CHAPTER-7

ASSESSMENT OF ENVIRONMENTAL FLOWS

7.1 INTRODUCTION

Environmental Flows (EF) are the flows of water in rivers that are necessary to maintain aquatic ecosystems. In other words, a flow regime in the river, capable of sustaining a complex set of aquatic habitats and ecosystem processes are referred to as environmental flow. The EF is designed to maintain or upgrade a river in desired, agreed or pre-determined status referred to as an “environmental management class” ranging from A (Negligible modification from natural condition) to F (Critically modified ecosystem).

The process for determining or estimating EF is termed as Environmental Flow Assessment (EFA) and there are more than 200 techniques suggested in literature for the same. EFA techniques determine the volume and temporal distribution of EF. The difficulty of estimation EF values lies in the lack of understanding the relationship between river flow and the multiple components of river ecology and the scarcity of data concerned to these relationships. For example, required river flow conditions are available only for a target fish species in a given river basin and this information is very specific and not applicable under different circumstances. Different types of flows with different amount of discharge are spread through dry and wet seasons. This fact plays a very important issue in the interaction of river flow with the surrounded ecosystem. According, to flow, regime of a river can be divided into:

- ***Low flows*** (Base flow): this occurs through out the year and is more in the wet season than in the dry season and defines if river flow through out the year. The delayed flow that reaches a stream essentially as groundwater flow is also called base flow. In the annual hydrograph of a perennial stream the base flow is easily recognized as the slowly decreasing flow of the stream in rainless periods.

- ***Small floods***: they are small in size, (as compared with high floods) a few number per year and they have a small period of time (days or weeks) (Refer Figure-7.1).
- ***Large floods***: they are infrequently and the timing is very short (hours or days) (Refer Figure-7.1).

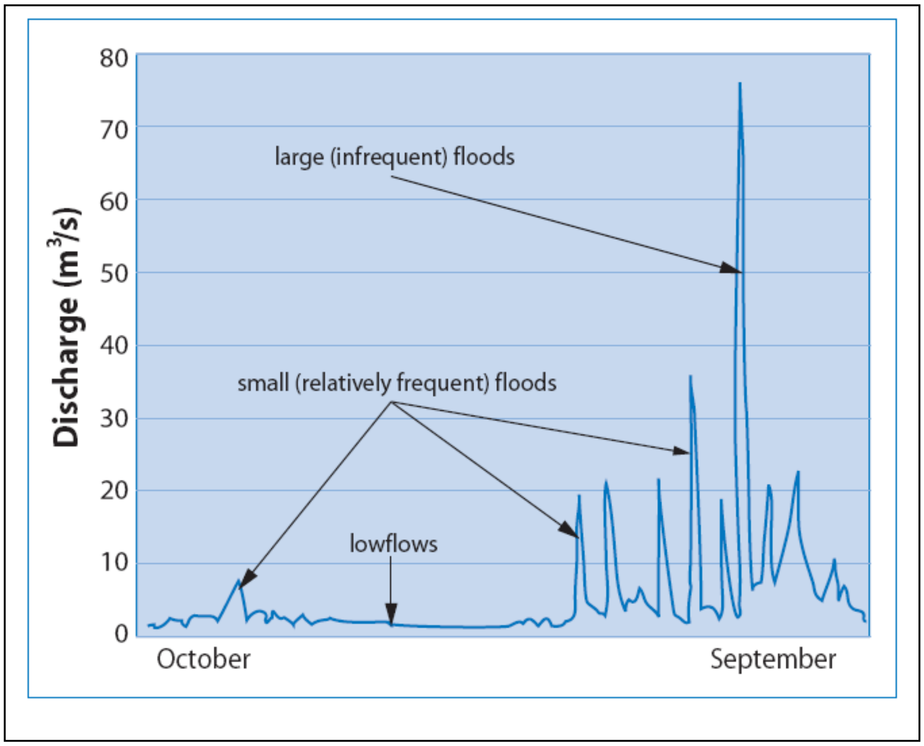

Figure 7.1: Typical Annual Hydrograph of daily flows in a river

Identification of these flow components and the understanding the ecosystem consequences of their loss or modification are one of the main objectives of Environmental Flow Assessment (EFA).

Further, flows in most of the river are being modified through impoundments such as dams and weirs, abstractions for agriculture, industrial and domestic supply, hydropower, drainage return flows and through structures for flood control. These interventions have had significant impacts, reducing the total flow of many rivers and affecting both; the seasonality of flows and the size and frequency of floods. In many cases, these modifications have adversely affected the river ecosystem, including the people living near the river banks. The river ecosystem includes both the channel and the floodplain. Regulations of river flows reduce or eliminate the linkage between the river and its floodplain margins.

