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Yield of Water Discharge and Rainfall Seasonality in and around Barnadi River Basin, Assam: India

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Abstract:

Water which is one of the basic resources on the earth acts as the means of sustenance and factor of development of all living organisms in the biosphere. Such a kind of elixir of life occurs in the surface, underground and atmosphere. The drainage basin being a source of water resource base provides availability and scope for easy supply of water for various uses. The yield of surface water in terms of water discharge caused by rainfall within a drainage basin plays an important role in the sustainable planning and management. A proper assessment and evaluation of these two surface water bases shall lead one to better understand the yield, frequency variation, seasonality and dependence as well amount of rainfall as the causal factors of these resources on one hand and budget of the water discharge on the other. The present paper attempts to evaluate the status of seasonal yield, dependence and variability of water discharge as well as rainfall in and around Barnadi River basin located in the middle part of the northern bank of Brahmaputra River in Assam. The analysis of this paper reveals that the seasonal yield of peak discharges of Barnadi river for the period of 1991-2010 are that 352.14 cumecs in autumn, 1157.92 in pre-monsoon, 2811.95 in monsoon and 870.84 cumecs in post- monsoon seasons. The frequency variation of rainfall particularly during monsoon season in the duration of 1978 – 2003 indicates a negative trend amounting 1439.42 mm and 1258.38 mm in 1978 and 2003.

Key words: Seasonality, dependence, surface water, peak water discharge.

Introduction:

The hydrographs of extreme floods and stages corresponding to flood peaks provide valuable data base for the purpose of hydrologic analysis and design. At a given location in a stream, flood peaks vary from year to year and their magnitudes constitute a hydrologic series which enables one to assign a frequency of a given flood-peak value. The floods in a catchment depend upon the characteristics of the catchment, rainfall and antecedent conditions, each one of these factors being in turn dependent on a host of constituent parameters. The spatial distribution pattern and yield of rainfall also determine the yield of water discharge in any river. An accurate assessment of spatial pattern of rainfall received in a catchment is important for rainfall as well as runoff modeling [1]. The spatial variability of rainfall increases with the decreasing rainfall. The low degree of rainfall variability indicates the high dependability of rainfall contributing the maximum possibility of water discharge in a river. As an important aspect of rainfall, rainfall variability is a measure of its dependability for different uses[2]. On the other hand, the overall deviation of the mean monthly rainfall values from the mean value of all the months of the year represents the seasonality which helps in identifying the rainfall regimes (Kanellopoulou, 2002). In general, Hydrographs for water discharge and Rainfall Seasonality Index of any area facilitates in understanding the frequency of flood events of given magnitudes and its relation to the nature of rainfall seasonality for a given location and time interval. This investigation will be useful for estimating the seasonal dependability of rainfall amount and the frequency variation of water discharge. The present study may provide the bases of understanding the

yield, frequency variation, seasonality and dependence as well amount of rainfall as the causal factors of the water discharge of the Barnadi river basin, Assam.

The Study Area:

The Barnadi River basin, mastered by the river Barnadi, is one of the major northern tributary river basins of the Brahmaputra. The Barnadi and its tributaries namely, the Kalpani, Dimila, Ranganoi etc. along with some wetlands like Ken, Dipling, Bodiasisha etc. cover the part of the present Udalguri and Darrang districts in the east and a northern part of the Baska and Rural Kamrup districts in the west of the river. The Barnadi river system is an important northern tributary river system of the Brahmaputra representing the district boundary of the old Darrang and old Kamrup of Assam (Fig 1). This tributary river of Brahmaputra originates from "Ranga Noi Stream" on the northern foothills of the Bhutan Himalaya at an altitude of 550 m above the mean sea level and flowing for about 205 km from north to south meets the Brahmaputra at the place "Rohinimukh" near North Guwahati. The basin of the river covers an area of 680.97 square km between $26^0 14' 30''$ N to $26^0 49'$ N latitudes and $91^0 44' 40''$ E to $91^0 53' 15''$ E longitudes. The basin covers the seven different parts of C.D. Blocks of the old Darrang and old Kamrup districts of Assam, namely the Bhergaon, Khoirabari, Kalaigaon and Sipajhar C.D. blocks in Darrang and Goreswar, Bihdiya – Jajikona and Bezera C.D. block in Kamrup districts.

