CONTRIBUTION OF CWPRS - WATER ALLOCATION AMONG USES

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INTRODUCTION

Water has been one of the essential resources for survival of mankind. The importance of water has been well understood since early ages of Kautilya and Mohanjedaro/Harappa era.

Water is required for different activities of human race; the major activities include water requirements for municipal and industrial, agriculture, irrigation, power generation, recreation, environmental protection and riparian rights. Water for the above activities is supplied as per national policy derived by the Union Government and implemented by Federal / State Governments. It is well known that availability of this valuable resources help in maintaining cordial relations amongst the users and managing institutes. The role of managing institutes becomes critical when the resources are limited in nature and the requirement of the community varies in space and time. Water is received in the form of rains over major part of India; barring the area that receive water in the form of snow in northern part of India. Further, rainfall is received in a short period of 4-6 months during south-west monsoon and return monsoon is experienced in certain states of India. Thus, major part of the water, which is received in a short period, is to be stored and critically released for all the activities during entire year. This leads to construction of reservoirs. Size of the reservoir would vary as per requirements at particular site.

Role of management personnel becomes more difficult while operating these structures, e.g. reservoirs constructed to meet requirement of power generation and flood moderation. It is well known that for maximization of power generation, it is essential to fill the reservoir at earliest possible time whereas the flood moderation objectives would require the diametrically opposite filling schedule of the reservoir.

Studies have been carried out to derive maximum possible benefits under the above requirements of power generation and flood moderation. Detailed studies of two reservoirs have been carried out at CWPRS. The results of the studies are presented.

STUDY AREA

River Brahmaputra

River Brahmaputra originates at an elevation of 5000 m above MSL near Mansarovar (*2,8,9*). The river flows for a length of 2900 km from the source upto confluence with river Ganga (Padma) in Bangladesh. The total catchment area of the basin is 5,80,000 sq. km out of which 1,95,000 sq. km is in India spread in the states of Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim and West Bengal. The river is known as Tsang Po for initial length of 1625 km in Tibet. The river enters India through Arunachal Pradesh where the river is known as Dehang (Siang) and flows for a distance of about 52 km from Passighat along the hilly track where two major rivers viz. Lohit and Dibang join the Siang opposite Kobo on West and Sadia on East. From this confluence the river is called as Brahmaputra and flows for a length of about 700 km upto Bangladesh border (Figure 1). The river is used as inland waterway from Sadiya to Dhubri and through Bangladesh to Calcutta. The Government of India has declared this waterway as National Waterway No.2.

River Brahmaputra has about twenty major tributaries joining from north bank and about thirteen tributaries meet the mainstream from south bank. The north bank tributaries start from high rainfall region and pass through fragile Himalayan ranges with steep slope. The south bank tributaries pass through relatively stable reaches with flat slope. The total stretch of river Brahmaputra consists of initial steep slope from origin to Tsela, followed by falls and steeper slope upto Indo China border and continuing upto Pasighat. The slope of river becomes flat from Passighat upto confluence with river Ganga and further upto outfall into Bay of Bengal.

