MODELING ON PROBABILITY ANALYSIS OF FLOOD FREQUENCIES AT BAHADURABAD STATION OF JAMUNA RIVER IN BANGLADESH

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Abstract

The daily average water level and discharge data from 1982 to 2016 at Bahadurabad stations of Jamuna River have collected from Bangladesh Water Development Board (BWDB) to examine the flood probability analysis. Gumbel, Powells, Ven te chow, Stocastic, normal distribution and Log Pearson distribution methods are used to investigate the dynamics of water circulation of the study site. Discharge data were analysed to predict and estimate probability of recurrence intervals for flood frequency by using Gumbel, Powells, Vent e chow and Stocastic probability methods. The results reveal that flood frequency probability vary through recurrence intervals in different scales. The maximum 50% probability is measured in two years return periods and minimum recorded 0.10 % probability in 1000 years return period. After 50 years recurrence intervals water discharge in Jamuna river can be 107740, 102120, 104660, and 13840 (m)3/s respectively Gumbel, Powells, Ven te chow and Stocastic methods. In 100 years recurrence intervals it will rise 116720, 110010, 113420, and 1560 (m) 3/s gradually. For flood frequency analysis Gumbel, Powells, and Ven te chow methods give the most probable maximum flood in the life period of structure. Stochastic method cannot be used for the safe design of a hydraulic structure.

Key words: Floods, Frequency, Probability, Recurrence intervals, Discharge, Jamuna River, Bangladesh.

1. Introduction

Flood frequency analysis is a technique used by hydrologists to forecast stream values consistent to specific return periods or recurrence interval of frequency probabilities along a river. The application of statistical frequency curves to floods was first introduced by Gumbel. Using annual peak flow data that is accessible for a number of years, flood frequency analysis is used to determine statistical evidence such as mean, standard deviation and skewness which is promote used to generate occurrence distribution graphs. Bangladesh is a flood prone country. Total 40% of the country is regularly inundated by the monsoon flood. The large flood, which is known as catastrophic event causes thousands of life and destroying built structures (Alam, 2015).

Through severe floods the affected area may exceed 75% of the country, as was seen in 1998; this volume is 95% of the total annual inflow (Islam, 2012). Assessing, only about 187,000 million m^3 of stream flow is caused by rainfall inside the country throughout the same period (Hofer, 2014). The floods have initiated desolation in Bangladesh during history, mainly during the years 1966, 1987, 1988, 1998, 2004, 2007 and 2016. South Asian floods also precious an enormous portion of Bangladesh in 2007. Bangladesh has an extensive sea coastline, rendering the nation very much at risk of broken well-known damage (Priyangika, 2015). Normally Inundating arises through the monsoon period from June to September.

The convectional rainfall of the monsoon is auxiliary to by respite rainfall initiated by the Himalayas (Ahmed, 1999). Dissolve water from the Himalayas is also a important feedback. Water is obligatory to produce rice, so usual saturating switches the condition of simulated irrigation that is time intense and expensive to figure. Deposited salt on grounds from high degrees of vaporization is detached during floods, checking the land from flattering barren (Brammer, 1990). At the period of 19th century, six leading floods were documented: 1842, 1858, 1871, 1875, 1885 and 1892 (Chowdhury, 2000). On the other hand eighteen key floods happened in the 20th century those of 1987, 1988 and 1951 were of catastrophic significance (Hofer, 1998). Additional current floods embrace 2004, 2007, 2010 and 2016. Catastrophic floods of 1987 arisen during July and August and precious 57,300 km^2 of land and assessed as a once in 30 to 70 years incident (Matin, 1987).

Extremely affected areas were on the western side of the Brahmaputra, this area lower the convergence of the Ganges and the Brahmaputra and substantial areas north of Khulna (Matin *et al*., 1988). In 1988 flood which was also the catastrophic consequence arisen through August and September (Mirza, 1991). This year waters flooded about 82,000 km^2 of land and its recurrence interval was assessed at 50 to 100 years (Mirza *et al*., 1992). Floods of 1998 above 75% of the entire area of the country was swamped including half of the capital city Dhaka, it was alike to the catastrophic flood of 1988 in relations of the range of the flooding (Islam *et al*., 2000). Variety of heavy rainfall indoors and outside the country and management of peak flows of the major rivers donated to the river, thirty million people were ended homeless and the demise toll extended above a thousand (Islam et al., 1999).

Moreover Flooding creates infection of crops and animals and impure water resulted in cholera and typhoid rashes and lots of diseases. Insufficient hospitals were useful because of damage from the flooding and those that were had too many patients, ensuing in ordinary injuries charming deadly due to absence of treatment. System of Communication within the country also became challenging (Del Ninno *et al*., 2003). Although the 1999 floods was not as serious as the 1998 floods but were silent very risky and expensive (Khandker, 2007). The floods occurred between July and September, affecting numerous deaths and various people were left homeless. Broad destruction had to be paid for with foreign support. The entire flood continued roughly 65 days (Mueller, 2010).

In 2004 flood was parallel to the 1988 and 1998 floods with two thirds of the country under water (Ahmad, 2004). Early October 2005, lots of villages were flooded when rain initiated the rivers of north-western Bangladesh to rush their banks (MFDM, 2006). In Bangladesh Jamuna River is one of the three main rivers. Main distributary channel of the Brahmaputra River as it runs from India to Bangladesh. The Jamuna streams south and links the Padma River near Goalundo Ghat before assembly the Meghna River adjacent Chandpur (Rasheed, 2008). Jamuna flows into the Bay of Bengal as the Meghna River (Rashid and Pramanik, 1990). The Jamuna is a characteristic pattern of a braided river and is extremely vulnerable to channel immigration and avulsion. It is branded by a network of connecting channels with numerous sandbars enclosed. The sandbars well-known in Bengali as chars do not conquer a stable point. The river deposits them in one year very often to be destroyed later and redeposit them in the next rainy season. The National River of Bangladesh that drainage area above Bahadurabad is 536,000 km^2 which is flowing north to south (Islam, 2005).

Using two methods of considering flood data for learning the frequency of floods are in common. The first one is annual flood assortment and the second is the partial duration sequence. An annual flood is defined as the highest fleeting topmost discharge in a water year (Chen *et al*., 2015). The use of simply one flood in each year is the most recurrent protestation to the use of annual floods. The objection renowned below annual floods is determined by inventory all floods that are superior than a designated base without concern to number within any given time period (Li *et al*., 2015).

A complaint to the use of the partial flood sequences is that the floods listed may not be completely autonomous events strictly successive flood peaks may essentially be one flood (Cheng *et al*., 2009). Historic floods afford possibly the most operative data obtainable on which to improper flood frequency resolves and where the data are reliable this material would be assumed the extreme weight in raising the flood frequency graph (Vasiliades *et al*., 2015).

2. Aims and objectives of this study

This study intent to estimate return periods associated with flood peaks of varying magnitudes from recorded floods using statistical methods as well as to compare different methods to find the methods that can be recommended for practical use for the safe design of hydraulic structures. The specific objectives are following:

- To analyze the variation of water level frequency from 1982 to 2016 years of the Jamuna river,
- To investigate the daily maximum water discharge from 1982 to 2016 years of the study area;
- To predict and estimate probability of recurrence intervals for flood frequency.

3. Data Sources and Methodology

Mainly this research has completed by primary and secondary data sources. The daily average maximum water levels (m) and daily maximum discharge (m)3/s data from 1982 to 2016 of the Bahadurabad gauging stations have collected from Bangladesh Water Department Board (BWDB) to examine the water level variation. Data related to the local people perceptions about the flood and water level trends collected through Focus Group Discussion (FGD). The probability techniques Gumbel, Powell's, Ven te Chow and Stocastic methods deployed to analyse the flood frequency and recurrence interval of Jamuna river. MS Excel has been used in this study for data analysis and presentation. Arc GIS 10.2.1 was used to synthesized the data in mapping purpose. Primary sources provide first-hand testimony or direct evidence concerning a topic under investigation.

3.1 Recurrence intervals for flood frequency analysis of Jamuna River

An estimate of the likelihood of an event such as an earthquake, landslide, or a river discharge flow to occur is recurrence interval. It is a statistical dimension usually based on historic data denoting the average recurrence interval over an extended period of time and usually used for risk analysis. The following analysis assumes that the probability of the event occurring does not vary over time and is independent of past events.