Methodology and Database:

The study is designed to proceed with hydro geomorphic approaches based on quantitative data. The data have been collected mainly from secondary sources, viz, (i) Survey of India (SOI) toposheets for the year 1971 (Scale-1:50,000 & No. 78

N/10 N/11, N/13, N/14,N/1 and N/16), (ii) Administrative Atlas Map of Assam,2001(Census of India), (iii) Discharge data are collected from Water Resource Department, Govt. of Assam (iv) Rainfall data for one ordinary meteorological gauge site within the basin and other sites outside the basin are collected from relevant gauge sites and internet websites. Two sets of hydrologic data – one set of annual peak discharge data for 1979 to 2008 and the other of peak stage data for 2000 to 2008 of the river at N.T. Road crossing site have been used for the preparation of hydrographs. In the same way, two sets of rainfall data – one set for Bhergaon Tea Estate for the duration w.e.f. 1978 to 2004 is used to show the seasonality index and seasonal distribution of rainfall and the other set represents the Annual Rainfall data of the important rain gauge sites in and around Barnadi River basin are collected to show the rainfall variability.

Objectives:

The main objectives of the study are-

(1) to examine the pattern of fluctuations of discharges represented by the hydrographs for Barnadi river
(2) to identify the inclusive rainfall regime of Barnadi river basin based on Seasonality Index.
(3) to highlight the seasonal yield & variability of rainfall in and around Barnadi River basin.

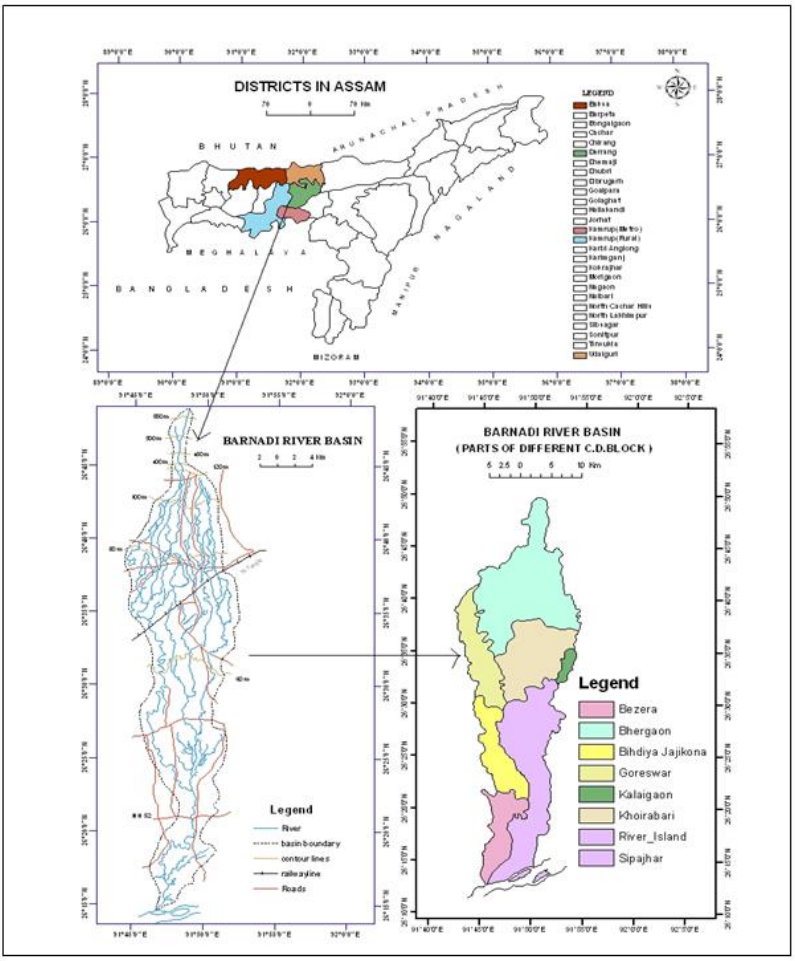

Fig. 1: Location of Barnadi River basin in Assam

Water Discharge Observation:

Hydrograph Study:

A Hydrograph is the graphical representation of different hydrological variables having the spatio-temporal dimension in case of a river or stream. Water discharge and its stages among many others high lights the spatio-temporal dimension. The basic aim of preparing different hydrographs is to study mainly

the temporal variations of different variables within the river as well as the basin at certain location, which ultimately provides the key knowledge of water potentiality of a stream, water storing capacity of reservoir and drought conditions. The study of peak discharge hydrograph has been found essential for analyzing river characteristics associated with floods embracing their locational and temporal distribution patterns [2].