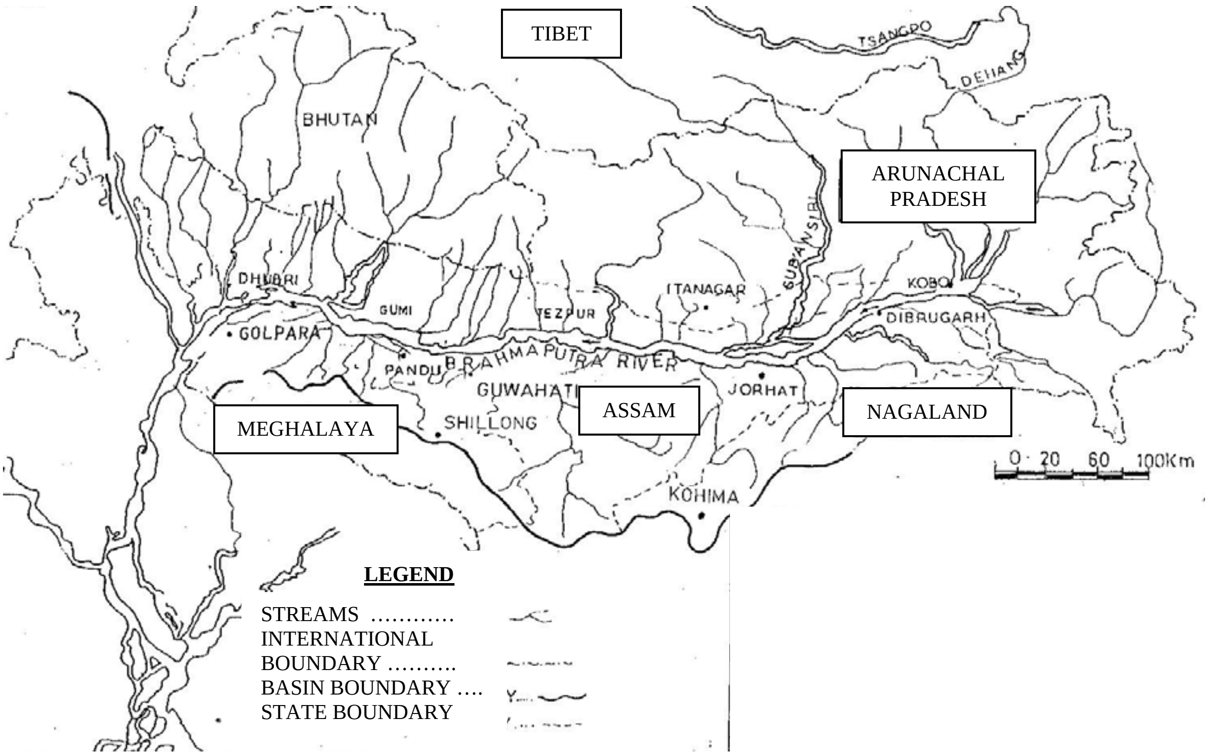

Figure 1 : Index Map of River Brahmaputra

River Brahmaputra flows in narrow valley of 86 km width with flood plains extending upto 40 km. The width of river channel varies from 1.2 to 19 km. The minimum width is near Pandu of 1.2 km followed by about 1.8 km near Jogi Ghopa.

River Brahmaputra is known for devastating floods, which damage valuable properties and endanger human life. Central Water Commission has compiled the reports submitted by states from 1953 to 1988 (*5*) and reported average area affected by floods as 79,000 sq. km out of which 36,900 sq km is cropped area. Total damages include 1.25 Million houses, over 1,00,000 cattle and human lives above 1500. The total estimated damages are about Rs. 15, 500 million. It is reported that estimated flood damages in 1987 and 1988 floods are Rs. 46.5 billion and Rs. 77.5 billion. In order to mitigate floods the Brahmaputra Board, set up by the Government of India, is investigating sites for creation of storages. In addition numerous flood protection works like embankments for protecting important towns on banks of river Brahmaputra have been constructed by Assam Government under the advice of committee of experts with representatives from Central Water Commission (CWC), CWPRS etc. Although numerous breaches due to erosion, etc have been experienced, the embankments have offered a reasonable degree of protection to a total area of 14.08 lakh ha up to 1990, which is nearly half of the flood prone area of 31.5 lakh ha in Brahmaputra valley. The towns affected by flood include Sadia at the confluence with Dibang and Lohit. In addition, erosion was also noticed at or near Majuli, Biswanath, Laoparra, Hawlighat, Mukalmua, Bohori and Dhubri on north bank and Mothola, Oakland, Desangmukh, Kokilagha-Neamatighat, Moriahola, Alikash, Dibrugarh, Palasbari, Goalpara, Fakirganj and south Salmara during different periods. Eight important protection works constructed along Brahmaputra river include schemes near Dibrugarh, Palasbari-Gumi, Goalpara and Dhubri.

Reservoirs in the Basin

The Government of India has set up Brahmaputra Board with different tasks that include construction of projects viz. in north-east region that are stretched in inter-state area. These projects could generate hydropower as well as attempt flood moderation. Reservoirs sited at Dehang and Subansiri were included in present studies.

STUDY APPROACH

The work for estimation of power potential and flood moderation due to reservoir across Dehang and Subansiri at dam site and along river Brahmaputra was assigned to CWPRS by the Brahmaputra Board. The task was carried out through following components –

a) Analysis of data for continuity and homogeneity
b) Estimation of dominant flow through exceedence analysis
c) Development of programs to carry out reservoir operation as per the agreed policy for the estimation of power potential and flood moderation
d) Routing of design floods with 100-year and 25-year return period through reservoir and along Brahmaputra river up to Dhubri

DATA USED

The detailed discussions were held with the Brahmaputra Board authorities as per the specific request made by the Board. Attempts have been made to carry out the task with minimum possible and easily collectable data in the study area. These data covers following components –

a) Series of Inflow to Reservoir
b) Geometry of reservoir defined through elevation-curve-capacity table/curve (Figure 2)
c) Hydro meteorological data that include evaporation and inflow to the reservoir
d) Salient features of reservoir with different elevations like Maximum Draw Down Level (MDDL), Spillway crest, Full Reservoir Level (FRL) and Tail Water Elevation Level (TWEL)
e) Rating curves of spillway and other outlets (Figure 2)