With this background, it is important to recognize the importance of different flows in the river ecosystem. According to Brown (2003), flow in rivers is generally needed for various purposes such as to:

- maintain river flow conditions like flow velocity, water depth and acceptable turbidity levels, making it possible for the river purify itself (dilution of effluents and waste water).
- maintain low flow which support livelihood of the people (people who use the river for drinking, washing, bathing, fishing, recreation and tourism, etc).
- sustain both terrestrial and aquatic ecosystem. For example, low flow provides water to wild animals, maintain soil-moisture in the banks, etc. Small floods stimulate spawning in fish and allow passage for migratory fish and germination of seeds on river banks. Large floods deposits nutrients on the banks and distribute seeds.
- recharge groundwater and aquifers by large floods, which maintain the perennial nature of rivers acting as source of water during dry season. Further, large floods flush sediments and natural obstructions in the river course and maintain a sufficient deep channel for navigation.
- preserve estuarine conditions: low flows maintain the required salt-freshwater balance and prevented the incursion of salinity. Large floods maintain links with the by scouring estuaries.

In general, flows enabling the river to play its role in the cultural and spiritual live of the people. This is very important in Indian context as some religious festivals reduce the quality and quantity of flow.

7.2 ENVIRONMENTAL FLOW ASSESSMENT TECHNIQUES

In a recent review of international environmental flows assessment, Tharme (2003) recorded 207 different methods within 44 countries. Broadly, these can be divided into four categories:

- **Hydrological Index Methods** (or rule of thumb, threshold, or standard setting, desktop methods, or flow duration curve methods)
- **Habitat Discharge Methods** (hydraulic rating or habitant rating methods)
- **Habitat Simulation Methods**
- **Holistic Approaches**

Regarding estimation of environmental flow downstream of dam, there is no methodology developed for Himalayan rivers which are subjected to various climatic, meteorological and geologic conditions. However, In the present study Building block methodology has been adopted.

7.2.1 Building Block Method

The Building Block Method (BBM) is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition. The objective of BBM is to determine ecologically acceptable, modified flow regimes for impounded rivers and other situations where flows are regulated (Arthington, 1998). An environmental flow regime is then constructed (month by month basis) through separate consideration of different components of the flow regime. Each component of flow being specified in terms of magnitude, time of year, duration and rate of rise and fall of flood flows. Each flow component is intended to achieve a particular ecological, geo-morphological or water-quality objective (Brown, 2006).

The BBM is holistic, but issues such as water quality and the flow requirements of water-dependent wildlife require more development and stronger linkages into the methodology. The BBM has advanced the field of environmental flow assessment in an entirely new direction, being an holistic methodology that addresses the health (structure and functioning) of all components of the riverine ecosystem, rather than focusing on selected species as do many similarly resource-intensive international methodologies.

7.4 ENVIRONMENTAL WATER REQUIREMENTS FOR DIBANG MULTIPURPOSE PROJECT USING BUILDING BLOCK METHODOLOGY

The BBM methodology assesses the requirements, which needs to be fulfilled throughout the year for estimation of Environmental flows. The requirements considered are:

- Irrigation water requirements
- Drinking water requirements
- Flow required to maintain water quality
- Flow required to sustain riverine ecology including fisheries

7.4.1 Irrigation and drinking water requirements

The proposed project is located in an area with low population density with no major sources of pollution. The major source of water for meeting irrigation and drinking requirements in the project area are rivers or nallahs which flow adjacent to the habitations. The water is conveyed to the point of consumption. Thus, no water is abstracted form river Dibang.

7.4.2 Flow required to maintain water quality

The population density of the catchment area has been considered as 30 persons/sq. km. As per the EIA/EMP report, the CAT plan has been prepared for an area of 59811.88 ha or 600 km^2. Thus, the total population contributing water pollution through sewage generation is 18,000. The total sewage generation shall be of the order of I008 m^3/day or 0.012 cumec. The water required for dilution shall be of the order of 2 cumec.

7.4.3 Flow required to sustain riverine ecology including fisheries

The BBM methodology used in this study constructs a synthetic hydrograph which must satisfy the water requirements in the river for maintaining a desired condition.