3.2 Gumbel Method

The Gumbel distribution is used to perfect the distribution of the maximum or the minimum of a number of samples of various distributions. This distribution might be used to represent the distribution of the maximum level of a river in a particular year if there was a list of maximum values for the past 34 years.

<u>Gumbel method</u>

$$P = 1\text{-}e^{-e^{-y}}$$

$$y = -0.834 - 2.303 \log \log \frac{T}{T-1}$$

$$X_T = \log \log \frac{T}{T-1}$$

$$y = \sigma_n \left(\frac{Q-\bar{Q}}{\sigma}\right) + \bar{y}_n$$

$$Q_T = \bar{Q} + \left(\frac{y-\bar{y}n}{\sigma}\right) + \sigma$$

It is useful in forecasting the chance that an extreme earthquake, flood or other natural disaster will occur. The accuracy of Flood frequency analysis by Gumbel methods is extraordinary (Table 3.1). The potential applicability of the Gumbel distribution to represent the distribution of maxima relates to extreme value theory, which indicates that it is likely to be useful if the distribution of the underlying sample data is of the normal or exponential type.

Table 3.1: Procedures of Gumbel methods to find out flood frequency.

T	yn	Qn	Qt	Ksigma	Q	1000cumec
2	0.30103	-1.20076	0.366762	-2229.20	62290.43	62.29
5	0.09691	-2.33439	1.500393	12341.35	76860.98	76.86
10	0.045757	-3.08496	2.250956	21988.32	86507.95	86.51
20	0.022276	-3.80491	2.970913	31241.93	95761.56	95.76
50	0.008774	-4.73682	3.902824	43219.78	107739.4	107.74
100	0.004365	-5.43516	4.601161	52195.49	116715.1	116.72
200	0.002177	-6.13095	5.296949	61138.45	125658.1	125.66
300	0.00145	-6.53732	5.703324	66361.58	130881.2	130.88
400	0.001087	-6.82548	5.991475	70065.19	134584.8	134.58
500	0.000869	-7.04891	6.21491	72936.99	137456.6	137.46
1000	0.000435	-7.74268	6.908682	47620	112139.6	112.14

Here, T= Recurrence intervals or time period; yn= Reduced mean; Qn= Reduced standard deviation; Qt= Annual flood peak; Q= Flood peak;

3.3 Powell's method

Powell's method strictly Powell's conjugate direction method is an algorithm proposed by Michael J. D. Powell for finding a local minimum of a function. The function need not be differentiable and no results are taken. The function must be a real valued function of a fixed quantity of real valued inputs. Table 3.2 shows the Jamuna River Flood frequency analysis by Powell's calculation.

Powells method

$$k = -\frac{\sqrt{\sigma}}{\pi}\left[\gamma + \text{In In}\frac{T}{T-1}\right]$$

constant, $\gamma = 0.5772$

Simplifying, $k = -1.1 - 1.795X_T$

Then, $Q = \bar{Q} + k\sigma$

Table 3.2: Measures of Powell's methods to find out flood frequency.

T	k	Q_t	y	σ	Q	1000cumec
2	0.30103	-1.20076	0.366762	-1033.76	45275.43	45.28
5	0.09691	-2.33439	1.500393	7397.313	53706.5	53.71
10	0.045757	-3.08496	2.250956	12979.42	59288.61	59.29
20	0.022276	-3.80491	2.970913	18333.91	64643.1	64.64
50	0.008774	-4.73682	3.902824	25264.74	71573.93	71.57
100	0.004365	-5.43516	4.601161	30458.43	76767.62	76.77
200	0.002177	-6.13095	5.296949	35633.17	81942.36	81.94
300	0.00145	-6.53732	5.703324	38655.47	84964.66	84.96
400	0.001087	-6.82548	5.991475	40798.52	87107.71	87.11
500	0.000869	-7.04891	6.21491	42460.25	88769.44	88.77
1000	0.000435	-7.74268	6.908682	47620	93929.19	93.93

Here, T= Time period; k= Sample size; Qt=Annual flood peak; y= Euler's constant; σ=Sigma; Q= Flood peak;

3.4 Ven te Chow method

Ven te chow frequency analysis based on the fact that in any given stretch of written language certain letters and combinations of letters occur with varying frequencies. It is much more essential for the present world to analysis the real situation of any other research specially flood frequency analysis. The most probable result revel in the current situation by the ven te Chow probability methods. Showing the Flood frequency measured by Ven te Chow methods (Table 3.3).

Ven te chow method

$$Q_T = a + bX_T$$

Where, $X_T = \log\log\frac{T}{T-1}$

$$\sum Q = an + b\sum X_T$$

$$\sum(QX_T) = a\sum X_T + b\sum(X_{T^2})$$

$$T = \frac{n+1}{m}$$

$$X_T = \log\log\frac{n+1}{n+1-m}$$

Table 3.3: Processes of Vent e Chow methods to find out flood frequency.

T	log(T/T-1)	Xt	Qt	Qt in 1000 cumec
2	0.30103	-0.52139	60340.35	60.34035198
5	0.09691	-1.01363	74550.18	74.55018143
10	0.045757	-1.33954	83958.32	83.95832497
20	0.022276	-1.65216	92982.84	92.98284213
50	0.008774	-2.05681	104664.2	104.6641539
100	0.004365	-2.36004	113417.7	113.4176533
200	0.002177	-2.66216	122139.2	122.1392126
300	0.00145	-2.83861	127233	127.233032
400	0.001087	-2.96373	130845	130.8449525
500	0.000869	-3.06075	133645.7	133.645654
1000	0.000435	-3.362	142341.9	142.3419498

Here, T= Recurrence intervals; Qt= Annual flood peak;

3.5 Stocastic method

In probability theory and related fields stochastic process is a mathematical object usually defined as a collection of random variables. The random variables were connected with or indexed by a set of numbers frequently viewed as points in time. Giving the interpretation of a stochastic process demonstrating numerical values of some system randomly changing over time such as the growth of a infective population. Table 3.4 presents the Jamuna river flood frequency.

Stochastic method

$$Q_T = Q_{min} + 2.3(\bar{Q} - Q_{min})log\left(\frac{n_f}{n}.T\right)$$

Where, $T = \frac{n}{m}$

Table 3.4: Techniques of Stocastic methods to find out flood frequency.

T	logT	58465.1444logT	39100+58465.1444logt	in 1000 cumec
2	0.30103	17599.76217	56699.76217	56.69976217
5	0.69897	40865.38223	79965.38223	79.96538223
10	1	58465.1444	97565.1444	97.5651444
20	1.30103	76064.90657	115164.9066	115.1649066
50	1.69897	99330.52663	138430.5266	138.4305266
100	2	116930.2888	156030.2888	156.0302888
200	2.30103	134530.051	173630.051	173.630051
300	2.477121	144825.2519	183925.2519	183.9252519
400	2.60206	152129.8131	191229.8131	191.2298131
500	2.69897	157795.671	196895.671	196.895671
1000	3	175395.4332	214495.4332	214.4954332

4. Study site

Bangladesh is a riverine country. It has different features of rivers. People near about 70% of Bangladesh is directly or indirectly involved with river activities. Jamuna River is one of the three key rivers of Bangladesh. Main distributaries channel of the Brahmaputra River is

Jamuna as it movements from India to Bangladesh. It streams south and links the Padma River near Goalundo Ghat, before conference the Meghna River near Chandpur then flows into the Bay of Bengal. Figure 4.1 represents the study area map of Jamuna River. The catchment of the mighty Brahmaputra-Jamuna river is about 5,83,000 sq km of which 293,000 sq km are in Tibet, 241,000 sq km in India and only 47,000 sq km within Bangladesh (Brouwer, *et al.*, 2007) Braided characteristic pattern of Jamuna River is extremely vulnerable to channel immigration and avulsion. It is branded by a network of connecting channels with numerous sandbars enclosed. The sandbars well-known in Bengali as chars do not conquer a stable point. The river deposits them in one year very often to be destroyed later and redeposit them in the next rainy season.