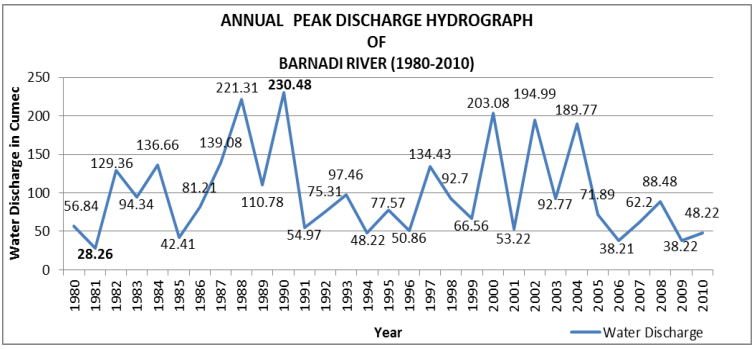

Fig 2: Peak Discharge Hydrograph of Barnadi River (1980-2008) for N.T. road crossing site

The figure 2 highlights the nature of fluctuation of annual peak discharges during the period of twenty nine years (1980-2010). The nature of fluctuation from the lowest peak discharge value of 28.26 m^3/s in 1981 to the highest one 230.48 m^3/s in 1990. The distribution shows a decreasing trend even as the peak floods are quite distinctly and highly variable. The general tendency of decreasing peak discharge through time has reflected the decreasing trend of water supply along the channel of rainfall as observed. Another possibility is that water flowing previously at high discharge level along the river might have been diverted in the areas above N.T. road crossing site because of the initiation of new channels from the master stream or breach of the embankment of the river.

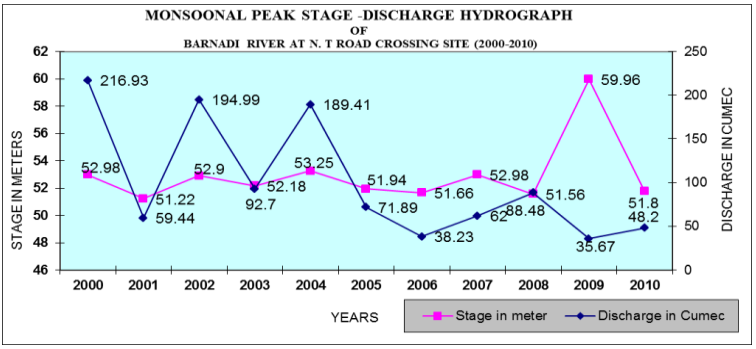

Fig. 3: Monsoonal Peak Stage Discharge Hydrograph of Barnadi River, 2000-2010

The figure 3 representing the maximum annual water levels (stage) during monsoon periods in different years from 2000 to 2010 have also signifies a general tendency of decreasing water supply along the Barnadi. The nature of fluctuation from the lowest peak discharge value of 48.20 m^3/s in 2010 to the highest one 216.9 m^3/s in 2000. The hydrograph drawn for maximum annual discharge for the same period has quite clearly reflected the same feature of water supply even as the stage hydrograph shows high rise during high peak flood in 2010. Both the figures above assist for better understanding about the future trend of stage and discharge of Barnadi River.

Rainfall:

Seasonal Yield:

Rainfall is an important driver in deciding the climate related events over any region on the earth. Pattern of rainfall is a complex phenomenon and is important to understand & interpret its variation over periods of time[3]. The Seasonal yield of rainfall for this entire Barnadi River Basin is analysed based on the collected rainfall data of Bhergaon Rain gauge Station for different seasons of different years. The analysis is done for the time period 1978 to 2003 with five years interval. The six numbers of bar diagram in the figure 4 highlight that maximum rainfall in the area is experienced during monsoonal

season (June – Sept) though the frequency varies temporally. These six numbers of bar diagram represents the seasonal variation of the rainfall received in the said rain gauge site for the sampled years 1978, 1983, 1988, 1993, 1998 and 2003. During the months of Dec-Feb (Autumn), maximum amount of rainfall is experienced in the year 1993 (228.25mm) but no rainfall during this season experienced in the year 1978.. In case of pre-monsoon season (Mar-May), maximum rainfall received in the year 1988 (755.25 mm) compared to the minimum amount experienced in 1978 (313.44 mm). The monsoonal season (June-Sept) shows a high fluctuation of rainfall amount which is indicated earlier. During post-monsoon season (Oct-Nov), the highest rainfall amount is received in the year 1993 (175.75 mm).

