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DEVELOPMENT OF DETENTION RESERVOIR FOR FLOOD MITIGATION USING SIMULATION

[1]Dr.Krishna Kamal Das, [2]Dr. Bibhash Sarma
[1]Lecturer (SG) in Civil Engineering, [2]Professor in Civil Engineering
[1]Department of Civil Engineering,
[1]Bongaigaon Polytechnic, Bongaigaon, Assam, India.

Abstract: For development of any river basin, the management of flood is an important factor. The planning for construction of detention reservoir for controlling flood is widely used all over the world. The impact of flood can be minimized by development of a detention reservoir for flood absorption for a given time. In this study, an attempt has been made for mitigation of flood considering the flood detention time and flood absorption capacities with respect to different elevations to accommodate the maximum design flood with respect to flood forecasting well in advance to minimize the flood hazards in downstream for the Kulsi river basin. Gumbel's extreme value distribution method is used for frequency modelling to obtain the amount of flood for various return periods**.** The annual and monthly design floods for the month of May, June, July, August and September for return period 1000 year, 100 year, 50 Year, 25 year, 20 year, 15 year, 10 year and 5 year are estimated. The flood absorption capacities form 100.0 m to 115.0 m elevation is estimated for every 1.0 m elevation interval and accordingly detention time for the absorbed flood are also estimated using simulation.

Keywords: **Detention reservoir, Flood mitigation, Gumbel distribution, Simulation, Chi Square distribution.**

1. INTRODUCTION

Water is the most important elements for the survival of life on earth. But this water sometimes causes woe to the life, causing natural disaster like flood. Every year due to devastating flood, Assam experienced huge losses in term of life and capital. The Brahmaputra valley of Assam is the most devastating flood prone area. The causes are mainly due to heavy rainfall during monsoon period, inadequate capacity of natural streams, soil erosion, silting of river bed etc. Though the complete control of flood is not possible from the economic point of view, its affects can be minimised by taking suitable measures well in advance. The management of flood is important for development of a river basin. In this paper the Kulsi River basin is undertaken for the study. There is a proposed multipurpose project in the Kulsi river, at the conception level. This project proposes a concrete dam at 1.5 km downstream of Ukiam village. The basin is situated on the southern part of the mighty river Brahmaputra between $25\,^{0}35^{/}$ N & $26\,^{0}07^{/}$ N and $90\,^{0}45^{/}$ E & $91^{0}00^{/}$E. The basin is located in Kamrup and Goalpara district of Assam, also West Khasi hills and East Garo hills district of Meghalaya for a total catchment area of 3770 Km^2. The catchment area upto dam site of the watershed is 1628 km^2. Fig.1 shows the location of Kulsi basin upto dam site. The Kulsi river drains from the northern slopes of Meghalaya hills. The flood in Kulsi basin is flashy in nature. Due to flatter slope in the plain area, drainage congestion takes place as other north flowing sub-tributaries of the basin like Deosila, Boko, Singra etc. joins together. This flood congestion problem becomes critical when the flood of the Brahmaputra also enter the area either due to overtopping of embankments or a breach in the embankment or due to backwater flow through Kulsi river. The river in its upper catchment up to village Kulsi has moderately steep slope and is confined between hill ranges. After Kulsi village, it enters the alluvial plains exhibiting flatter slope and it continues till its confluence with the Brahmaputra

Fig.1: Location map of Kulsi basin upto dam site

2. LITERATURE REVIEW

The detention reservoir is a widely applied strategy for mitigation of floods down stream worldwide. The detention reservoir may be constructed within the area or in some place upstream. Hettiarachchi (2016) discussed the detention reservoirs as a flood control measure for the protection of cities located in flood plains of major rivers of a country. He outlined about the types of flood detention reservoirs and how it works. Ngo et al. (2016) in their case study combined hydrologic simulation software with an evolutional optimizer to minimize flood damage in downstream in Seoul, Korea, by considering a detention reservoir. A mathematical model between peak discharge and return period was developed by Mukherjee (2013). He used Gumbel's extreme value distribution in his model. Bhagat (2017) carried out flood frequency analysis of lower Mahi river using the Gumbel's distribution method. He also verified the suitability of Gumbel's distribution for predicting the expected flow in the river. Mujere (2011), carried out a study on Nyanyadzi river floods. He used Gumbel's distribution method and concluded that the Gumbel's distribution method was appropriate for frequency modelling of Nyanyadzi river floods. Onen and Bagatur (2017) presented models for forecasting of flood frequency factor for the Gumbel's distribution by gene expression programming and regression model for fast and practical way of estimating the flood frequency factor for calculating the magnitude of return period. The results obtained by the simplified method were compared with the original approaches. Khaddor et al.(2021) discussed the impact of detention reservoir on flood management on Ain Mechlawa reservoir of Tangier city in Northern Morocco. Kaboosi and Jelini (2017) evaluated the efficiency of detention reservoirs for flood control on the Jafar Abad River in Golestan province, Iran.