The hydrograph simulates the natural conditions in the river to fulfill the different flow regimes present through out the year. The identification and incorporation of these important flow characteristics will help to maintain the river's channel structure, diversity of the physical biotopes and processes. Four main seasons are identified along the year:

Season I: This season is considered as high flow season influenced by monsoon. It covers the months from May to September. The minimum flow during this period is assumed as 30% of average flow (10 daily or monthly).

Season II: This season is considered as average flow period. It covers the month of October in which the proposed minimum flow is taken as 20% of average flow. This period is a transitional period between the wet and dry period.

Season III: This season is considered as low or lean or dry flow season. It covers the months from November to March. The proposed minimum flow is taken as 15% of average flow during this period.

Season IV: This season is considered as average flow period and is same as that of season II. It covers the month of April in which the proposed minimum flow is taken as 20% of average flow. This period is a transitional period between the dry and wet period.

The proposed minimum flows are estimated for the two cases:

i) For case in which 17 years (1985-86 upto 2002-03), monthly average flow data is considered (refer **Table 7.1**).

ii) For 90 % dependable year (1994-95) (refer **Table 7.2**).

TABLE 7.1
Flow required to sustain riverine ecology including fisheries for Average flows for the period of 1985-86 to 2002-03

Month	Discharge (cumec)	Percentage	Flow required (cumec)
May	1040.5	30	312
June	1775.6	30	533
July	1593.4	30	478
August	1417.6	30	425

September	915.2	30	275
October	758.7	20	152
November	372.0	15	56
December	330.8	15	50
January	364.1	15	55
February	427.8	15	64
March	442.5	15	66
April	731.8	20	146

TABLE 7.2
Flow required to sustain riverine ecology including fisheries for 90% dependable year

Month	Discharge (cumec)	Percentage	Flow required (cumec)
May	1548.6	30	465
June	603.2	30	181
July	1111.5	30	333.5
August	484.1	30	145
September	799.6	30	240
October	462.7	20	93
November	310.4	15	47
December	352.0	15	53
January	384.5	15	58
February	502.4	15	75
March	817.2	15	123
April	838.5	20	168

The Environmental flow requirements using Building Block Methodology are estimated for the two cases:

i) For case in which 17 years (1985-86 up to 2002-03), monthly average flow data is considered (refer **Table 7.3**)

ii) For 90 % dependable year (1994-95) (refer **Table 7.4**).

TABLE 7.3
Environmental Flows required as per Building block methodology for Average flows for the period of 1985-86 to 2002-03

Month	Irrigation water requirement (cumec)	Drinking water requirement (cumec)	Flow required to maintain water quality (cumec)	Flow required to sustain riverine ecology (cumec)	Total flow (cumec)
May	0	0	2	312	314
June	0	0	2	533	535
July	0	0	2	478	480
August	0	0	2	425	427
September	0	0	2	275	277
October	0	0	2	152	154
November	0	0	2	56	58
December	0	0	2	50	52
January	0	0	2	55	57
February	0	0	2	64	66
March	0	0	2	66	68
April	0	0	2	146	148

TABLE 7.4
Environmental Flows required as per Building block methodology for 90% dependable year

Month	Irrigation water requirement (cumec)	Drinking water requirement (cumec)	Flow required to maintain water quality (cumec)	Flow required to sustain riverine ecology (cumec)	Total flow (cumec)
May	0	0	2	465	467
June	0	0	2	181	183
July	0	0	2	333.5	335.5
August	0	0	2	145	147
September	0	0	2	240	242
October	0	0	2	93	95
November	0	0	2	47	49
December	0	0	2	53	55
January	0	0	2	58	60
February	0	0	2	75	77
March	0	0	2	123	125
April	0	0	2	168	170

7.5 ESTIMATION OF STAGE-DISCHARGE RELATIONSHIP

In Dibang river cross section data was collected for various locations downstream of the proposed Dibang Multipurpose Project, and no stage discharge relationship was available. Therefore the first step was to generate a synthetic form of normal depth discharge relationship. Since, only cross section area (A) and corresponding wetted perimeter (P) is available at different stages; the discharges were obtained using Manning's equation. A relation between normal depth and discharge is obtained for sites, where the cross section of the river was available. Assumptions taken in Manning's equation are:

- *Steady uniform flow condition.*
  The critical period of analysis in this project occurs during dry season, when rainfall is not expected and runoff can be taken as zero, therefore, additional discharge from lateral inflow for a selected reach is zero, seepage is negligible, and discharge is assumed to be steady, and uniform.
- *One-dimensional analysis.*
  In one-dimensional analysis, the mean velocity is used as a representative velocity for the entire cross section and is defined on the basis of the longitudinal component. Hence, the velocities in the other than the main direction of flow are not considered.

