CUMULATIVE IMPACT & CARRYING CAPACITY STUDY OF DIBANG SUB BASIN IN BRAHMAPUTRA RIVER VALLEY

FINAL REPORT

Volume I
July 2016

Prepared for:

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

GOVERNMENT OF INDIA
Indira Paryavaran Bhavan, Jorbagh Road, New Delhi - 110 003

Prepared by:

R. S. Envirolink Technologies Pvt. Ltd.
402, BESTECH CHAMBER COMMERCIAL PLAZA,
B-BLOCK, SUSHANT LOK-I, GURGAON
PH. +91-124-4295383, www.rstechnologies.co.in

CONTENTS

VOLUME-I

LIST OF TABLES

LIST OF FIGURES

VOLUME-II

LIST OF ANNEXURES

EXECUTIVE SUMMARY

1.0 INTRODUCTION

Central Water Commission (CWC), Government of India had initiated the task of conducting “Cumulative Impact and Carrying Capacity Study of Dibang sub-basin including Downstream Impacts” with an objective to assess the cumulative impacts of hydropower development in the Dibang river sub basin in Brahmaputra river valley basin. Ministry of Environment, Forest & Climate Change (MoEF&CC) later took over all the river basin/carrying capacity studies being conducted by Central/State agencies and therefore, RS Envirolink Technologies Pvt. Ltd., Gurgaon (RSET) was awarded the study by MOEF&CC.

Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of MoEF has provided the Terms of Reference (TOR) for the study. The study initiated in May 2015 involved extensive field data collection especially in monsoon season to establish baseline status, data analysis and cumulative impact assessment, followed by recommendations for long term sustainable hydropower development in the basin. CEIA study of Dibang Basin has been prepared with a view to provide optimum support for various natural processes and allowing sustainable activities. The study covers the following:

- Inventorisation and analysis of the existing resource base
- Determination of regional ecological fragility/sensitivity
- Review of hydropower development plans
- Evaluation of cumulative impacts on various facets of environment due to hydropower development
- Broad framework of environmental action plan to mitigate the adverse impacts on environment, in the form of:
    - Preclusion of an activity
    - Modification in the planned activity
    - Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to various developmental projects. The key outcomes of the study are:

- Sustainable and optimal ways of hydropower development of Dibang river, keeping in view of the environmental setting of the basin
- Requirement of environmental flow throughout the year with actual flow, depth and velocity at different level
- Downstream impacts on Assam due to hydropower development in Dibang basin in Arunachal Pradesh

2.0 HYDROPOWER PROJECTS IN DIBANG BASIN

As per the latest information compiled for the basin study, total hydropower potential of Dibang basin in terms of identified projects is 9973 **MW**. As per the information provided by the Power Department, there are 18 hydropower projects in Dibang basin, out of which 14 HEPs have been allotted and remaining 4 are yet to be allotted. Apart from the projects on the main river, hydropower projects are planned on all major tributaries and sub-tributaries with installed capacity ranging from **22 MW** to **3097 MW**. Out of these 18 HEPs, 2 projects are located on Mathun River; 2 on Dri River; 1 on Ange Pani, a left bank tributary of Dri River; 2 on Talo (Tangon) River; 1 on Anon Pani, a left bank tributary of Talo (Tangon) River; 1 on Dri and Talo (Tangon) Rivers; 2 on Emra River, a right bank tributary of Dibang River; 1 on Ahi River, a right bank tributary of Dibang River; 2 on Ithun River, a left bank tributary of Dibang River; 1 on Ithi Pani, a right bank tributary of Ithun River; 1 on Dibang River; 1 on Ashu Pani, a left bank tributary of Dibang River; and 1 on Sissiri River, a right bank tributary of Dibang River. A comprehensive list of all these 18 HEPs has been prepared along with their present status and the same is given at **Table 1**.

Table 1: Comprehensive List of Hydropower Projects in Dibang Basin

S. No.	Name of Project	Name of Agency	Allotted Capacity (MW)	Revised Capacity (MW)	River/ Stream	Status of EC
1	Mihumdon	Reliance Power Ltd.	400	400	Dri	TOR accorded by MoEF&CC in 2011; expired and not revalidated
2	Etabue	Yet to be allotted	165	165	Ange Pani	Yet to be allotted
3	Agoline	Yet to be allotted	375	375	Dri	Yet to be allotted
4	Etalin	Jindal Power Limited	4000	3097	Dri and Talo (Tangon)	Appraised by EAC, decision pending till completion of basin study
5	Dibang Multipurpose	NHPC Ltd.	3000	2880	Dibang	EC and FC accorded by MoEF&CC
6	Amulin	Reliance Power Ltd.	420	420	Mathun	TOR accorded by MoEF&CC in 2010; expired and not revalidated
7	Emini	Reliance Power Ltd.	500	500	Mathun	TOR accorded by MoEF&CC in 2010; expired and not revalidated
8	Malinye	Yet to be allotted	335	335	Talo (Tangon)	Yet to be allotted
9	Attunli	Jindal Power Limited	500	680	Talo (Tangon)	TOR accorded by MoEF&CC
10	Anonpani	Etalin Hydro Electric Power Company Ltd.	23	22	Anon Pani	NA
11	Emra-I	Athena Energy Venture Pvt. Ltd.	275	275	Emra	Yet to apply for TOR
12	Emra-II*	Athena Energy Venture Pvt. Ltd.	390	390	Emra	TOR rejected by EAC*; instead asked to carry out basin study
13	Elango	Yet to be allotted	150	150	Ahi	Yet to be allotted
14	Ithun-I	JVKIL Consortium	25	84	Ithun	TOR accorded by MoEF&CC during March 2013; TOR expired and not revalidated
15	Ithun-II	JVKIL Consortium	20	48	Ithun	TOR accorded by MoEF&CC during February 2013; TOR expired and not revalidated
16	Ithipani	JVKIL Consortium	20	22	Ithi Pani	NA
17	Ashupani	Arti Power & Venture Pvt. Ltd.	30	30	Ashu Pani	Yet to apply for TOR
18	Sissiri	Soma Enterprise Ltd.	222	100	Sissiri	TOR accorded by MoEF&CC in 2009 for 222 MW: TOR expired and not revalidated for revised capacity of 100 MW
	Total		**10850**	**9973**		

**Extracts of Minutes of 34th Meeting of EAC held during January 2010:*
The Committee noted that the proposed site has not been visited by the project proponents and the information submitted in the documents are based on the PFR prepared by NHPC under the Prime Minister's 50,000 MW Hydro Power initiative. The project area both at dam site and power house site are inaccessible since August 2008. No road exists on either banks of river Emra to reach the project site. No bridge at present exists to cross Dibang river to reach either bank of Emra river (tributary of Dibang river). As no comprehensive survey of the area has been done physically the Committee did not agree to approve the TOR. The project proponent informed that the whole Emra Basin has been allotted to them by the Government of Arunachal Pradesh. Unless Ministry of Environment and Forests accords permission the concerned authorities may not allow them to enter the area. In view of this they requested permission for Basin Study of Emra Basin so that they can enter the area. The Committee agreed to this and suggested that the TOR given for Basin Study for Lohit Basin should be followed in this case also. The proponent may come back after the study and with a fresh TOR.

Out of total 18 planned projects in Dibang basin, only 2 projects are with installed capacity of less than 25 MW i.e. projects not covered under EIA Notification for environment clearance. Out of the rest 16 projects, 14 projects are with installed capacity of 50 MW or greater i.e. requiring environment clearance from MoEF&CC; remaining 2 will require environment clearance from the State Level Committee. A summary of EC status of hydropower projects in Dibang basin is given below:

Summary of the projects status with respect to environment clearance is given below:

Projects identified but yet to be allotted (Agoline, Malinye, Etabue, Elango)	4
Projects less than 25 MW (Anonpani, Ithipani)	2
Projects yet to apply for Scoping (Emra I, Ashupani)	2
Projects accorded Scoping Clearance; expired and not revalidated (Sissiri, Ithun I, Ithun II, Mihumdon, Emini, Amulin)	6
Scoping not recommended by EAC (Emra II)	1
Project with valid scoping clearance, Public Hearing yet to be conducted (Attunli)	1
Project accorded EC and FC (Dibang Multipurpose Project)	1
Project discussed in EAC, final decision pending till completion of basin study (Etalin)	1
Total Number of Planned HEPs	**18**

3.0 BASIN CHARACTERISTICS

The Dibang river basin is a part of Brahmaputra River System and is one of the major rivers traversing through Arunachal Pradesh. There are six major river basins in Arunachal Pradesh viz. Kameng, Subansiri, Siang (Dihang), Dibang, Lohit and Tawang with large number of their tributaries drain the waters of vast catchment area into the mighty Brahmaputra. The Dibang originates from the snow covered southern flank of the Himalaya/Trans Himalaya close to the Tibet border at an elevation of more than 5000 m. It cuts through deep gorges and difficult terrain in its upper reach through the Great Himalayan range in Dibang Valley and Lower Dibang Valley districts of Arunachal Pradesh and finally meets the river Lohit near Sadia in Assam. The total length of Dibang from its source to its confluence with Lohit river is about 223 km and the catchment area is about 13,933 sq km. The combined flow meets Brahmaputra near Kobo Chapori.

Dibang river drainage is comprised mainly of Dri and Talo (Tangon) rivers. Dri river originates at an altitude of 5355 m to 5375 m in the glacier ranges of the Greater Himalaya in the northern side of the basin. Talo (Tangon) river originates in the high hills of Himalaya near Kayapass in the eastern side of the basin. Both the rivers meets at Etalin to form Dibang river. As it flows down in southern direction of the basin several other tributaries like Emra river, Ahi river, Ithun river, Ilupani, Ashupani, Iphipani, Deopani, Sissiri, Kundli rivers, etc. join it along its course.

The boundary of Dibang river basin in Arunachal Pradesh in general coincides with boundaries of two districts viz. Lower Dibang Valley and Dibang Valley, however it includes entire catchment of Sissiri river, main right bank tributary of Dibang river in sloping plains and another left bank tributary i.e. Deopani. After entering state of Assam it is joined by off-shoots of Sissiri river on its right bank and those of Deopani and Kundli rivers like Emme and Difu rivers on left bank. Thereafter Dibang is joined by Lohit to form Brahmaputra river.

Total catchment area of Dibang river basin delineated as above is 13933 sq km with 13300 sq km in Arunachal Pradesh and 633 sq km in Assam. Approximate length of Dibang river in Arunachal Pradesh is 203.80 km while it traverses another 19.60 km in Assam to merge with Lohit river to form Brahmaputra river.

