Chapter 8

Problem of Flood and Inundation Mapping

8.1 Introduction

Flooding can be defined as the process of inundation of an area by unexpected or sudden rise of water due to snowmelt, extreme rainfall intensity in the upper reaches as well as in the lower reaches of a basin or due to dam failure in which life and property in the affected area are under risk (Nyarko, 2000). India is among the most disaster-prone countries in the world. Floods are the most widespread, recurring natural calamity in India causing large scale devastation to life and property. About 46 million hectares of land of the country are prone to flood hazard of which the geographical area accounts for some 14% and cultivable area accounts for 25% of total land (ADB Report, 2009). However in the last two decades the flood behavior has changed and extreme flood events in the country have been noticed that can be attributed to anthropogenic activities in the river basin (Bishaw, 2012). The major factors responsible for flooding in India are: prolonged heavy monsoonal showers, river bed aggradation due to silting and damming of rivers, avulsion and channel shift, back flooding and seawater flooding, reduction in the water carrying capacity of the rivers due to constructions along and within the river channels and flood plains and failure of natural and man-made dams (Kale, 2004). Floodplains are areas situated adjacent to rivers and streams that suffer to recurring floods. Leopold et.al (1964) defined floodplain as “a strip of relatively smooth land bordering a stream and overflowed at the time of high flood” (Gogoi et.al, 2013). The distribution of the amount of heavy and intense rainfall determines the occurrence and distribution of flood in an area. During the monsoons the heavy to very heavy rainfall are associated with cyclonic storms and depression, orographic lifting of monsoon winds along mountain barriers and breaks in monsoon (Ramaswamy, 1987). The cyclonic disturbances produce heavy rainfall over the plains of the Ganga basin and the Punjab plains. The break in monsoon is a special situation wherein the axis of the seasonal monsoon trough which shifts from its normal position and lies close to the foothills of Himalaya. This situation causes heavy rainfall in all the major river basins and their tributaries in the northeast, central Himalaya and its adjoining areas. These areas experience rise in flood and bring along them huge quantities of silt and deposit them on the river beds as well as floodplains. The breaks generally occur during July and August and persist for a week or so (Dhar et.al, 2006). The orography of the country also plays a major role in causing heavy rainfall on the hilly slopes. The Mishimi hills, Abor Hills and the Dafla hills in the Himalayan region of Arunachal Pradesh and Khasi-Jaintia Hills in Meghalya causes the moisture laden monsoonal winds to shed their moisture on the hilly terrain (Dhar et.al, 2006).

Avulsion, channel migration and natural changes in the elevation of river bed channels due to excessive siltation are some of the underlying causes that enhance the spatial dimension and the effect of floods, particularly in the Brahmaputra and the Ganga River Basins (Goswami, 1985; Sarma and Basummalick, 1984). Sometimes major changes in channel morphology and its water carrying capacity are related to seismic related slope failures. Such changes have been reported after the earthquake of 1897 and 1950 in Assam (Goswami, 1998). Besides the meteorological and basin morphology factors man-made factors which include indiscriminate destruction of forest cover in the river basins over for a long period of time, improper agricultural practices like jhum in the upper reaches, obstruction to free flow of water as a result of construction of embankments, bunds along the river banks and narrow bridge openings are some of the factors that have aggravated the flood scenario in the country.

The Brahmaputra Valley in Assam is among the most acutely hazard-prone regions of the country having more than 40% of its land i.e about 3.2 million hectares susceptible to flood damage. This makes 9.4% of the country‘s total flood-prone area. The erosion hazard is also extremely severe in several vulnerable reaches. About 7% of land in the state‘s 17 riverine districts has been lost because of river erosion over the past 50 years. Flood is the major cause of loss of life .and property in Assam. Floods of devastating nature threaten the existence of flood management structures by severe erosion. Surface runoff of extremely heavy rainfall during the monsoon and high sediment loads from upper watersheds that are geologically unstable and degraded because of deforestation and changing land use are the main causes of floods are in the valley.