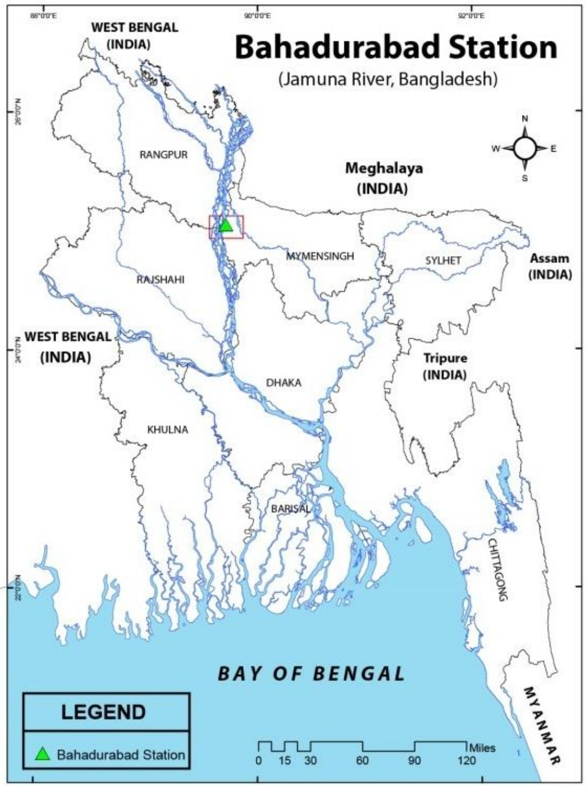

Figure 4.1: Study area

5. Result and Discussion

Probability is the portion of the likelihood that an event will occur. Probability is computed as a number between 0 and 1 where lightly speaking 0 indicates impossibility and 1 indicates inevitability. The advanced the probability of an event is the more certain that the event will occur. In the long term flood frequency analysis constructed on recorded past events can nonetheless amount valuable predictions of future probabilities and risks. Flood frequency analysis deals with the incidence of peak discharges, whereas frequency analysis generally provides the statistical basis of hydraulic geometry. Percentage of frequency analysis has been much castoff in engineering. Rapid variations of water surface level in stream frequencies through time, in arrangement with the event from time to time of overbank flow in level bottomed valleys, have endorsed intensive study of the discharge relationships and the probability characteristics of peak flow.

5.1 Water levels Log normal distribution of Janmuna River

In probability theory log-normal distribution is an incessant probability spreading of a random variable whose logarithm is normally distributed. Table 5.1 represents the Log normal distributions of water levels frequency in Jamuna River (1984 to 2016). Hence if the random variable X is log-normally distributed then Y= ln (X) has a normal distribution. Similarly if Y has a normal distribution, then the exponential function of Y is X= exp (Y) has a log-normal distribution. A random variable which is log-normally distributed proceeds only positive actual values. A log-normal progression is the statistical recognition of the multiplicative produce of many independent random variables each of which is positive. This is justified by considering the central limit theorem in the log domain. The log-normal distribution is the maximum entropy possibility distribution for a random variety X for which the mean and inconsistency of ln (X) are specified.

Table 5.1: Log normal distributions of water levels frequency in Jamuna River (1984 to 2016).

Year	Data	Rank	PP	T	W(y)	Variate	X_T log Normal
1994	18.74	33	0.97	1.03	2.66	-1.89	18.93
2006	18.83	32	0.94	1.06	2.38	-1.57	19.09
1986	19.15	31	0.91	1.1	2.2	-1.35	19.18
1992	19.18	30	0.88	1.13	2.07	-1.19	19.26
2001	19.32	29	0.85	1.17	1.96	-1.05	19.33
2009	19.37	28	0.82	1.21	1.86	-0.93	19.38
1990	19.38	27	0.79	1.26	1.78	-0.82	19.44
2005	19.47	26	0.76	1.31	1.7	-0.72	19.48
1989	19.57	25	0.74	1.36	1.63	-0.63	19.53
1985	19.61	24	0.71	1.42	1.56	-0.54	19.57
2011	19.64	23	0.68	1.48	1.5	-0.46	19.61
1987	19.68	22	0.65	1.55	1.44	-0.38	19.65
2008	19.71	21	0.62	1.62	1.39	-0.3	19.68
2010	19.78	20	0.59	1.7	1.33	-0.22	19.72
1999	19.81	19	0.56	1.79	1.28	-0.15	19.76
2003	19.89	18	0.53	1.89	1.23	-0.07	19.79
1993	19.9	17	0.5	2	1.18	0	19.83
2013	19.91	16	0.47	2.13	1.23	0.07	19.86
1997	19.92	15	0.44	2.27	1.28	0.15	19.90
2015	19.93	14	0.41	2.43	1.33	0.22	19.94
1996	19.99	13	0.38	2.62	1.39	0.3	19.97
1991	20.08	12	0.35	2.83	1.44	0.38	20.01
2002	20.09	11	0.32	3.09	1.5	0.46	20.05
1984	20.1	10	0.29	3.4	1.56	0.54	20.09
2000	20.16	9	0.26	3.78	1.63	0.63	20.13
2004	20.18	8	0.24	4.25	1.7	0.72	20.18
2014	20.2	7	0.21	4.86	1.78	0.82	20.23
1998	20.34	6	0.18	5.67	1.86	0.93	20.28
2007	20.34	5	0.15	6.8	1.96	1.05	20.34
1995	20.36	4	0.12	8.5	2.07	1.19	20.41
2012	20.56	3	0.09	11.33	2.2	1.35	20.49
1988	20.61	2	0.06	17	2.38	1.57	20.60
2016	20.71	1	0.03	34	2.66	1.89	20.76

Log normal distribution also has been connected with other names such as McAlister, Gibrat and Cobb Douglas. From the graph it is clear to find out probability frequency of Jamuna river water levels with its observed value regression line, upper bound and lower bound. Reduce variate is an acceptance value of probability frequency analysis. A log-normal process is the statistical realization of the multiplicative product of many independent random variables each of which is positive. This is justified by considering the central limit theorem in the log domain. It is clear from the Log normal distribution graph (Figure 5.1) below shows the maximum water level at Bahadurabad in Jamuna river between 1984 and 2016. The line graph illustrates the water level frequency of jamuna river from 1984 to 2016.

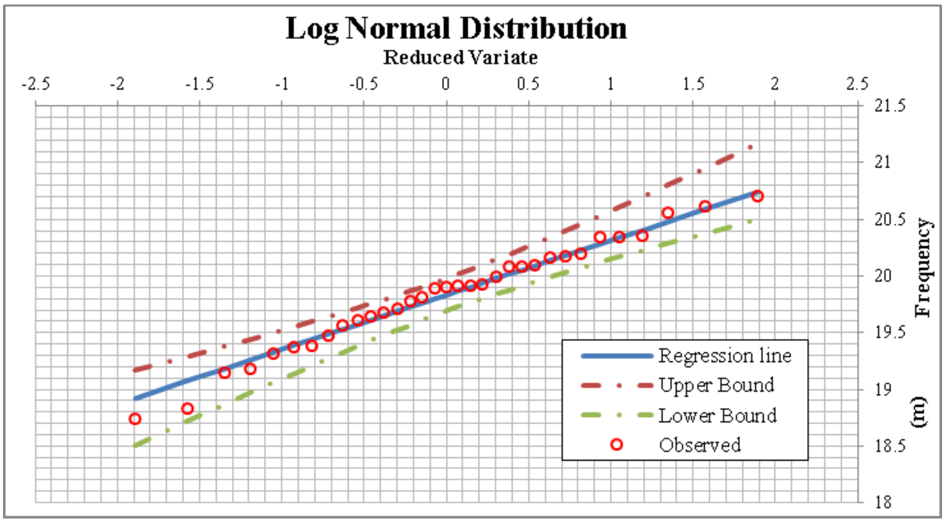

Figure 5.1: Frequency distribution of Jamuna River during 1984-2016 years.

5.2 Water levels Log Pearson distribution of Jamuna river

The log Pearson distribution is a clan of continuous probability distributions. Table 5.2 shows the Log Pearson distributions of water levels frequency in Jamuna River. The log Pearson system was originally planned in an exertion to model visibly skewed observations. It was well known at the time how to adjust a theoretical model to fit the first two cumulates or moments of observed data. Any probability distribution can be extended directly to form a location scale familiar. Except in compulsive cases a location scale tribe can be made to fit the observed mean and variance randomly well. The log-Pearson type distribution has been one of the most frequently used distributions for hydrologic frequency explores since the endorsement of the Water Resources. The Water Resources Assembly also cited that this distribution be formfitting to sample data by consuming mean, standard deviation and coefficient of skewness of the logarithms of stream data the method of moments.

