accurately, knowledge of the local conditions and a socio-economic assessment of floods consequences --- considerations into account in a manner which makes the derived parameters useful separately and also in combination. Moreover, the parameters adopted should be simple to calculate and be insensitive to the inaccuracies inherent to the basic data used in deriving them….Floods in rivers are characterized traditionally in terms of the peak discharge and stage. However, these parameters alone are unsuitable for comparing floods occurring at different locations, and thus in assessing their extremeness (Papp 2000).

3. The Flood Consequences in General

3.1 The Flood Welfare

Flooding is a regular occurrence of many river systems world-wide. Although the magnitude of the flood may vary, floods probably offer more opportunities for people than any other hazard. Flooding maintains soil fertility by depositing fresh layers of alluvium and flushing salt out of soils. The Euphrates, Indus, Nile, Tigris and Yangtze have all supported civilisations as a result of their fertile floodplains. Even today many agricultural systems on floodplains are in harmony with low magnitude high frequency floods.

The flood plain has locational advantages alongside water sources, river transport and for waste disposal. Flat floodplain areas are often used for buildings and transport networks due to the relative ease of construction. Human habitation of floodplain locations, including higher risk areas increased in the 20th century. This was due to urban development, growth of population and construction of more roads and railways. Thus people have increasingly become exposed to the flood risk and the hazard has increased in relative importance without an actual increase in flood events. As such flood consequences are of two types, i.e., constructive or welfare consequences and destructive or hazardous consequences.

3.2The Flood Hazard

A few flood events cited here had devastating consequences to the people. The Yellow River of China breached its levees 1500 times from 602 BC causing sever misery to the people, hence called the "Sorrow of China". The Kosi River of Bihar is also notorious for its capricious nature. Due to its shifting courses, the river has ruined an area of 7,770 sq km. Many settlements were wiped out and huge losses of property, cattle and even human lives were inflicted. The river Siang experienced an unprecedented flash flood on 11^{th} June, 2000, which was a hot sunny day in the area. The water level suddenly rose to 20-30 m in places. The rise of water level recorded in Yingkiang was 12.2m within an hour, 26 people were killed 2000 missing and 15 important bridges were washed away during this mega flood event(www.dailyexcelsior.com,2009;www.daily.axom.faithweb.com , 2009)

3.2.1 1889 Johnstown Pennsylvania U.S. Floods

Johnstown, Pennsylvania has had a series of disastrous flash floods. On May 31, 1889, 2209 people died when a dam broke. Nearly 400 children were killed and 99 entire families were wiped out. More than 750 bodies were buried in one grave and were never identified.

In the 1889 flood, the South Fork Dam that broke was originally built to hold back a reservoir on the Pennsylvania Mainline Canal system. A swank sporting club for rich Pittsburgh industrialists enjoyed the reservoir behind the dam. In late May of 1889, following heavy rains, the water behind the club's earthen dam rose two feet overnight. Runoff from nearby hills, denuded by logging, exacerbated the rise. The city of Johnstown, 14 miles away, was smothered by a wave. More than 1,500 homes and 280 businesses were destroyed (Reed 1998).

3.2.2 1976 Big Thompson, Colorado U.S. Flood

On July 31, 1976, 140 people were killed when up to 14 inches of rain fell on the headwaters of the Big Thompson Canyon. The steep narrow canyon was filled with tourists and the flood occurred on a summer Saturday night. Damages exceeded $30 million. The Big Thompson flood has had extensive impacts on the community of geologists, hydrologists, meteorologists, engineers and social scientists who work in Colorado. There have been two symposia to commemorate lessons from the Big Thompson Floods (Gruntfest 1987; Gruntfest 1997).

3.2.3 1993 Midwestern U.S. Floods

Damages from the l993 flood in the Midwest exceeded $18 billion. The flood inundated 10,300 square miles in nine states and 52 people lost their lives. There is uncertainty about whether these events qualified as 50 year, 100 year or 500 year events. In l993 only 52 lives were lost as a reflection of improved flood forecasting and warning systems. The Great Flood occurred between April and August and actually consisted of a series of floods. Within the immense storm systems were at least 175 cores of heavy rain, each producing more than 6 inches of rain in short periods and numerous flash floods (Changnon 1996).