4.0 BIODIVERSITY PROFILE OF DIBANG BASIN

4.1 Terrestrial Ecology

4.1.1 Forest Cover

Total forest cover in Dibang basin covering mainly two districts of Arunachal Pradesh i.e. Dibang Valley and Lower Dibang Valley is 9321 sq km (71.54%) as compared to state's average forest cover of 80.30%. Total Dense forest cover is about 51.19% of which Very Dense Forest covers 13.02% of area while Moderately Dense forests cover 38.17% of its area.

4.1.2 Forest Types

The forests in Dibang basin fall under Eastern Circle with headquarters at Teju whereas the Protected Areas in the basin are under the administrative control of Addl. Principal Chief Conservator Forests (Wildlife & Biodiversity), Itanagar. The two Protected Areas in the basin are Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary. The details of forest types in the basin are primarily based upon Working Plans of the Roing Forest Division and Anini Social Forest Division, Management Plans of Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary and information provided by the Department of Environment and Forests, Government of Arunachal Pradesh. Their distribution in the basin is also described as per Forest Working Plans as well as supplemented with information gathered during field surveys in the area. The major forest types encountered in the area have been described based on the classification of Champion and Seth (1968).

- Upper Assam Valley Tropical Evergreen Forest (Tropical Evergreen Forest) (1B/C2)
- Eastern sub-montane Semi-evergreen Forest (Tropical Semi-evergreen forest) – (2B/C1b)
    - Low hills and plains semi-evergreen forest
    - Riverine semi-evergreen forest
- East Himalayan moist mixed deciduous forests (Sub tropical Broadleaved Forests) – (3/C3b)
- Assam Sub-tropical Pine Forests – (9/C2)
- East Himalayan Wet Temperate Forests (Temperate Broadleaved Forests) – (11B/C1)
- East Himalayan Mixed Coniferous Forest (Temperate Conifer Forests) – (12/C3a)
- Alpine Pastures (Alpine Forests) – 15/C3)
- Secondary Forests (1B/2S)
    - Degraded Forests
    - Bamboo and Musa Forests
    - Grasslands

4.1.3 Floristics

In all 1548 higher plant species belonging to 186 families have been documented which include 1329 Angiosperms, 17 Gymnosperms and 202 Pteridophytes. Among the lower plants bryophytes are represented by 21 species and lichens are represented by 16 species (**Table 2**). Amongst angiosperms orchids, bamboos, canes and rhododendrons are the important plant groups that are predominantly found in the basin. Orchidaceae is represented by 199 species, rhododendrons by 27 species and bamboos and canes together are represented by 43 species.

Angiosperms is the largest group wherein the dominant family in the basin is Orchidaceae with 199 species followed by Poaceae with 85 species, Asteraceae with 53 species, Ericaceae with 42 species, Lamiaceae with 40 species and Fabaceae with 34 species. Among Gymnosperms Pinaceae is the largest family with 9 species and amongst

Pteridophytes Polypodiaceae is the largest family with 35 species followed by Pteridacae with 28 species while Politrichaceae is the largest family among Bryophytes with 7 species.

Table 1: Summary of number plants species in Dibang basin

HIGHER PLANTS				
Group	Angiosperms	Gymnosperms	Pteridophytes	Total
Species	1329	17	202	**1548**
Genus	635	14	86	**735**
Families	153	5	28	**186**
LOWER PLANTS				
Group	Bryophytes	Lichens		
Species	21	16		
Genus	18	16		
Families	13	15		

4.1.4 Dominant Plant Groups in Dibang Basin

Orchids

Out of 199 orchid species documented in this report, 150 are epiphytes and 46 are terrestrial orchids while there are three species which have mycotrophic habit (living in association with mycorrhiza).

Gastrochilus calceolaris and *Paphiopedilum fairrieanum* are listed under Critically Endangered Category as per IUCN Redlist while *Bulleyia yunnanensis* has been listed under Endangered category. Red Data Book by BSI has listed *Paphiopedilum fairrieanum* under Endangered category while *Galeola falconeri* and *Vanda coerulea* have been placed in Indeterminate and Rare categories.

Six orchid species reported from Dibang basin are endemic to Arunachal Paradesh viz. *Calanthe densiflora, Dendrobium cathcartii, Dendrobium hookerianum, Eria ferruginea, Galeola falconeri* and *Paphiopedilum fairrieanum.*

Rhododendrons

In Dibang basin, 27 species of rhododendrons are reportedly found. Out of these 10 are trees and rest of them are shrubs. Majority of the species occur at elevations between 2000 and 3000m and majority of them are found in and around Mayudia Pass. Three species *Rhododendron falconeri, Rhododendron megacalyx* and *Rhododendron pruniflorum* are endemic to Arunachal Pradesh

Bamboos and Canes

In Dibang basin 23 species of bamboos are found of which 6 belong to genera *Bambusa* & *Dendrocalamus* each, 2 each belong to *Cephalostachyum* and *Thamnocalamus*.

Canes (Rattans – climbing palms) belong to genus *Calamus* of family Arecaceae. Out of 20 species of canes found in Arunachal Pradesh, 12 species have been reported from Dibang basin. *Calamus leptospadix* is an endemic species

Threatened & Endemic Plant Species

In Dibang basin, all there are 30 plant species that are either under different threat categories as per IUCN or under Red Data Book categories.

According to conservation status categories of IUCN Redlist four species i.e. *Dipterocarpus gracilis, Gastrochilus calceolaris, Paphiopedilum fairrieanum* and *Saurauia punduana* has been categorized as Critically Endangered (CE). Eight species reported from the Dibang basin are under Endangered (EN) category, five species are under Vulnerable (VU) and three species are under Near Threatened (NT) category of IUCN ver 3.1.

According to Red Data Book of published by Botanical Survey of India (BSI), out of 33 species reported from Arunachal Praedsh under various categories, twelve species are reported from Dibang basin. *Acer oblongum*, *Paphiopedilum fairrieanum*, *Livistona jenkinsiana* has been categoreis under Endangered (EN) category, *Coptis teeta* and *Diplomeris hirsuta* are categories under Vulnerable (VU) category, six species are under rare category

Endemic Plant Species

Fifty three plant species that are endemic to Arunachal Pradesh have been recorded from Dibang basin. These belong to 28 families and 42 genera. These species predominantly attributed to six plant families (i.e., Orchidaceae – 6 species; Gesneriaceae – 5 species, Balsaminaceae - 4 species; and Ericaceae, Rubiaceae, Begoniaceae and Acanthaceae represented by 3 species each). Three of these species viz. *Acer oblongum, Livistona jenkinsiana* and *Paphiopedilum fairrieanum* are under Endangered category according to BSI Red Data Book while *Begonia scintillans* and *Sapria himalayana* are under Rare category. IUCN has placed *Coptis teeta* and *Paphiopedilum fairrieanum* under Endangered and Critically Endangered categories.

Medicinal Plants

This region harbours a wide range of medicinal plants used in Ayurvedic, Homoeopathic and Unani medicines or used by the local people. An inventory of medicinal plant species used by local tribal people was prepared from data collected through literature survey (Rehty *et al.*, 2010; Nimasow *et al.*, 2012) Some of the medicinal plants of Dibang basin like *Acorus calamus, Adiantum capillus-veneris, Ageratum conyzoides, Artemisia nilagirica, Angiopteris evecta, Bauhinia purpurea, Breonia chinensis, Calamus* spp., *Cannabis sativa, Cinnamomum* spp., *Curcuma* spp., are quite common in the tropical and sub-tropical parts of Dibang basin. *Hedychium spicatum, Coptis teeta, Phyllanthus amarus, Rhus chinensis, Senna alata, Solanum* spp., *Tamarindus indica* and *Zanthoxylum* spp., are some other important medicinal plants of the region used by local populace in their daily life. These plants are used internally for treating stomachic diarrhea, dysentery, cough, cold, fever and asthma and externally for rheumatism, skin diseases, cuts, boils and injuries.

4.1.5 Faunal Elements

Mammals & Birds

A list of 158 mammalian fauna reported from the dibang basin prepared from published literature and data provided by Zoological Survey of India (ZSI), Department of Environment and Forests, Government of Arunachal Pradesh i.e. Fauna of Arunachal Pradesh, State Fauna Series, 13 (2006). Family Muridae is the largest family represented by 25 species while Vespertilionidae is represented by 19 species, Sciuridae by 13 species and Rhinolophidae, Mustelidae and Felidae is represented by 9 species each.

Dibang basin too is a good representative of avian diversity harbouring more than 650 species of birds. Three Birding areas have been identified in Dibang basin by IBA Important Birding Areas

inventory of the birds reportedly found in entire Dibang basin was prepared based upon IBA's checklist and the data provided by Zoological Survey of India (ZSI) i.e. Fauna of Arunachal Pradesh, State Fauna Series, 13 (2006). According to it **679 species** of birds belonging to **90 families.**

Butterflies

Based upon the data compiled from field surveys and secondary sources, Forest Working Plans, Management Plans of Protected areas, etc. a list of butterflies was prepared. According to it total of 373 species of butterflies are found in the basin. These species belong to seven families – Hesperiidae, Lycaenidae, Hesperidae, Nymphalidae, Papilionidae, Pieridae, Riodinidae and Satyridae. Nymphalidae was most dominant family represented by 141 species. Great Mormon, De Nicéville's Windmill, Eastern Courtier, Broad-banded Sailer, Pale Hockeystick Sailer, Pale Hockeystick Sailer, Scarce White Commodore, Bamboo Treebrown, Autumn Leaf, Common Duffer, Khaki Silverline and Common Pierrot are categorised as Schedule I species (WPA, 1972)..

Herpetofauna

Herpetofauna comprise of amphibians that include frogs, toads, newts, salamanders, etc. and reptiles which include snakes, lizards, turtles, terrapins, tortoises, etc. An inventory of herpetofauna comprising reptiles and amphibians was prepared from the Forest Working Plans, management plans of Protected Area and Fauna of Arunachal Pradesh Vol. I. Total 23 species are reported from the Dibang basin of which 17 species are of reptiles and6 species are of amphibians.

Reptiles

Reptilian fauna is comprised of 17 species belonging to 12 families. Colubridae is the largest family represented by six species followed by Agamidae and Elapidae with 3 species each. IUCN Red List has kept Burmese Python (*Python molurus bivittatus*), King Cobra (*Ophiophagus hannah*) under Vulnerable category. Five species are under least concern category and rest of the species is not evaluated under IUCN Red List

Amphibia

In Dibang basin 6 species of Amphibians are reportedly found which belong to 3 families, which comprises of toads and frogs. Ranidae is the largest family with 3 species followed by Bufonidae with 2 species. All species of frog falls in IUCN Red List Least Concern category.

4.1.6 Protected Areas

There are two Sanctuaries i.e. Dibang Wildlife Sanctuary and Mehao WLS in Dibang Basin. In addition Dibang Dihang Biosphere Reserve covers parts of Dibang Valley district.