Seasonality Index:

S.I helps in identifying the rainfall regimes based on the monthly distribution of rainfall. In order to define the seasonal contrasts, the S.I. (Walsh and Lawer 1981: Kanellopoulou, 2002), which is a function of mean monthly and annual rainfall, is computed using the formula stated below. The basic assumption in the evaluation of the index is that rainfall is uniformly distributed throughout the year. The overall deviation of the mean monthly rainfall values from the mean value of all the months of the year represents the seasonality (Kanellopoulou, 2002) [4]. The mathematical form of the index is given by

$$\mathbf{SI} = \frac{1}{\bar{R}} \sum_{n=1}^{12} \left| X_n - \frac{\bar{R}}{12} \right|$$

Where, **S.I.** = Seasonality Index, X_n = Monthly Average rainfall, $\bar{R}$ = Average Annual rainfall of the station.

YIELD OF AVERAGE SEASONAL RAINFALL AT BHERGAON RAINGAUGE STATION OF BARNADI RIVER BASIN, ASSAM
(1978, 1983, 1988, 19993, 1998 & 2003)

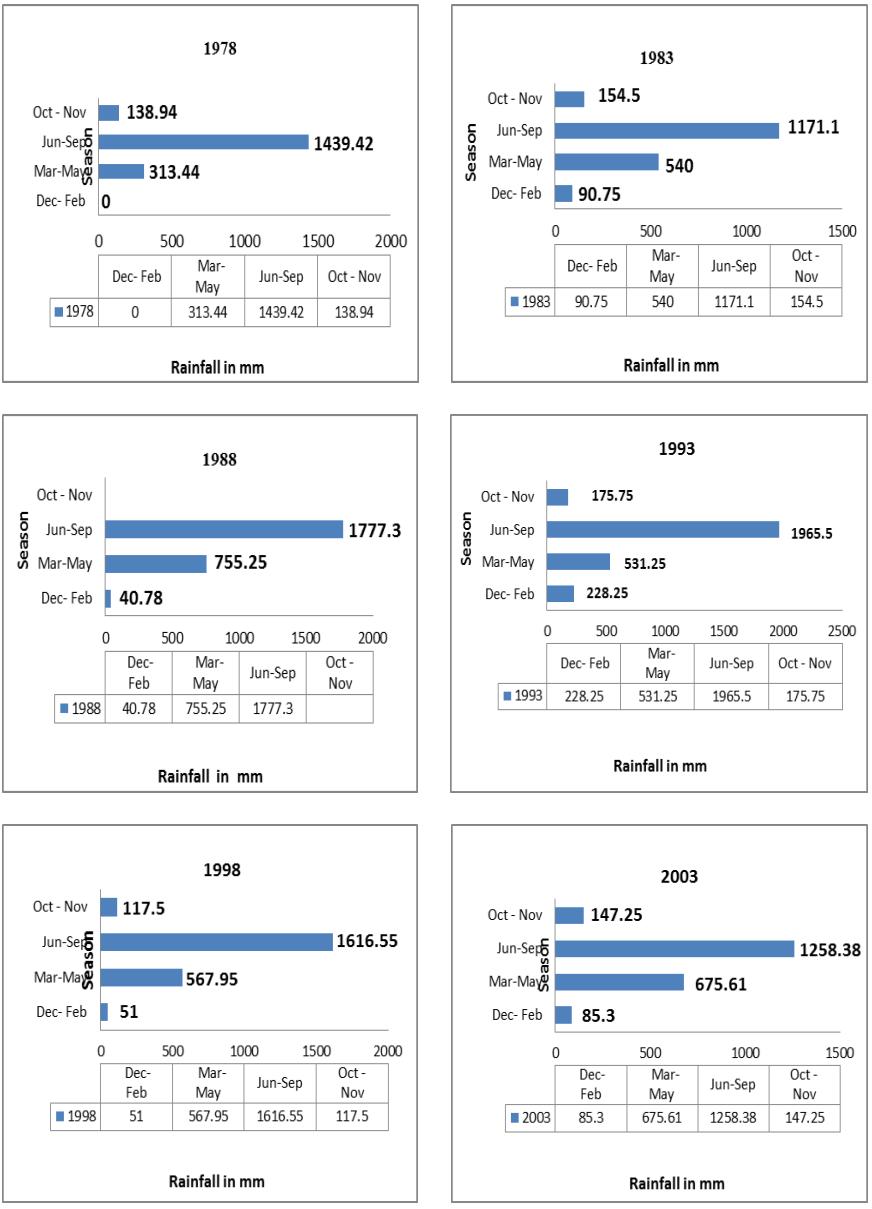

Fig. 4: Frequency Variation of Average Seasonal Rainfall Experienced at Bhergaon Tea Estate within Barnadi River Basin, (1978- 2003)

Theoretically, the S.I value can vary from zero (if the months have equal rainfall) to 1.83 (if all the rainfall occurs in one month). The table 1 shows the different class limits of S.I and representative rainfall regimes (Kanellopoulou, 2002). Though the method uses the distribution of rainfall for all the 12 months, the index as table shows identifies the seasonal pattern when the value is more than 0.6. The rainfall records of Bhergaon Rain gauge Station w.e.f.1978 to 2004 have been collected to compute the seasonality index value of Barnadi River basin. For this study, rainfall statistics of 1 meteorological centre, i.e. Bhergaon Tea Estate Rain gauge site, Udalguri, Assam, located in the basin has been collected for the last 23 years (1978-2004). The computed