Manning's equation can be written in terms of discharge as:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

where:

Q is the discharge (m3/s).

n is the roughness coefficient (dimensionless).

A is the area of the cross section perpendicular to flow (m2).

R is the hydraulic radius in meters (R=A/P).

S is the slope of the river bed.

The selection of *n* value was done by tables using a description of the river conditions "in situ". According with Chow, the roughness coefficient for a natural minor stream (top width at flood stage < 100 ft), mountain river stream, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages. River bed conforms of boulders, cobbles and few boulders range from [0.03-0.05]. Therefore, the analysis has been carried out for Manning's n as 0.03, 0.04, and 0.05. Three different curves of Water Depth vs. Discharge were obtained for each dam site analyzed.

The river bed slope is taken as average value between two adjacent sites, where cross-section and river bed data was available. The slope is $S = \Delta H/\Delta L$, where ΔH is difference in bed elevation between two sites and ΔL is the distance between project sites. The details are given in **Tables 7.5 and 7.6**.

TABLE 7.5
Bed levels of river Dibang at various sections downstream of dam site

S. No.	Distance downstream of dam site (km)	River bed level (m)
1	0 (dam site)	292.037
2	1	285.961
3	2	283.457
4	4	270.889
5	5	270.005
6	6	269.183
7	7	266.297
8	8	263.479
9	9	261.235
10	10	258.392
11	11	252.247
12	12	248.105
13	15	231.254
14	18	219.254
15	21	205.958
16	24	192.584
17	27	181.302
18	30	174.340
19	33	168.192
20	36	151.519
21	39	138.036
22	42	131.803
23	45	129.650
24	48	128.137
25	52	123.171
26	54	119.991
27	57	115.305
28	60	111.360
29	63	110.010

TABLE 7.6
River slopes between various stretches of river Dibang downstream of dam site

S. No.	River Stretch downstream of dam site (km)	Slope
1	0 -2	0.00429
2	2-4	0.006284
3	4-6	0.000853
4	6-9	0.002649
5	9-12	0.004377
6	12-15	0.005617
7	15-18	0.004
8	18-21	0.004432
9	21-24	0.004458
10	24-27	0.003761
11	27-30	0.002321
12	30-33	0.002049
13	33-36	0.005558
14	36-39	0.004494
15	39-42	0.002078
16	42-45	0.000718
17	45-48	0.000504
18	48-51	0.001655
19	51-54	0.00106
20	54-57	0.001562
21	57-60	0.001315
22	60-63	0.00045

The normal depth relationship at various cross-sections is given in **Tables 7.7 to 7.25**.

TABLE 7.7

Discharge at cross-section 2 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	48	36	29
1.0	92	69	55
1.5	140	105	84
2.0	188	141	113
2.5	239	179	143

TABLE 7.8
Discharge at cross-section 4 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	70	53	42
1.0	169	127	101
1.5	261	195	156
2.0	354	266	213
2.5	452	339	271

TABLE 7.9
Discharge at cross-section 6 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	11	9	7
1.0	29	22	17
1.5	44	33	27
2.0	60	45	36
2.5	77	58	46

TABLE 7.10
Discharge at cross-section 9 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	209	156	125
1.0	319	239	191
1.5	441	330	264
2.0	572	429	343
2.5	699	524	419

TABLE 7.11
Discharge at cross-section 12 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	465	349	279
1.0	790	592	474
1.5	1146	860	688
2.0	1537	1152	922
2.5	1961	1471	1177
3.0	2418	1814	1451

TABLE 7.12
Discharge at cross-section 15 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
1.5	8	6	5
2.0	26	20	16
2.5	61	46	36
3.0	116	87	70
3.5	196	147	118
4.0	304	228	182
4.5	443	333	266
5.0	593	445	356

TABLE 7.13
Discharge at cross-section 18 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	N=0.04	n=0.05
1.0	67	50	40
1.5	565	424	339
2.0	718	538	431
2.5	2088	1566	1253
3.0	4232	3174	2539

TABLE 7.14
Discharge at cross-section 24 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	6	4	3
1.0	44	33	27
1.5	158	118	95
2.0	409	307	246
2.5	835	626	501
3.0	1460	1095	876
3.5	2275	1706	1365
4.0	3338	2503	2003

TABLE 7.15
Discharge at cross-section 27 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	14	10	8
1.0	93	70	56
1.5	240	180	144
2.0	464	348	278
2.5	786	589	471