The river Dhansiri and its tributaries play an important role in controlling the hydrological phenomenon of the Golaghat district and few parts along the foothills of the Karbi Anglong district. Flood occurring in the middle and lower reaches of the basin is characterized by their extremely large magnitude, high frequency and extensive devastation. The problem is more pronounced in the downstream of NH-37 crossing at Numaligarh. Floods of extreme high magnitude occurred in the sub basin in the years 1954, 1955, 1959, 1960, 1970, 1976, 1986, 1987, 1988, 1989 and 1991. A study conducted by Dhar and coworkers (1966, 1975, 1981, 1986, 1992, 1993a, 1994, 1998, 2002) found that during the span of sixteen years from 1986 to 2001 the river Dhansiri recorded 21 and 157 flood events at gauging sites Golaghat and Numaligarh respectively. Out of these 3 and 47 flood events at gauging sites Golaghat and

Numaligarh respectively were > or = 2m above the danger level and thus can be termed as major flood events.

The river during its course passes through a hilly terrain in the upper catchment. It causes flood only in the foot hill areas of Kohima district, around Dimapur town and the period of inundation is only a day or two at the most. As the river enters Assam as such no major inundation problem occurs upto Bokajan. The problem of flooding becomes more complicated only in the lower reaches which include Sarupathar, Golaghat, Khoomtai and Bokakhat circles.

Some of the relevant benchmark information of the basin in relation to flood is:

- Area of the flood plains in the basin: 2368 sqkm
- Revenue Circles in the flood plain and no. of villages under each of the revenue circle affected by flood:
    - ➢ Khoomtai circle: 17 nos.
    - ➢ Golaghat: 32 nos.
    - ➢ Sarupathar: 44 nos.
    - ➢ Bokakhat: 25 nos.
- Extent and Duration of inundation in the affected villages: Average duration of inundation from 14 to 41 days and extent of flooding varies from 5736 ha to 9059 ha
- Agricultural areas in the flood plain: 117100 ha
- Under Bokakhat circle flood inundation in Kurubahi area will carry a special mention as the world famous Kaziranga National Park is very adjacent to the affected area

The Kaziranga National Park is subjected to inundation and erosion from the Brahmaputra River as well as major local tributaries, such as the Dhansiri River. Currently, breach of the existing embankments or bank overtopping is one of the reasons for high flood hazard. The Dhansiri River joins the Brahmaputra upstream of the Kaziranga National Park (KNP). The KNP's unique wildlife of the park normally leaves the plains during the monsoon (due to their inundation from Brahmaputra flood water and local rainfalls) and moves into the southern hills through a depression running parallel to the national highways. However, a breach in the existing Brahmaputra embankment (upstream of the KNP) causes deep flooding in this natural depression cutting the animals off from the safer highlands. Also, longer term flow through the plain could lead to the formation of a channel of Brahmaputra River, cutting off the wildlife permanently from the plain land.

8.2 Causes of Flooding

The river basin is located within the monsoonal regime which brings heavy rainfall during the rainy summer season. The monthly rainfall data collected from three locations of the basin reveal that the basin receives heavy amount of rainfall during the months of July and August. The average annual monsoon rainfall is 1152.8 mm. The monthly total rainfall data from 2001-2010 and yearly extreme value of rainfall has been collected for three rainfall recording stations namely Golaghat, Bokajan and Kheronighat from Indian Meteorological Department, Guwahati center and presented graphically below in fig.8.1, fig. 8.2 and fig.8.3 respectively. The rainfall data shows that highest rainfall occurs during the months from May to August and during these months, the monthly total rainfall varies between 300mm to 500mm

During the monsoons, overtopping of rivers banks and embankments by flood water affect the low lying areas along the sides of banks of the rivers, outside natural levees and embankments. The situation further deteriorates as a result of water logging in many places due to the presence of rain waters accumulating in the flood plain which fail to drain into the river. The areas along the river bank remains inundated for several weeks or even months after recession of flood waves.