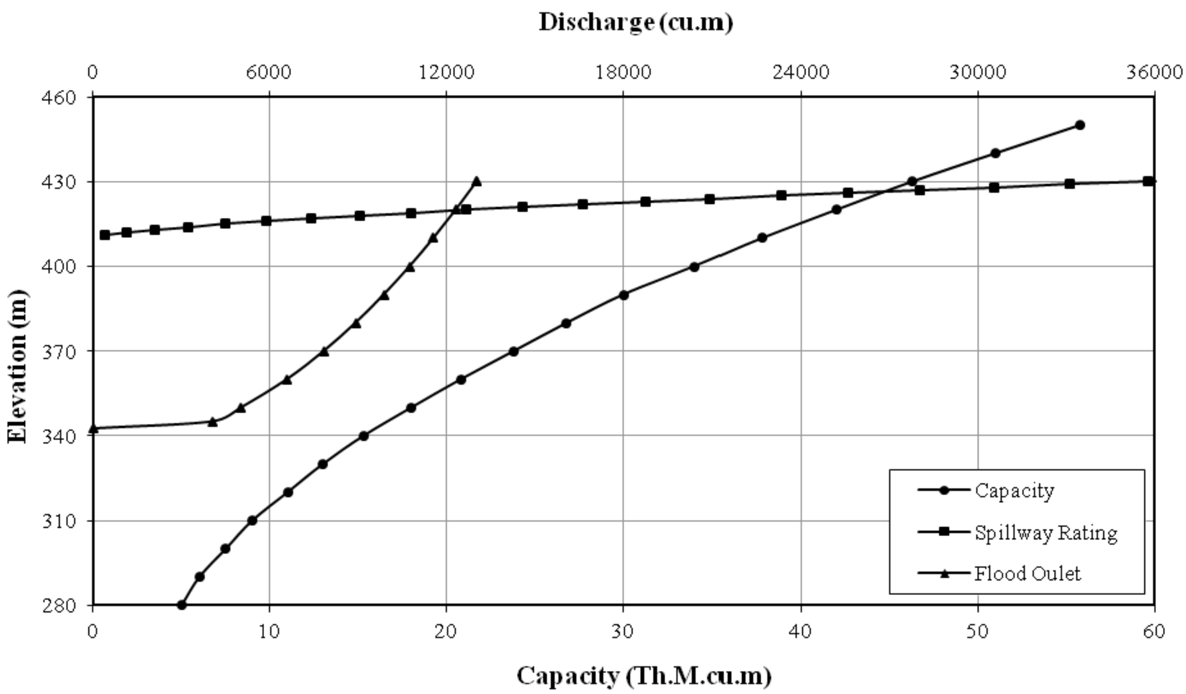

Figure 2 : Geometry and Rating Curves at Dehang Reservoir

Out of the above, all items except (d) were supplied by the Brahmaputra Board and rating of spillways and outlets were derived by CWPRS. Details of inflow series used in study are given in Appendix 1.

RESERVOIR OPERATION STUDY

Initially data series for received for both the reservoirs were reviewed and analyzed for continuity and homogeneity (*1,3*). Attempts were made to derive flows in basin for known dependability using different statistical distributions. These were however discontinued at the request of client.

Another important aspect in these studies was time step to be used for computations. It is appropriate to state here that the situation is similar to the operational requirements. Thus, it can be noticed that for power potential estimation larger step of a week or day or month can be taken. However, for the studies related to flood moderation, a shorter step of few hours or at least day is required. These aspects were considered and a time step of a day was selected.

River Brahmaputra rises in Tibet and enters Indian Territory near Jido in Arunachal Pradesh. The details are given in 2.0 above. Brahmaputra Board has identified sites at Passighat on river Dehang (Siang) and at 1st dam site on river Subansiri. Initially, the project was identified with power generation as the principal objective. Flood moderation was added later to be in line with trend of multi objective project. As the requirements of reservoir operation under these scenarios are conflicting in nature, tailor-made programs were written for completing the task. The stages of development of a series of programs are described (*6,7,10 to 13*).

RESERVOIR OPERATION MODEL

A special purpose tailor-made program TAPFLO was developed to simulate reservoir operation and to generate the results that could be used for trade-off-analysis. This type of analysis is carried out to avail maximum benefits under conflicting scenario. This situation mostly arises in case of multipurpose projects. The trade-off analysis is carried out to determine optimum benefits from both the objectives. A cut off point is identified at which benefit from one objective decreases at the cost of increase in benefit from other objective.

Model developed at CWPRS is based on water balance of reservoir, which can be described through following

BEC = PRMST + INFLO – EVAP – RELEV

where
BEC = Storage in reservoir at the end of day
PRMST = Storage in reservoir at the beginning of the day
INFLO = Inflow volume
EVAP = Volume of water lost by evaporation
RELEV = Total volume of water released = PDRAV + ADRAV + SPILV + FLOV
PDRAV = Volume of water released for power generation
ADRAV = Volume of water released for additional power generation
SPILV = Volume of water released over spillway
FLOV = Volume of water released through flood outlets

The equation is solved through iterative procedure as outflow from reservoir depends on reservoir level that prevails during the computation period. Initially an assumption is made for BEC and average elevation of the reservoir is determined. Outflows corresponding to this elevation are derived and storage capacity at the end of day is determined. The two values are compared and the process is repeated till difference between assumed and estimated capacity is within the tolerance. TAPFLO has 5 sub-routines that are invoked through main program. The program estimates power potential from a project in two stages. In the first stage power potential is estimated through simulation of reservoir using historic inflow series. It is known that power to be generated depends on the product of discharge and head and as such, estimation of firm power potential would require number of trials to arrive at value with specific failure criteria. In this study, 10% failures are allowed i.e. if one considers time step of day, 37 failures can be allowed in a year. BINARY SEARCH technique is used to minimize the number of trials while deriving the power potential at a project. The program works out the power potential in the first stage and elevations at the end of each time step are stored. In the second stage, Binary Search technique is used to derive minimum elevation that will not influence power potential estimated in first stage. A search for minimum storage is made between storage at MDDL and the storage derived on each day during the first stage simulation.

MAIN PROGRAM - It acts as a relay for calling different sub-routines and exercising overall control of the software.

BSERC – The binary search is carried out in this sub-routine considering the status of performance during the previous simulation run. This sub-routine is used for searching the maximum possible hydropower in the first stage of simulation and minimum storage required during the second stage. There is an option to select the parameter to be searched as a multiple of pre-determined integer.

