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Assessment of Design Flood Peaks For Rongai Barrage in Meghalaya

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ABSTRACT

The Rongai Valley Irrigation Scheme of Meghalaya envisages construction of a barrage founded on firm rock. For design of this barrage, a 50-yr return period flood peak is required. To analyse incremental cost and additional risk covered, floods of various return periods are needed. Probable Maximum Flood (PMF) peak is required to visualise potential flood hazard downstream.

Design flood peaks of various return periods, SPF and PMF assessed are presented in the paper. The approach adopted is based on the practical view point that : since water use projects cannot be delayed till data of adequate quality and quantity are available, recourse is to be taken to arrive at the best judgement assessments after analysing whatever information is readily available.

1. THE PROJECT

The Rongai Valley Irrigation Scheme was conceived to introduce modern methods of irrigation with a view to eliminating the devastating effects of Jhum cultivation in Meghalaya State. The project is located south-west of West Garo Hill district. The scheme envisages construction of a barrage founded on firm rock over river Rongai near Chibinang village (lat : 25 53′ Long : 90 6′) to divert 6 cumec of water for irrigation requirements of 4775 Ha GCA and 3880 Ha CCA with crop intensity of 148% :

Pond Level	*: 33.80 m*	
Crest Level	*: 29.50 m*	
Average bed level	*: 29.00 m*	
Firm rock level in river bed	*: 21.50 m*	
Length of barrage	*: 74.00 m*	*(6 nos bays of 10m width & 6 nos piers of 2m width & 1 no. fishway of 2m width)*

2. THE BASIN

The Rongai stream originates from Arbela Hill ranges at an altitude of 995 m in Garo Hills. After traversing 63 km in the hilly range with thick forest of bamboo and trees, it enters the plains near Chibinang village and meets the

Jingiram river near Phulbari which joins the Brahmaputra on the southern bank near South Salmara(Fig.1).

Catchment area upto the barrage site is 410 sq.km. The basin receives copious rainfall during most part of the year with an annual rainfall normal of about 2550 mm. June, July and August are usually the months of heavy rains contributing over 51% while Nov,Dec,Jan and Feb are considered to be dry contributing about 2% of annual rainfall only. Rains during April and May are sometimes heavy.

3. *DESIGN FLOOD CRITERIA*

i)As per IS : 11223-1985 : Guidelines for fixing spillway capacity : Spillway of small dams with gross storage between 10 and 60 Million cum and hydraulic head between 12 and 30 m are to be designed to safely pass a 100-yr flood.

ii) As per IS : 6966 (1989) :Criteria for Hydraulic design of barrages and weirs : For purpose of design of items other than free board , a design flood of 50 year frequency may normally suffice. In such cases where risks and hazards are involved,a review of this criteria based on site conditions may be necessary. For designing the free board, a minimum of 500 year frequency flood or the standard project flood may be desirable.

iii) As per CWC Criteria(1968)for pick-up weirs, according to importance and level conditions, a flood of 50 to 100 years should be adopted.

The project proposal envisages construction of a barrage founded on firm rock and it is considered appropriate to adopt a flood of 50-yr return period as design flood for fixing the waterway as per CWC criteria. Justification with analysis of risks and hazard potential is necessary for adopting a higher return period flood such as 500-yr flood or standard project flood for design of this barrage. For design of cofferdam and flood embankments,a 10-yr or 25-yr flood may be appropriate. Further, keeping in view the need to avoid a catastrophe, the designer may like to assess the hazard potential downstream and check the safety of the structures for Probable Maximum Flood (PMF). To meet these requirements of the designer, floods of various return periods have been assessed and presented in this paper.

4. *DESIGN STORM DEPTH*

The project region lies south-west of West Garo hills in sub-zone 2b (South Brahmaputra basin) which receives heavy and very heavy rainfall during South-West monsoon season when low pressure systems originating from Bay of Bengal pass over the region. The project basin, however, receives less rainfall than the eastern part of Meghalaya on the windward side.

4.1 Storm Depths Of Various Return Periods

Iso-pluvial maps giving 24-hr storm depths of 50-yr and 100-yr return period are given in Flood Estimation report No.SB/8/1984 of Central Water Commission (CWC) :

24-hr Point raindepth:	320 (50-yr)	1-day raindepth:	278 (50-yr)
	360 (100-yr)		313 (100-yr)

As per the practice of India Meteorological Department (IMD) the maps are based on the frequency analysis of observational day point rainfalls corrected for clock-hour by multiplying with a factor of 1.15. However, recent studies (Rao, 1991) indicated that this correction is not warranted. At best while arriving at the 48-hr or 72-hr hyetograph, hourly incremental values may be arranged in a pattern of one bell for each day of the storm with time distance between two peak intensities of two consecutive days kept between 15 and 24 hrs such that the maximum cumulative 24-hr depth is between $X1+35$ and $(0.5)^m \cdot X2$, where X1 and X2 are 1-day and 2-day depths in mm and $m = 0.175 + 0.0004\, X_2$, but this would hardly affect the peak of flood hydrograph. Accordingly, the values read from these maps need to be decreased by dividing with 1.15.