3. FLOOD FREQUENCY ANALYSIS

For planning, design and management of any hydraulic structures the estimation of design flood for a desired return period is very essential. Flood frequency analysis is a method to forecast how frequently a particular event will occur. For predicting the expected flood for a specified return period Gumbel's extreme value distribution method is used. This is a statistical method used for prediction of floods.

3.1 Annual peak discharge

The annual peak discharge is obtained from the discharge data collected from the Hydrology (NE) Directorate of the Central Water Commission, Brahmaputra & Barak Basin Organization, Shillong for the runoff series of 39 years for planning of the Kulsi multipurpose project.

3.2 Design flood

The estimation of design flood is done with Gumbel's extreme value distribution method. For estimation of magnitude of design flood for different return periods, the following equations are used to fit the Gumbel's distribution.

$$X_T = \overline{X} + K\sigma$$

Where, X_T = magnitude of T year flood.

K= frequency factor expressed as

$$K = \frac{y_T - \bar{y}_n}{S_n}$$

Y_T = reduced variate given by

$$Y_T = -\ln\ln\frac{T}{T-1}$$

S_n = reduced standard deviation, a function of sample size N taken from Gumbel's extreme value distribution table (K. Subramanya, 2014).

$\bar{Y}_n$= reduced mean, a function of sample size N, taken from Gumbel's extreme value distribution table (K. Subramanya, 2014).

σ = standard deviation, given by

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(X-\bar{X})^2}{N-1}}$$

N = sample size and $\bar{X}$= Average discharge

Using the equations of Gumbel's extreme value distribution method, the various result obtained are discussed below. For computation of return period and reduced variate the maximum peak discharge are arranged in descending order and ranks are allotted. The return period is assigned to each flood and corresponding to each flood the reduced variate is calculated.

The maximum design flood that may be expected from the annual peak discharge in the basin for specified return period is computed using the formula mentioned above and represented in table-1.

Table-1: Design floods (X_T) and return period (T) for annual peak flow

Parameters	Return period (T) (year)							
	1000	100	50	25	20	15	10	5
Y_T	6.907	4.600	3.902	3.199	2.970	2.674	2.250	1.500
Design flood (X_T) (Mcm/month)	713.575	524.452	467.141	409.462	390.738	366.430	331.713	270.178

Graphs are plotted for return period (T) vs discharge (X) (fig-2) and reduced variate (Y_T) vs discharges (X) (fig-.3). If the graphs indicate a straight line, then it may be concluded that the Gumbel's method is well fit for the observed data.

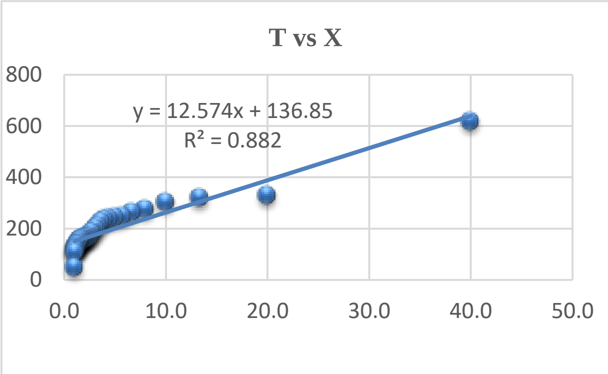

Fig-2: Flood frequency plot (return period vs discharge)