However, it was not known how to construct probability distributions. This need became specious when trying to fit known theoretical models to observed data that showed skewness. Pearson's examples include survival data which are usually uneven. Figure 5.2 shows the frequency of water levels at Bahaduraabad of Jamuna River through 1984-2016 years by the log Pearson distribution. From the graph it is clear to find out probability frequency of Jamuna river water levels with its observed value regression line, upper bound and lower bound. The Log Pearson distribution graph below shows the maximum water level at Bahadurabad in Jamuna river between 1984 and 2016. The line graph illustrates the water level frequency of jamuna river from 1984 to 2016. The variation of water levels in Jamuna river showed significant rise over the period while the percentage of water level variation increase upward trend.

Table 5.2: Log Pearson distributions of water levels frequency in Jamuna River (1984 to 2016).

Year	Data	Rank	PP	T	w	Variate	X_T LogPearson
1994	18.74	33	0.97	1.03	2.66	-2.04	18.87
2006	18.83	32	0.94	1.06	2.38	-1.65	19.05
1986	19.15	31	0.91	1.1	2.2	-1.4	19.16
1992	19.18	30	0.88	1.13	2.07	-1.21	19.25
2001	19.32	29	0.85	1.17	1.96	-1.05	19.33
2009	19.37	28	0.82	1.21	1.86	-0.91	19.39
1990	19.38	27	0.79	1.26	1.78	-0.8	19.45
2005	19.47	26	0.76	1.31	1.7	-0.69	19.5
1989	19.57	25	0.74	1.36	1.63	-0.59	19.55
1985	19.61	24	0.71	1.42	1.56	-0.49	19.59
2011	19.64	23	0.68	1.48	1.5	-0.41	19.63
1987	19.68	22	0.65	1.55	1.44	-0.32	19.67
2008	19.71	21	0.62	1.62	1.39	-0.24	19.71
2010	19.78	20	0.59	1.7	1.33	-0.16	19.75
1999	19.81	19	0.56	1.79	1.28	-0.09	19.79
2003	19.89	18	0.53	1.89	1.23	-0.01	19.82
1993	19.9	17	0.5	2	1.18	0.06	19.86
2013	19.91	16	0.47	2.13	1.23	0.13	19.89
1997	19.92	15	0.44	2.27	1.28	0.21	19.93
2015	19.93	14	0.41	2.43	1.33	0.28	19.96
1996	19.99	13	0.38	2.62	1.39	0.35	20
1991	20.08	12	0.35	2.83	1.44	0.43	20.04
2002	20.09	11	0.32	3.09	1.5	0.5	20.07
1984	20.1	10	0.29	3.4	1.56	0.58	20.11
2000	20.16	9	0.26	3.78	1.63	0.66	20.15
2004	20.18	8	0.24	4.25	1.7	0.75	20.19
2014	20.2	7	0.21	4.86	1.78	0.84	20.24
1998	20.34	6	0.18	5.67	1.86	0.93	20.28
2007	20.34	5	0.15	6.8	1.96	1.04	20.34
1995	20.36	4	0.12	8.5	2.07	1.16	20.39
2012	20.56	3	0.09	11.33	2.2	1.29	20.46
1988	20.61	2	0.06	17	2.38	1.47	20.55
2016	20.71	1	0.03	34	2.66	1.73	20.68

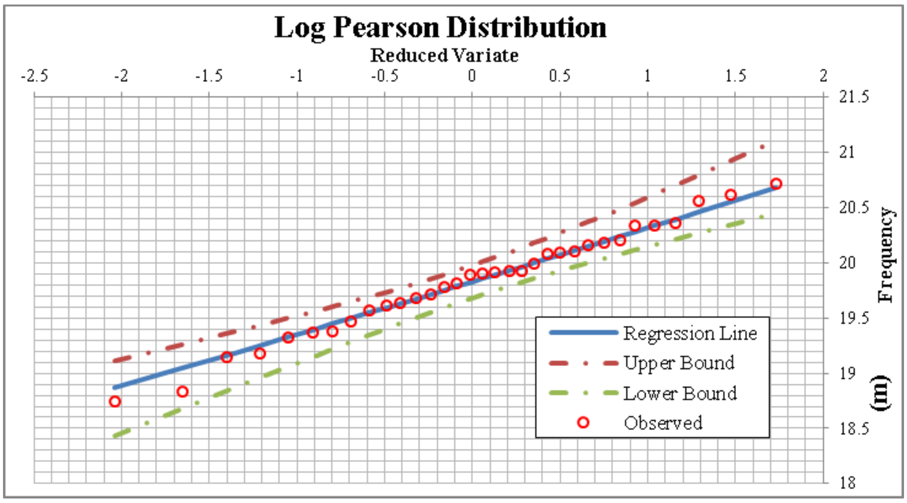

Figure 5.2: Log Pearson distribution of Jamuna River during 1984-2016 years.

5.3 Yearly discharge trends of Jamuna river

Discharge is the volume rate of water course that is transported concluded a given cross sectional area. It includes any deferred solids dissolved chemicals or biologic material in totalling to the water itself. Fluvial hydrologist studying natural river systems may define discharge as stream flow while an engineer effective a basin system might define discharge as discharge which is contrasted with inflow. Table 5.3 presents the variations of average water discharge of Jamuna River. Jamuna is the name recognized to the braided river downstream of the old Brahmaputra distributary and is one of three huge sand bed rivers that annoyed the low lying deltaic floodplain of Bangladesh (Ashworth, 1996). The Jamuna River growths in the Tibetan plateau and 93 percent of its catchment lays outward of Bangladesh (Alam, 2015). The Jamuna associates with the Ganges and then the Meghna finally discharging curved on the Bay of Bengal (Ashworth, 1996). Jamuna have a antiquity of 250 years (Bhuiyan *et al*., 2010).

Table 5.3: Variations of average water discharge of Jamuna River (1984 to 2016).

Years	Discharge (m)3/s
1982-1986	56800
1987-1991	66460
1992-1996	66297
1997-2001	68850.99
2002-2006	67590.12
2007-2011	51543.38
2012-2016	74095.90
Average	64519.62
Maximum	74095.90
Minimum	2036.82

5.4 Monthly discharge trends of Jamuna river

Monthly discharge means the volume of water flowing over a river frequency in a same month over the year by year. This is the total capacity of water flowing through a channel at any given point and is stately in cubic metres per second (cumecs). The discharge from a drainage basin depends on precipitation, evapotranspiration and loading aspects. Drainage basin discharge = precipitation – evapotranspiration +/- changes in storage (Wikipedia, 2017). Table 5.4 examines the monthly discharge of jamuna river during 34 years.

Figure 5.3 Showing the January month maximum water discharge of Jamuna River at Bahadurabad gauging station during 34 years. It reveals how the form changes in the month of January reliant in the time of 1982-2016. From the graph it is clear that in 2004, 2006 and 2007 years had more amount of water discharge recorded during 34 years, which was 12000 (m)3/s above. The lowest discharge recorded in the years of 2012 and 2013 through 1982-2016 year. Straight line represents the discharge trend line.

Figure 5.4 represents the Jamuna river maximum discharge of February month during 34 years at Bahadurabad gauging station. It can be seen from the graph, the more water discharge was recorded in the years of 2006 and 2007. Straight line represents the discharge trend line. The fewer water discharges recorded in 2013.

Table 5.4: Variations of water discharge of Jamuna River (1982 to 2016).