Protected Area	Area (Sq km)
Dibang Wildlife Sanctuary	4149.00
Mehao Wildlife Sanctuary	281.50
Dibang Dihang Biosphere Reserve	5112.50 Core Area = 4094.80; Buffer Area = 1016.70

4.2 Aquatic Ecology

4.2.1 Physico-Chemical Water Quality

In order to assess the overall water quality of Dibang river and its tributary streams a Water Quality Index was used which has been developed at Washington State Department of Ecology, Environmental assessment Programme. The water quality of various streams of Dibang basin during sampling is good to excellent in general as WQI remained above 87.

4.2.2 Biological Water Quality

Phytoplankton

In all total, 86 species of phytoplankton were identified in the samples collected from various sampling locations in the study area. The phytoplankton community comprised of

47 species of Bacillariophyceae, 24 species of Cyanophyceae, 8 species of Chlorophyceae and 4 species of Conjugatophyceae, 2 species of Ulvophyceae and one species of Euglenophyceae. Most common species are *Achnanthes crenulata, Achnanthes exigua* var. *exigua, Achnanthidium biasolettianum* var. *biasolettiana, Cocconeis placentula* var. *lineata, Ceratoneis arcus* var. *recta, Encyonema silisiacum, Gomphonema olivaceum, Navicula cryptotenella, Navicula radiosaffalax, Surirella angusta, Gloeocapsa punctata, Anabaena aequalis, Rivularia angulosa, Cladophora* sp. and *Nitzschia linearis*.

Phytobenthos

In all total 70 species of Phytobenthos were identified from all the locations during surveys comprised of 5 classes with Bacillariophyceae as dominant class in the study area having 45 species, followed by Cyanophyceae with 15 species. Other classes recorded from the area are Chlorophyceae, Coleochaetophyceae and Conjugatophyceae. The genus *Cymbella* was the most dominant genus represented by 6 species followed by Navicula with 5 species. *Achnanthes crenulata* are most common and abundant species as they were recorded from 19 sampling sites during all samplings. Other common species recorded from the all sampling sites area *Oscillatoria* sp., *Cymbella excisa* var. *angusta, Achnanthidium biasolettianum, Didymosphenia geminate, Scytonema* sp., *Gloeocapsa* sp., *Pediastrum* sp., *Navicula radiosaffalax, Navicula radiosaffalax, Planothidium lanceolata* var. *elliptica, Achnanthidium subhudsonis* and *Achnanthidium biasolettiana* var. *biasolettiana.*

Zooplankton

Zooplankton were represented by protozoa, rotifer and crustacean (copepods and cladoceran). Among protozoans Actinophrys and Arcella genera were observed at most of the sites in Dibang Basin, The Rotifers are represented by species of *Keratella, Brachionus, Epiphanes, Philodina,* and *Asplanchna*. Among Crustaceans *Daphnia* and *Bosmina* species of order Cladocera were found, whereas Copepods were represented by *Cyclopes* sp. (water fleas) only.

Macro-invertebrates

Macro-invertebrates are widely used to determine biological conditions and acts as an in-line monitoring system for pollution. They are important part of food chain especially for fish. During the study, macro–invertebrate fauna comprised of 25 species falling under 5 orders belonging to 24 families. Ephemeropterawas the dominant order representing six families and 11 genera followed by order Diptera with 4 families and 5 genra. *Psephenus herricki* was the most abundant species and was recorded from 12 sampling sites during the surveys followed by *Hydropsyche* sp., *Heptagenia* sp., *Acroneuria* sp., *Caenis* sp. and *Centroptilum* sp.

Biological Water Quality

The water quality assessment of Dibang river and its tributories were assessed by calculating BMWP and ASPT values which are an indicative of river water qualiy. BMWP score calculated varied from 44 to 81 when the river flow is very high. Therefore water quality of Dibang river and its tributaries is good to excellent throughout the basin

Fish and Fisheries

In order to understand the fishery resources of Dibang basin information was collected from State Fishery Department, Itanagar which was supplemented with published. Nath & Dey, 2000 had reported 45 species of fishes from Dibang river system. During the field survey experimental fishing was done. According to it Dibang basin harbours 74 species of fishes belonging to 8 Orders and 26 families. Cyprinidae is largest family with 36 species accounting for nearly 50% of total fish fauna while Cobitidae and Sisoridae are the next largest families with 5 and 4 species each and families like Balitoridae and Ambassidae are represented by 3 species each.

Seven species are under Endangered category according to CAMP report (1998) of which 3 are under globally Endangered category while 4 species are categorized as nationally 'Endangered' species. Five species are placed under global 'Vulnerable' while 8 species are under 'Vulnerable' category nationally. *Schizothorax richardsonii* (Snow trout) has been placed under 'Vulnerable' category an important species of cold waters where it is the predominant species of trouts. However key species of warmer waters are Mahseers (*Tor tor* and *Tor putotora*). The category of 'Near Threatened' only one species is listed.

According of list of threatened freshwater fish species prepared by National Bureau of Fish Genetic Resources (NBFGR, 2010), 5 species have been categorized as Endangered while 12 species are placed in Vulnerable category. According to IUCN criterion *Tor putitora* while 4 species are under Vulnerable category. **Golden mahseer has been declared as Arunachal Pradesh State fish (Anon, 2011).**

5.0 ENVIRONMENTAL FLOWS

The environmental flow is an important aspect in the development of hydropower projects. Release of environmental flow is to be ensured immediately downstream of the diversion structure at all times to sustain the ecology and environment of project area.

For assessment of environmental flow focus is on the characteristic features of the natural flow regime of the river. The most important of these are degree of perenniality; magnitude of base flows in the dry and wet season; magnitude, timing and duration of floods in the wet season; and small pulses of higher flow, that occur between dry and wet months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired future condition of the river, and thus should not be eradicated during development of the river's water resources.

Fish assemblages often include a range of species and reflect the integrated effects of environmental changes. Their presence is used to infer the presence of other aquatic organisms, since the adult fish occupy the top of the food chain in most aquatic systems. Fish species in river can guide to prepare specification of the flows necessary to meet their needs, and be useful in the monitoring and management of those flows. It is often surmised that if management of flows for fish maintenance is successful, then flow requirements for aquatic invertebrates will also be satisfied. This is because of the larger scale of fish habitat.

Therefore, the approach adopted for environmental flow assessment is based on meeting the needs of dominant fish species with larger habitat requirement. Entire Dibang basin has been divided in two predominant fish zones viz. Mahseer Zone and Trout Zone. Mahseer being a large fish requires more flow in all the seasons and this aspect has been kept in mind while recommending environment flow for projects in Mahseer zone. Mahseer zone covers the main Dibang river below confluence of Dri and Talo (Tangon) rivers Projects fall in Mahseer zone are Dibang, Ashupani, Ithun – I, Ithun – II, Ithipani, Elango, Emra – I & Emra – II HEPs. Rest of the basin where remaining HEPs are located falls in trout zone.

A minimum depth requirement of 40 cm and 50 cm is considered for trout and mahseer zones respectively to assess the environmental flow requirement in lean season. Higher depth is considered for intermediate period and monsoon period to ensure mimicking of natural discharge pattern. For intermediate period in Mahseer zone, a depth range of 60-75 cm is considered and for monsoon season a depth range of 85-100 cm is considered. Similarly, for intermediate period in trout zone, a depth range of 55-65 cm is considered and for monsoon season in trout zone, a depth range of 70-80 cm is considered as minimum requirement.

As the depth is calculated at the deepest point and cannot be the only criteria for the habitat requirement; a second level assessment is done to check the reduction in river top width. If the reduction in top width is more than 50%, then next higher percentage is recommended to ensure that reduction in top width is not reduced more than half the original width under natural discharge condition in different seasons/period.

The most critical reach for assessing release of environmental flow is immediately downstream of diversion structure till first significant tributary meets river. To assess environmental flow requirements, a flow simulation study has been carried out using one dimensional mathematical model MIKE 11 developed by Danish Hydraulic Institute, Denmark.

There are 18 hydro projects being planned in the Dibang river basin on different tributaries. Two projects are less than 25 MW i.e. they do not fall under the purview of EIA notification; therefore they are not covered for the modeling exercise.

None of the projects have started construction; only some of the projects are at various stages of survey and investigation and remaining projects have yet to start the survey and investigation work as well and therefore data availability of such projects is very limited. Out of 16 projects, which are of installed capacity greater than or equal to 25 MW; 4 projects viz. Agoline, Etabue, Elango and Malinye HEPs have not yet been allotted to anyone. Reliable discharge data and river cross sections are not available for these projects, therefore, they have been excluded from modeling exercise. For one more projects, Ashupani HEP (30 MW), discharge data/river cross sections are not available, therefore it could not be included in the modeling exercise. Hence 11 projects have been chosen for simulation modeling based on data availability and to ensure that major tributaries and main Dibang river are covered in this modeling exercise. As Etalin project has diversion structure on Dri River as well as Talo (Tangon) River, for the purpose of Environmental flow assessment these two have been studied separately.

Out of the full year flow series (90% DY), three average values have been calculated viz.four leanest months, four monsoon months and remaining four months (pre and post monsoon).

Flow simulations have been carried out for 10%, 15%, 20%, 25%, 30%, 40%, 50% and 100% releases of the average discharge for each of above three scenarios. Various key parameters for establishing habitat requirement have been calculated which include water depth, flow velocity and top width of waterway.

Keeping in view the EAC/MoEF&CC's requirement of minimum release in lean season as 20% of average discharge in four leanest months in 90% dependable year of discharge series, the same has been considered as the minimum for lean season. Even if the modeling results show that the lesser value can meet the habitat requirement in any period/season, 20% of the average discharge in four leanest months has been kept as the minimum value.

For projects such as Dibang Valley and Sissiri HEPs which have dam toe powerhouses and intermediate river stretch is very small, continuous running of at least one turbine has been found a better way to ensure that river does not run dry and environmental flow requirements are adequately met with.