3.0	1212	909	727
3.5	1800	1350	1080
4.0	2553	1915	1532

TABLE 7.16
Discharge at cross-section 30 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	5	4	3
1.0	31	24	19
1.5	95	71	57
2.0	200	150	120
2.5	249	187	150
3.0	476	357	286
3.5	1046	784	628
4.0	1924	1443	1154
4.5	3083	2312	1850

TABLE 7.17
Discharge at cross-section 33 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	20	15	12
1.0	105	79	63
1.5	422	316	253
2.0	1104	828	662
2.5	2413	1810	1448
3.0	4618	3463	2771

TABLE 7.18
Discharge at cross-section 36 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	33	25	20
1.0	173	130	104
1.5	644	483	386
2.0	1818	1363	1091
2.5	3970	2978	2382
3.0	9409	7056	5645

TABLE 7.19
Discharge at cross-section 39 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	11	8	6

1.0	75	56	45
1.5	182	137	109
2.0	591	443	355
2.5	692	519	415
3.0	3674	2755	2204

TABLE 7.20
Discharge at cross-section 48 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.35	7	5	4
0.85	67	50	40
1.35	360	270	216
1.85	944	708	566
2.35	1616	1212	970
2.85	3101	2325	1860

TABLE 7.21
Discharge at cross-section 51 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.3	9	7	5
0.8	107	80	64
1.3	381	286	229
1.8	867	650	520
2.3	1808	1356	1085
2.8	3493	2620	2096

TABLE 7.22
Discharge at cross-section 54 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	26	20	16
1.0	227	170	136
1.5	814	611	489
2.0	1809	1356	1085
2.5	3994	2996	2396
3.0	5299	3974	3179

TABLE 7.23
Discharge at cross-section 57 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.68	56	42	33
1.18	230	172	138

1.68	587	440	352
2.18	962	722	577
2.68	1858	1393	1115
3.18	3441	2580	2064

TABLE 7.24
Discharge at cross-section 60 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	45	34	27
1.0	191	143	114
1.5	829	622	497
2.0	2008	1506	1205
2.5	3747	2810	2248

TABLE 7.25
Discharge at cross-section 63 km downstream of dam site

Water Depth (m)	Discharge (cumec)		
	n=0.03	n=0.04	n=0.05
0.5	46	35	28
1.0	57	43	34
1.5	245	184	147
2.0	5166	3874	3099
2.5	9540	7155	5724

The environmental flow for Dibang Multipurpose project has been estimated using the building block methods. Alternatively, numerical relationship can be derived between Normal depth and discharge corresponding to different values of n as shown in **Table 7.26**.

TABLE 7.26
Numerical relations for Normal depth-discharge relationship

Distance downstream of dam site	n=0.03	n=0.04	n=0.05
2	$Q=94.24y^{0.9972}$	$Q=70.674y^{0.9967}$	$Q=56.634y^{0.9931}$
4	$Q=160.81y^{1.1536}$	$Q=121.02y^{1.1}$	$Q=96.355y^{1.1544}$
6	$Q=26.597y^{1.196}$	$Q=20.642y^{1.1463}$	$Q=16.263y^{1.1672}$
9	$Q=337.02y^{0.7505}$	$Q252.29y^{0.7531}$	$Q=201.59y^{0.752}$
12	$Q=831.86y^{0.9195}$	$Q=23.96y^{0.9194}$	$Q=499.17y^{0.9196}$
15	$Q=2.126y^{3.5687}$	$Q=1.6168y^{3.5601}$	$Q=1.3728y^{3.592}$
18	$Q=1288.3y^2-3182.5y+2111.8$	$Q=96.29y^2-2387.1y+1576.4$	$Q=772.57y^2-1907.9y+1259.6$
24	$Q=47.752y^{3.0795}$	$Q=34.277y^{3.1248}$	$Q=26.459y^{3.1401}$