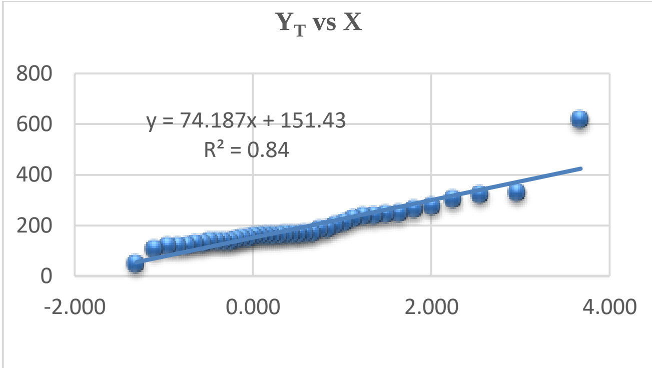

Fig-3: Flood frequency plot -reduced variate (Y_T) vs discharge

A graph is also plotted for X_T vs T (for some return period, T < N) (fig-4). It is observed that the plot results in a straight line for X_T vs T. Hence the observed data fits the frequency curves satisfactorily.

Design floods for the month of May, June, July, August and September are also calculated separately for each month. Since this is the monsoon season and maximum rainfall occurs in this period. The design floods for 1000 year, 100 year, 50 year, 25 year, 20 year, 15 year, 10 year and 5 year are shown in table -2. The design flood is the maximum in July.

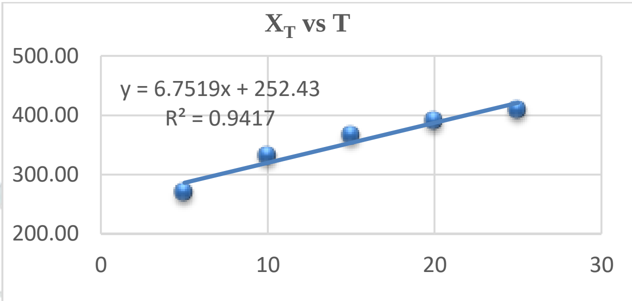

Fig-4: Flood frequency plot –flood flow (X_T) vs return period (T)

Table-2: Design floods for the month May, June, July, August and September

Months		Return period(year)						
	1000	100	50	25	20	15	10	5
		Design flood (Mcm)						
May	200.323	144.907	128.136	111.241	105.756	98.636	88.466	70.442
Jun	385.5954	280.203	248.308	216.175	205.744	192.202	172.861	138.580
Jul	**743.5452**	**528.552**	**463.487**	**397.938**	**376.660**	**349.035**	**309.581**	**239.651**
Aug	453.7015	337.389	302.189	266.726	255.215	240.270	218.925	181.092
Sep	364.4754	274.918	247.814	220.509	211.646	200.138	183.703	154.573

4. GOODNESS OF FIT TEST

Goodness of fit test for Gumbel distribution has been examined using Chi Square and the results obtained are tabulated in table-3.

Table-3: Goodness of fit using Chi Square

X^2 (Computed)	Degree of freedom	X^2 (From Table)		Remarks
		90% Confidence	95% Confidence	
6.0364	3	6.2514	7.8147	Passed at 90 % and 95% confidence

Source: χ^2 from Table: N. G. Das -statistical Methods

5. FLOOD ABSORPTION CAPACITY AND DETENTION TIME

The flood absorption capacity and detention time have been estimated by simulation. The storage capacity at a particular elevation is calculated using the equation obtained from best fitted curve derived from elevation- capacity relationship as shown in fig-5.

The flood absorption capacities are obtained for every 1.0 m elevation interval. The flood absorption capacity increases as the elevation decreases. The flood absorption capacities with respect to a particular elevation are shown in table-4.

The flood absorption capacity at 115.0 m elevation is zero, since it is the full reservoir level. If the reservoir level is decreased by 1.0 m, the flood absorption capacity increases to 20.800 Mcm. If the reservoir level is decreased by 2.0 m, the flood absorption capacity increases to 41.062 Mcm and so on. At elevation 100.0 m, the flood absorption capacity is 255.413 Mcm. So, depending on the design flood the reservoir level may be lowered to a predetermined elevation to accommodate the excess storm water for a definite time. The storm water so stored can be released gradually when the flood water in downstream receded.