Changnon's edited collection evaluates the direct, secondary, and tertiary impacts of the flood. The study shows the difficulties of estimating losses. For the state of Iowa the official loss estimates range from $3.4 billion to $5.7 billion. Detailed discussion on agricultural and social impacts can be found in pages 282-297. At the national level, the floods did not significantly affect the national economy. The flood did not change the nation's gross domestic product in 1993 but it was expected to increase the gross domestic product by .01 percent in 1994 due to expenditures for flood repairs. One of the greatest flood problems was the damage to surface river transportation systems. Barge traffic was halted (Changnon

1996).

3.2.4 1993 Mississippi, US Flood

Following the l993 Mississippi River floods the town of Valmyer, Illinois took the recovery funds and moved the entire town to higher ground. The town of 900 people moved to a 500 acre cornfield and woodland on a bluff above the ruins of the old town. Two years after the flood most of the residents were living in their new homes. The town also experienced serious flooding in l910, 1943, 1944, and 1947. Financing and construction involved 22 government agencies and costs were approximately $28 million (Watson, B., 1996). Their flood problems were replaced by a different set of issues related to community structure. Initial flood loss estimates were between $12 and 15.7 billion. Although regional impacts in the nine-state area were extreme, flood losses in the national economy were not noticeable (Timmerman and Amato 1995; Changnon 1996).

3.2.5 1997 Grand Forks, North Dakota, U.S. Flood

When the spring flood receded in 1997, the city of 50,000 had sustained more than $1 billion in damage. Of its 11,000 houses, 8,000 were damaged, and another 750 lost outright. Hundreds of businesses suffered serious losses. Most churches, schools, and public institutions were closed. Grand Forks endured the largest per capita disaster in U.S. history (Findley 1998).

3.2.6 *2006 Dire Dawa, Ethiopia Flood*

The 2006 flood has inflicted severe direct and indirect damages on social, infrastructure and economic sectors of Dire Dawa. It caused the death of 256 people, 244 missing and 15,000 people displaced from their dwellings. Of the total fatalities, the proportions of women fatalities were 134 as compared to 83 men fatalities; and the remaining 39 fatalities were children. This flood also severely damaged infrastructure and housing sector. A total of 1628 houses were entirely and partially damaged with a total value of $10.23 million in the housing sector alone. The total value of direct and indirect damages on agriculture, trade and industry sector including cost of demolition and removal of debris was about $2.6 million. The overall direct and indirect disaster impacts occurred in agriculture, trade & industry and infrastructural sector in the 2006 flooding as per the result of ECLAC calculation was $14.9 million (Tadesse and Jayawardena 2006).

3.2.7 Floods from 1951-2003 in Italy

In a study of socio-economic impacts of major floods in Italy found 1394 casualties, half of which occurred during the time period from 1951–1970. Besides, taking into account the entire analyzed period (1951–2003), the study has pointed out that almost 50% of examined floods caused more than 5 casualties and almost 10% more than 100 (Lastoria et al. 2006).

4. Purpose and Scope

This paper presents a new state wide technique that can be used to estimate the magnitude and dimension of floods in flood plains of perennial rivers in Assam. The equations have been developed by incorporating data such as maximum annual water discharge, maximum annual water level, minimum annual water level and danger level recommended by CWC.

This paper also provides (1) a comparison of observed annual maximum and minimum flood flows with danger level from stream flow-gauging stations from N. H. crossing of the Puthimari River; (2) a technique for identifying high magnitude flood by comparing flood flows with that standard flow which marked the danger level; (3) an evaluation of the larger flood consequences by summing up all individual scores of flood damages in a single column for characterizing floods affects or damages in the basin, moreover (4) the PRB could be a sample basin for the region to study the magnitude of floods from the hydrologic and non-hydrologic or socio-economic points of view as well. Throughout this paper, annual maximum water discharge, annual minimum water discharge, annual maximum water level and annual minimum water level refers to the annual maximum water discharge, annual minimum water discharge, annual maximum water level and annual minimum water level for the water year.