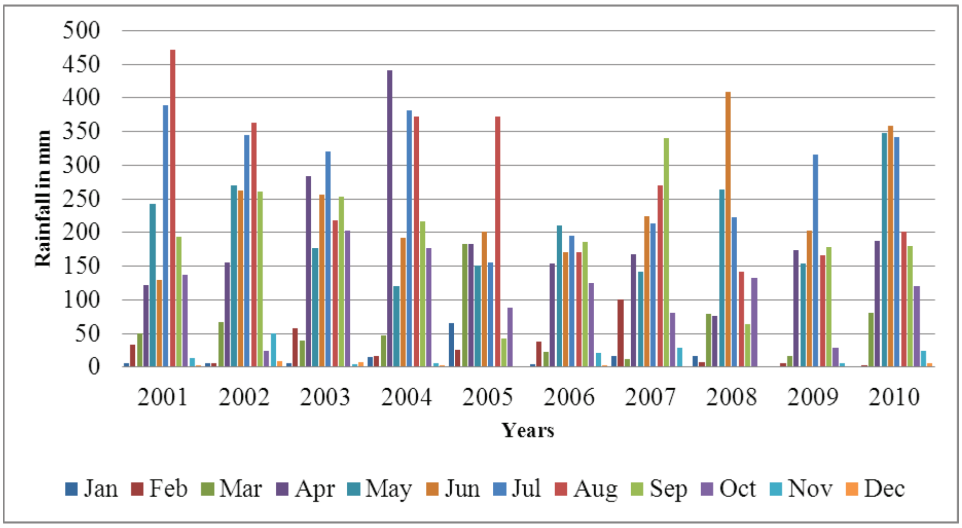

Figure 8.1: Monthly Total Rainfall for Golaghat during 2001-2010

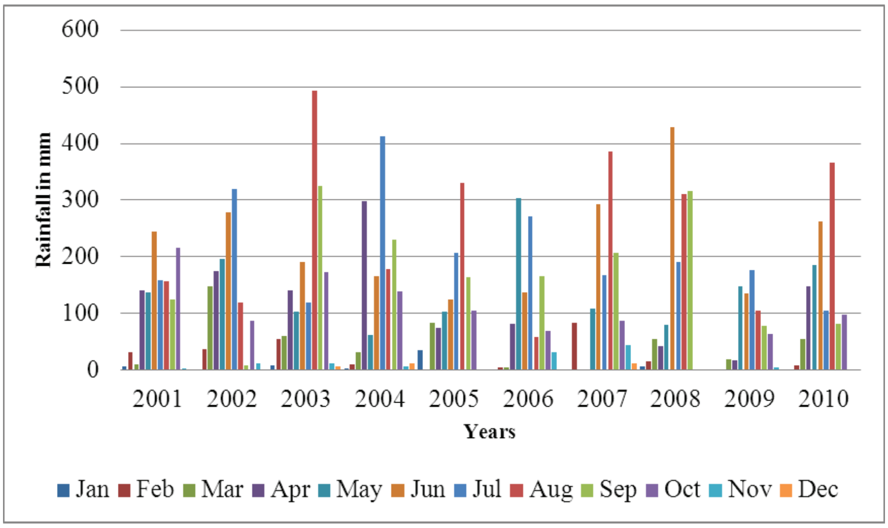

Figure 8.2: Monthly Total Rainfall for Bokajan during 2001-2010

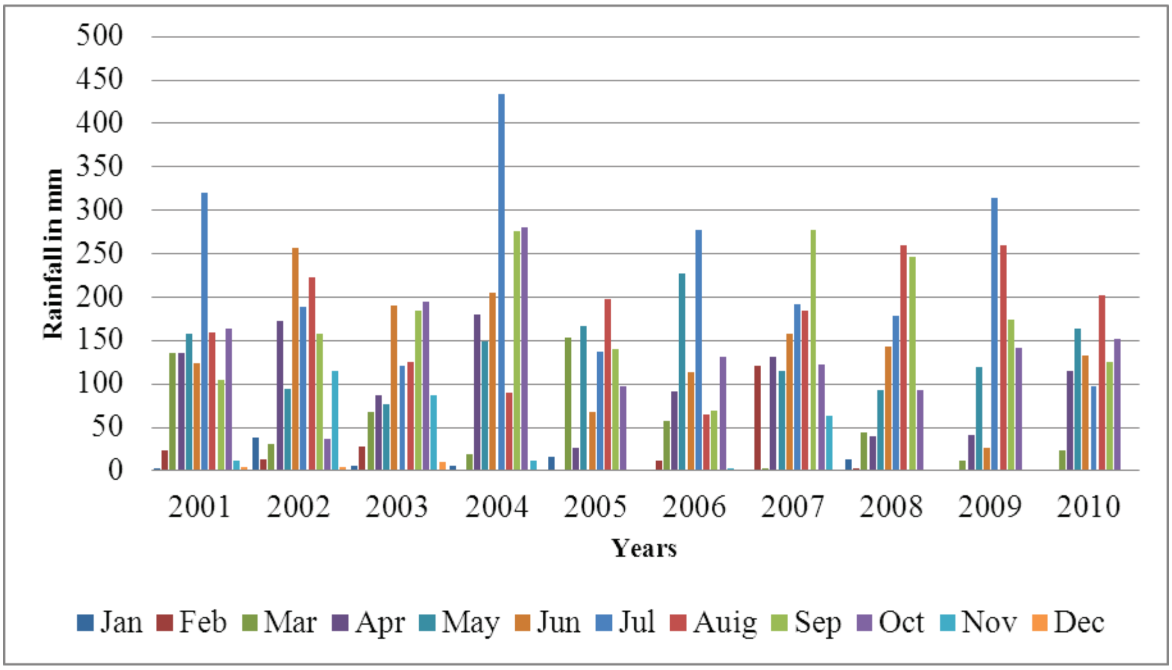

Figure 8.3: Monthly Total Rainfall for Kheronighat during 2001-2010

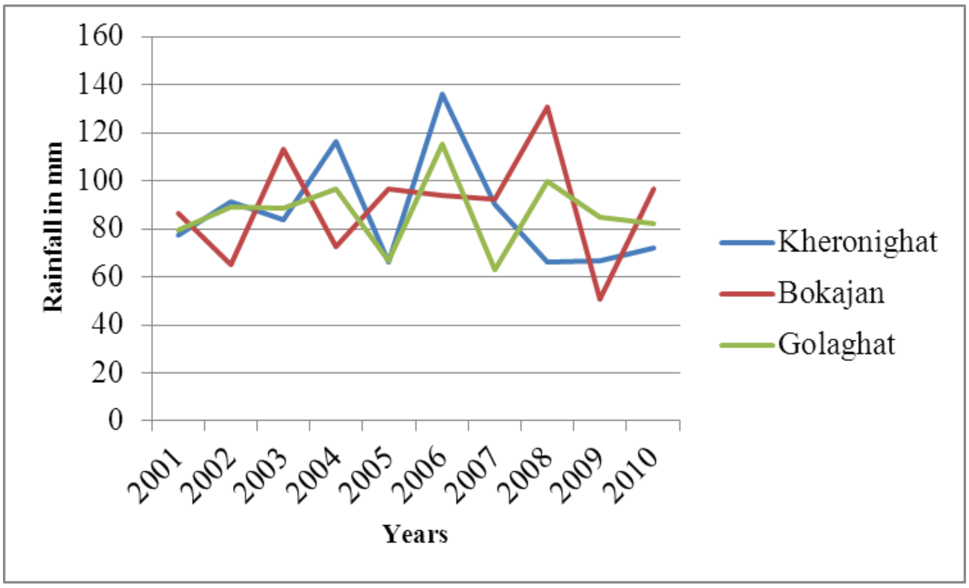

Figure 8.4: Graph showing the yearly extreme values of rainfall during 2001-2010

From the graph it is observed that highest rainfall occurred during 2004 within the span of 10 years. Apart from the meteorological factor the river morphology is also responsible for causing flood in the area. The river Dhansiri is intensely meandering river channel resulting in the bankline migration and bank erosion. This results in deposition of silts in the river bed which ultimately causes aggradation of the river bed thus resulting in the overtopping of banks and flooding in the adjoining area. Floods of very high magnitude in turn may contribute to channel widening and river bank erosion which is associated with changes in the channel pattern (Schumm et.al, 1963).Another reason that can be attributed to flooding in the study area is the unscientific agricultural practice of jhum cultivation in the upper reaches of the river basin. This practice leads to large scale destruction of forest cover which causes erosion. Erosion brings silts with the rains which then get deposited in the river bed thereby raising its level. This causes overtopping of banks with flood waters. Moreover the exposed land surface will increase surface runoff leading to flood events in the lower reaches. Breaching of embankments along the river also causes floods in the area mainly near its mouth containing the Kaziranga reach.