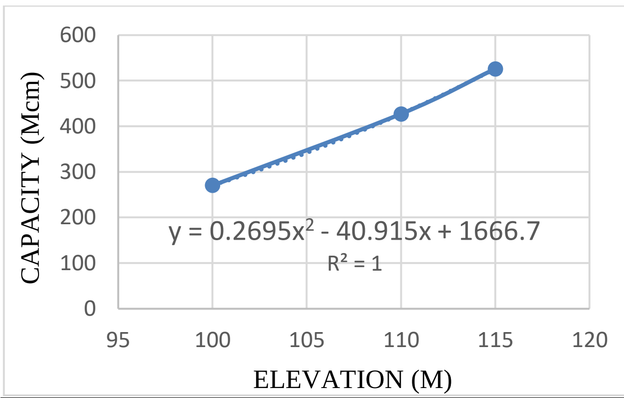

Fig-5: Elevation vs capacity plot

Detention time is the duration of time for which a specified quantity of storm water can be temporarily holding in the reservoir. Detention time for the annual design floods for return period 1000 year, 100 year, 50 year, 25 year, 20 year, 15 year, 10 year and 5 year are calculated for every 1.0 m elevation from elevation 115.0 m to 100.0m. The detention time with respect to elevations and flood absorption capacities for the annual design flood are also shown in table-4. The time of detention is increases with the decrease in elevation. Detention time for the design floods for return period 1000 year, 100 year, 50 year, 25 year, 20 year, 15 year, 10 year and 5 year are also calculated for every 1.0 m elevation for the month of May, June, July, August and September (monsoon months) respectively, which are presented in table-5, table-6, table-7, table-8 and table-9.

Table 4: Elevation –flood absorption- detention time for annual design flood

Return period (year)		1000	100	50	25	20	15	10	5
Design flood (Mcm/hour)		0.991	0.728	0.649	0.569	0.543	0.509	0.461	0.375
Elevation (m)	Flood absorption (Mcm)	Detention time (hour)							
115.00	0.000	0.00	0	0	0	0	0	0	0
114.00	20.800	20.99	28.56	32.06	36.58	38.33	40.87	45.15	55.43
113.00	41.062	41.43	56.37	63.29	72.20	75.66	80.68	89.13	109.43
112.00	60.785	61.33	83.45	93.69	106.88	112.01	119.44	131.94	161.98
111.00	79.968	80.69	109.78	123.25	140.62	147.35	157.13	173.57	213.11
110.00	98.613	99.50	135.38	151.99	173.40	181.71	193.76	214.04	262.79
109.00	116.718	117.77	160.24	179.90	205.24	215.07	229.34	253.34	311.04
108.00	134.285	135.49	184.35	206.97	236.13	247.44	263.86	291.47	357.86
107.00	151.312	152.67	207.73	233.22	266.07	278.82	297.31	328.43	403.23
106.00	167.801	169.31	230.37	258.63	295.06	309.20	329.71	364.22	447.17
105.00	183.750	185.40	252.26	283.21	323.11	338.59	361.05	398.84	489.68
104.00	199.161	200.95	273.42	306.96	350.20	366.99	391.33	432.29	530.74
103.00	214.032	215.96	293.84	329.89	376.35	394.39	420.55	464.57	570.38
102.00	228.365	230.42	313.51	351.98	401.56	420.80	448.71	495.68	608.57
101.00	242.158	244.34	332.45	373.24	425.81	446.22	475.82	525.62	645.33
100.00	255.413	257.71	350.65	393.67	449.12	470.64	501.86	554.39	680.65