Distance downstream of dam site	n=0.03	n=0.04	n=0.05
27	$Q=83.912y^{2.463}$	$Q=61.866y^{2.481}$	$Q=49.483y^{2.4809}$
30	$Q=29.967y^{2.8226}$	$Q=23.171y^{2.795}$	$Q=18.079y^{2.8192}$
33	$Q=134.46y^{3.0705}$	$Q=102.39y^{3.0699}$	$Q=81.838y^{3.0705}$
36	$Q=223.91y^{3.1365}$	$Q=168.62y^{3.1311}$	$Q=134.88y^{3.1312}$
39	$Q=74.055y^{2.9834}$	$Q=54.886y^{2.9995}$	$Q=42.891y^{3.031}$
48	$Q=138.7y^{2.9415}$	$Q=102.48y^{2.9636}$	$Q=81.982y^{2.9636}$
51	$Q=201.89y^{2.6369}$	$Q=152.76y^{2.6221}$	$Q=118.73y^{2.6695}$
54	$Q=227.59y^{3.0249}$	$Q=168.46y^{3.0124}$	$Q=134.78y^{3.0124}$
57	$Q=148.49y^{2.6004}$	$Q=111.27y^{2.609}$	$Q=88.336y^{2.6104}$
60	$Q=264.95y^{2.8106}$	$Q=199.17y^{2.8066}$	$Q=158.715y^{2.8114}$
63	$Q=3845.4y^2-671.09y+2511.2$	$Q=2884.34y^2-5028.7+1884.4$	$Q=2307.7y^2-2307.7y+1507.8$

7.6 RELEASE OF MINIMUM FLOW

The environmental flow for Dibang Multipurpose Project has been estimated using building block method. The proposed Minimum Flow on the basis of average flow during 17 years data for the proposed Dibang Multipurpose project is given in **Table 7.27**.

TABLE-7.27

Environmental Flows required as per Building Block Methodology

Month	EF considering average flows for a period of 17 years (cumec)	EF considering 90% dependable year (cumec)
May	314	467
June	535	183
July	480	335.5
August	427	147
September	277	242
October	154	95
November	58	49
December	52	55
January	57	60
February	66	77
March	68	125
April	148	170

The hydrograph, which has been formulated using Building Block Method, simulates the natural conditions in the river to fulfill the different flow regimes present through out the year. The identification and incorporation of these important flow characteristics will help to maintain the river's channel structure, diversity of the physical biotopes.

The release of minimum flows on the basis of average flow during 17 years data has been estimated. In addition, there will be contribution from Ashu Pani stream which confluences with river Dibang about 1.5 km downstream of the dam site. The details of flows of Ashu Pani are given in **Annexure-II**. Thus, till the confluence of Ashu Pani with Dibang, the flow will be equal to the minimum releases from the dam, after which there will be contribution from Ashu Pani as well. The proposed Minimum Flow and contribution from Ashu Pani is given in **Table 7.28**. The corresponding depth of flows on the basis of average flow during 17 years data is given in **Table 7.29**.

TABLE 7.28
Contribution of Environmental flows and Ashu Pani discharge

Month	EF considering average flows for a period of 17 years (cumec) (flow upto 1.5 km downstream of the dam)	Contribution from Ashu Pani Nallah (cumec)	Total flow (cumec) (flow 1.5 km downstream of the dam)
May	314	6.6	320.6
June	535	11.8	546.8
July	480	10	490
August	427	9.4	436.4
September	277	5.7	282.7
October	154	4.5	159.5
November	58	2.3	60.3
December	52	2	54
January	57	2.2	59.2
February	66	2.7	68.7
March	68	2.7	70.7
April	148	4.4	152.4

The minimum depth required for fish sustenance of fish species observed in the study area is 0.5 to 0.7 m. The depth available for minimum flows recommended is above or equal to this range.

As per the recommendations of the study, a detailed optimization study was conducted to compare the energy optimisation vs. firm power optimization. The results are summarized in **Table 7.30**.

TABLE 7.29

Environmental Flows required and corresponding water depth considering average flows for a period of 17 years as per Building Block Methodology (n=0.04)

Month	Environmental Flow (cumec)	Depth of flow (m) 3 km d/s of dam	Depth of flow (m) 6 km d/s of dam	Depth of flow (m) 12km d/s of dam	Depth of flow (m) 24 km d/s of dam	Depth of flow (m) 36 km d/s of dam	Depth of flow (m) 48 km d/s of dam	Depth of flow (m) 60 km d/s of dam
May	314	2.42	10.94	16.80	2.05	1.23	1.47	1.18
June	535	3.94	17.44	30.02	2.43	1.46	1.76	1.43
July	480	3.57	15.85	26.64	2.34	1.41	1.70	1.38
August	427	3.21	14.32	23.49	2.26	1.35	1.63	1.32
September	277	2.16	9.81	14.65	1.96	1.18	1.41	1.13
October	154	1.29	5.95	7.86	1.64	0.98	1.16	0.92
November	58	0.53	2.55	2.73	1.20	0.72	0.84	0.65
December	52	0.50	2.31	2.42	1.16	0.70	0.81	0.63
January	57	0.52	2.51	2.67	1.19	0.72	0.83	0.65
February	66	0.60	2.85	3.14	1.25	0.75	0.87	0.68
March	68	0.61	2.93	3.24	1.26	0.76	0.88	0.69
April	148	1.23	5.72	7.48	1.61	0.97	1.14	0.91