Based on the above criteria, environmental flow requirements have been established for each project separately and final recommendations are given in **Table 3** as below:

Table 3: Summary of Environmental Flow Release Recommendations

S. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Intermediate River Length* (km)	EFR (as % of average values of corresponding season/period in 90% DY)			EFR (Minimum Absolute Values in cumec)		
						Lean	Monsoon	Intermediate	Lean	Monsoon	Intermediate
1	Dibang Multipurpose	2880	Dibang	Dibang	1.20	20 cumec throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year					
2	Etalin (Dri Limb)	3097	Dri	Dri	16.50	20.00	12.20	13.30	30.64	50.00	30.64
3	Etalin (Talo Limb)		Talo	Talo	18.00	20.00	10.00	13.30	19.52	26.17	19.52
4	Attunli	680	Talo	Talo	10.68	20.00	10.00	15.00	17.60	23.60	19.80
5	Agoline#	375	Dri	Dri	9.38	20.00	30.00	25.00	-	-	-
6	Etabue#	165	Ange Pani	Dri	3.10 **	20.00	30.00	25.00	-	-	-
7	Mihumdon	400	Dri	Dri	9.39	20.00	25.00	20.00	8.46	25.58	15.91
8	Emini	500	Mathun	Dri	6.43	20.00	20.00	20.00	22.73	54.96	42.73
9	Amulin	420	Mathun	Dri	8.62	20.00	15.00	15.00	19.02	34.48	26.81
10	Emra I	275	Emra	Dibang	6.12	20.00	25.00	20.00	14.83	48.95	21.95
11	Emra II	390	Emra	Dibang	1.30 ***	20.00	25.00	20.00	15.24	50.33	22.56
12	Elango#	150	Ahi	Dibang	-	20.00	30.00	25.00	-	-	-
13	Ithun I	84	Ithun	Dibang	6.35	20.00	20.00	20.00	7.02	18.82	10.53
14	Ithun II	48	Ithun	Dibang	4.47	25.00	25.00	25.00	6.70	18.00	10.08
15	Ashupani#	30	Ashupani	Dibang	11.10 **	20.00	30.00	25.00	-	-	-
16	Sissiri	100	Sissiri	Dibang	0.50	20% of average discharge of four leanest months (3.87 cumec) in 90% DY throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year					

* Intermediate River length is the distance along the river between diversion site and tail water discharge point i.e. the river reach, which will be deprived of flow due to diversion of water to HRT. Adequate environment flow will ensure that river in this reach should have sufficient water throughout the year.
** Intermediate river length is distance along the river from diversion site up to tributary's confluence with main river.
*** Intermediate river length is distance along the river from diversion site up to reservoir tail of downstream project.
# Simulation Modelling could not be carried out due to non-availability of data, EFR is recommended based on Standard TOR of MoEF&CC for Hydropower projects.

6.0 DOWNSTREAM IMPACTS

6.1 Introduction

There are 18 HE projects proposed in Dibang basin. Most of the projects are in different stages of planning and development. During the monsoon period there will be significant discharge in Brahmaputra river. The peaking discharges of these hydroelectric projects which are quite less in comparison to Brahmaputra discharge will hardly have any impact on Brahmaputra. Some impact in form of flow regulation can be expected during the lean season peaking from these projects. Most of the projects are likely to be operated at MDDL during monsoon period and at FRL during the lean season. Further during the lean season the peaking discharge release of the projects in upper reaches of Dibang basin will be utilized by the project at lower reaches of the basin and net peaking discharge from the lower most project of the basin in general will be the governing one for any impact study.

In Dibang basin, Dibang Multipurpose Project is the lowermost storage project on main river. The peaking discharge of Dibang Multipurpose Project is about 1441 cumec for lean season peaking of 6.5 hours. Accordingly the downstream impact study has been carried out for the condition taking releases from power plant considering 6.5 hours peaking distributed in morning and evening and discharge varying from 111 cumec to 1441 cumec including environmental releases from dam.

For the downstream impact study the typical half hourly Lean season releases during 24 hour from Dibang Multipurpose Project has been estimated and the study has been carried out for this estimated release scenario and for natural condition of river (without considering Dibang Multipurpose Project).

Hydro-dynamic modelling has been carried out on MIKE 11 model which is simulating steady, quasi-unsteady and unsteady flows in a network of open channels. Model has been set up to 512 km downstream of Dibang Multipurpose Project i.e. Pandu G&D site (Guwahati) with the help of surveyed river cross sections.

The chainage of some of the important locations from Dibang Multipurpose Project as per MIKE11 model set up where discharge pattern and water level has been estimated are as follows:

- At chainage 45 km near Assam border above Dibang - Lohit confluence
- At chainage 61 km just before Dibang - Lohit confluence
- Dibru Saikhowa National Park – 78 km & 108 km
- Dibrugarh – 130 km
- Bokaghat (near Kaziranga National Park) –297 km
- Tezpur – 383.5 km
- Guwahati – 490.5 km

6.2 Flow Simulation Results in Natural Condition of River

In the natural condition of river, the water levels at different locations of the study reach as simulated are given in **Tables 4 and 5**.

Table 4: Water level at different locations in natural condition of river for average Lean season discharge

Place	Chainage from Dibang Multipurpose Project (km)	Average non-monsoon discharge (cumec)	Bed level of river (m)	Simulated water level (m)
At chainage 45 km (Near Assam border above Dibang-Lohit confluence)	45	477	135.25	136.506

Place	Chainage from Dibang Multipurpose Project (km)	Average non-monsoon discharge (cumec)	Bed level of river (m)	Simulated water level (m)
At chainage 61 km (Just above Dibang-Lohit confluence)	61	590	111.41	119.160
At Dibru- Saikhowa National Park (78 km d/s of Dibang Multipurpose Project; just below confluence of Dibang River and Lohit River	78	1180	111.36	119.094
At Dibru- Saikhowa National Park (108 km d/s of Dibang Multipurpose Project; below confluence of Siang, Dibang and Lohit)	108	2600	103.543	107.242
Dibrugarh	130	2641	92.375	96.002
Bokaghat-Kaziranga	297	2951	86.570	93.190
Tezpur	383.5	4475	67.212	73.518
Guwahati	490.5	5377	30.96	41.529

Table 5: Stabilized water levels computed through simulation for peaking release from Dibang HEP

Time	At chainage 45 km near Assam border	At chainage 61 km d/s just before Dibang – Lohit confluence	At chaimage 78 km Dibru – Saikhowa National Park upper segment	At chaimage 108 km Dibru – Saikhowa National Park lower segment	Near Dibrugarh	Bokaghat (Kaziranga)	Near Tezpur	Near Guwahati
hr	m	m	m	m	m	m	m	m
0.0	136.131	119.093	119.028	107.233	95.998	93.178	73.508	41.799
0.5	136.136	119.095	119.034	107.234	95.999	93.178	73.508	41.800
1.0	136.192	119.101	119.046	107.234	95.999	93.178	73.508	41.800
1.5	136.415	119.110	119.061	107.235	96.000	93.178	73.508	41.800
2.0	136.706	119.120	119.076	107.236	96.000	93.178	73.508	41.800
2.5	136.870	119.131	119.088	107.238	96.000	93.178	73.508	41.800
3.0	136.941	119.139	119.098	107.239	96.001	93.178	73.508	41.800
3.5	136.937	119.146	119.106	107.241	96.001	93.178	73.508	41.800
4.0	136.875	119.150	119.110	107.242	96.001	93.178	73.508	41.800
4.5	136.785	119.153	119.112	107.244	96.001	93.178	73.508	41.800
5.0	136.681	119.153	119.113	107.245	96.000	93.178	73.508	41.800
5.5	136.582	119.152	119.111	107.245	96.000	93.178	73.508	41.800
6.0	136.488	119.150	119.108	107.246	96.000	93.178	73.508	41.800
6.5	136.410	119.146	119.104	107.246	95.999	93.178	73.508	41.800
7.0	136.343	119.142	119.100	107.246	95.999	93.178	73.508	41.800
7.5	136.289	119.136	119.094	107.245	95.998	93.178	73.509	41.800
8.0	136.243	119.130	119.088	107.245	95.998	93.178	73.509	41.800
8.5	136.210	119.124	119.081	107.244	95.998	93.178	73.509	41.800
9.0	136.185	119.117	119.074	107.242	95.998	93.178	73.509	41.800
9.5	136.169	119.111	119.067	107.241	95.998	93.179	73.509	41.800
10.0	136.157	119.104	119.060	107.240	95.998	93.179	73.509	41.800
10.5	136.146	119.097	119.053	107.239	95.998	93.179	73.509	41.800
11.0	136.138	119.091	119.046	107.238	95.998	93.179	73.509	41.800
11.5	136.134	119.088	119.039	107.236	95.998	93.179	73.509	41.800
12.0	136.138	119.090	119.034	107.235	95.998	93.179	73.509	41.800
12.5	136.193	119.097	119.033	107.235	95.998	93.179	73.509	41.800
13.0	136.415	119.107	119.039	107.235	95.999	93.179	73.509	41.800
13.5	136.707	119.120	119.050	107.235	95.999	93.179	73.509	41.800
14.0	136.877	119.133	119.062	107.236	95.999	93.179	73.509	41.800
14.5	136.967	119.145	119.074	107.236	95.999	93.179	73.509	41.800
15.0	136.993	119.154	119.084	107.238	95.999	93.179	73.509	41.800
15.5	136.964	119.161	119.091	107.239	95.999	93.179	73.509	41.800
16.0	136.887	119.165	119.095	107.240	95.999	93.179	73.509	41.800
16.5	136.790	119.168	119.098	107.241	95.998	93.179	73.509	41.800
17.0	136.683	119.168	119.098	107.242	95.998	93.179	73.509	41.800
17.5	136.584	119.167	119.097	107.242	95.998	93.179	73.509	41.800
18.0	136.489	119.164	119.094	107.243	95.997	93.179	73.509	41.800
18.5	136.410	119.160	119.090	107.243	95.997	93.179	73.509	41.800

Time	At chainage 45 km near Assam border	At chainage 61 km d/s just before Dibang – Lohit confluence	At chaimage 78 km Dibru – Saikhowa National Park upper segment	At chaimage 108 km Dibru – Saikhowa National Park lower segment	Near Dibrugarh	Bokaghat (Kaziranga)	Near Tezpur	Near Guwahati
hr	m	m	m	m	m	m	m	m
19.0	136.344	119.156	119.086	107.243	95.997	93.179	73.509	41.800
19.5	136.289	119.150	119.080	107.242	95.997	93.179	73.509	41.800
20.0	136.243	119.144	119.074	107.241	95.996	93.179	73.509	41.800
20.5	136.210	119.138	119.068	107.241	95.996	93.179	73.509	41.800
21.0	136.185	119.131	119.061	107.240	95.996	93.179	73.509	41.800
21.5	136.169	119.124	119.054	107.238	95.997	93.179	73.509	41.800
22.0	136.157	119.117	119.047	107.237	95.997	93.179	73.509	41.800
22.5	136.146	119.109	119.040	107.236	95.997	93.179	73.509	41.800
23.0	136.138	119.102	119.033	107.235	95.998	93.179	73.509	41.800
23.5	136.133	119.096	119.028	107.234	95.998	93.179	73.509	41.801

6.3 Comparison of Discharge and Water Level Pattern of Different Simulations

A comparison of discharge and water level pattern at salient locations for different simulations is given in following **Table 6.**

Table 6: Comparison of discharge and water level pattern at salient location for different simulations