Table 5: Elevation –flood absorption- detention time for the month of May

Return period (year)		1000	100	50	25	20	15	10	5
Design flood (Mcm/hour)		0.278	0.201	0.178	0.155	0.147	0.137	0.123	0.098
Elevation (m)	Flood absorption (Mcm)	Detention time (hour)							
115.00	0.000	0.00	0	0	0	0	0	0	0
114.00	20.800	74.76	103.35	116.88	134.63	141.61	151.83	169.29	212.61
113.00	41.062	147.59	204.02	230.73	265.77	279.55	299.73	334.19	419.70
112.00	60.785	218.47	302.02	341.55	393.42	413.83	443.70	494.71	621.29
111.00	79.968	287.42	397.34	449.34	517.59	544.43	583.73	650.83	817.37
110.00	98.613	354.43	489.98	554.10	638.26	671.36	719.83	802.58	1007.94
109.00	116.718	419.51	579.94	655.84	755.45	794.63	851.99	949.93	1193.00
108.00	134.285	482.65	667.22	754.55	869.15	914.22	980.22	1092.90	1372.55
107.00	151.312	543.85	751.82	850.22	979.36	1030.15	1104.51	1231.48	1546.60
106.00	167.801	603.11	833.75	942.87	1086.08	1142.40	1224.87	1365.67	1715.13
105.00	183.750	660.43	913.00	1032.49	1189.31	1250.99	1341.30	1495.48	1878.15
104.00	199.161	715.82	989.57	1119.08	1289.05	1355.90	1453.79	1620.90	2035.67
103.00	214.032	769.27	1063.46	1202.65	1385.31	1457.15	1562.34	1741.94	2187.67
102.00	228.365	820.79	1134.67	1283.18	1478.07	1554.73	1666.96	1858.58	2334.17
101.00	242.158	870.36	1203.21	1360.69	1567.35	1648.64	1767.65	1970.85	2475.15
100.00	255.413	918.00	1269.07	1435.17	1653.14	1738.87	1864.40	2078.72	2610.63

Table 6: Elevation –flood absorption- detention time for the month of June

Return period (year)		1000	100	50	25	20	15	10	5
Design flood (Mcm/hour)		0.536	0.389	0.345	0.300	0.286	0.267	0.240	0.192
Elevation (m)	Flood absorption (Mcm)	Detention time (hour)							
115.00	0.000	0.00	0	0	0	0	0	0	0
114.00	20.800	38.84	53.45	60.31	69.28	72.79	77.92	86.64	108.07
113.00	41.062	76.67	105.51	119.06	136.76	143.70	153.82	171.03	213.34
112.00	60.785	113.50	156.19	176.25	202.45	212.72	227.70	253.18	315.81
111.00	79.968	149.32	205.48	231.88	266.34	279.85	299.57	333.08	415.48
110.00	98.613	184.13	253.39	285.94	328.44	345.09	369.41	410.74	512.35
109.00	116.718	217.94	299.91	338.44	388.75	408.45	437.23	486.15	606.41
108.00	134.285	250.74	345.05	389.38	447.25	469.93	503.04	559.32	697.68
107.00	151.312	282.54	388.81	438.75	503.97	529.52	566.82	630.24	786.15
106.00	167.801	313.32	431.17	486.56	558.88	587.22	628.59	698.92	871.82
105.00	183.750	343.11	472.16	532.81	612.00	643.03	688.34	765.35	954.68
104.00	199.161	371.88	511.76	577.49	663.33	696.96	746.07	829.54	1034.75
103.00	214.032	399.65	549.97	620.61	712.86	749.00	801.78	891.49	1112.01
102.00	228.365	426.41	586.80	662.17	760.60	799.16	855.47	951.18	1186.48
101.00	242.158	452.17	622.24	702.17	806.54	847.43	907.14	1008.64	1258.14
100.00	255.413	476.92	656.30	740.60	850.69	893.82	956.79	1063.84	1327.01

Table 7: Elevation –flood absorption- detention time for the month of July

Return period (year)		1000	100	50	25	20	15	10	5
Design flood (Mcm/hour)		1.033	0.734	0.644	0.553	0.523	0.485	0.430	0.333
Elevation (m)	Flood absorption (Mcm)	Detention time (hour)							
115.00	0.000	0.00	0	0	0	0	0	0	0
114.00	20.800	20.14	28.33	32.31	37.63	39.76	42.91	48.38	62.49
113.00	41.062	39.76	55.94	63.79	74.29	78.49	84.70	95.50	123.37
112.00	60.785	58.86	82.80	94.43	109.98	116.19	125.39	141.37	182.62
111.00	79.968	77.44	108.93	124.23	144.69	152.86	164.96	185.98	240.25
110.00	98.613	95.49	134.33	153.19	178.42	188.50	203.42	229.35	296.27
109.00	116.718	113.02	158.99	181.31	211.18	223.11	240.77	271.45	350.66
108.00	134.285	130.03	182.92	208.60	242.96	256.69	277.01	312.31	403.44
107.00	151.312	146.52	206.12	235.05	273.77	289.24	312.13	351.91	454.60
106.00	167.801	162.49	228.58	260.67	303.61	320.76	346.14	390.26	504.14
105.00	183.750	177.93	250.31	285.44	332.46	351.25	379.04	427.35	552.05
104.00	199.161	192.85	271.30	309.38	360.35	380.70	410.83	463.19	598.35
103.00	214.032	207.25	291.56	332.49	387.25	409.13	441.51	497.78	643.03
102.00	228.365	221.13	311.08	354.75	413.19	436.53	471.08	531.11	686.09
101.00	242.158	234.49	329.87	376.18	438.14	462.89	499.53	563.19	727.53
100.00	255.413	247.32	347.93	396.77	462.12	488.23	526.87	594.02	767.35