8.3 Flood Frequency Analysis

The magnitude and frequency of meteorological floods can be estimated. River basin planning studies and the design of bridges and road networks rely upon flood frequency analyses. Fundamentally the goal of flood frequency analysis is to determine or at least estimate the probability that various discharge levels will be exceeded in the future. Hydrologic designs commonly employ estimates of the discharge exceeded with a 1 percent probability. The flood discharge exceeded in any year with a probability of 1 percent is called the 100-year flood. In general, if a flood discharge is exceeded with a probability p, then on average that discharge level will be exceeded once every T=1/p year. T is called the recurrence interval or return period of the flood (Bloom, 1992)

Frequency analysis is one of the important tools to interpret the past records of hydrological events such as discharge, flood level, etc. in order to evaluate future probabilities of such occurrences For the Dhansiri (south) river basin High Flood Level data series from site Numaligarh is collected for the period 1982 to 2005 .The best suitable statistical distributions for flood frequency analysis for High Flood Level data series is Log-Pearson Type III method. In this method the variate is first transformed into lograthmic form and the transformed data is then analysed (Subramanya, 2005). In the present study the variate in the high flood level data (X).The calculations of the flood frequency analysis are presented in Appendix 5. Using the above mentioned method design flood level for return periods 2, 10, 25, 50 and 100 at gauge site Numaligarh have been calculated out and presented in the table 8.1.

Result of the flood frequency analysis using Log Pearson Type III method

The Log-Pearson Type III Equation for calculating design HFL for any return period is given by

$Y_t = \ddot{Y} + K_y * \sigma_y$ Where, Y= Log X

$\sigma y = \sqrt{\sum(Y-\ddot{Y})^2/N-1}$

Cs= Coefficient of skew of variate Y = $N\sum(Y-\ddot{Y})^3/(N-1)(N-2)(\sigma y)^2$

$\ddot{Y}=\sum Y/N$ (mean of Y values)

N= sample size= number of years of record

K y= f (Cs ,T), a frequency factor which is a function of T and C_s

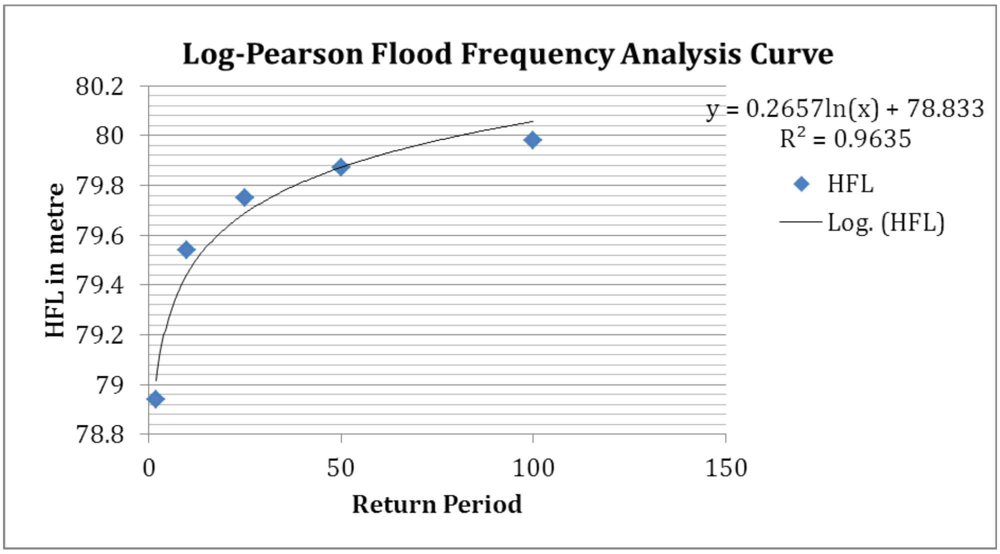

Fig 8.5: Flood Frequency Analysis Curve

Table 8.1: Return period and corresponding water level of the river Dhansiri

Return period	Water Level in metre
2	78.94
10	79.54
25	79.75
50	79.87
100	79.98

From the flood frequency analysis it is revealed that the lowest intensity of rainfall occurs almost every year in the study area and the frequency of highest intensity flood is 100 years. Thus flood in the river basin is an annually recurring event which causes heavy loss of life and property disrupting the socio-economic environment of the basin. A graphical representation of loss has been presented in the figures below:

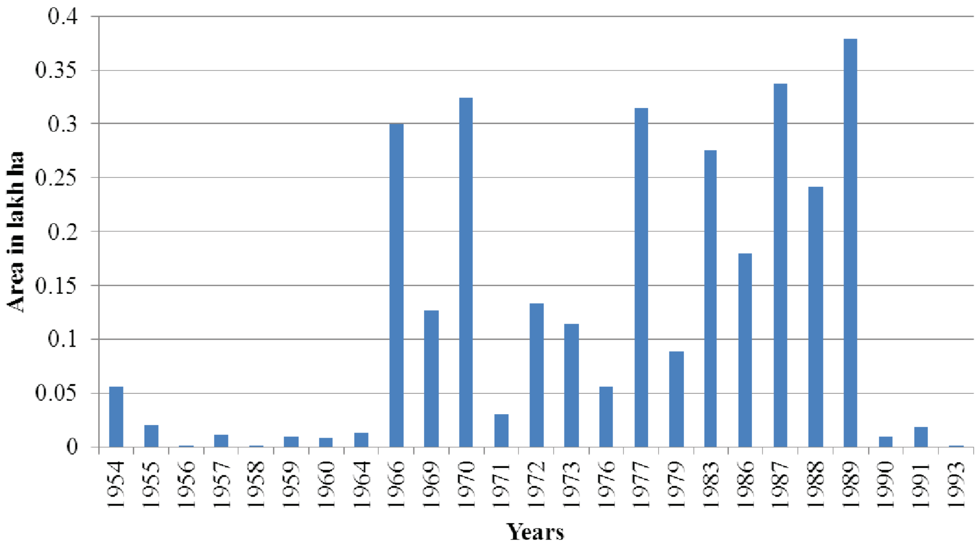

Fig. 8.6: Graph showing cropped area in lakh hectare damaged by flood for the period 1954-1993

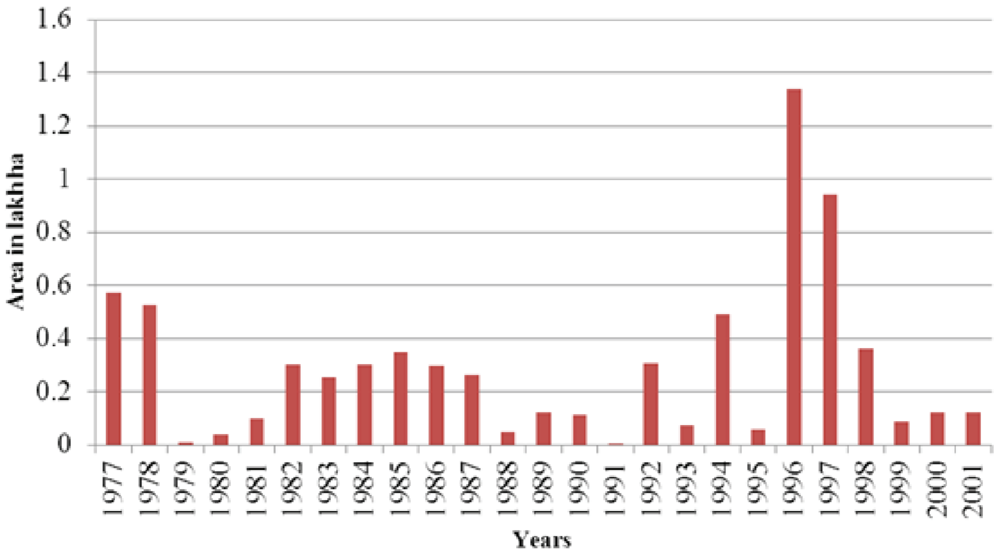

Fig. 8.7: Graph Showing Total Area in lakh hectare Damaged by Flood for the period 1977 -2001

8.4 Flood Inundation Mapping

Flood inundation mapping showing the risk zone of a river basin is a crucial management approach to regulate landuse to limit the damages in frequently flooded areas. The flood frequency analysis has revealed that the recurrence interval of flood of lowest intensity is less than 1.5 years. Thus the river basin is frequently flooded with the onset of monsoonal season.