Months	Monthly average discharge (1982-2016) (m)3/s
Jan	6650.33
Feb	5332.26
Mar	6687.52
Apr	10508.81
May	19940.27
Jun	37750.99
Jul	60528.67
Aug	50098.65
Sep	46095.14
Oct	33402.70
Nov	15406.30
Dec	8742.31
Maximum	60528.67
Minimum	2036.82

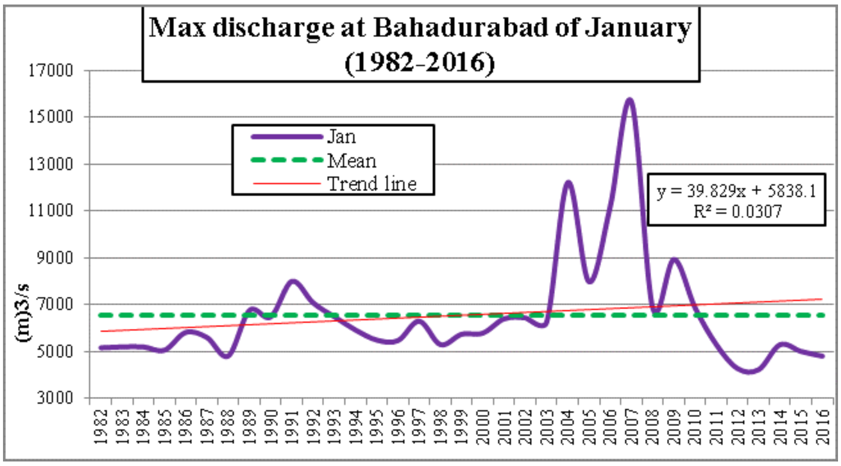

Figure 5.3: Monthly maximum discharge of Jamuna river (1982-2016)

Figure 5.5 illustrates the monthly maximum discharge at Bahadurabad gauging ststion of Jamuna River in March through 1982-2016 years. It demonstrates how the discharge changes depending in the time of 34 years. From the graph, it is clear in 1992, 1994, 2004, 2008 and 2008 had nearly an equal amount of water discharge recorded approximately 11000 (m)3/s . At the time of 2007, the amount of discharge rise rapidly near 16000 (m)3/s and the lowest recording occurred in 2013 with less than 2000 (m)3/s.

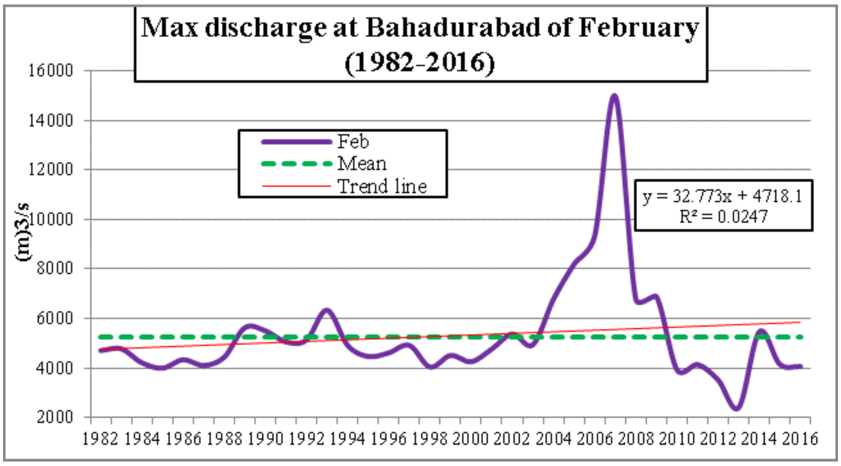

Figure 5.4: Monthly maximum discharge of Jamuna river (1982-2016)

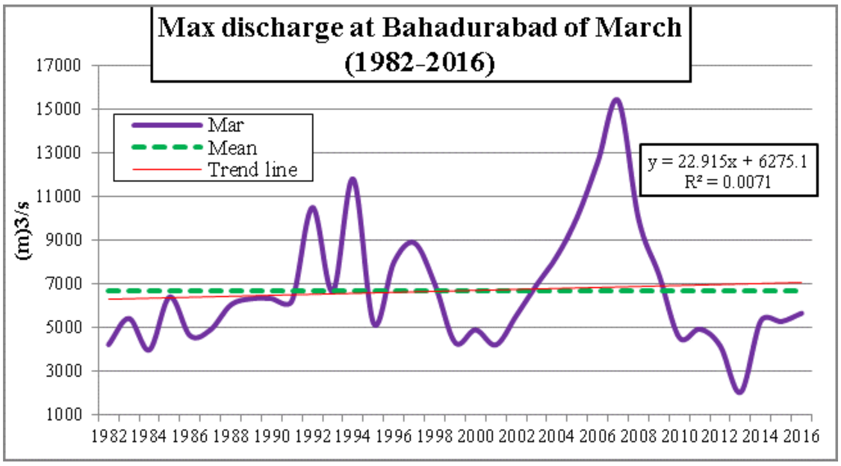

Figure 5.5: Monthly maximum discharge of Jamuna river (1982-2016)

Describes the monthly maximum water discharge of Jamuna River in April (Figure 5.6). From the graph, it is clear the highest and lowest water discharge was recorded during the 2005 and 2007 of the 1982-2016 years whiles the amount of water discharge is remaining unstable. Straight line represents the discharge trend line.

Figure 5.7 illustrates the monthly maximum discharge at Bahadurabad gauging station of Jamuna River in the month of May. First of all, the most noticeable feature of the line graph is that the water discharge reaches the first peak in 1995 just above 39000 (m)3/s respectively. Straight line represents the discharge trend line.The next striking feature of this graph has the lowest point in 2014, which is approximately 7000 (m)3/s.

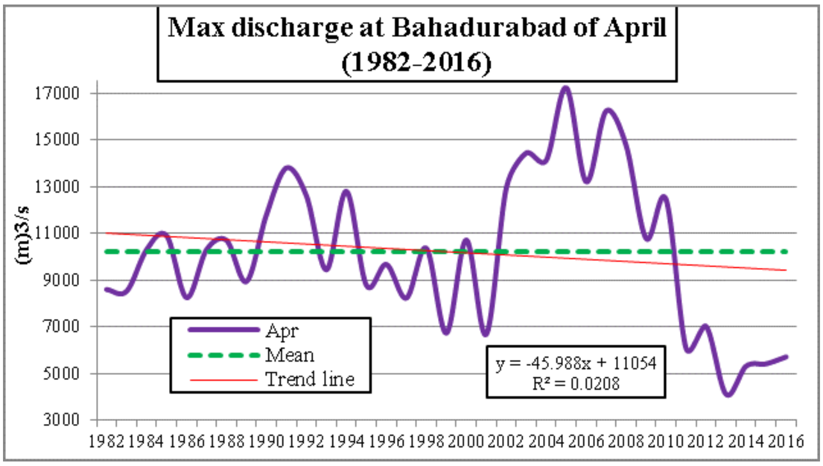

Figure 5.6: Monthly maximum discharge of Jamuna river (1982-2016)

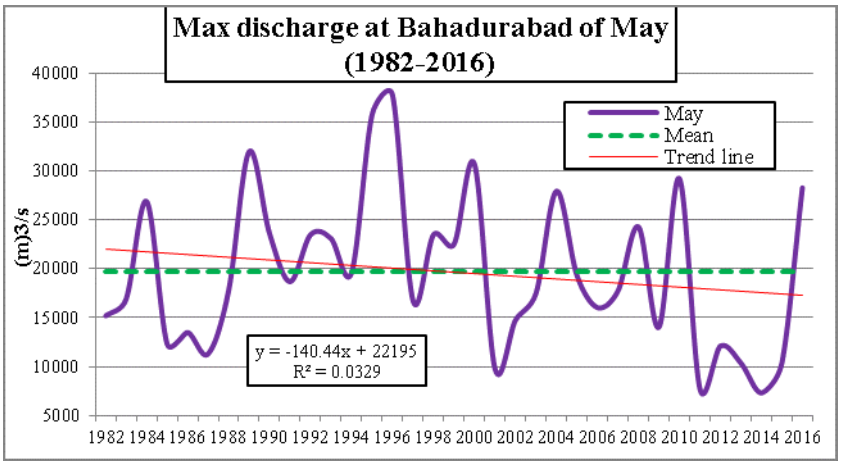

Figure 5.7: Monthly maximum discharge of Jamuna river (1982-2016)

The line graph below shows the maximum water discharge at Bahadurabad in Jamuna river of January month between 198 and 2016 (Figure 5.8). It exposes how the form changes in the month of June reliant in the time of 1982-2016. From the graph it is clear that in1992, 1995, 1998 and 2004 years had more amount of water discharge recorded during 34 years, which was 65000 (m)3/s above. Straight line represents the discharge trend line. The lowest water discharge was recorded in the years of 2009 through 1982-2016 years. Figure 5.9 represents the Jamuna river monthly maximum water discharge of July month during 34 years at Bahadurabad gauging station. It can be seen from the graph, the more water discharge was recorded in the years of 1994, 1998, 2004 and 2016. The fewer water discharges were recorded in 2001 and 2009. Straight line represents the discharge trend line. Figure 5.10 explains the maximum discharge at Bahadurabad gauging ststion of Jamuna River in August through 1982-2016 years. It shows how the water discharge changes liable in the time of 34 years. From the graph, it is clear that in 1987, 1997, 2000, and 2015 had nearly an equal amount of water discharge recorded approximately 68000 (m)3/s. At the time of 1998 the amount of discharge rise rapidly near 86000 (m)3/s and the lowest recording occurred in 2006 with less than 30000 (m)3/s.