5. The Study Area

The Puthimari River is one of the north bank tributaries of the Brahmaputra River in Assam (Fig.1). After originating in Bhutan Himalaya at an altitude of 3750 m the river flows north to south through the Nalbari and Kamrup districts of Assam to meet the Brahmaputra River at an acute angle. The river has a catchment area of 1,787 sq km and lies between 26°10/N - 27°18/N latitude to 91°27/E - 91°50/E longitudes. The upper catchment of the river falls in Bhutan with an area of 596 sq km and lower catchment lies in Assam which has an area of 1,191 sq km. The width of the catchment varies from 36 km in the lower most portions to 3.40 km in the upper most portion of Bhutan Himalaya.

The area of the flood plain in the basin is 385sq km out of which an area of 374.38 sq km is more prone to flood. The total number of villages of the basin is 448 and 234 villages are in the flood plains. The agricultural land covers an area of 68,126 ha. Out of which, 47,638 ha are located in the flood plain of the basin.

6. Database and Methodology

The base map of Puthimari River Basin has been prepared in a Map Info environment by using Survey of India toposheets. Geomorphologically, the river basin is divided into two major sections: (i) the Upper catchment or Catchment of the Bhutan Himalaya, and (ii) Lower Catchment or Alluvial Catchment of Assam. The Lower Catchment is the study area for the paper.

The hydrological data such as water level and water discharge have been collected from two different sources depending on its availability. The first segment of water level data from 1955 to 1993 has been collected from Brahmaputra Board and second segment from 1994 to 2008 has been collected from CWC. The water discharge data used here are from 1955 to 1993 which have been collected from Brahmaputra Board, Assam. The stage hydrographs have been prepared using maximum and minimum water levels. The flood magnitudes or flood lifts have been found out for each year deviating from Danger Level. The flood damage data of the study area have been collected from Revenue Authority, Govt. of Assam for the year of 1976, 1982 and 1986-2007. These data have been processed, tabulated and represented by bar diagrams.

The tabulated flood damage data such as flood affected area, affected cropped area, no. of affected villages, affected population, have been again used taking as indices to find out flood magnitude. Individual score of each index has been put in a rank table against its damages/losses caused by floods. After that, all individual score has been summed up in a column of "Total scores". Finally, bar graphs have been prepared and compared with stage and discharge hydrographs to draw a comparative conclusion.

The two common statistical techniques used here for flood frequency analysis are log-normal distribution and log-Pearson Type III distribution. The magnitude and frequency of floods at N. H. crossing gauge site have been determined using flood-frequency curves for a period of 39 years from 1955 to 1993. These curves relate maximum annual discharge to probability of occurrence or recurrence interval of 2, 5, 10, 25, 50, 100 and 200 years.

Probability of occurrence is the chance that a given flood magnitude will be equalled or exceeded in any year. If there is 1 chance in 10, the probability is .1. Recurrence interval is the reciprocal of the probability of occurrence. For example, a flood with a probability of occurrence of .O1 in any year has a recurrence interval of 100 years. This does not mean that a 100-year flood will only occur every 100 years or 100 years from now. The 100-year flood is a flood of such magnitude that the odds are 1 in 100 (or 1 percent chance or .O1 probability) that it will be exceeded in any year. Several 100-year floods could occur in a single year.

7. Results and Discussion

7.1 Magnitude of Floods

Figures 2 and 3 depict the time series analysis of stage and discharge hydrograph from 1958 to 2008 and 1955 to 1993, respectively. The flood of 1988 has been found as the highest flood ever recorded in the PRB with (54.81-51.81) 3.0m deviation from DL. The flood marked the highest water level (54.81m) and water discharge (1588.38cumecs) ever recorded in flood history of the PRB. Interestingly, this flood has been found 2nd largest (Fig.4) from the hazard perspective. The 2nd and 3rd largest floods have been identified (Fig.2) in the years of 1993 and 2007 flowing (54.54m-51.81m) 2.73m and (54.44m-51.81m) 2.63m above the DL, respectively. From the hazard view point, both the two floods of 1993 and 2007 have been ranked as 4th and 3rd largest from the left. These variations occurred, perhaps, due to discrepancies during the post flood affects assessment period.