DSEXR – The excess water stored above the FRL or MSL is to be released according to the pre-determined policy. The task is carried out in this sub-routine.

INTER - This sub-routine interpolates the value in second array considering to a value specified in first array.

RDRTN – The sub-routine reads input data as per option(s) specified by the user.

RELRUP – This is a core sub-routine and is assigned with the task of reservoir simulation in two stages. In the first stage, simulation for estimation of power generation is carried out using water balance of the reservoir. In the second stage, the minimum storage on each day of monsoon is searched in such a way that the power potential estimated in the first stage is not affected. The sub-routine also considers the current state of storage in reservoir, limbs of inflow hydrograph and the storage space dedicated for flood moderation purpose to determine excess storage. Simulation is carried out as per prevailing / decided policy. The reservoir simulation is carried out by dividing the total capacity in two pools as conservative pool and flood moderation pool. Different fractions of live storage capacity are utilized in a dedicated manner for flood moderation purpose. Conservation pool is formed by utilizing storage upto certain fractions of total capacity. Flood moderation pool is kept above conservation pool.

It is also known that the available storage capacity can give flood moderation values upto identified flood only. This flood is to be decided before hand. In the present studies, inflow series for the reservoirs was subjected to exceedence analysis and the results are presented in Figure 3. The curves were reviewed and dominant discharge of 12,000 cum/s for Dehang and 2500 cum/s for Subansiri were derived.

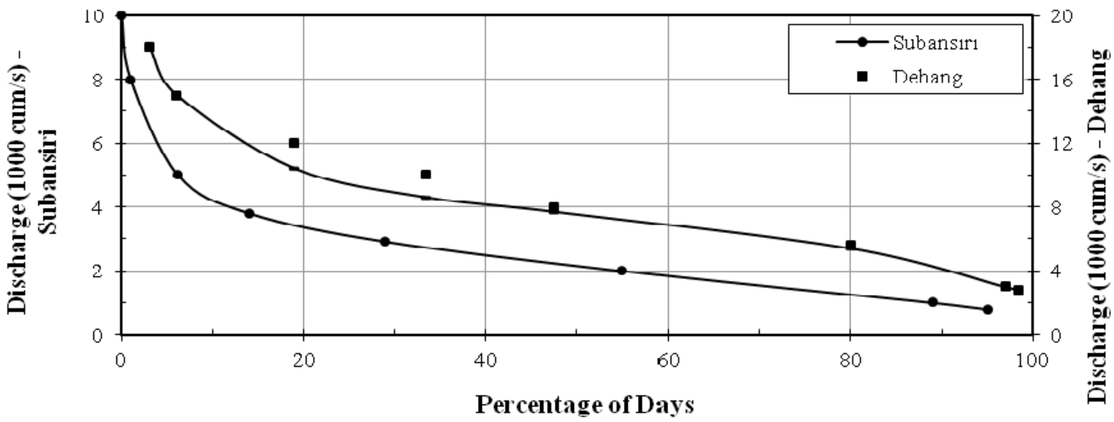

Figure 3 : Exceedence Curves – Dehan and Subansiri Reservors

The simulation is carried out for estimation of power potential with 10% failure. In this stage of simulation releases are made to satisfy the power requirement only and excess flow, if any, is stored in conservative pool. This process is continued till top of conservative pool is reached. Hereafter, the reservoir storage in flood moderation pool is to be used in a dynamic way to derive maximum benefits under flood moderation objective. The trend of inflow is reviewed and release from the reservoir is restricted to the dominant flow till the top of flood moderation pool is reached. Thereafter, inflow to the reservoir is released till the end of rising limb is identified. During recession limb, the releases are continued at dominant discharge till flood moderation pool is totally depleted; by releasing discharges greater than the inflow to empty the flood moderation pool at the earliest. The salient features of program TAPFLO are given below:

a) User is free to select a range of consecutive years from the master file for estimation of firm power potential with 10% failure allowance.
b) Variable range of power potential for invoking the program can be specified.
c) The power potential estimation could be carried out by reserving different percentages of live storage space exclusively for flood moderation in a dedicated manner eg. If 10% of live storage space is to be dedicated for flood moderation, one has to specify top of conservation pool defined through Monsoon Storage Limit (MSL) as 90% of total live storage.

d) After specified storage limit i.e. either MSL or FRL is attained, inflows in excess of power draft are to be released. The priorities for releases in current version are
   i. Through additional power draft
   ii. Over spillway
   iii. Flood outlets
e) Maximum release is limited to the dominant flow
f) Software is developed in a modular way. Therefore, minimum changes would be required for any subsequent changes in policy of increasing the releases.
g) The releases from reservoir are stored in a separate file for routing down the river channel.

Studies for estimation of power potential carried out by allocating different fractions of live storage for flood moderation purpose in dedicated manner. Six fractions as 0.0, 8.5, 14.92, 22.38, 29.84 and 37.3 T.M.cu.m were used in case of Dehang reservoir and five fractions as 0, 2.7, 6.36, 8.48 and 10.6 T.M.cu.m were used for flood moderation in case of Subansiri reservoir. Sample results showing summary of simulation of Dehang reservoir are presented in Table 1.