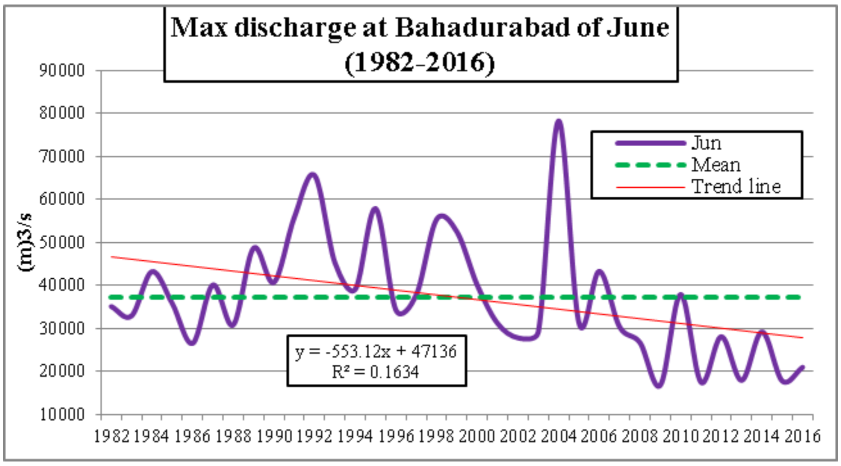

Figure 5.8: Monthly maximum discharge of Jamuna river (1982-2016)

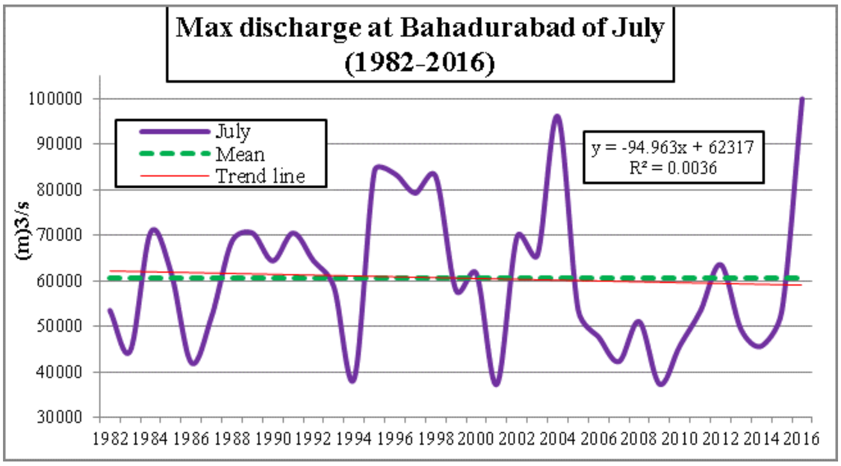

Figure 5.9: Monthly maximum discharge of Jamuna river (1982-2016)

Figure 5.11 expressing the monthly maximum water discharge of Jamuna River in September through 1982-2016. From the graph, it is clear that, the highest and lowest water discharge was recorded during the 1984, 2013 and 2011 of 34 years whiles the amount of water discharge is remaining unstable. Straight line represents the discharge trend line. Figure 5.12 demonstrates the monthly maximum discharge at Bahadurabad gauging station of Jamuna River in the month of October. First of all, the most noticeable feature of the line graph is that the discharge reaches the first peak in 1988 second in 1994 just above 60000 (m)3/s respectively. Straight line represents the discharge trend line.The next striking feature of this graph is the water discharge have the lowest point in 2011, which is approximately 12000 (m)3/s above.

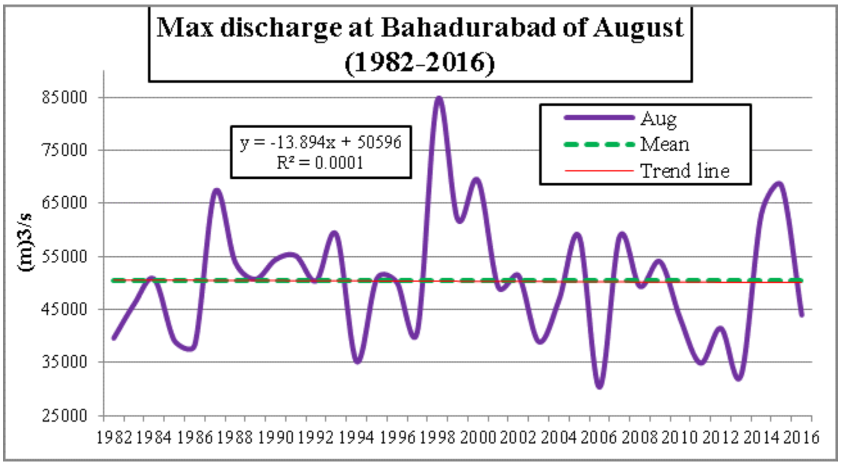

Figure 5.10: Monthly maximum discharge of Jamuna river (1982-2016)

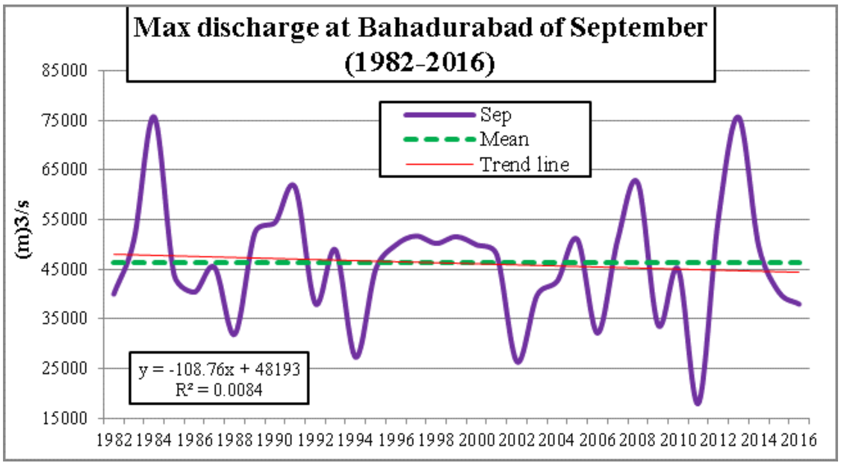

Figure 5.11: Monthly maximum discharge of Jamuna river (1982-2016)

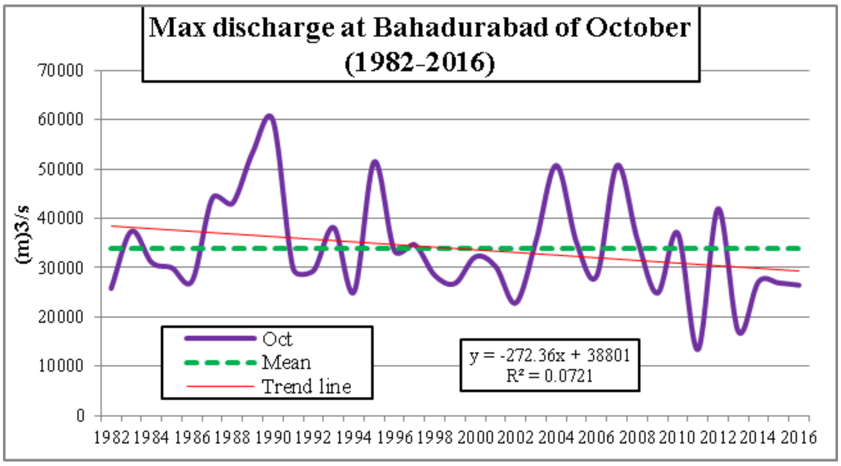

Figure 5.12: Monthly maximum discharge of Jamuna river (1982-2016)

The Jamuna is braided in nature. Within the braided belt of the Jamuna, there are lots of chars of different sizes. Displaying the November month maximum discharge of Jamuna River at

Bahadurabad during 34 years (Figure 5.13). It exposes how the form changes in the month of November trusting in the time of 1982-2016. From the graph it is clear that in 2005 years had more amount of water discharge recorded in during 34 years, which was 27000 (m)3/s above. Straight line represents the discharge trend line.The lowest water discharge was recorded in the years of 2014 through 1982-2016 years. Figure 5.14 grants the Jamuna river monthly maximum water discharge of December month during 1982-2016 years at Bahadurabad gauging station. It can be seen from the graph, the more water discharge was recorded in the years of 2004 and 205. The fewer water discharges was recorded in 2012 and 2014. Straight line represents the discharge trend line.