At chainage 45 km d/s of Dibang Multipurpose Project near Assam border before Dibang - Lohit confluence (River bed EL 135.25 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**477**
Water level in natural condition of river (m)	**136.506**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**170.73 - 1338.39**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**136.131 - 136.993**
At chainage 61 km d/s of Dibang Multipurpose Project just before Dibang - Lohit confluence (River bed EL 111.41 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**590**
Water level in natural condition of river (m)	**119.160**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**265.52 - 1169.18**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**119.088 - 119.168**
Dibru - Saikhowa National Park upper segment located about 78 km d/s of Dibang Multipurpose Project (River bed EL 111.36 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**1180**
Water level in natural condition of river (m)	**119.094**
Discharge pattern due to peaking release from Dibang Multipurpose Project	**1114.10 - 1251.18**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**119.028 - 119.113**
Dibru - Saikhowa National Park upper segment located about 108 km d/s of Dibang Multipurpose Project (River bed EL 103.74 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**2600**
Water level in natural condition of river (m)	**107.242**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**2619.90 - 2651.18**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**107.233 - 107.246**
Dibrugarh located about 130 km d/s of Dibang Multipurpose Project (River bed EL 92.375 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**2641**
Water level in natural condition of river (m)	**96.002**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**2628.56 - 2642.73**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**95.996 - 96.001**
Bokaghat (Kaziranga) located about 297 km d/s of Dibang Multipurpose Project (River bed EL 86.57 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**2951**
Water level in natural condition of river (m)	**93.190**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**2935.39 - 2936.80**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**93.178 - 93.179**
Tezpur located about 383.5 km d/s of Dibang Multipurpose Project (River bed EL 67.212 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**4475**

Water level in natural condition of river (m)	**73.518**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**4458.50 - 4460.03**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**73.508 - 73.509**
Guwahati located about 490.5 km d/s of Dibang Multipurpose Project (River bed EL 30.96 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**5377**
Water level in natural condition of river (m)	**41.529**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**5358.31 – 5360.16**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**41.799 - 41.801**

6.4 Outcome of peaking study

It can be concluded that in general the impact of peaking of hydroelectric projects of Dibang basin on Brahmaputra river is almost NIL in terms of discharge and water level fluctuations from Bokaghat up to Guwahati. This is due to very wide reach and large discharge carrying capacity of Brahmaputra river. In this reach of the Brahmaputra river the discharge and water level pattern will be approximately close to the natural condition discharge and water level pattern.

The Lean season peaking discharge releases in Dibang basin ultimately will result a stabilized discharge/water level series from Bokaghat onward resulting a discharge of about 2900 cumec at Bokaghat with water level about at EL 93.178 m, and a discharge of about 5300 cumec at Guwahati with water level about at EL 41.80 m. All these patterns are approximately same to the natural condition discharge and water level pattern.

Further, from Dibang Multipurpose Project location and up to Dibrugarh there will be daily fluctuations in discharge and water level due to peaking. These fluctuations will be of the order of 170.73 – 1338.39 cumec with water level variation from El 136.131 – 136.993 m at 45 km d/s of Dibang Multipurpose Project near Assam border before Dibang – Lohit confluence, discharge variation 265.52 – 1169.18 cumec with water level variation from El 119.088 - 119.168 m at 61 km d/s of Dibang Multipurpose Project just before Dibang – Lohit confluence, at Dibru- Saikhowa National Park (78 & 108 km chainage) 1114.10 – 1251.75 cumec with water level variation from El 119.028 - 119.113 m and 2619.90 – 2651.18 cumec with water level variation of 107.233 – 107.246 m respectively. Corresponding figures near Dibrugarh are 2628.56 – 2642.73 cumec with water level variation from EL 95.996 -96.001 m.

7.0 CUMULATIVE IMPACT ASSESSMENT

The objective of cumulative environment impact assessment is to assess stress/ load due to hydropower development in the basin and envisage a broad framework of environmental action plan to mitigate the adverse impacts. In CIA study of Dibang basin, where 18 hydropower projects are planned, focus of impact assessment is towards the broader issues or cumulative impacts of overall development

7.1 Impacts on Terrestrial Ecology

Cumulative impacts on terrestrial ecology have been discussed under the following heads:

- Direct Forest Cover Loss
- Forest Cover Loss due to Nibbling effect/ loss
- Impact of Spatial and Temporal crowding
- Impact on Biodiversity Values
- Impacts on Wildlife
- Impact on RET & Endemic Species
- Loss of Riparian Habitats

7.2 Impacts on Aquatic Ecology

The impacts on aquatic ecology happen in following ways:

- Reduced flows in downstream stretches
- Altered flow regime in different seasons viz. lean, monsoon, pre and post monsoon
- Discontinuity of river flow i.e. conversion of free flowing river into alternating small stretches of free flowing lotic ecosystem to lentic ecosystems of reservoirs and deprived stretches of river (run-of-the-river with long head race tunnels).
- Submergence
  - Alteration of river system from lotic to lentic environment
  - Loss of forest land
  - Alteration of landscape/aesthetics of area
- Alteration of river flow pattern downstream resulting due to variation in energy generation requirements in different periods.
  - Alteration of local ecosystem/ increased moisture conditions
  - Disruption of migration behaviour of fishes and other migratory animals
  - Health risks/Increased incidence/ proneness to unknown diseases
  - Downstream flooding due to sudden peaking

Of the 18 planned projects in Dibang basin, 4 are planned on main Dibang river, 3 on Talo and 2 on Mathun river. Four projects on Dri/Dibang river will affect **92.08 km** of river wherein the river will be flowing either through tunnels or will be converted into reservoir leading to significant alteration of free flowing fresh water ecosystem of Dibang river. More than 45% of Dri/Dibang river stretch will be affected by 4 projects. Similarly more than one third of Talo river will be affected by 3 proposed projects. However 48% of Mathun river will be affected due to 2 projects. Only 38% of Ithun river is likely to be affected by 2 projects. Six projects are planned on tributaries of Dri/Talo/Dibang rivers, one each of Ange Pani, Anonpani, Ahi river, Ithipani, Ashupani and Sissiri river.

Impacts on ecology have been studied under following heads in the report:

- Impact on Free Riverine Stretch
- Impacts due to Damming of River
- Direct Impacts of Reservoir based projects
- Impact on Fish Populations
- Impact on Fish Migration
- Major impact on Fishes
  - Loss of Habitat
  - Impact on Fish Migration
  - Modification of Discharge
  - Water Temperature and Water Quality Changes
  - Increased Exposure to Predation

7.3 Impact assessment

All the 15 projects, for which project details were available (No data for three projects viz. Agoline, Elango and Malinye is available and have not been allotted yet), were assessed. Based upon environmental and bio-dievrsity parameters comparative sensitivity, Biodiversity and overall score is tabulated below in **Table 7**.

Table 7: Relative Impact Scoring

Project	Sensitivity Score	Biodiversity Score	Overall Score
Amulin	54	48	49
Anonpani	63	23	32
Ashupani	62	45	48
Attunli	66	48	52
DMPP	89	91	91
Emini	59	51	52

Project	Sensitivity Score	Biodiversity Score	Overall Score
Emra-I	77	63	65
Emra-II	76	62	65
Etabue	74	54	58
Etalin	71	46	51
Ithipani	72	40	47
Ithun-I	70	47	52
Ithun-II	71	44	50
Mihumdon	56	54	54
Sissiri	54	35	41

As seen from the above table; apart from DMPP projects such as Emra-I, Emra-II, Etabue, Ithipani, Ithun-I & Ithun-II have scored high on sensitivity parameters. However when all the 15 projects were assessed with respect to Biodiversity Values (15 parameters) i.e. Floristic and Faunal diversity as well as fishes and in their respective Study Areas, Dibang Multipurpose Project still scores the highest. Other projects with relatively high scores on biodiversity values, which have also scored high on Sensitivity Values, are Emra-I, Emra-II and Etabue HEPs. Mihumdon was low on Sensitive score, however, scored high on Biodiversity Score. Cumulative Impact Assessment scores were obtained combining sensitivity and biodiversity richness parameters. Relative impact scoring has been kept in view while making recommendations for individual projects.

8.0 CONCLUSIONS AND RECOMMENDATIONS

During the Cumulative Impact Assessment (CIA) study various issues and concerns relevant to implementation of proposed 18 hydropower projects in Dibang basin were assessed. Baseline data superimposed with the project parameters of proposed HEPs have been used to analyse cumulative impacts of hydropower development in the basin. Recommendations have been made for sustainable and optimal ways for hydropower development in the basin keeping in view the environmental baseline characteristics of Dibang basin as well its major tributaries along with environmental flow recommendations for all as already mentioned above. Project specific recommedations are given as below:

Dibang Multipurpose Project

The project is in most advanced stage in basin, with environment and forest clearance in DPR and DPR is under revision due to changes proposed during environment clearance process. The project has reduced the dam height by 10 m leading to change of installed capacity from 3000 MW to 2880 MW. Environmental flow provisions as finalised during the environment clearance have been assessed by modeling study and are found to be adequate. Keeping this in view, no additional modification or changes are recommended for this project.

Etalin and Attunli HEPs

In addition to Dibang Multipurpose Project, these two are the only projects which have made substantial progress in terms of Survey and Investigation and preparation of environmental impact assessment study reports. Etalin's DPR has already been accorded TEC by Central Electricity Authority; EIA & EMP studies have been completed along with public consultation process and have been discussed in EAC, however, environment clearance is not recommended because basin study was not complete at that time. Adequate free flow river stretch is maintained with upstream and downstream projects in both the cases and with the provision of environmental flow recommendations, impacts of reduced flow in de-watered stretch will also be mitigated. Therefore, no changes are required for these two projects as well.

Emra I and Emra II HEPs

Emra I and Emra II projects have been allotted to M/s Athena Energy by GoAP vide MoA dated 02/02/2008 with the provision of developing Emra river in two or more schemes/stages. Survey and investigation have not made any significant progress. Environment clearance process has yet to start from scoping clearance stage. These two projects have been considered on the basis of the desktop information provided by the developer; however, whether more projects in the Emra basin can be sustainably develop, cannot be assessed based on the limited information. Therefore, it is recommended that development of Emra basin should remain limited to two schemes in the present form. No more projects should be considered on Emra River unless a detailed basin study eshtablishes their sustainability.

Malinye, Elango, Agoline and Etabue HEPs

These four projects have not been allotted yet, and therefore, not much information is available for a detailed assessment. Malinye HEP falls within Dibang Wildlife Sanctuary and there is no possibility of shifting the project downstream in order to avoid falling within the sanctuary and there is no free stretch between Malinye and Attunli HEPs according to the tail water level of the project provided by the state government matches with the FRL of Attunli HEP. Therefore based upon the location of Malinye HEP is recommended to be dropped.