As the design flood for the month of July is maximum so flood absorption and detention time for that month is explained here. The design flood for 1000, 100, 50, 25, 20, 15, 10 and 5 year return period are 743.545 Mcm, 528.552 Mcm, 463.487 Mcm, 397.938Mcm, 376.660 Mcm, 349.035 Mcm, 309.581Mcm and 239.651Mcm respectively in July. The flood absorption capacity at 114.0 m elevation is 20.800 Mcm and detention time of 1.0 m flood cushion (lowering of reservoir level) for design flood for 1000, 100, 50, 25, 20, 15, 10 and 5 year return period are 20.14 hrs, 28.33 hrs, 32.31 hrs, 37.63 hrs, 39.76 hrs, 42.91 hrs, 48.38 hrs and 62.49 hrs respectively in July. Similarly, the flood absorption capacity at 110.0 m elevation is 98.613 Mcm and detention time of 5.0 m flood cushion for design flood 1000, 100, 50, 25, 20, 15, 10 and 5 year return period are 95.49 hrs, 134.33 hrs, 153.19 hrs, 178.42 hrs, 188.50 hrs, 203.42 hrs, 229.35 hrs and 296.27 hrs respectively in July and so on. So, with reference to flood forecasting the reservoir water level may be lowered to a predetermined level to accommodate the design floods for a definite time and release the same when flood receded in the downstream.

Table 8: Elevation –flood absorption- detention time for the month of August

Return period (year)		1000	100	50	25	20	15	10	5
Design flood (Mcm/hour)		0.630	0.469	0.420	0.370	0.354	0.334	0.304	0.252
Elevation (m)	Flood absorption (Mcm)	Detention time (hour)							
115.00	0.000	0.00	0	0	0	0	0	0	0
114.00	20.800	33.01	44.39	49.56	56.15	58.68	62.33	68.41	82.70
113.00	41.062	65.16	87.63	97.84	110.84	115.84	123.05	135.04	163.26
112.00	60.785	96.46	129.72	144.83	164.08	171.48	182.15	199.91	241.67
111.00	79.968	126.90	170.65	190.53	215.87	225.60	239.63	263.00	317.94
110.00	98.613	156.49	210.44	234.96	266.19	278.20	295.51	324.32	392.07
109.00	116.718	185.23	249.08	278.09	315.07	329.28	349.76	383.86	464.06
108.00	134.285	213.10	286.57	319.95	362.49	378.84	402.40	441.64	533.90
107.00	151.312	240.12	322.91	360.52	408.45	426.87	453.43	497.64	601.60
106.00	167.801	266.29	358.09	399.80	452.96	473.39	502.84	551.86	667.16
105.00	183.750	291.60	392.13	437.81	496.01	518.39	550.63	604.32	730.57
104.00	199.161	316.06	425.02	474.52	537.61	561.86	596.81	655.00	791.84
103.00	214.032	339.66	456.75	509.96	577.76	603.82	641.38	703.91	850.97
102.00	228.365	362.40	487.34	544.11	616.45	644.25	684.32	751.05	907.95
101.00	242.158	384.29	516.77	576.97	653.68	683.16	725.66	796.41	962.79
100.00	255.413	405.33	545.06	608.55	689.46	720.56	765.38	840.00	1015.49