average S.I. value of the said rain gauge station is 0.85. As seen from the table 1 the average Seasonality Index (S. I.) in the site within the Barnadi River Basin is 85 percent. On the basis of this average Seasonality Index (S. I.) for the 23 years of the site, the adjacent area of this rain gauge site may be categorized under the fifth rainfall regime i.e. markedly seasonal with a long dry season as indicated by Kennellopoulou, 2002 (Table 1). The individual values for different years represent different indication of rainfall regime.

Table 1: Annual S.I. values, S.I. Classes & Rainfall Regime of Bhergaon Raingauge Station within Barnadi River Basin (1978-2004)

Year	Average Annual Rainfall in mm	Seasonality Index (SI) Values	Year	Average Annual Rainfall in mm	Seasonality Index (SI) Values	Average S.I. (1978 – 2004)	S. I. Classes & Rainfall Regime (after Kennellopoulou, 2002)	
							S. I. Classes	**Rainfall Regimes**
1978	1891.8	0.78	1992	2112.70	0.88	Average = 0.85 Total = 20.51	< 0.19	**Very Equable**
1979	1886.08	0.95	1993	2900.75	0.85			
1980	1955.63	0.87	1994	2027.48	0.77		0.20 – 0.30	**Equable but with definite wetter season**
1981	1703.40	0.85	1995	2560.91	0.83			
1982	1937.5	0.85	1996	1327.65	0.74		0.40 – 0.59	**Rather seasonal with a short drier season**
1983	1956.35	0.74	1997	2436.7	0.96			
1984	2121.5	0.95	1998	2353.00	0.87		0.60 – 0.79	**Seasonal**
1985	1997.95	0.92	1999	**635.22	0.99 (Jun –N)			
1986	1573.5	0.67	2000	*765.25	0.57 (M-M)		0.80 – 0.99	**Markedly Seasonal with a long drier season**
1987	2427.35	0.98	2001	N. A.	N.A.			
1988	2573.33	0.71	2002	2324.21	0.86		1.00 – 1.19	**Most Rain in 3 months or less**
1989	N. A.	N. A.	2003	2166.54	0.78			
1990	2199.72	0.79	2004	***1428	0.58 (J-S)		>1.20	**Extreme almost all**

1991	2404.5	0.77						rain in 1 – 2 months
N.A. - Not Available, * Three Months Total ** Six Months Total *** Nine Months Total								

Rainfall Variability:

Representation of climatic data by isopleths is the most important single cartographic method used by Climatologists. It is difficult to compute the exact degree of rainfall variability of any region. The various statistical formulae have been derived to represent it in the form of a co-efficient of variability. The most common one is C.V. = SD / MEAN (100), Where C. V. = Co-efficient of Variability, S. D. = Standard Deviation and MEAN = Mean Value. Rainfall variability is an important aspect of rainfall, which is a measure of its dependability for different uses [5]. The low degree of variability represents high dependability. Generally C.V. increases with the decrease of rainfall amount. But, the annual figures for co-efficient of variation underestimates the real values and therefore it is necessary to know the distribution of variability of seasonal rainfall. The fig 4 represents the isopleths map showing the nature of rainfall variability of the adjacent regions of Barnadi River taking the rainfall data of some important rain gauge stations in and around Barnadi river namely Majbat, Tangla, Bhergaon Tea estate, Nagrijuli, Hastinapur, Naokata, Rangia and Gauhati. The frequency of C. V. values as indicated in the table 2 highlight that Rangia and Bhergaon Rain gauge stations have comparatively minimum C.V. values (13.45% & 14.37%) indicating Maximum reliability of rainfall. The Tangla and Naokata rain gauge stations indicate the high C.V. values indicating minimum reliability and concentration of rainfall amount. The average C. V values of rainfall for the duration of 102 years (1901-2002) for the bordering districts of Barnadi River namely Darrang and Kamrup are is represented in the table 3.

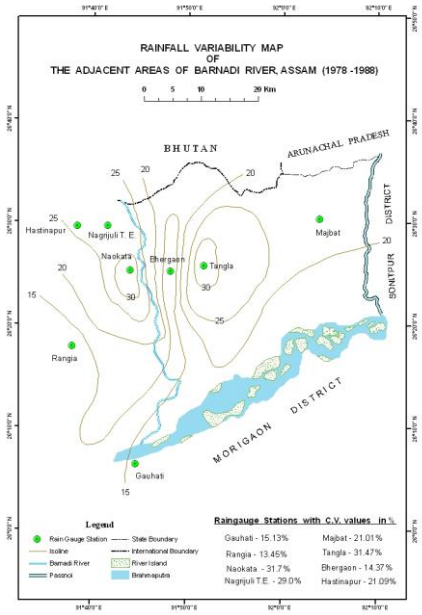

Fig. 4 : Rainfall Variability Map of the Adjacent Areas of Barandi River, Assam (1978-88).

Table 2 : S.D, Average and C.V. values of average annual rainfall of the adjacent rain gauge stations of Barnadi River, Assam

Rain gauge Stations	S.D. of Rainfall (1978-88)	Average Rainfall (1978-88)	C.V. (in %)
Majbat	2645.44	12588.64	21.01
Tangla	3813.73	12118.00	31.47
Bhergaon T.E.	287.82	2002.22	14.37
Nagrijuli T.E.	592.0	2042.3	29.0
Hastinapur	486.95	2309.05	21.09
Naokata	684.27	2157.62	31.71
Rangia	214.87	1597.48	13.45
Guwahati	1622.67	10727.18	15.13
Source : Brahmaputra Board, Govt. of Assam			

Table 3 : S.D. , Average and C.V. values of Average Annual Rainfall of Kamrup & Darrang district, Assam (1901-2002)

DISTRICT	PERIOD	TIME INTERVAL	S.D.	AVERAGE RAINFALL (mm)	C.V. values in %	Average C.V. Value for 102 Years in %
Kamrup	1901-1930	30 years	376.42	3447.19	10.92	13.83 % (1901-2002)
	1931-1960	30 years	408.24	3564.69	11.45	
	1961-1990	30 years	717.55	3499.51	20.50	
	1991-2002	12 years	436.87	3510	12.45	
Darrang	1901-1930	30 years	311.94	2779.76	11.22	12.54 % (1901-2002)
	1931-1960	30 years	328.41	2829.82	11.61	
	1961-1990	30 years	424.74	2813.25	15.10	
	1991-2002	12 years	353.42	2890.52	12.23	

Source : I.M.D Websites.

The average C. V. values of rainfall of the two bordering districts of Barnadi River for the duration of 102 years (1901-2002) are found to be 13.83% for kamrup & 12.54% for Darrang district, representing high reliability of rainfall (Table 3). The Rainfall Variability map of Brahmaputra Valley in Assam (Fig. 5 & Table 4) also highlights the dependability or reliability of rainfall in different rain gauge stations of Brahmaputra Valley for the duration of 30 years w.e.f 1980-2009). The Barnadi river basin lies in the middle part of Gauhati and Tezpur I.M.D. stations and the nature of rainfall variability of this sub basin is represented in the fig.5.