Etabue HEPs diversion site is on Ange Pani and powerhouse is planned on left bank of Dri river downstream of Mihumdon HEP powerhouse (on right bank) and upstream of Agoline HEP. Diversion on Ange Pani will reduce the contribution of intermediate catchment downstream of Mihumdon diversion. As the project features are not yet final, it is recommended that at least one kilometre of free flow stretch should be maintained between FRL of Agoline and TWL of Etabue. As Agoline HEP is also not allotted, based on limited available features, it TWL is approximately giving a 970m free river stretch with Etalin FRL on Dri river. A minimum of one kilometer free flow stretch is recommended to be maintained by Agoline from the FRL of Etalin HEP.

Mihumdon, Amulin, Emini, Ithun I and Ithun II HEPs

Mihumdon, Emini and Amulin HEPs are with Reliance Power and Ithun I and Ithun II are with JVKIL consortium. All these five projects have taken scoping clearance which have lapsed and have not been applied for revalidation/extension by developers. No significant progress is made on DPR preparation as well. Projects have been considered and reviewed based on the PFR information and scoping clearance issued by MoEF&CC. Environmental flows have been assessed and recommended for individual project and should be incorporated in DPR during its preparation and finalisation.

Anonpani and Ithipani HEPs

Anonpani and Ithipani are two small projects i.e. less than 25 MW installed capacity and therefore are not covered under EIA notification. Anonpani is in advance stage and is making progress whereas Ithipani is only at PFR stage. Projects are found to be sustainable based on the present project features and environmental baseline setting, therefore, no specific recommendations have been made.

Ashupani HEP

Ashupani is a 30 MW proposed project on Ashupani river and the features available as of date are from PFR prepared by NHPC under 50,000 MW initiative. Project was allotted to Arti Power & Ventures Pvt. Ltd. in 2013 and no progress is made till date. Reservoir tail appears to be encroaching in the Mehao Wildlife Sanctuary. Detailed project features are not available to verify this fact. Project is planned as inter-basin transfer where water of

Ashupani will be diverted to a powerhouse on the bank of Digi Nala. This will make about 11 km of the Ashupani river, downstream of dam up to confluence with Dibang, dry but for the environmental flow. Catchment area at diversion site is only 67 sq km. It is recommended that project should be planned keeping it completely outside the boundary of Mehao Wildlife Sanctuary. Environmental flow provisions are very critical for this project where out of 28 km of the total Ashupani river length, about 11 km will be left with environmental flow only. Therefore, the environmental flow recommendations should be strictly implemented and provisions should be made in the project design in DPR itself.

Sissiri HEP

Sissiri HEP's installed capacity has already been reduced to from 222 MW to 100 MW and revised DPR is under preparation. Scoping clearance obtained in 2009 has lapsed and never applied again for re-issue/revalidation. Environmental flow provisions have been assessed and same needs to be incorporated to make project environmentally sustainable. It is recommended that environment flow provisions are incorporated in the DPR at this stage as it may require some changes in terms of turbine configuration/features. It is further recommended that developer should proceed with fresh scoping clearance and environment study.

CHAPTER-1
INTRODUCTION

1.1 BACKGROUND

Central Water Commission (CWC), Government of India had initiated the tendering process for selection of consultant to undertake Environmental Impact Assessment (EIA) Study for Dibang river sub basin in Brahmaputra river valley with an objective to assess the cumulative impacts of hydropower development in the basin. RS Envirolink Technologies Pvt. Ltd., Gurgaon had been selected to undertake the task on completion of the bidding process. Ministry of Environment, Forest & Climate Change (MoEF&CC) later took over all the river basin/carrying capacity studies being conducted by Central/State agencies and therefore, RS Envirolink Technologies Pvt Ltd, Gurgaon (RSET) was awarded the study by MOEF&CC.

Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of MoEF&CC has provided the Terms of Reference (TOR) for the study. The study initiated during May 2015 involved extensive field data collection especially in monsoon season to establish baseline status, data analysis and cumulative impact assessment, followed by recommendations for long term sustainable hydropower development in the basin.

As per MoEF&CC's OM dated 28 May, 2013, Cumulative Impact Assessment Studies and carrying capacity studies are linked to Environment Clearance and Forest Clearance process and are pre-requisite for considering EC/FC cases for individual projects of any river basin. Therefore, it was felt important that CIA/Carrying capacity studies should be completed as early as possible without compromising the quality of the study. The matter was deliberated in 86th Meeting of the Expert Appraisal Committee for River Valley and Hydroelectric Projects held on 24-25th August, 2015 with a view to reduce the time frame of basin studies without compromising on the quality of work.

The Ministry informed EAC that a meeting was held with BSI, ZSI and CWC to understand the data availability and whether such data available with them can be used for basin studies and baseline data collection can be optimised /done away with. ZSI and BSI have confirmed that they have substantial amount of published as well as un-published data, which can be shared for the study. The Consultants engaged for the purpose of the studies can review the suitability of the data. Hydrological data is always provided by the CWC and they will provide full support to the study. EAC observed that there should not be any issue with quality of data provided by BSI and ZSI. This data will be very useful for defining the basin level setup. However, such data may not be site specific as will be needed for the study. For this purpose, EIA studies carried out in the basin in the recent time can also be used for sourcing the project specific data. EAC also observed that consultants should take the responsibility of defining the baseline to meet the study requirement and they should supplement BSI/ZSI data with data from other secondary sources as well. Further, EAC recommended that one season data should be collected by consultants as per the terms of reference issued earlier for these studies and since monsoon is critical season for such studies, the field data can be collected in the month of September 2015. This would reduce the time frame of the study from 21 months to 12 months without compromising on the quality of the study.

The Dibang sub-basin or Dibang basin, as the term is generally used in the report, has about 10000 MW of hydropower potential, which is planned to be harnessed by setting up 18 hydropower projects spread throughout the basin. Department of Hydro Power Development, Government of Arunachal Pradesh has allotted 14 projects, which are at various stages of survey and investigation. Four projects are yet to be allotted which are Agoline, Malinye, Etabue and Elango HEPs.

Such a large-scale development expected to take place over a period of next 10-15 years in otherwise pristine area, can cause serious environmental impacts and will exert tremendous pressure on carrying capacity of Dibang basin. EIA notification of September 2006, issued under Environmental Protection Act, 1986, has the provision of evaluating the impacts of individual projects of capacities 25 MW or more by SEAC/EAC before issuing environmental clearances. However, in a situation in Dibang basin where several projects are planned in cascade utilising the same natural resource; assessment of cumulative impacts and carrying capacity study of the entire basin is essential to plan development in environmental friendly manner and to mitigate and manage the impact comprehensively. Therefore, the present study "Cumulative Impact and Carrying Capacity Study of Dibang sub-basin" shall be prepared with a view to provide optimum support for various natural processes and allowing sustainable activities within carrying capacity of Dibang sub-basin.

The study covers the following:

- Inventorisation and analysis of the existing resource base
- Determination of regional ecological fragility/sensitivity
- Review of hydropower development plans
- Evaluation of cumulative impacts on various facets of environment due to hydropower development
- Broad framework of environmental action plan to mitigate the adverse impacts on environment, in the form of:
    - Preclusion of an activity
    - Modification in the planned activity
    - Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to various developmental projects.

1.2 SCOPE OF WORK

The scope of work has been defined by CWC based on Terms of Reference provided by EAC and same is being followed for the study. The scope of work, with respect to baseline data collection and use of secondary data, with a view to reduce the time frame of the study has been modified based on the discussion in 86th EAC meeting and intimated to us by MoEF&CC vide their letter dated November 03, 2015. The study area is entire Dibang Basin up to the confluence of Siang, Dibang and Lohit to form Brahamputra.

1.3 OUTCOME OF THE STUDY

The key outcomes of the study are:

- Sustainable and optimal ways of hydropower development of Diabng river, keeping in view of the carrying capacity and environmental setting of the basin
- Requirement of environmental flow throughout the year with actual flow, depth and velocity at different level
- Downstream impacts on Assam up to Guwahati due to hydropower development in Dibang basin in Arunachal Pradesh

1.4 OUTLINE OF PRESENT DRAFT FINAL REPORT

The present draft final Report shall cover following:

- **Chapter 1**: Introduction; covers general background and introduction of the study, expected outcomes of the study, study area and information on coverage of the present report.

- **Chapter 2:** Hydro power development in Dibang basin; provides information of existing and planned hydro power development in Dibang river basin of Arunachal Pradesh.

- **Chapter 3:** Methodology adopted for the study, information on various sampling locations, etc.

- **Chapter 4:** Basin characteristics of the study area

- **Chapter 5:** Hydro-meteorology provides data on flows and meteorological observations

- **Chapter 6:** Environmental baseline data for terrestrial ecology covers information on forest types, floristic and faunal diversity of study area through secondary sources and primary survey data

- **Chapter 7:** Environmental baseline data for aquatic ecology covers physico-chemical and biological characteristics as well as information of fish and fisheries from primary and secondary sources

- **Chapter 8:** Environmental flows: This chapter covers literature survey for different available methodologies nationally or internationally for environmental flow assessment as well as flow releases to be considered for various simulations.

- **Chapter 9:** Downstream impacts due to hydro development; Chapter covers assessment of downstream impacts up to Assam with the help of hydro-dynamic modelling due to peaking.

- **Chapter 10:** Cumulative Impact Assessment: assesses impacts due to planned hydro development in basin.

- **Chapter 11:** Conclusion & Recommendations

CHAPTER-2
HYDROPOWER DEVELOPMENT IN DIBANG BASIN

2.1 HYDROPOWER POTENTIAL

Topography of Arunachal Pradesh provides ideal conditions for development of hydropower projects. Six major river basins in state viz. Lohit, Dibang, Siang, Subansiri, Kameng and Tawang and several smaller river systems offer conducive conditions for hydropower development. CEA ranking study has identified 89 major hydropower projects in state with total potential of 49,126 MW. Under PM's 50,000 MW initiative, Central Government has identified 42 schemes in the state with an installed capacity of 27,293 MW, for preparation of Pre-feasibility Reports (PFRs).

2.2 HYDROPOWER PROJECTS IN DIBANG BASIN

As per the latest information compiled for the basin study, total hydropower potential of Dibang basin in terms of identified projects is **9973 MW**. As per the information provided by the Power Department, there are 18 hydropower projects in Dibang basin, out of which 14 HEPs have been allotted and remaining 4 are yet to be allotted. Apart from the projects on the main river, hydropower projects are planned on all major tributaries and sub-tributaries with installed capacity ranging from **22 MW** to **3097 MW**. Out of these 18 HEPs, 2 projects are located on Mathun River; 2 on Dri River; 1 on Ange Pani, a left bank tributary of Dri River; 2 on Talo (Tangon) River; 1 on Anon Pani, a left bank tributary of Talo (Tangon) River; 1 on Dri and Talo (Tangon) Rivers; 2 on Emra River, a right bank tributary of Dibang River; 1 on Ahi River, a right bank tributary of Dibang River; 2 on Ithun River, a left bank tributary of Dibang River; 1 on Ithi Pani, a right bank tributary of Ithun River; 1 on Dibang River; 1 on Ashu Pani, a left bank tributary of Dibang River; and 1 on Sissiri River, a right bank tributary of Dibang River. A comprehensive list of all these 18 HEPs has been prepared along with their present status and the same is given at **Table 2.1**. For locations of these projects in Dibang Basin see **Figure 2.1**.