TABLE 1

SUMMARY OF DEHANG RESERVOIR SIMULATION

MDDL	- 310.000 m	F R L	- 430.0 m
FLOOD SPACE	- 8.500 T.M.cu.m	FIRM POWER	- 5065.0 MW

WATER YEAR	NO.OF FAILURES	ANNUAL MAXIMUM			MAXIMUM STORAGE		YEAR END STORAGE	CARRYOVER STORAGE
		DISCHARGE	RELEASE	RELIEF	MONSOON	FWS		
		(cu.m/s)			(T.M.cu.m)			
1949	104	9644.7	4229.5	5415.2	36.35	36.23	9.00	0.00
1950	31	20637.4	12000.0	8637.4	46.30	46.30	37.80	28.80
1951	0	12788.8	12000.0	788.8	38.47	46.30	18.38	9.38
1952	0	6970.9	3574.5	3396.4	37.80	41.29	23.82	14.82
1953	80	5279.1	4049.2	1229.9	28.85	28.25	9.00	0.00
1954	15	24460.3	24439.0	21.3	46.30	39.86	9.00	0.00
1955	31	12620.8	3377.4	9243.4	38.06	37.79	9.77	0.77
1956	13	11264.0	3502.2	7761.8	37.80	37.80	9.00	0.00
1957	41	13664.5	3656.1	10008.4	37.80	37.80	10.74	1.74
1958	0	14070.0	3836.0	10234.0	37.80	38.10	15.93	6.93
1959	30	13810.0	12000.0	1810.0	38.12	37.64	9.00	0.00
1960	26	19772.0	3697.7	16074.3	46.30	39.78	23.53	14.53
1961	0	21996.0	12000.0	9996.0	46.30	40.35	26.99	17.99
1962	0	29630.0	29609.9	20.1	46.30	41.15	21.01	12.01
1963	0	13782.0	12000.0	1782.0	40.03	38.57	19.29	10.29
1964	0	14235.0	12000.0	2235.0	40.85	38.62	18.68	9.68
1965	4	14219.0	12000.0	2219.0	40.73	38.59	9.00	0.00
1966	20	14159.0	12000.0	2159.0	40.37	38.62	13.32	4.32
1967	0	14723.0	12000.0	2723.0	41.39	38.73	23.37	14.37
1968	0	13897.0	12000.0	1897.0	40.65	40.08	27.57	18.57
1969	0	18820.0	12000.0	6820.0	46.30	39.20	24.90	15.90
1970	0	13420.0	12000.0	1420.0	40.91	38.16	18.44	9.44
1971	0	14671.0	10357.4	4313.6	40.66	38.21	21.87	12.87
1972	0	14597.0	12000.0	2597.0	42.52	38.18	21.14	12.14
1973	0	13741.0	12000.0	1741.0	39.78	38.74	23.82	14.82
1974	0	13440.0	12000.0	1440.0	40.09	38.46	17.25	8.25
1975	0	13588.0	12000.0	1588.0	41.73	38.60	12.02	3.02
1976	23	16747.0	5244.2	11502.8	37.80	41.01	27.84	18.84
1977	0	24020.0	23999.9	20.1	46.30	40.29	24.49	15.49
1978	40	21050.0	12000.0	9050.4	38.58	37.81	9.00	0.00
1979	137	16739.7	6293.2	10446.5	34.48	33.80	9.00	0.00
1980	203	15225.0	5005.4	10219.6	21.52	17.03	9.00	0.00

1981	145	11110.0	6144.6	4965.4	31.70	31.50	9.00	0.00
1982	138	13378.4	4941.9	8436.5	32.96	31.18	9.00	0.00
1983	97	15004.7	4759.8	10244.9	37.86	37.64	9.00	0.00
1984	99	17598.6	4222.6	13376.0	39.92	37.75	9.00	0.00
1985	93	19847.7	12000.0	7847.7	42.63	37.72	9.00	0.00
1987	33	30171.2	30151.1	20.1	46.30	40.33	30.46	21.46

NO. OF FAILURES = 1403

PERMISSIBLE FAILURES = 1406

Pilot studies were carried out using part data for Dehang and Subansiri reservoirs. The results of the studies were reviewed and later on total data series of 38 years for Dehang and 22 years for Subansiri reservoir was used for the simulation. The review of results was taken and curves were plotted to carry out trade off analysis between storage space dedicated for flood moderation against power generation and flood moderation (Figure 4). The latter benefits were evaluated through reduction in peak flow of each year.

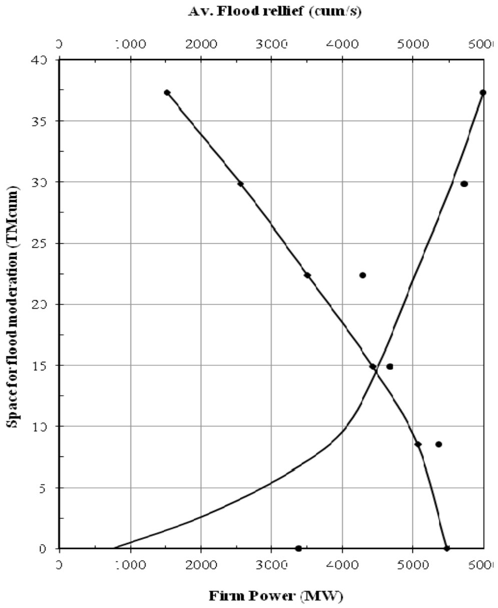

Figure 4 : Trade Off Analysis Curves – Dehang site

A review of the curves show that a storage of 8.50 T.M.cu.m in Dehang reservoir can be considered as cut off point that would yield optimum benefits for both objectives. Similar analysis was carried out for Subansiri reservoir and cut off point has been assessed as 2.7 T.M.cu.m.