If we consider the floods for the entire period of 51 years from 1958 to 2008, it has been found that the river flow has always been above the danger level ranging from 0.29m to 3.0m except in 1970, 1992, 1994 and 2001 (Fig. 2). Moreover, the maximum water discharges of the river from 1955 to 1993 have been seen more than that water discharge which marked the DL (Fig. 3) excluding the years of 1955, 1956, 1957, 1959, 1970, 1971, 1986 and 1992. By comparing both the graphs (Fig.2 & Fig.3) it is clear that flood occurred every year except 1970, 1992 and 1994. The maximum annual mean water discharge of the river has been always above that particular discharge which marked the DL.

The magnitudes of floods from hazard view point have been slightly different than the hydrological data analysis of the 21 years time period from 1976 to 2007. It has been found that flooding is a common phenomenon during this period in the PRB. It occurs almost each and every year. The floods of 2004, 1988 and 2007 have been found the 1st, 2nd and 3rd largest respectively (Fig.4). But, the floods of 1988 and 1993 can be considered as the largest ever occurred in the 2nd half of the 20th Century causing widespread loss to the people of the basin. On the other hand, the flood of 2004 has been the mega flood of 1st decade of the 21st century.

The estimation of floods in the PRB for 2, 5, 10, 25, 50, 100 and 200 year return period has been found as 558.2389317, 868.7015852, 1094.534716, 1400.241784, 1641.775763, 1893.886307 and 2159.613442 cumecs by using log normal distribution method (Table. 1& Fig. 5). On the other hand, the values of flood estimation for the same return periods have been found by applying log-Pearson Type III distribution method with slight variation as 556.715873, 867.9928106, 1096.431747, 1408.13343, 1656.248935, 1916.831554 and 2193.139899 cumecs (Table. 1 & Fig. 6). It has been found that the 20 floods already occurred in the PRB showing more than 50% probability by log-normal and log Pearson Type III methods as well. The floods of 1988 and 1993 have been seen the largest ever occurred with more than 4% probability in both the distribution cases.

Table.1: Estimated annual maximum discharge of the Puthimari

River at N. H. crossing

T (Return Period)	Probability %	Log-normal(in cumecs)	Log-Pearson Type III (in cumecs)
2	50	558.2389317	556.715873
5	20	868.7015852	867.9928106
10	10	1094.534716	1096.431747
25	4	1400.241784	1408.13343
50	2	1641.775763	1656.248935
100	1	1893.886307	1916.831554
200	0.5	2159.613442	2193.139899

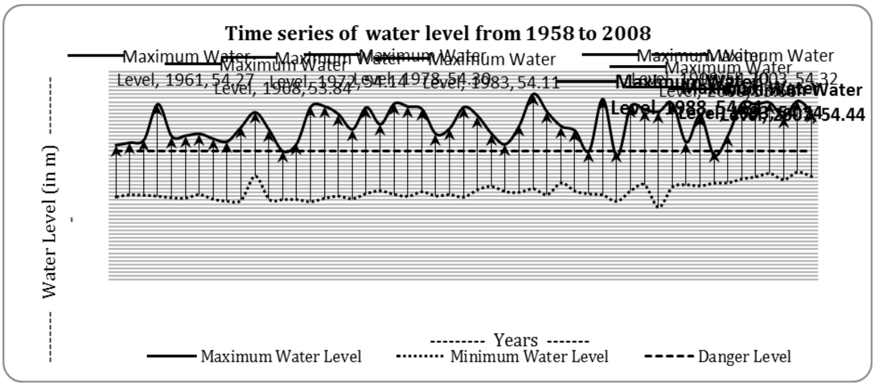

Fig.2: Magnitude of floods based on time series of water level in the Puthimari River Basin of Assam from 1958 to 2008