Table 9: Elevation –flood absorption- detention time for the month of September

Return period (year)		1000	100	50	25	20	15	10	5
Design flood (Mcm/hour)		0.506	0.382	0.344	0.306	0.294	0.278	0.255	0.215
Elevation (m)	Flood absorption (Mcm)	Detention time (hour)							
115.00	0.000	0	0	0	0	0	0	0	0
114.00	20.800	41.09	54.48	60.43	67.92	70.76	74.83	81.52	96.89
113.00	41.062	81.12	107.54	119.30	134.07	139.69	147.72	160.94	191.27
112.00	60.785	120.08	159.19	176.60	198.47	206.78	218.67	238.24	283.13
111.00	79.968	157.97	209.43	232.34	261.11	272.04	287.69	313.42	372.49
110.00	98.613	194.80	258.26	286.51	321.99	335.47	354.76	386.50	459.34
109.00	116.718	230.57	305.68	339.11	381.10	397.06	419.89	457.46	543.67
108.00	134.285	265.27	351.69	390.15	438.46	456.82	483.09	526.31	625.50
107.00	151.312	298.91	396.28	439.62	494.06	514.75	544.35	593.05	704.81
106.00	167.801	331.48	439.46	487.53	547.90	570.84	603.66	657.67	781.61
105.00	183.750	362.99	481.23	533.87	599.97	625.10	661.04	720.18	855.91
104.00	199.161	393.43	521.59	578.64	650.29	677.53	716.48	780.58	927.69
103.00	214.032	422.81	560.54	621.85	698.85	728.12	769.98	838.87	996.96
102.00	228.365	451.12	598.08	663.49	745.65	776.88	821.54	895.04	1063.72
101.00	242.158	478.37	634.20	703.57	790.69	823.80	871.17	949.11	1127.97
100.00	255.413	504.55	668.92	742.08	833.96	868.89	918.85	1001.05	1189.71

6. DISCHARGE CARRYING CAPACITY OF KULSI RIVER

The discharge carrying capacity of a river is an important factor to be considered for development of any river basin. Since the discharge carrying capacity of a river directly influence the flood, so it is very important to estimate the discharge carrying capacity of the river for management of flood in a basin. To estimate the discharge carrying capacity of a river, the cross-sectional area of the river as well as the velocity of flow in that section is essential. The discharge carrying capacities at 2.0 Km, 10.75 Km, 20.60 Km, 36.40 Km, 78.0 Km and 114.90 km downstream of dam are estimated during monsoon period.

Table 10: Discharge carrying capacity of Kulsi river

Location	Area of flow (m^2)	Average velocity (m/s)	Discharge carrying capacity (Mcm/month)
2.00 Km D/S	682.94	2.0	3540.361
10.75 Km D/S	367.89	2.0	1907.142
20.60 Km D/S	728.74	2.0	3777.788
36.40 Km D/S	452.08	2.0	2343.583
78.0 Km D/S	194.55	2.0	1008.547
114.9 Km D/S	640.39	2.0	3319.782

The velocity of flow in Kulsi river generally varies from 1.2 m/s to 2.8 m/s (Islam et al. 2012). For this study the average velocity is considered as 2.0 m/s and accordingly discharge carrying capacity in the river is estimated and presented in table-10.

7. STATUS OF FLOOD IN KULSI BASIN

To know the contribution to flood by Kulsi river discharge in the basin, the maximum design flood is compared with the discharge carrying capacities of Kulsi river at sections 2.0 Km, 10.75 Km, 20.60 Km, 36.40 Km, 78.0 Km and 114.90 Km downstream of dam site.. From table-2 it is seen that the maximum design flood is expected in the month of July. The maximum design flood in July is 743.545 Mcm for 1000 year return period.

From table-10 it has been observed that, the Kulsi river is capable of discharging 3540.361Mcm/month, 1907.142 Mcm/month, 3777.788 Mcm/month, 2343.583 Mcm/month, 1008.547 Mcm/month and 3319.782 Mcm/month respectively at 2.0 Km, 10.75 Km, 20.60 Km, 36.40 Km, 78.0 Km and 114.90 Km downstream of the dam. The discharge carrying capacity of Kulsi river is far more than the maximum design flood. So, it may be concluded that, there is no contribution to flood from the discharge of Kulsi river in the basin.

But due to flatter slope in the plain area of lower reaches, drainage congestion takes place and as a result some area from Kukurmara and Chamaria get inundated. The problem of drainage congestion is also influenced by other north flowing sub-tributaries of the basin like Deosila, Boko, Singra etc. when their discharges joined together in the lower reaches. This problem becomes critical when the flood of the Brahmaputra also enter the area either due to overtopping of embankments or a breach in the embankment or due to backwater flow through Kulsi river. The drainage congestion also takes place due deposition of silt in the river bed.