While arriving at the 50-yr and 100-yr depths, IMD had used the 2-parameter EV-1 distribution. 1-day storm depths of other return periods can be easily evaluated as shown in Table 1 :

4.2 Maximum 1-day Point PMP Atlas

Referring to IMD Atlas, maximum 1-day point PMP for the project basin has been obtained as 520 mm. IITM Atlas indicated a value of 600 mm. Moisture Maximisation Factor (MMF) recommended for eastern India by IMD is 1.35. Accordingly, maximum 1-day point SPS for the project basin will be 385 mm as per IMD Atlas and 444 mm as per IITM Atlas.

4.3 Maximum 1-day Point Rainfalls

Maximum 1-day point raindepths observed at stations adjoining the project area (Fig.2) are compiled in Table 2 :

Table-1 : 1- Day Point Rainfall Depths of Various Return Periods

Return Period (T)	Y_T	K_T	X_T	EV-1 Distribution Equation
5	1.500	0.720	158	$XT=X+K_T.\sigma$
10	2.251	1.306	195	
25	3.199	2.045	243	$K_T = -0.45+0.78\ Y_T$
50	3.903	2.594	278	
100	4.601	3.139	313	$Y_T =-0.834-2.303\log\log[T/T-1]$
300	5.703	3.998	368	
400	5.991	4.223	383	$X = 111.41$
500	6.215	4.398	394	$\sigma = 64.22$
10,000	9.212	6.735	544	
100,000	11.515	8.532	659	

Table-2 Severe Storms: Observational Day. Depths

Station (m)	Alt (m)	Storm Dates	Raindepth Recorded (mm) Ist Day	2nd Day	3rd Day	4th Day	5th Day	Annual Normal (mm)
Dhubri	35	8-12.6.1909	51	76	146	368	36	2587
Rupsi Obs.	45	26-30.5.1989	3	14	479	25	7	-
Mohinderganj	166	23-27.8.1918	40	95	302	60	0	2178
Tura	370	25-29.6.1932	45	37	55	305	8	3293
Dalu	-	13-17.6.1956	320	243	142	79	103	2734
Bilasipara	40	28-30.9.1906 1.10.1906	20	167	300	97	0	2618
Lakhipur	40	21-25.6.1959	24	18	731	632	27	2444

There is no raingauge station within the catchment. Lakhipur station recorded a depth of 731 mm on 23 June and 632 mm on 24 June 1959 which are larger than 1-day point PMP values given by IMD/IITM Atlas. Raindepths recorded on these days by other stations in the region are less than half the depth recorded at Lakhipur. Extremely rare events with depths close to probable maximum precipitation depths do occur in nature some times and such local high depths over a very limited area need to be isolated in consonance with the definition of SPS requiring exclusion of extremely rare events.

Tura station at more or less same altitude as the project basin and on the same leeward side of prevailing wind direction, has recorded 305 mm of raindepth on 28th June 1932. Rupsi observatory which is 65 Km North-West of barrage site has recorded 479 mm of raindepth on 28th May 1989. Dhubri Station,also located in the plains on the northern bank of the Brahmaputra, about 45 km North-West of barrage site, recorded 368 mm of raindepth on 11 June 1909. These values are comparable to the SPS depth assessed from IMD/IITM Atlas,though SPS depth of 305 mm appears to be more realistic considering physiography and altitude of the project catchment.

4.4 Results

Keeping in view the design storm depth estimates from different approaches presented above,the storm depths of various return periods in Table 3 are considered appropriate.

Table 3 : Design Storm Raindepths Adopted

Return Period (yrs)	Point 1-day Raindepth (mm)
5	158
10	195
25	243
50	278
100	313
300	368
400	383
500 (SPS)	394
10,000 (PMP)	544

5. TEMPORAL DISTRIBUTION PATTERN

Flood Estimation Report No. SB/8/1984 of CWC indicated that :

50-yr 12-hr raindepth = 200 mm

Then, P_{12}/P_{24} = 200/278 = 0.72

or $$P_t/P_T = (t/T)^{0.475} \quad \ldots\ldots. \quad (2)$$

for t=12 hrs and T=24 hrs

The author in a recent study (1990) analysed 4-hourly rainfall data of 13 stations collected during five severe storms over Chambal basin and has shown that higher the 24-hr rainfall amount, more uniform is the distribution i.e. closer to rectangular pattern. Kapoor et al (1986) analysed self recording raingauge data of a large number of 24-hr, 48-hr and 72-hr storms for developing synthetic hyetograph of design storm and concluded that higher the storm rainfall amount greater the value of the exponent in eqn (2) which means that more uniform would be the rainfall distribution. Representing raindepth-duration relationship by :

$$P_t / P_T = (t/T)^n \quad .....(3)$$

where Pt and PT are cumulative raindepths for duration t and T hrs, variation of the exponent, n is given by :

$$n = 0.465 + P \times 0.0003 \quad ..... (4)$$

where P = storm raindepth in mm.