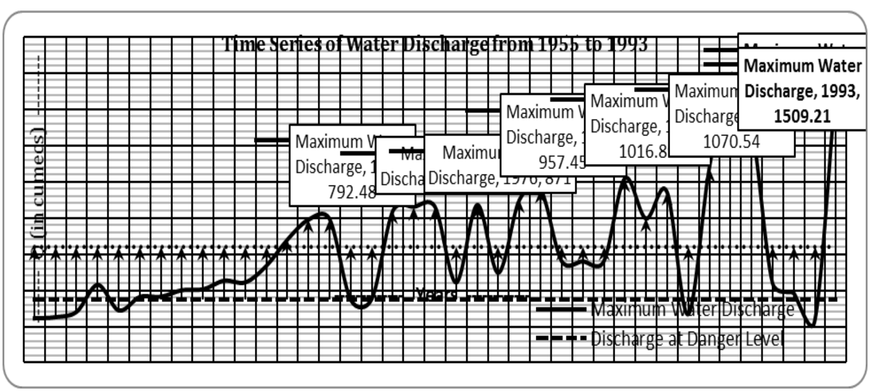

Fig. 3: Magnitude of floods based on time series of water discharge in the Puthimari River Basin of Assam from 955 to 1993

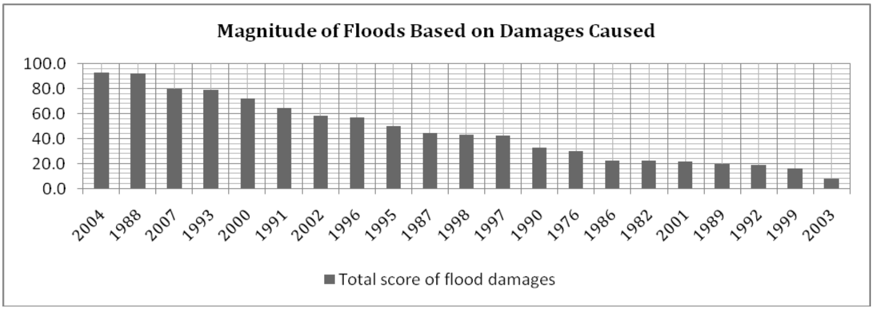

Fig. 4: Magnitudes of floods from hazard perspectives in the Puthimari River Basin of Assam from 1967-2007

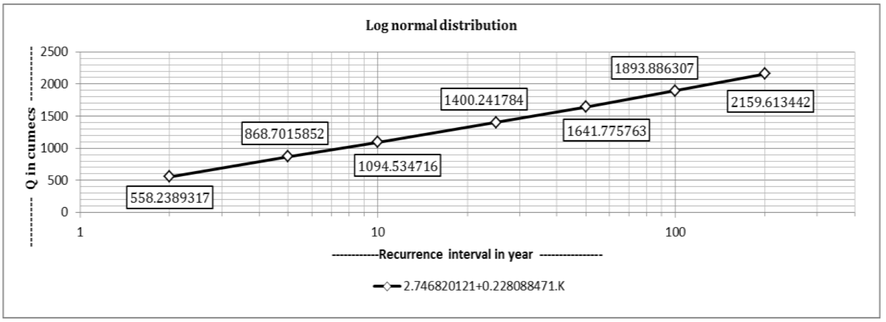

Fig. 5: Flood frequency analysis of the Puthimari River by Log-normal method for recurrence interval of 2, 5, 10, 25, 50, 100 and 200 years

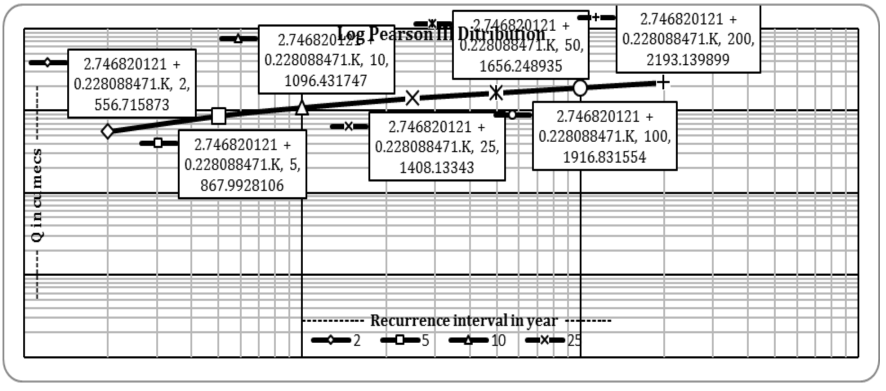

Fig. 6: Flood frequency analysis of the Puthimari River by log Pearson III method for recurrence interval of 2, 5, 10, 25, 50,100 and 200 years