The drainage congestion in the lower reaches of Kulsi river can be minimized by removal of silt and sand from the river bed. The quality of Kulsi river sand is very good and suitable for use in constructions. This is a cleaning mechanism of river bed, which helps in minimizing the drainage congestion in the lower reaches of Kulsi basin. The drainage congestion at Kukurmara can also be minimized by increasing the span of RCC bridge on NH-37.

8. CONCLUSION

For development of any river basin the management of flood is an important factor. Application of detention reservoir for control of flood is widely used in several countries in the world. The purpose of the detention storage is generally not to reduce the total runoff notably, it only redistribute the runoff over a longer period of time. The aim of detention storage is to give time to reduce the flood in downstream and also to reduce the soil erosion problems.The detention reservoirs are needed for temporary storage of flood water and released the same in a controlled manner. The annual and monthly design floods for the month of May, June, July, August and September for return period 1000 year, 100 year, 50 Year, 25 year, 20 year, 15 year, 10 year and 5 year are estimated using Gumbel's extreme value distribution method.

The design flood is maximum in July. In July design floods are 743.545 Mcm, 528.552 Mcm , 463.487 Mcm , 397.938 Mcm, 376.660 Mcm, 349.035 Mcm, 309.581 Mcm and 239.651 Mcm respectively for return period 1000 year, 100 year, 50 Year, 25 year, 20 year, 15 year, 10 year and 5 year.

The flood absorption capacities form 100.0 m to 115.0 m elevation is estimated for every 1.0 m elevation interval. As the water elevation decreases the flood absorption capacities are increases. The flood absorption capacities at 114.0 m, 113.0 m, 112.0 m are 20.800 Mcm, 41.062 Mcm, 60.785 Mcm respectively. Similar analysis is done at every 1 m interval up to 100 m elevation. The flood absorption capacity at 100.0 m elevation is 255.413 Mcm.

At elevation 114.0 m (i.e. for 1.0 m flood cushion) the flood absorption capacity is 20.800 Mcm and detention times for 1000, 100, 50, 25, 20, 15, 10 and 5 year design floods are 20.14 hrs, 28.33 hrs, 32.31 hrs, 37.63 hrs, 39.76 hrs, 42.91 hrs, 48.38 hrs and 62.49 hrs respectively for design flood in July. At elevation 110.0 m (i.e. for 5.0 m flood cushion) the flood absorption capacity is 98.613 Mcm and detention times for 1000, 100, 50, 25, 20, 15, 10 and 5 year floods are 95.49 hrs, 134.33 hrs, 153.19 hrs, 178.42 hrs, 188.50 hrs, 203.42 hrs, 229.35 hrs and 296.27 hrs respectively. Similarly, the flood absorption capacities and detention times at every 1 m interval is calculated up to 100.0 m elevation.

The discharge carrying capacity of Kulsi river is estimated to check whether the river has sufficient cross-sectional area for carrying the maximum design flood safely. Since the maximum design flood is expected in July, hence design flood of July is compared with the discharge carrying capacity of the river.

The maximum design flood in July is 743.545 Mcm for 1000 year return period. The discharge carrying capacities of Kulsi river are 3540.361Mcm/month, 1907.142 Mcm/month, 3777.788 Mcm/month, 2343.583 Mcm/month, 1008.547 Mcm/month and 3319.782 Mcm/month respectively at 2.0 Km, 10.75 Km, 20.60 Km, 36.40 Km, 78.0 Km and 114.90 Km downstream of the dam. The discharge carrying capacity of Kulsi river is far more than the maximum design flood. So, it may be concluded that discharge from Kulsi river is not causing any flood in its upper reaches. Though the discharge from Kulsi river do not causes flood itself in the upper reaches, the drainage congestion takes place due to flatter slopes in the downstream reaches.

The drainage congestion in the lower reaches of Kulsi river can be minimized by removal of silt and sand from the river bed. The quality of Kulsi river sand is very good and suitable for use in constructions. This is a cleaning mechanism of river bed, which helps to minimize the drainage congestion in the lower reaches of Kulsi basin.

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