Table 2.1: Comprehensive List of Hydropower Projects in Dibang Basin #

S. No.	Name of Project	Name of Agency	Allotted Capacity (MW)	Revised Capacity (MW)	River/ Stream	Status of EC
1	Mihumdon	Reliance Power Ltd.	400	400	Dri	TOR accorded by MoEF&CC in 2011; expired and not revalidated
2	Etabue	Yet to be allotted	165	165	Ange Pani	Yet to be allotted
3	Agoline	Yet to be allotted	375	375	Dri	Yet to be allotted
4	Etalin	Jindal Power Limited	4000	3097	Dri and Talo (Tangon)	Appraised by EAC, decision pending till completion of basin study
5	Dibang Multipurpose	NHPC Ltd.	3000	2880	Dibang	EC and FC accorded by MoEF&CC
6	Amulin	Reliance Power Ltd.	420	420	Mathun	TOR accorded by MoEF&CC in 2010; expired and not revalidated
7	Emini	Reliance Power Ltd.	500	500	Mathun	TOR accorded by MoEF&CC in 2010; expired and not revalidated
8	Malinye	Yet to be allotted	335	335	Talo (Tangon)	Yet to be allotted
9	Attunli	Jindal Power Limited	500	680	Talo (Tangon)	TOR accorded by MoEF&CC
10	Anonpani	Etalin Hydro Electric Power Company Ltd.	23	22	Anon Pani	NA
11	Emra-I	Athena Energy Venture Pvt. Ltd.	275	275	Emra	Yet to apply for TOR
12	Emra-II*	Athena Energy Venture Pvt. Ltd.	390	390	Emra	TOR rejected by EAC*; instead asked to carry out

S. No.	Name of Project	Name of Agency	Allotted Capacity (MW)	Revised Capacity (MW)	River/ Stream	Status of EC
						basin study
13	Elango	Yet to be allotted	150	150	Ahi	Yet to be allotted
14	Ithun-I	JVKIL Consortium	25	84	Ithun	TOR accorded by MoEF&CC during March 2013; TOR expired and not revalidated
15	Ithun-II	JVKIL Consortium	20	48	Ithun	TOR accorded by MoEF&CC during February 2013; TOR expired and not revalidated
16	Ithipani	JVKIL Consortium	20	22	Ithi Pani	NA
17	Ashupani	Arti Power & Venture Pvt. Ltd.	30	30	Ashu Pani	Yet to apply for TOR
18	Sissiri	Soma Enterprise Ltd.	222	100	Sissiri	TOR accorded by MoEF&CC in 2009 for 222 MW: TOR expired and not revalidated for revised capacity of 100 MW
	Total		10850	9973		

*# Based upon list provided by Department of Hydro Power Development, Arunachal Pradesh (**Annexure I, Volume II**)*
**Extracts of Minutes of 34th Meeting of EAC held during January 2010:*
The Committee noted that the proposed site has not been visited by the project proponents and the information submitted in the documents are based on the PFR prepared by NHPC under the Prime Minister's 50,000 MW Hydro Power initiative. The project area both at dam site and power house site are inaccessible since August 2008. No road exists on either banks of river Emra to reach the project site. No bridge at present exists to cross Dibang river to reach either bank of Emra river (tributary of Dibang river). As no comprehensive survey of the area has been done physically the Committee did not agree to approve the TOR. The project proponent informed that the whole Emra Basin has been allotted to them by the Government of Arunachal Pradesh. Unless Ministry of Environment and Forests accords permission the concerned authorities may not allow them to enter the area. In view of this they requested permission for Basin Study of Emra Basin so that they can enter the area. The Committee agreed to this and suggested that the TOR given for Basin Study for Lohit Basin should be followed in this case also. The proponent may come back after the study and with a fresh TOR.

Out of total 18 planned projects in Dibang basin, only 2 projects are with installed capacity of less than 25 MW i.e. projects not covered under EIA Notification for environment clearance. Out of the rest 16 projects, 14 projects are with installed capacity of 50 MW or greater i.e. requiring environment clearance from MoEF&CC; remaining 2 will require environment clearance from the State Level Extert Appriasal Committee. A summary of Environmental Clearance (EC) status of hydropower projects in Dibang basin is given below:

Summary of the projects status with respect to environment clearance is given below:

Projects identified but yet to be allotted (Agoline, Malinye, Etabue, Elango)	4
Projects less than 25 MW (Anonpani, Ithipani)	2
Projects yet to apply for Scoping (Emra I, Ashupani)	2
Projects accorded Scoping Clearance; expired and not revalidated (Sissiri, Ithun I, Ithun II, Mihumdon, Emini, Amulin)	6
Scoping not recommended by EAC (Emra II)	1
Project with valid scoping clearance, Public Hearing yet to be conducted (Attunli)	1
Project accorded EC and FC (Dibang Multipurpose Project)	1
Project discussed in EAC, final decision pending till completion of basin study (Etalin)	1
Total Number of Planned HEPs	**18**

2.3 PROJECTS DESCRIPTION

Efforts have been made to collect the data of all the planned and allotted projects in the basin. Data is being procured from Department of Hydro Power Development, Government of Arunachal Pradesh as well as by contacting project promoters so that all the relevant information required to make basin level impact assessment can be compiled for data analysis. In addition, minutes of meeting of Expert Appraisal Committee (EAC) of Ministry of Environment, Forests & Climate Change (MoEF&CC) or State Expert Appraisal Committee (SEAC) of Arunachal Pradesh have also been referred to for the meetings where Dibang projects have been considered for TOR or EC.

Information in the form of PFR/ DPR has been collected for Etalin, Dibang Multipurpose, Attunli, Emra I, Emini, Amulin, Mihumdon, Emra II, Agoline, Etabue, Sissiri, Ithun-I, Ithun-II and Ashupani HEPs and Anon Pani and Ithi Pani SHEPs. Information collected is compiled in the form of Salient Features of each project and is given from **Tables 2.2** to **2.17**. The layout maps as per PFR/ DPR of these projects are also given as **Figures 2.2** to **2.16**.

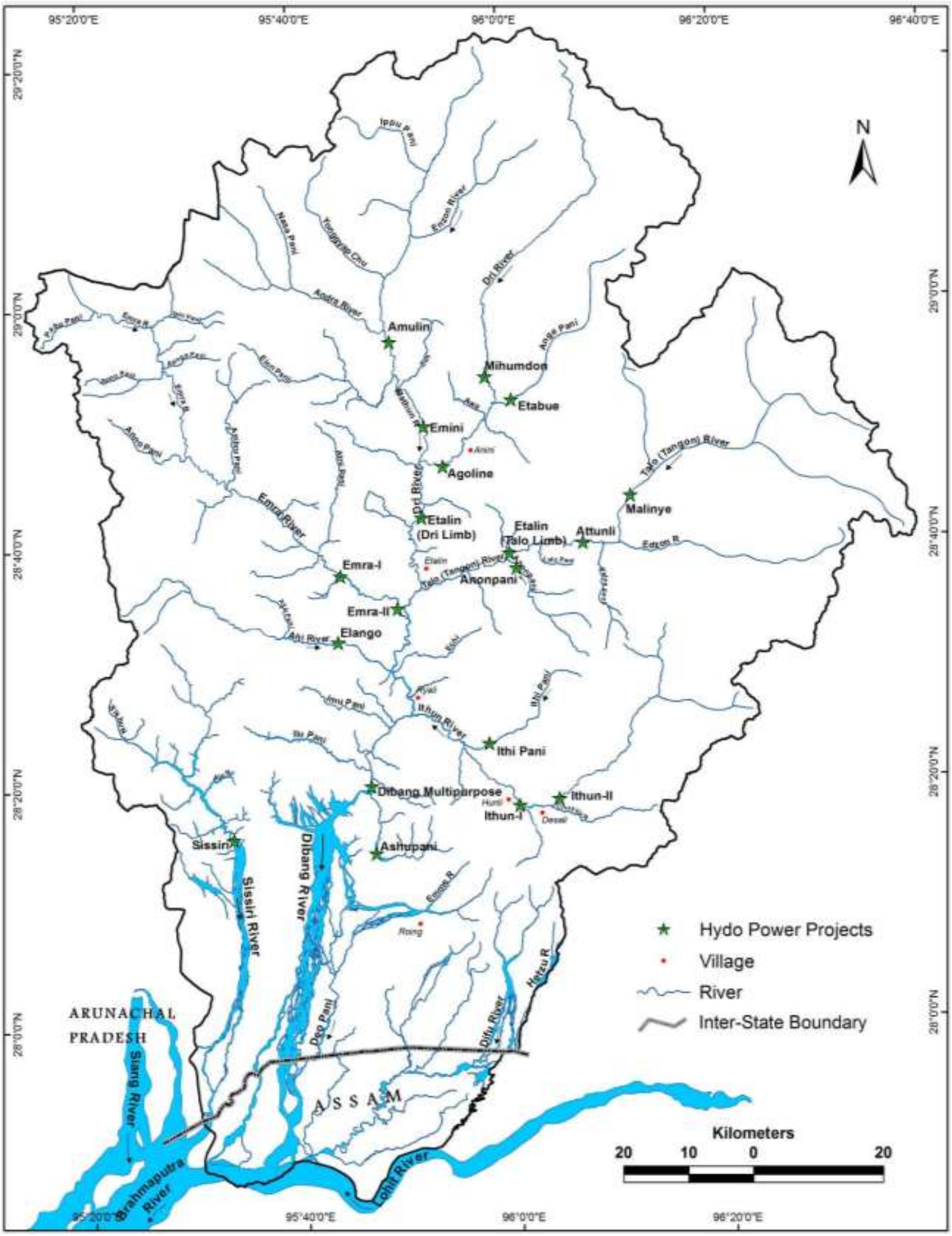


Figure 2.1: Planned Hydro-Development in Dibang Basin

Table 2.2: Salient Features of Mihumdon HEP (400 MW)

LOCATION	
District	Dibang Valley
Name of River	Dri
Diversion Site	1.6m U/S of confluence of Ngra Pani with Dri river
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	968
LAND REQUIREMENT (Ha)	
Total	**1044**
DIVERSION STRUCTURE	
Type	Earth Core Rockfill Dam
Height from river bed level (m)	65
Top of Structure (m)	1675
FRL (m)	1670
MDDL (m)	1660
Average Bed level (m)	1610
Gross Storage at FRL (MCM)	26.4
Gross Storage at MDDL (MCM)	19.4
HEADRACE TUNNEL	
Shape	Horse Shoe
Length (m)	7000
Number	1
Diameter (m)	7
SURGE SHAFT	
Number	1
Diameter (m)	18
Height (m)	100
PRESSURE SHAFT	
Type	Inclined
Number	1
Diameter (m)	5.5
Vertical Drop (m)	273
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	400
Tail water level (m)	1340 (max)
TURBINE	
Type	Vertical Francis
Number's	4
POWER BENEFITS	
90% Dependable Energy (MU)	1451.75

(*Source*: Pre Feasibility Report by NHPC Ltd.)