Table.2: Flood damages of the Puthimari River Basin in Assam from 1976 to 2007

Year	Area Affected		Cropped Area Affected		Villages Affected		Population Affected	
	(in Lakhs ha)	(in%)	(in Lakhs ha)	(in%)	In No.	(in%)	(in Lakhs)	(in%)*
1976	0.16	13.43	0.039	05.72	NA	NA	0.25	07.55
1982	0.08	06.72	0.010	01.47	050	11.16	0.24	05.25
1986	0.03	02.52	0.027	03.96	088	19.64	0.37	08.09
1987	0.22	18.47	0.140	20.55	NA	NA	1.38	30.18
1988	0.97	81.44	0.510	74.86	388	86.61	4.22	92.30
1989	0.05	04.20	0.047	06.90	027	06.03	0.25	05.47
1990	0.06	05.04	0.070	10.28	067	14.96	0.26	05.69
1991	0.18	15.11	0.143	20.99	097	21.65	1.72	31.39
1992	0.12	10.08	0.018	02.64	045	10.04	0.11	02.01
1993	0.33	28.06	NA	43.45	360	80.36	4.12	75.26
1995	0.17	14.50	0.137	20.04	110	24.55	1.27	23.18
1996	0.47	39.48	0.461	67.69	095	21.21	0.91	16.54
1997	0.24	20.23	0.029	04.25	138	30.80	0.39	07.04
1998	0.11	09.32	0.048	07.09	074	16.52	1.07	19.58
1999	0.06	04.77	0.005	00.71	018	04.02	0.97	17.71
2000	0.57	47.87	0.328	48.08	131	29.24	1.65	30.12
2001	0.02	01.79	0.005	00.68	033	07.37	3.23	41.30
2002	0.25	21.10	0.109	16.00	203	45.31	1.75	22.32
2003	0.03	02.16	0.008	01.22	033	33.00	0.02	00.29
2004	0.79	66.20	0.209	30.73	424	94.64	6.96	89.01
2007	0.65	54.18	0.320	47.02	426	95.09	5.12	65.49

Source: Revenue Department, Govt. of Assam. *Percentage of population for 1976 is based on 1971, likewise from 1982 to 1990 is 1981, from 1991 to 2000 is 1991 and from 2001 to 2007 is projected population of 2001.

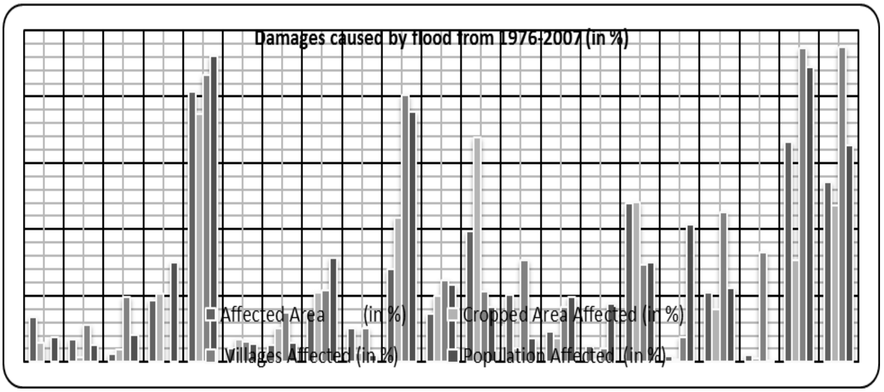

Fig.7: Percentage of flood damages in the Puthimari River Basin of Assam from 1976 to 2007