Rule Curve Derivation

Water level in reservoir generally varies between MDDL and FRL in monsoon and fair weather season. Thus, any curve joining these two points can be considered as rule curve. TAPFLO program was used to derive the rule curve for Dehang and Subansiri reservoirs. The reservoir level attained at the end of each day was stored for different scenario. These were analyzed and maximum, average and minimum level attained on each day was derived. It was noticed that the highest level of 430 m, 410 m and 362.5 m is attained for maximum, average and minimum scenario. Out of these rule curves, average rule curve was considered during the flood moderation studies. Initial level of 410 m in case of Dehang reservoir and 322.5 m in case of Subansiri reservoir was derived for use in flood moderation studies.

Flood Moderation for 100 year and 25 year Return Period Flood

As per the prevailing practice, 25-year return period flood is generally used for deriving protection measures and 100-year flood is generally considered for flood moderation. Hydrographs corresponding to these floods were superimposed on the top of rule curve under average scenario to review the flood moderation at dam site. A separate version of TAPFLO was developed by keeping all features and used for reservoir routing. The outflow hydrographs from reservoir were reviewed and it was noticed that flood moderation of 15,000 cum/s can be achieved as peak flow of 27,000 cum/s gets moderated to 12,000 cum/s. Similarly 25-year flood was routed through reservoir and it was noticed that peak flood of 20,000 cum/s was attenuated a peak of flow 12,000 cum/s, yielding flood moderation of 8000 cum/s. Similar analysis carried out for Subansiri reservoir yielded flood moderation of 800 cum/s for 25 year flood. Result of reservoir routing of 100 yr flood through Dehang reservoir is shown in Table 2.

TABLE - 2

DEHANG RESERVOIR - 100 YEAR FLOOD ROUTING

INITIAL LAKE LVEL = 410.000 m TIME STEP = 12 hrs FIRM POWER = 5065 MW

Day No	INITIAL		INFLOW	EVAPO-RATION	POWER DRAFT	ADDL. DRAFT	FLOOD RELES	SPILL DISCH	TOTAL RELES	FINAL	
	LEVEL (m)	STOR-AGE (T.M.cu.m)	(cu.m/s)	(M.cu.m)	(cu.m/s)	(CU.M/S)	(CU.M/S)	(CU.M/S)	(CU.M/S)	STORAGE (T.M.cu.m)	LEVEL (m)
1	410.000	37.800	17500.0	.86	3225.68	2600.00	5084.97	1089.35	12000.0	38.037	410.564
2	410.564	38.037	17600.0	.86	3216.55	2600.00	4253.06	1930.39	12000.0	38.278	411.138
3	411.138	38.278	17700.0	.87	3207.30	2600.00	3251.74	2940.96	12000.0	38.523	411.722
4	411.722	38.523	17800.0	.87	3197.94	2600.00	2133.58	4068.47	12000.0	38.773	412.316
5	412.316	38.773	18100.0	.87	3188.32	2600.00	754.28	5457.40	12000.0	39.036	412.942
6	412.942	39.036	18200.0	.88	3178.43	2600.00	.00	6221.57	12000.0	39.302	413.577
7	413.577	39.302	18250.0	.88	3168.48	2600.00	.00	6231.52	12000.0	39.572	414.218
8	414.218	39.572	19600.0	.89	3157.48	2600.00	.00	6242.52	12000.0	39.899	414.998
9	414.998	39.899	22900.0	.89	3142.90	2600.00	.00	6257.10	12000.0	40.369	416.117
10	416.117	40.369	25800.0	.90	3123.63	2600.00	.00	6276.37	12000.0	40.964	417.534
11	417.534	40.964	27000.0	.91	3101.45	2600.00	.00	6298.55	12000.0	41.611	419.075
12	419.075	41.611	26000.0	.92	3079.52	2600.00	.00	6320.48	12000.0	42.215	420.501
13	420.501	42.215	22300.0	.93	3061.58	2600.00	.00	6338.42	12000.0	42.659	421.533
14	421.533	42.659	18600.0	.94	3049.35	2600.00	.00	6350.65	12000.0	42.943	422.194