A flood inundation map no.1 showing the spatial extent of flooding in the area is prepared in GIS. The inundated areas are delineated from the annual flood layer of 1999 and 2001 downloaded from the website of Bhuvan and flood inundation maps for years 2004 and 2007 available in the Dartmount Flood Observatory website (DFO,2006) in ArcGIS 9.2. DFO releases World Atlas of Flood Hazard that illustrates river floods observed by MODIS, LANDSAT 7, RADARSAT, NOAA-AVHRR (Advanced Very High Resolution Radiometer) and other satellites since 1985 (Prasad et.al., 2006).These maps were available through the Dartmouth University website. The 2004 flood layer showing the inundation extent is considered to be the biggest recorded flood event in the history of the state (Goswami, 2008). All the 27 district of the state have been affected by this flood and the total damage was estimated at Rs.6500 crore (Goswami, 2008). It is also observed from the graph in figure 8.4. An inundation map no.2 showing the spatial extent of inundation of 25 year return flood has been used as a reference for zonation of the inundation map no.1. Based on the spatial extent of 25 year return flood, and pattern of inundation of various years the chronically inundated areas have been identified. The rest of flood plain between the chronically inundated and near foot hills has been termed as occasional and the areas occupied by the hilly terrains have been marked as inundation free zone. The area under the different risk zones is graphically presented in figure 8.1 and table 8.2

Table 8.2: Area under different inundation risk zones

Risk Zones	Area in sq.km
Chronically Inundated	687.7505
Occassionall Inundated	1695.907
Inundation Free Zone	2141

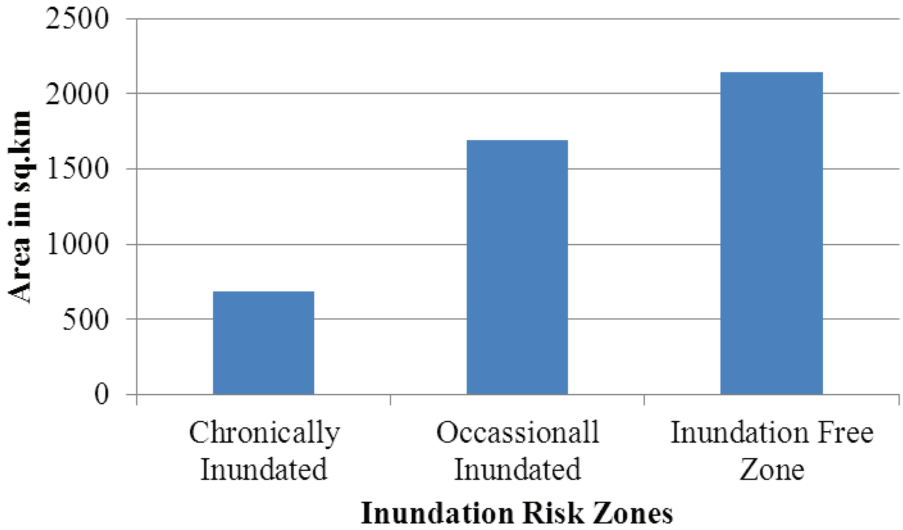

Figure 8.8: Graph showing the area under different inundation risk zones

From the inundation map (Fig 8.9) it is observed that Golaghat district is mostly affected by the annual flood of the Dhansiri River. The area under chronic inundation has been found to be 687.75 sq.km. On the Flood Inundation map the revenue village map of Golaghat district is overlaid and the villages falling under the chronically flooded area is found out. From the overlay analysis it is found that 276 nos. villages of Golaghat district are chronically affected by flooding. The list of the villages falling under the chronically inundated zone in presented in Appendix 6. The occasionally inundated areas are those around the foot hills and the inundation free zone is the hilly region in the basin. The area under the occasionally inundated and inundation free zone are 1695.9 sq.km and 2141 sq.km respectively. The total area that undergoes flooding in the Kaziranga National Park is 378 sq.km.

Data on flood damage caused due to flooding in the Golaghat district is collected from the revenue circle office and is presented in table 8.3 for the period from 2004-2012.