7.2 Consequences of Floods

The hazardous consequences of flood in Puthimari River Basin are common for every year. The three flood waves of 1988 (Table. 3), reported to be the most severe and the most devastating recorded so far wherein the floods water inundated **74.86%** (0.510 lakhs ha) of cropped land, affecting **86.61%** i.e., 388 villages including **92.30**% (4.22 lakhs) of population (Table. 2 & Fig.7) and claimed the lives of 5 people and 374 cattle (Table 3).. The flood of 2004 affected **66.20 %** (0.79 lakhs ha) of land, **30.73**% (0.209 lakhs ha) of cropped area including **89.01**% (6.96 lakhs) population of **424** (94.64%) villages taking the toll of 22 people (Table. 2, 3 & Fig.7). This flood reported the largest damage to the dwellers of the basin just next to the floods of 1988. Moreover, **65.49%** population of **426** villages had been affected including **54.18**% (0.65 lakhs ha.) of total geographical area and **47.02%** (0.320 lakhs ha.) cropped land. If we consider all floods from 1976 to 2007, it has been found that the 4 floods of 1988, 1993, 2004 and 2007 had the more than 30% hazardous consequences in the basin. In addition, the flood of 1988 has been seen to be more than 75% flood damages in all aspects, marking the highest flood ever occurred in the PRB.

Table.3: Flood frequency, flood duration, human and cattle loss in the Puthimari River Basin of Assam from 1976 to 2007

Year	No. of Human Lives Loss	No. of Cattle Loss	No. of Flood Waves	Flood Duration in Days
1976	-	116	3	15
1982	5	-	NA	NA
1986	-	-	3	3
1987	-	22	5	15
1988	5	374	3	NA
1989	-	3	NA	NA
1990	-	18	NA	NA
1991	4	238	7	19
1993	4	324	NA	NA
1995	-	11	NA	NA
1996	-	6	NA	NA
1997	1	-	NA	NA
1998	1	27	NA	NA

1999	-	-	4	10
2000	2	47	7	17
2002	2	-	5	25
2003	-	-	3	35
2004	22	842	NA	NA
2007	10	-	NA	NA

Source: C.W.C. Guwahati. Note: N A–Data Not Available

8. Conclusion

The magnitude of flood varies from year to year and one perception to another. The flood magnitude has the variation from hydrological viewpoint to socio-economic perspectives. The flood of 2004 has been seen to be the 1st from hazard view point. But the flood of 1988 has been found the highest flood from hydrological perspective ever occurred in the PRB.

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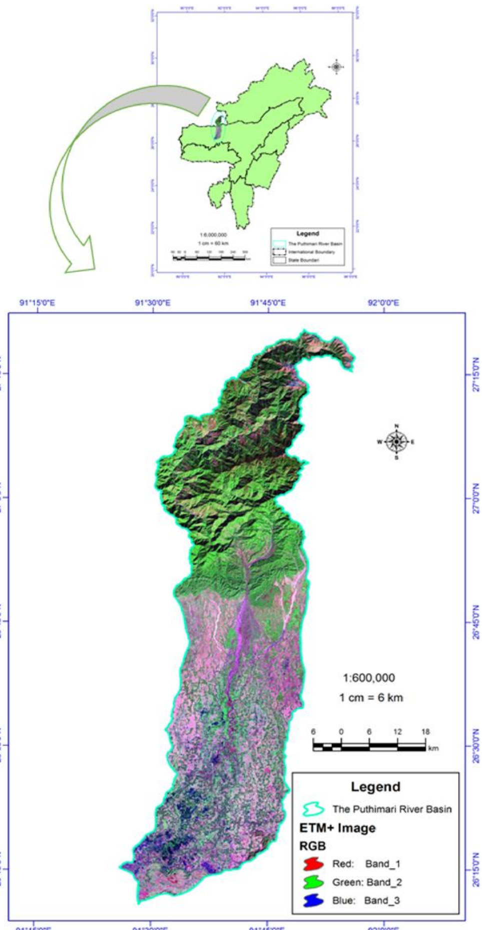

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