15	422.194	42.943	17500.0	.94	3040.66	2600.00	.00	6359.34	12000.0	43.180	422.744
16	422.744	43.180	17000.0	.94	3033.16	2600.00	.00	6366.84	12000.0	43.395	423.245
17	423.245	43.395	16600.0	.95	3026.34	2600.00	.00	6373.66	12000.0	43.593	423.704
18	423.704	43.593	16185.0	.95	3020.12	2600.00	.00	6379.88	12000.0	43.773	424.123
19	424.123	43.773	15780.0	.95	3014.52	2600.00	.00	6385.48	12000.0	43.935	424.500
20	424.500	43.935	15386.0	.95	3009.49	2600.00	.00	6390.51	12000.0	44.080	424.838
21	424.838	44.080	15000.0	.96	3005.04	2600.00	.00	6394.96	12000.0	44.209	425.137
22	425.137	44.209	14630.0	.96	3001.12	2600.00	.00	6398.88	12000.0	44.322	425.399
23	425.399	44.322	14260.0	.96	2997.73	2600.00	.00	6402.27	12000.0	44.418	425.624
24	425.624	44.418	13900.0	.96	2994.86	2600.00	.00	6405.14	12000.0	44.500	425.813
25	425.813	44.500	13560.0	.96	2992.48	2600.00	.00	6407.52	12000.0	44.566	425.967
26	425.967	44.566	13220.0	.96	2990.57	2600.00	.00	6409.43	12000.0	44.618	426.088
27	426.088	44.618	12890.0	.96	2989.14	2600.00	.00	6410.86	12000.0	44.655	426.175
28	426.175	44.655	12570.0	.96	2988.15	2600.00	.00	6411.85	12000.0	44.679	426.230
29	426.230	44.679	12250.0	.96	2987.61	2600.00	.00	6412.38	12000.0	44.689	426.253
30	426.253	44.689	11945.0	.96	2987.51	2600.00	.00	6412.49	12000.0	44.685	426.245
31	426.245	44.685	11646.0	.96	2987.83	2600.00	.00	6412.17	12000.0	44.669	426.207
32	426.207	44.669	11355.0	.96	2988.55	2600.00	.00	6411.45	12000.0	44.640	426.140

Flood Routing along River Brahmaputra

Study of change in shape of hydrograph during travel along river is referred as flood routing. Numerous models have been derived that carry out this job through different sets of equations. Selection of model depends on the aspects like availability of data, time and resources like trained manpower and computational facilities. In the present case 1-D model (*4*) based on the solution of St. Venant's equation was used to route flow along river Brahmaputra. The model requires data to define river geometry, roughness coefficient, boundary data and initial conditions. Out of these, cross sections of river supplied by Brahmaputra Board were used for defining river geometry. Sufficient data for deriving roughness coefficient of river Brahmaputra were not available and following values of Manning's equations were used

Sr. No.	**Reach of River Brahmaputra**		**Manning's n used**
	From	**To**	
1	Dehang dam site	Dibrugarh	0.035
2	Dibrugarh	Tezpur	0.030
3	Tezpur	Gumi	0.028
4	Gumi	Dhubri	0.025

Discharge hydrograph was used for upstream boundary and normal flow conditions governed by Manning's equation were specified downstream boundary. Initial conditions were derived through backwater computations.

Routing of flows of river Brahmaputra was carried out in two stages for estimation to assess flood moderation benefits further downstream of the dam site. Initially 100 and 25 years flood hydrographs were routed along the river from dam site to Dhubri(NN100 in Figure 5). The routed hydrographs at different locations viz. Dibrugarh, Tezpur, Jorhat, Gumi, Goalpara and Dhubri were obtained and saved for further use. In the next stage, respective outflow hydrograph of release from Dehang (DN100) or Subansiri (NS100) reservoir was replaced for 100 and 25 years flood. The routing process was repeated for combined releases from Dehang and Subansiri reservoirs (DN100) and resulting hydrographs at the same location were saved. A comparison of hydrographs obtained in flood routing was carried out to derive flood moderation benefits at different locations along river Brahmaputra. Similar exercise was carried out for Subansiri reservoir and combination of Dehang and Subansiri reservoirs. A sample plot of flood hydrographs at Gumi is shown in Figure 5 for 100 year flood routing.

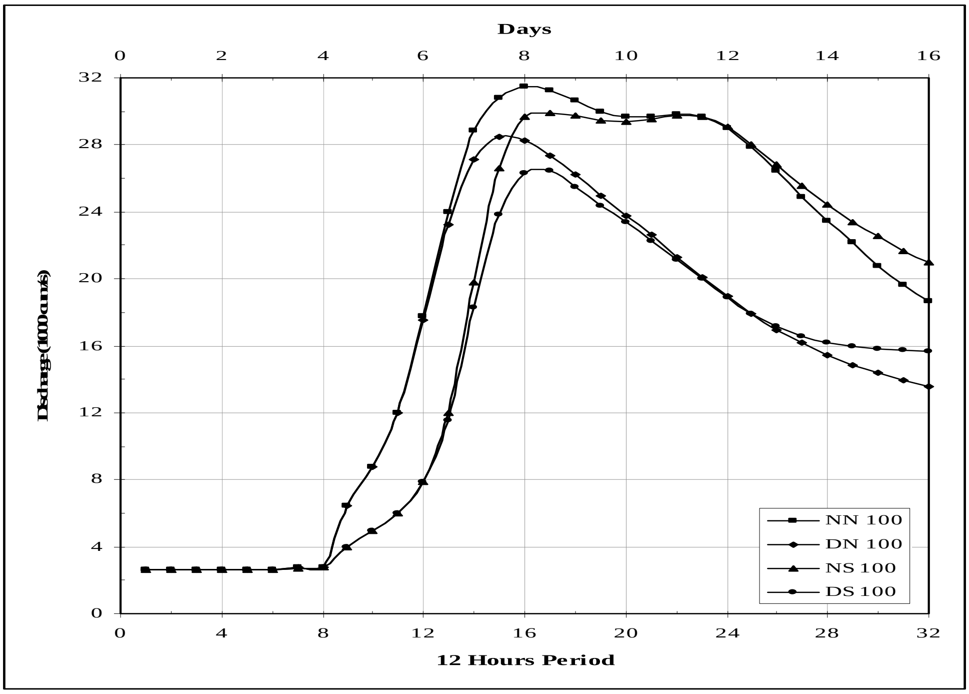

Figure 5 : 100 Year Flood Routing-Gumi

The extracts of routing are shown in Table 3.