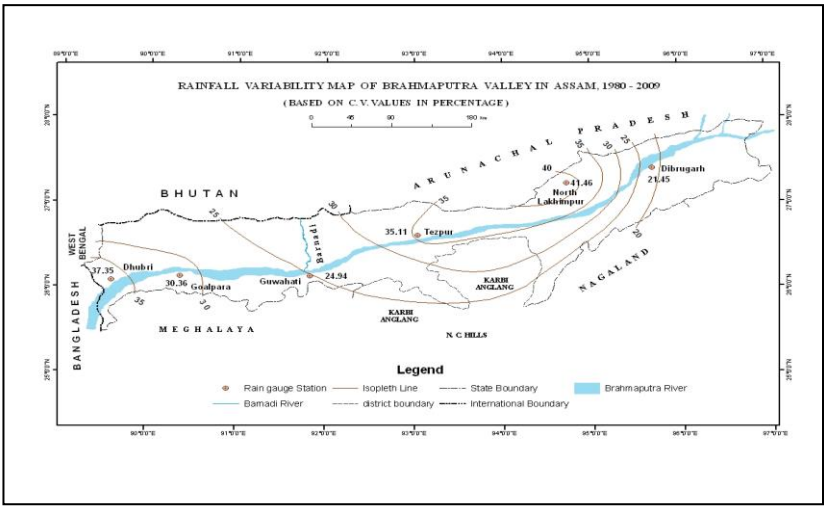

Fig. 5 : Rainfall Variability Map of Brahmaputra Valley, Assam (1980-2009)

Table 4 : Average, S. D. & C. V. values of Rainfall in different rain gauge stations of Brahmaputra valley in Assam (1980-2009)

Rain gauge Site	Duration in years	Interval (in years)	Average Rainfall in mm	S. D.	C. V. in %
Dhubri	1980 - 2009	30 years	1951.23	728.82	37.35
Goalpara	1980 – 2009	30 years	2384.21	723.93	30.36
Gauhati	1980 - 2009	30 years	1626.82	405.73	24.94
Tezpur	1980 - 2009	30 years	1760.45	618.14	35.11
N. Lakhimpur	1980 – 2009	30 years	2384.41	988.47	41.46
Dibrugarh	1980 - 2009	30 years	2181.77	467.89	21.45

Source; Water Resource Department, Govt. of Assam

Conclusion:

The Barnadi River, the natural boundary of old Darrang and Kamrup district has the variation in water level and discharge due to different relevant causes resulting in the variation of flood magnitude. The non availability of adequate data has come in the way for proper analysis of the frequency variation of stage & discharge of this river. The figure 2 & 3 represents the variation of peak discharge for the duration of twenty nine years (1980-2008) and the variation of monsoonal peak stage and discharge for the duration of eleven years (2000-2010). The nature of fluctuation from the lowest peak discharge value of 28.26 m^3/s in 1981 to the highest one 230.48 m^3/s in 1990. Detailed investigations on the nature of the spatial and temporal distribution and fluctuations of the stages and water discharge at various stations in the channels and the basin may be highly helpful to understand the floods and associated problems. Consecutively, the figure 4 highlights the Frequency Variation of Average Seasonal Rainfall with five years interval experienced at Bhergaon rain gauge station within Barnadi River Basin, (1978- 2003). The comparative analysis of seasonal yield of rainfall highlights that during autumn (Dec-Feb), maximum rainfall experienced in the year 1993 (228.25mm). During the Pre-Monsoon (Mar-May) and Monsoon (June-Sept) seasons, yields of maximum rainfall are 755.25 mm (1988) & 1965.5mm (1993) respectively. In the Post-Monsoon season, the

highest yield experienced in the year 1993 (175.75 mm).The Average Seasonality Index value & the associated rainfall regime for the Barnadi River basin has been highlighted in the table 1, based on the available rainfall data of Bhergaon rain gauge station for the duration of 27 years (1978-2004). The computed average S.I. value for 23 years' duration (1978-2004) of the said rain gauge station is 0.85. The fig. 4 and table 2 highlight the nature of rainfall variability of the adjacent areas of Barnadi River in Assam, based on the available rainfall data of equal interval of eight rain gauge stations. The C.V. values of rainfall data of the period of 102 years for the two bordering district of Barnadi River, namely Darrang & Kamrup are 12.54% & 13.83%.as indicated in the table 3. The present study does not end unless various parameters related to the topic are completely analyzed and understood.

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