Taking n=0.475 for point rainfall depths of 200-300 mm, which is conservative when compared to the value given by eqn(4),n is increased by 0.03 for every additional 100 mm raindepth :

Table 4 : Temporal Distribution of Point Rainfall

1-day point raindepth (mm)	Mean (mm)	Exponent, n	P_{12} / P_{24}
upto 100	50	0.415	0.750
100 -200	150	0.445	0.735
200 -300	250	0.475	0.719
300 -400	350	0.505	0.705
400 -500	450	0.535	0.690
500 -600	550	0.565	0.676
600 -700	650	0.595	0.662

6. COMPUTATION OF FLOOD PEAKS

Flood Peak, Qp in cumecs is given by ;

$$Q = K.R(A^{0.7}) \quad ....(5)$$

where K = a factor varying with area, A read from Fig: A-6 of Flood Estimation Report of CWC for Sub-Zone 2b

= 0.706 for A = 410 sq.km.

R = Point rainfall depth in cm corresponding to duration, Td and

$$Td = 3.33\ A^{0.213}$$

$$= 12 \text{ hrs for } A = 410 \text{ sq.km.}$$

Flood peaks of various return periods are assesed using eqn.(5) and given in Table 5 :

Table 5: Design Flood Peaks

Return Period (yrs)	1-day point raindepth (mm)	12-hr/24 hr point rain-depth ratio (mm)	12-hr point raindepth (mm)	Flood Peak (cumecs)
5	158	0.735	116	550
10	195	0.735	143	680
25	243	0.719	175	830
50	278	0.709	200	950
100	313	0.705	221	1050
300	368	0.705	259	1240
400	383	0.705	270	1290
500(SPF)	394	0.705	278	1320
10,000(PMF)	544	0.676	368	1750

Bank-ful capacity of the river channel using Mannings n=0.02 is assessed as 500 cumecs with water surface slope of 1/1200 and velocity of flow of 2.6 m/sec. It has been reported that the river has over-topped the banks only once in 1990 during the last 2 decades and it is thus reasonable to consider a 10-yr flood peak to be around 500 cumecs. However,keeping in view the lack of site specific data,it is considered prudent to adopt the flood peaks assessed using eqn (5) and given in Table 5.

8. CONCLUDING REMARKS

Design flood assessment and prescription for dimensioning of a water resource project or its structures is to be approached keeping in view the concerns of the project designer viz., flood magnitudes and risks. To meet the requirements of the designer, floods of various return periods, have been assessed.

The approach adopted in the case study presented is based on the practical view point: Since water use projects cannot be delayed till data of adequate quality and quantity are available, recourse is to be taken to arrive at best judgement assessments on the basis of available information, keeping in view the need to preserve the concept of rare *events, at the same time avoiding compounding one unlikely event with another to unrealistic extremes.*

Hydrological and Meteorological data collection after setting up the appropriate instrumentation network is essential to enable review and implement corrective measures if found necessary.