Table 8.3 Damage caused by Flood in Golaghat District during 2004-2012

	2004-2005	**2007-2008**	**2011-2012**
No. of Villages	101 nos.	132 nos.	206 nos.
No. of affected people	10259 nos.	86696 nos.	70294 nos.
Total agricultural area affected	42763 ha	10322 ha	1 lakh 211 ha
Total cropped area damaged	4405 ha	240.95 ha	50,000 ha

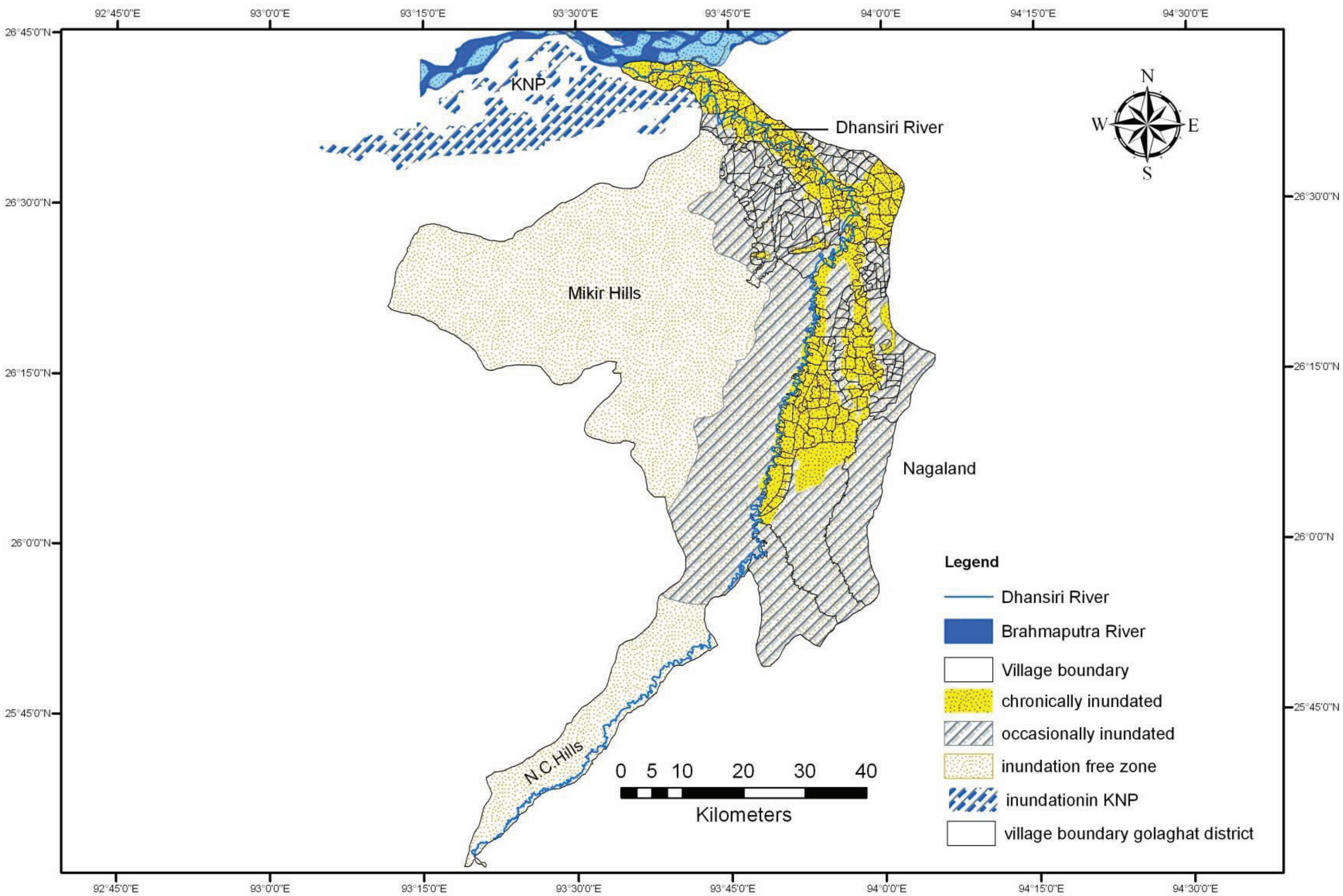

Fig 8.9: Flood Inundation Map of Dhansiri (South) River Basin