TABLE - 3

100 YEAR FLOOD ROUTING ALONG RIVER BRAHMAPUTRA

SL. NO.	LOCATION NODE #	DIBRUGARH (13)		GUMI (58)		DHUBRI (69)	
		Q (cu.m/s)	WL (m)	Q (cu.m/s)	WL (m)	Q (cu.m/s)	WL (m)
1	Peak flow	25450	109.94	31440	38.83	30069	30.41
2	Corresponding Peak by routing Dehang releases	12000	108.53	28511	38.13	26063	30.14
3	Relief due to Dehang	13450	1.41	2929	00.70	4006	00.27
4	Corresponding Peak by routing Subansiri releases	25450	109.94	29900	38.67	29533	30.33
5	Relief due to Subansiri	-	-	1540	00.16	535	00.08
6	Corresponding Peak by routing Dehang and Subansiri releases	12000	108.53	26446	37.85	23589	29.96
7	Relief due to Dehang and Subansiri	13450	1.41	4994	00.98	6480	00.45
Note : Tributary flows of Subansiri alone are added.							

e.g. it can be seen that for 100 year peak flood of 25,450 cum/s, a flood relief of 13,450 cum/s at Dibrugarh, 2929 cum/s at Gumi and 4006 cum/s at Dhubri can be obtained for the scenario of single reservoir at Dehang.

CONCLUSIONS

Studies have been carried out for estimation of power potential and flood moderation benefits at Dehang and Subansiri reservoirs using special purpose tailor made program developed at CWPRS. Important conclusions of the study are :

1) Trade off analysis among the benefits from power generation and flood moderation was carried out by dedicating fraction of live storage for flood moderation. The results of analysis show that cut off point for deriving optimum benefit is obtained for storage of 8.5 T.M.cu.m for Dehang reservoir and 2.7 T.M.cu.m for Subansiri reservoir.

2) The corresponding firm power potential with 10% failure is estimated as 5065 MW at Dehang and 1475 MW at Subansiri sites respectively.

3) Three sets of rule curves were derived through simulation of reservoir using 38 years and 22 years data for Dehang and Subansiri reservoirs respectively. The results indicate that rule curves attain highest level of 430 m, 410 m and 362.5m at Dehang site under maximum, average and minimum scenario respectively. The corresponding levels in case of Subansiri reservoir are 334 m, 322.5 m and 312 m respectively.

4) Highest value of rule curve under average scenario is used as initial lake level for routing 100 and 25 year flood through the reservoir. A moderation of 15,000 cum/s and 8000 cum/s could be obtained at Dehang site for 100 year and 25 year flood respectively. Similar studies have been carried out for Subansiri reservoir and a flood moderation of 800 cum/s could be obtained for 25 years flood.

5) Routing of 100 year and 25 year flood hydrographs has been carried out along the stretch of river from dam site upto Dhubri using 1D hydrodynamic model of river Brahmaputra. Attempts have been made to derive flood moderation benefits at different locations in river Brahmaputra from Dibrugarh to Dhubri. It was noticed that flood moderation of 13450 cum/s could be obtained for 100 year flood due at Dehang reservoir alone; resulting in reduction in water level of 1.41 m at Dibrugarh. Details are given in Table 3.

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APPENDIX - I

DISCHARGE DATA USED FOR SIMULATION

<table>
<tr><th rowspan="2">RIVER</th><th rowspan="2">SITE</th><th colspan="2">PERIOD</th><th rowspan="2">REMARKS</th></tr>
<tr><th>FROM</th><th>TO</th></tr>
<tr><td>DEHANG</td><td>RANAGHAT
(0006)</td><td>1949
(1)
1963
(2)</td><td>1957

1975
(2)</td><td rowspan="4">1) The year indicated refers to starting year during the water-year. Thus 1949 indicates the water year 1 May 1940 to 30 April 1950.

2) These data were made available at ten day interval and were used to derive daily values.

3) For 1983-84 data at dam site are used from 1 May to 31 December 1983 and data at Passighat are used from 1 January to 30 April 1984.

4) Discharge values are in cu.m/s.</td></tr>
<tr><td>DEHANG</td><td>PASSIGHAT
(0007)</td><td>1958
1976
1984
1987</td><td>1962
1978
1985</td></tr>
<tr><td>DEHANG</td><td>29TH MILE</td><td>1979</td><td>1983
(3)</td></tr>
<tr><td>SUBANSIRI</td><td>CHOULDOWAGHAT
(0925)

1st Dam Site</td><td>1960
1966

1972
1973</td><td>-
1969

-
1988</td></tr>
</table>