TABLE 7.30

Comparison of energy optimisation vs. firm power optimization

	Energy Optimisation							Firm Power Optimisation					
Period	**Inflows into the Reservoir**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**
	Mm^3	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**
JUN-94	1337.99	2313.76	9.26	1308.30	527.54	2313.77	24.00	2313.77	9.26	1308.30	527.54	2313.77	24.00
	1337.99	2462.92	9.85	1335.83	561.54	2462.91	24.00	2462.91	9.85	1335.83	561.54	2462.91	24.00
	1337.99	2562.84	10.25	1353.66	584.33	2562.84	24.00	2562.84	10.25	1353.66	584.33	2562.84	24.00
JUL-94	521.16	1142.26	4.57	588.25	274.14	2662.03	10.30	2459.00	9.84	1273.15	590.16	2640.72	22.35
	521.16	1142.26	4.57	588.25	274.14	2662.03	10.30	2010.27	8.04	1157.41	482.47	2251.93	21.42
	573.28	1142.26	4.57	588.25	301.56	2662.03	10.30	1305.35	5.22	841.75	344.61	1899.84	16.49
AUG-94	960.34	2120.68	8.48	1096.65	508.96	2645.55	19.24	899.85	3.60	615.87	215.96	1737.51	12.43
	960.34	2120.68	8.48	1096.65	508.96	2645.55	19.24	1293.02	5.17	798.61	310.33	2026.79	15.31
	1056.37	740.31	2.96	380.42	195.44	2670.70	6.65	1086.97	4.35	631.31	286.96	2222.60	11.74
SEP-94	418.26	997.41	3.99	469.46	239.38	3000.00	7.98	908.37	3.63	481.03	218.01	2552.91	8.54

	Energy Optimisation							Firm Power Optimisation					
Period	**Inflows into the Reservoir**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**
	Mm^3	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**
	418.26	997.41	3.99	469.46	239.38	3000.00	7.98	885.38	3.54	469.46	212.49	2548.02	8.34
	418.26	997.41	3.99	469.46	239.38	3000.00	7.98	885.38	3.54	469.46	212.49	2548.02	8.34
OCT-94	690.85	376.25	1.50	176.48	90.30	3000.00	3.01	981.74	3.93	520.83	235.62	2545.93	9.25
	690.85	1635.91	6.54	724.05	392.62	3000.00	13.09	1371.18	5.48	706.02	329.08	2662.67	12.36
	759.94	1784.04	7.14	785.11	470.99	3000.00	14.27	1443.41	5.77	736.53	381.06	2698.97	12.84
NOV-94	399.77	1021.93	4.09	448.52	245.26	3000.00	8.18	915.28	3.66	462.96	219.67	2734.73	8.03
	399.77	1021.93	4.09	448.52	245.26	3000.00	8.18	641.81	2.57	324.68	154.03	2734.25	5.63
	399.77	1021.93	4.09	448.52	245.26	3000.00	8.18	651.02	2.60	324.68	156.25	2793.33	5.59
DEC-94	268.19	676.52	2.71	296.47	162.37	3000.00	5.41	372.91	1.49	183.03	89.50	2861.02	3.13
	268.19	676.52	2.71	296.47	162.37	3000.00	5.41	377.69	1.51	183.04	90.65	2915.94	3.11
	295.00	676.52	2.71	296.47	178.60	3000.00	5.41	399.54	1.60	191.25	105.48	2970.64	3.23
JAN-95	304.13	771.22	3.08	338.12	185.09	3000.00	6.17	445.88	1.78	210.81	107.01	3000.00	3.57