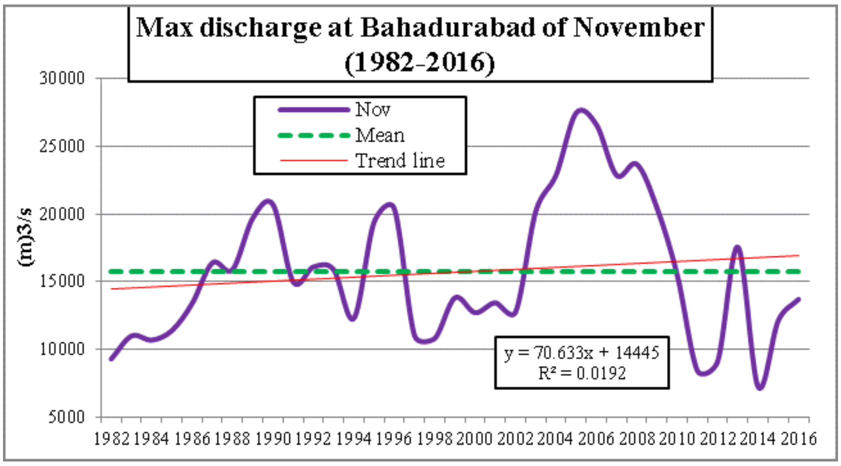

Figure 5.13: Monthly maximum discharge of Jamuna river (1982-2016)

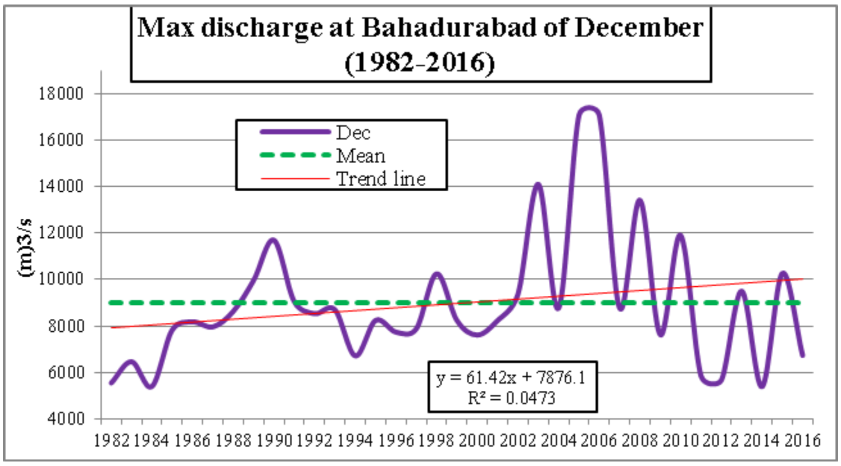

Figure 5.14: Monthly maximum discharge of Jamuna river (1982-2016)

5.5 Probability of flood and flood frequency

Predictions of frequency of flooding are based on stream gauging records using the annual maximum or peak discharge or the highest value measured at Bahadurabad station station for a given year of Jamuna river. Each annual peak period is dispersed a ranking called the magnitude number. The highest river level for that year is given a magnitude number of 1 and lower stages for other years are numbered in increasing magnitude for the duration of the record. The number of items specially data points in the record is ‘n’. Noticeably ‘n’ is basically the number of years for which data has been collected and will vary from river to river. It can be Calculated the recurrence interval for a assumed stage consuming the following equation known as the Weibull equation: RI = (n + 1) / m (Wikipedia., 2019). The recurrence interval for a actual river stage simply expect the river to reach that height. Table 5.5 shows the Jamuna river flood frequency of different methods.

Annual peak stream flow for recurrence intervals at a given location change if there are major changes in the flow patterns at that location perchance caused by an impoundment or alteration of flow. Statistical techniques concluded a procedure termed frequency analysis are used to evaluation the probability of the occurrence of a given precipitation event. The recurrence interval is established on the probability that the specified event will be totalled or surpassed in any given year. Example, like assume there is a 1 in 50 chance that 6.60 inches of rain will fall in a certain area in a 24 hour period during any given yearof Jamuna river.

Probability a common confusion occurs that a 100 year flood is likely to occur only once in a 100 year period. The probability P_e that one or more floods happening through any period will exceed a given flood threshold can be expressed using the binomial distribution as like:

$$\boxed{P_e = 1 - \left[1 - \left(\frac{1}{T}\right)\right]^n}$$

Where, T is the threshold return period and 'n' is the number of years in the period. The probability of exceedance P_e is also designated as the natural, essential or hydrologic risk of failure. Conversely, the predictable value of the number of 100 year floods occurring in any 100 year period is 1.

Table 5.5: Probable frequency of floods by using Gumble, powell's, Ven te Chow and stochastic methods.

T	Gumbel	Powell	Ven Te Chow	Stochastic	P	P(%)
2	62.29	62.14	60.34	56.7	0.5	50.00
5	76.86	74.96	74.55	79.97	0.2	20.00
10	86.51	83.44	83.96	97.57	0.1	10.00
20	95.76	91.58	92.98	115.2	0.05	5.00
50	107.74	102.12	104.66	138.4	0.02	2.00
100	116.72	110.01	113.42	156	0.01	1.00
200	125.66	117.88	122.14	173.6	0.005	0.50
300	130.88	122.47	127.23	183.9	0.003333	0.33
400	134.58	125.73	130.84	191.2	0.0025	0.25
500	137.46	128.25	133.65	196.9	0.002	0.20
1000	112.14	136.1	142.34	214.5	0.001	0.10

*Discharge in 1000 cumec.

Ten year floods have a 10% chance of stirring in any given year (P_e =0.10) 500 year have a 0.2% chance of occurring in any assumed year (P_e =0.002) etc. The present chance of an X year flood occurring in a solitary year can be calculated by isolating 100 by X. A similar analysis is frequently applied to coastal flooding or rainfall data. The recurrence interval of a storm is infrequently equal to that of an associated riverine flood. Figure 5.15 inspects the graphical distribution of Jamuna river flood frequency analysis by using four probability methods. Since the 100 year flood level is statistically calculated using past current data as more data derives in the level of the 100 year flood will change expressly if a huge flood hits in the current year. As more data are collected or when a river basin is altered in a way that touches the flow of water in the river inventors re-evaluate the frequency of flooding. Certainly, a 100 year flood occurrence can have a significant and permanent impact on every characteristic of the local environment. If stream flow statistics define what a 100 year flood is, do you think similar statistics could define the opposite event a 50 or 100 year scarcity? Positively it can and although a drought doesn't have the instantaneous and shocking impact that a flood has. It can still have Spartan possessions on the local environment just as a flood does only it is haggard out over a longer time period.