REFERENCES

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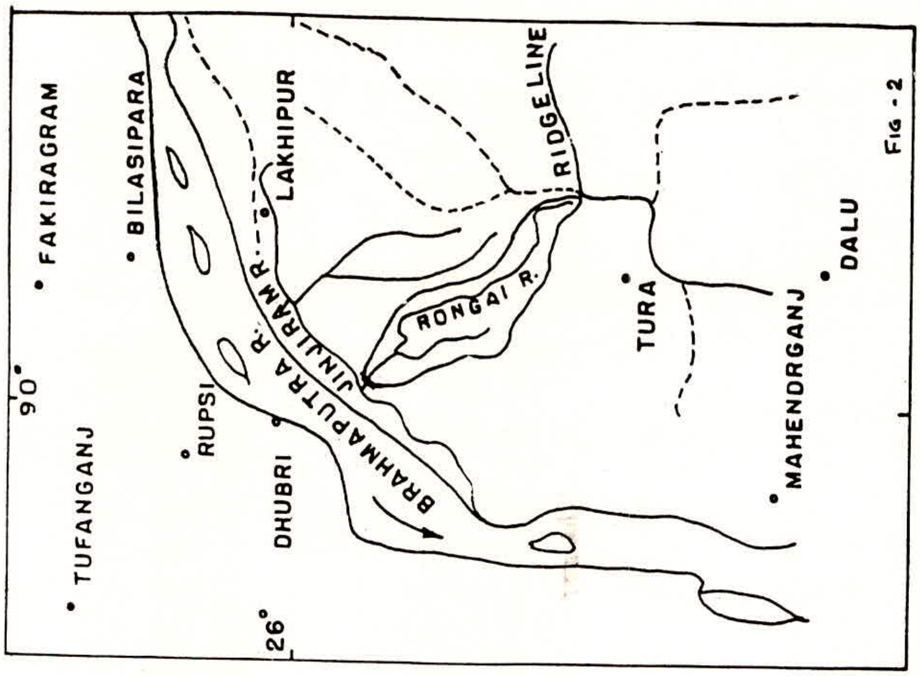
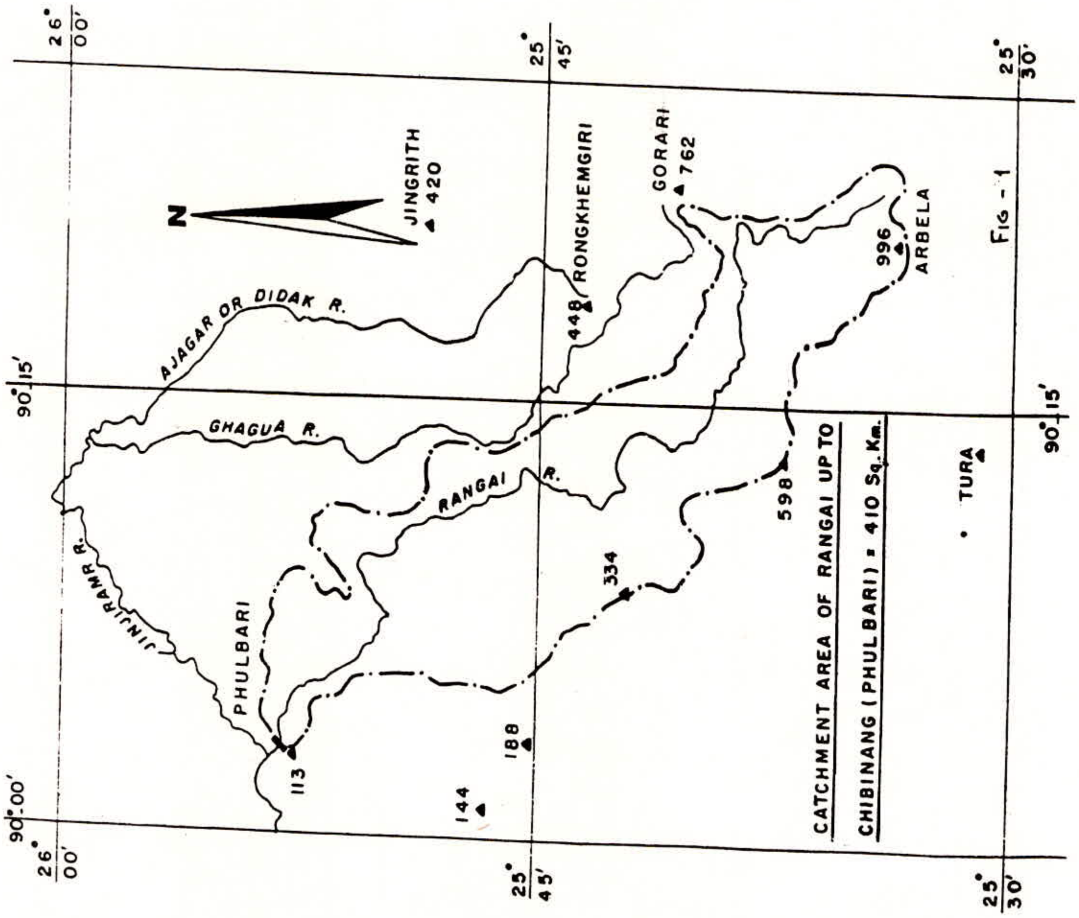


TUFANGANJ
FAKIRAGRAM
BILASIPARA
RUPSI
DHUBRI
LAKHIPUR
BRAHMAPUTRA R.
JINJIRAM R.
RONGAI R.
RIDGELINE
TURA
DALU
MAHENDRGANJ
90°
26°

Fig - 2



26° 00'
25° 45'
25° 30'
90° 00'
90° 15'
N
JINGRITH ▲ 420
AJAGAR OR DIDAK R.
RONGKHEMGIRI
448
GORARI ▲ 762
GHAGUA R.
RANGAI R.
PHULBARI
113
188
144
334
598
996
ARBELA
TURA
CATCHMENT AREA OF RANGAI UP TO
CHIBINANG (PHULBARI) = 410 Sq. Km.

Fig - 1