	Energy Optimisation							Firm Power Optimisation					
Period	**Inflows into the Reserv oir**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**
	Mm^3	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**
	304.13	771.22	3.08	338.12	185.09	3000.00	6.17	452.00	1.81	210.80	108.48	3000.00	3.62
	334.54	771.22	3.08	338.12	203.60	3000.00	6.17	411.75	1.65	189.39	108.70	3000.00	3.29
FEB-95	332.21	844.59	3.38	370.41	202.70	3000.00	6.76	460.61	1.84	208.33	110.55	3000.00	3.68
	332.21	844.59	3.38	370.41	202.70	3000.00	6.76	476.50	1.91	211.97	114.36	3000.00	3.81
	265.77	844.59	3.38	370.41	162.16	3000.00	6.76	844.61	3.38	370.41	162.17	3000.00	6.76
MAR-95	434.07	1111.38	4.45	487.94	266.73	3000.00	8.89	1317.08	5.27	578.70	316.10	3000.00	10.54
	434.07	1111.38	4.45	487.94	266.73	3000.00	8.89	1305.05	5.22	578.70	313.21	3000.00	10.44
	477.48	1111.38	4.45	487.94	293.40	3000.00	8.89	1222.81	4.89	547.14	322.82	3000.00	9.78
APR-95	706.06	1823.13	7.29	802.41	437.55	3000.00	14.59	1825.51	7.30	824.07	438.12	3000.00	14.60
	706.06	1823.13	7.29	802.41	437.55	3000.00	14.59	1874.82	7.50	848.38	449.96	3000.00	15.00
	706.06	3000.00	12.00	1324.67	684.00	3000.00	24.00	2381.41	9.53	1084.49	571.54	3000.00	19.05
MAY-95	724.46	3000.00	12.00	1399.18	684.00	3000.00	24.00	2892.62	11.57	1359.55	684.00	3000.00	23.14

	Energy Optimisation							Firm Power Optimisation					
Period	**Inflows into the Reservoir**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**	**Power (P)**	**Corres. No. of Units**	**Corres. Discharge**	**Energy with 95% m/c avail.**	**Peaking Capability**	**Peaking Hours**
	Mm^3	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**	**MW**		**m^3/s**	**GWH**	**MW**	**Hrs.**
	724.46	2434.36	9.74	1208.27	584.25	2813.43	20.77	2727.39	10.91	1360.36	636.76	2792.81	23.44
	796.91	2566.38	10.27	1333.13	659.03	2627.70	23.44	2192.71	8.77	1163.52	578.87	2545.14	20.68
TOTAL	**21616.38**				**12102.38**						**11330.87**		
AVERAGE		**1401.68**	**5.61**	**670.13**	**336.18**	**2881.35**	**11.94**	**1307.18**	**5.23**	**669.87**	**314.75**	**2695.09**	**11.99**
MAXIMUM		**3000.00**	**12.00**	**1399.18**	**684.00**	**3000.00**	**24.00**	**2892.62**	**11.57**	**1360.36**	**684.00**	**3000.00**	**24.00**
MINIMUM		**376.25**	**1.50**	**176.48**	**90.30**	**2313.77**	**3.01**	**372.91**	**1.49**	**183.032**	**89.50**	**1737.51**	**3.11**

Based on the findings of the energy optimisation vs. firm power optimization study, it is proposed to operate at least one turbine during lean season. This will lead to loss of (12102.38 - 11330.87) 771.52 million units of energy. The loss in terms of average Annual Peaking Capability shall be (2881.35 – 2695.09) = 186.26 MW (**Table 7.30**) The comparison of required Environmental Flows with respect to flows being released is given in **Table 7.31**.

TABLE 7.31
Comparison of required Environmental Flows vis-à-vis proposed release of water

Month		EF considering average flows for a period of 17 years (downstream of project) in cumecs	Releases through machines based on optimization studies in cumecs
June	I	535	1308.30
	II	535	1335.83
	III	535	1353.66
July	I	480	1273.15
	II	480	1157.41
	III	480	841.75
August	I	427	615.87
	II	427	798.61
	III	427	631.31
September	I	277	481.03
	II	277	469.46
	III	277	469.46
October	I	154	520.83
	II	154	706.02
	III	154	736.53
November	I	58	462.96
	II	58	324.68
	III	58	324.68
December	I	52	183.03
	II	52	183.04
	III	52	191.25
January	I	57	210.81
	II	57	210.80
	III	57	189.39
February	I	66	208.33
	II	66	211.97
	III	66	370.41
March	I	68	578.70
	II	68	578.70
	III	68	547.14
April	I	148	824.07

Month		EF considering average flows for a period of 17 years (downstream of project) in cumecs	Releases through machines based on optimization studies in cumecs
	II	148	848.38
	III	148	1084.49
May	I	314	1359.55
	II	314	1360.36
	III	314	1163.52

It can be observed that on account of loss in hydropower the project shall maintain discharge higher than the required Environmental Flow during lean season. In the intervening stretch from dam site to dam toe power house, a minimum flow of 15 cumec will be maintained throughout the year.