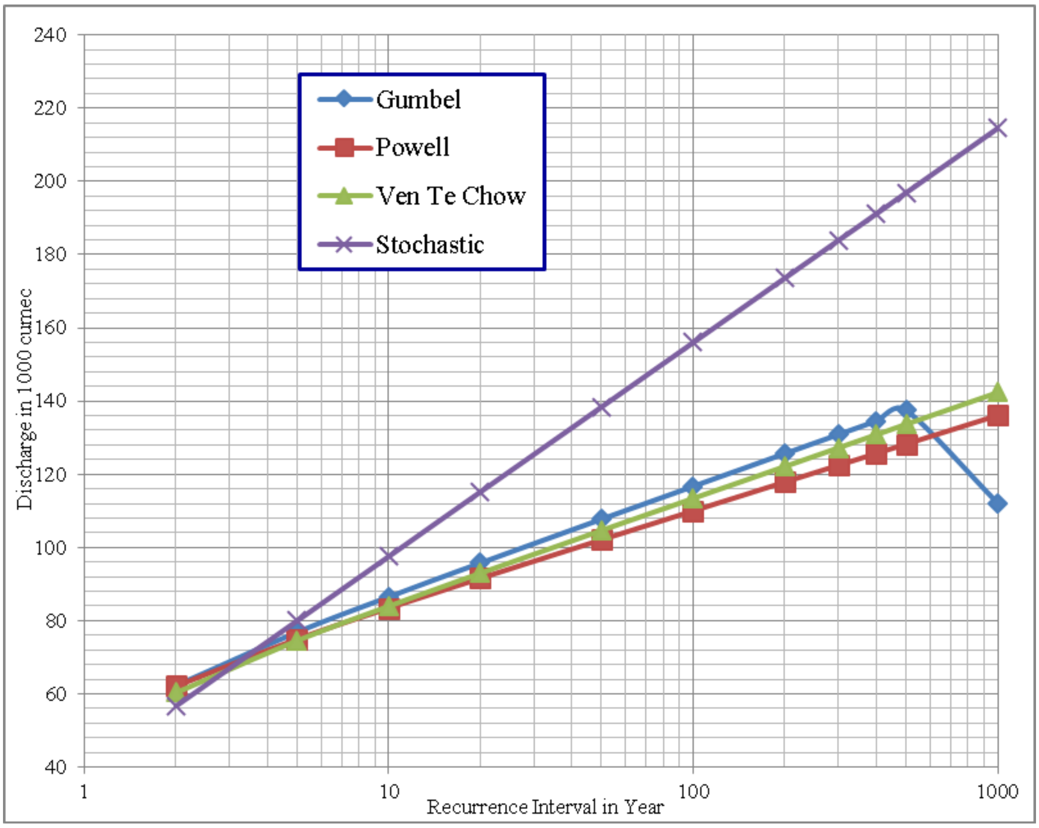

Figure 5.15: Graphical demonstration of flood frequency

6. Conclusion

This investigation focused on the probability of flood frequency analysis of Jamuna river in Bangladesh. Flood frequency poses significant challenges to agricultural sector and therefore to livelihoods and the country's overall economic development. Adverse impacts include increased humidity and lack of humidity, water intrusion and massive declines. This study frequency of flood analysis involves in the estimation of how often a specified event will occur. The enquiry comprises using observed annual peak flow data to calculate statistical information such as mean values, standard deviation, skewness and recurrence interval. Consistent flood frequency approximations are vital for floodplain management, to protection of public infrastructure, minimize flood related cost to government and private initiatives, for designing and locating hydraulic structures and assessing hazards related to the development of flood plains and prevalent control.

This study collected the water levels records from the BWDB (Bangladesh Water Department Board) of 32 (1984-2016) years. The results reveal that flood frequency vary through time in different scales. The maximum water levels were recorded 20.61 meter for the August month in the period of 1988 and the minimum water levels was recorded 12.19 meter at February month in 2016. The maximum average water levels logged about 18.59 meter in the year of 1988 and the minimum was 13.39 in the year of 1997. The Jamuna river maximum water levels at Bahadurabad gauging ststion demonstrates how the water levels changes depending in the time of (1984-2016). From the analysis of first objective it is clear that January, February, March, April, November and December had nearly an equal amount of water levels recorded approximately 14 meter. During the June to September, the amount of water levels rise rapidly near 19 meter and the lowest recording occurred February with less than 14 meter. Up until the July, the amount of water levels reached a peak with more than 18.5. Again, there was a sudden decline just after next month, which continued until September. The most noticeable feature of this objective is that the water levels reach the first peak in August and second in September just above 18.0 meter respectively. The next striking feature of the water levels has the lowest point in February, which is approximately 13.5 meter. To compare, the water levels over the years, it is apparent that water level in January is lower than December. The analysis shows that in every year June, July, August and September months contains the high volume of water levels. June and July was the peak month of most of the years. January, February, March, November and December represent the lower volume of water of Jamuna River.

The daily maximum discharge at Bahadurabad station of Jamuna river. Discharge is a vital hydrologic element that recorded maximum discharge 99999.99 (m)3/s in 2016 in the month of July and minimum discharge recorded 2036.82 (m)3/s in 2013 in the period of March month. It shows that the discharge has increased over the time. In the year of 1998 maximum discharge recorded 84520 (m)3/s in August month, in 2004 maximum discharge recorded 78315.1 (m)3/s in June month. The Jamuna river of Bangladesh, minimum discharge recorded 2036.82 (m)3/s in 2013, 16734.81(m)3/s in 2009, 7303.52 (m)3/s in 2014 in the month of March, June and May. Yearly maximum discharge at Bahadurabad of Jauna River can be seen that discharge increased steadily June to July and slightly decreased August to September. Maximum water discharge recorded in July 53000 (m)3/s and lowest discharge recorded in March below 5000 (m)3/s in the year of 1982. Maximum average water discharge was recorded 68000 (m)3/s in the month of July to August in 1987. It is clear that discharge goes down slightly in the month of September to October. The year with the highest water discharge is 70000 (m)3/s in July. Water discharge was steady by three month January to march in 1988 and it was 5000 (m)3/s.

In the years of 1998 how the pattern changes reliant. It presents that June, July and August had more amount of water discharge was recorded which was 88000 (m)3/s above. The lowest water discharge recorded in the month of February during this year. The water discharge changes liable in the time of (1982-2016) years. It is vibrant that in 1987, 1997, 2000, and 2015 had nearly an equal amount of water discharge recorded approximately 68000 (m)3/s. At the time of 1998 the amount of discharge rise rapidly near 86000 (m)3/s and the lowest recording occurred in 2006 with less than 30000 (m)3/s. It exposes how the form changes in the dry season month of January, February, March, November and December trusting in the time of 1982 to 2016. At the time of 2005 had more amount of water discharge recorded in during 34 years, which was 27000 (m)3/s above. The lowest water discharge was recorded in the years of 2014 through 1982-2016 years.

To investigate the third objectives, flood frequency of Jamuna river gradually increased 20 years interval due to causes of some hydraulic variation, specially water levels and discharge. 2 years intervals flood frequency of Jamuna River presents by Gumbel methods 62290 (m)3/s, by Powell's methods 62140 (m)3/s, by Ven te Chow method 60340 (m)3/s, and by Stocastic method 56700 (m)3/s where flood occurrence probability 50 percent. 5 years return period flood frequency offering 76860 (m)3/s by Gumbel method, 74960 (m)3/s by Powell's method, 74550 (m)3/s by Ven te Chow method, 79970 (m)3/s by Stocastic method. These four methods also grants flood frequency about 10 years intervals of Jamuna river 86510 (m)3/s, 83440 (m)3/s, 83960 (m)3/s, 97570 (m)3/s by using Gumbel, Powell's, Vent e Chow and Stocastic methods.

This study exposes the relationship between water levels and water discharge that is the main factor of probable frequency flood in Jamuna. After 50 years return period probable discharge estimated by using Gumbel, Powell's, Vent e Chow and Stocastic methods are 107740 (m)3/s, 102120 (m)3/s, 104660 (m)3/s, 138400 (m)3/s. By this process 100 years' intervals or return period flood frequency of Jamuna river predict that 116720 (m)3/s, 110010 (m)3/s, 113420 (m)3/s, 156000 (m)3/s by using according to four probability methods Gumbel, Powell's, Ven te Chow and Stocastic methods. If the probabilities of flood frequency rise up by this progression so, 1000 years intervals flood frequency apparent 0.10 %.

Jamuna river is very different from its surrounding area based on physical characteristics. Flood occurred here by naturally and manufactured activities. Using Probability methods Gumbel, powell's, Vent e Chow and Stocastic had been measured in this study. Result of this research calculation by using M S Excel, Weiball P P and probability techniques. Jamuna River is completely essential for several purposes for a country. The river Jamuna is subjected to multiple uses for community water supply, irrigation, industrial water supply, bathing, and disposal of sewage and industrial effluents. It is an essential natural resource for sustaining all forms of life in a major part of Bangladesh, but perennial increase of population and urban activities in Bangladesh are placing tremendous pressures and demands on this natural resource. There is a heavy pressure of water supply and sanitation on river Jamuna in Bangladesh. At the end of analytical description it is clear from the all graphical management Gumbel, Powell's, Ven te Chow represents nearly the same frequency of floods. Stocastic methods cannot be used by flood frequency probability distribution. So, probability of recurrence intervals in this research must be effective in the future plan for mitigating, minimising loss and damage against floods.

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