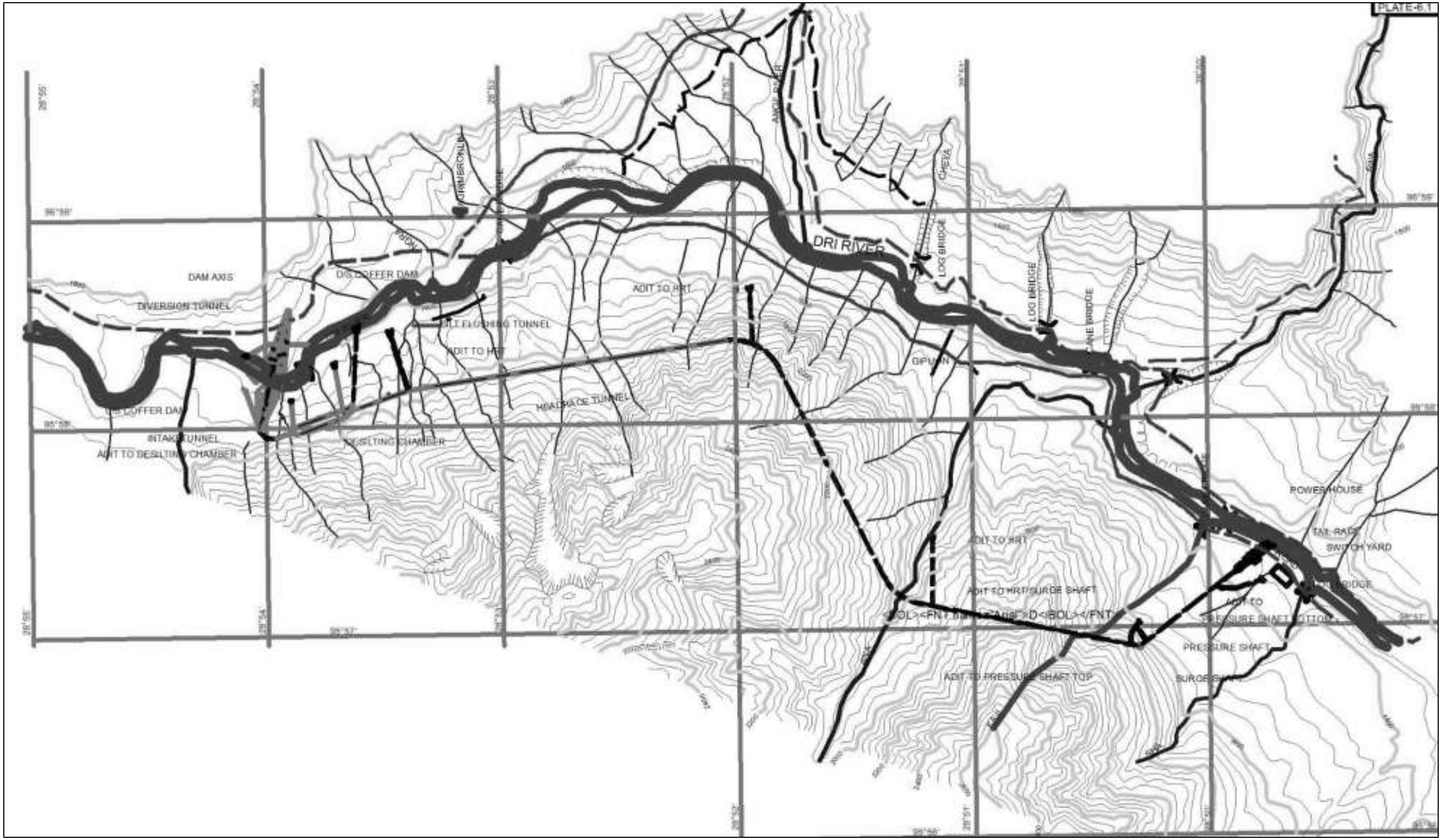


Figure 2.2: Layout Map of Mihumdon HEP (as per PFR by NHPC Ltd.)

Table 2.3: Salient Features of Etabue HEP (165 MW)

LOCATION	
District	Dibang Valley
Name of River	Ange Pani
Diversion Site	500m U/S of confluence of Apeh Pani nala with Ange Pani river
Type	Run-of-the river with pondage
HYDROLOGY	
Catchment area at diversion site (Sq km)	443
LAND REQUIREMENT (Ha)	
Total	**421**
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from deepest foundation level (m)	78
Top of Structure (m)	1695
FRL (m)	1690
MDDL (m)	1670
Average Bed level (m)	1640
Gross Storage at FRL (MCM)	1.17
Gross Storage at MDDL (MCM)	0.39
HEADRACE TUNNEL	
Shape	Horse Shoe
Number	1
Length (m)	10000
Diameter (m)	3.9
SURGE SHAFT	
Number	1
Diameter (m)	7
Height (m)	113
PRESSURE SHAFT	
Type	Vertical
Number	1
Diameter (m)	3.2
Vertical drop (m)	342
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	165
Tail water level (m)	1260 (max.)
TURBINE	
Type	Vertical Pelton
Number's	2
POWER BENEFITS	
90% Dependable Energy (MU)	683.66

(*Source*: Pre Feasibility Report by NHPC Ltd.)

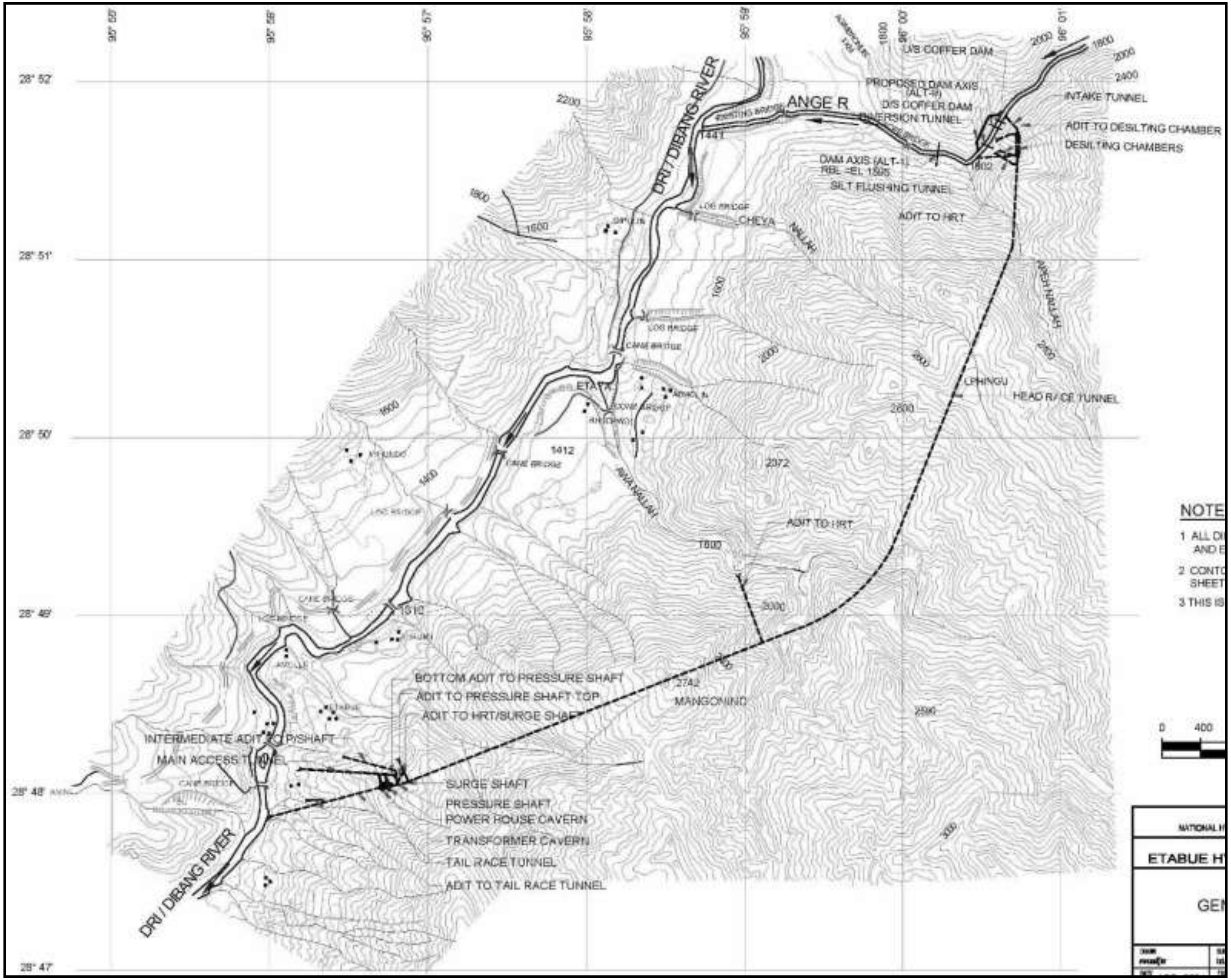


Figure 2.3: Layout Map of Etabue HEP (as per PFR by NHPC Ltd.)

Table 2.4: Salient Features of Agoline HEP (375 MW)

LOCATION	
District	Dibang Valley
Name of River	Dri
Diversion Site	U/S of confluence of river Mathun with river Dri
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	1,550
LAND REQUIREMENT (Ha)	
Total	**795**
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from deepest foundation level (m)	95
Top of Structure (m)	1255
FRL (m)	1250
MDDL (m)	1240
Deepest foundation level (m)	1160
Gross Storage at FRL (MCM)	25
Gross Storage at MDDL (MCM)	13
HEADRACE TUNNEL	
Shape	Horse Shoe
Length (m)	3200
Number	1
Diameter (m)	8.4
SURGE SHAFT	
Number	1
Diameter (m)	24
Height (m)	65
PRESSURE SHAFT	
Type	Steel Lined
Number	1
Diameter (m)	7
Vertical height (m)	152
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	375
Size (m)	23 (W) x 100 (L) x 45 (H)
TURBINE	
Type	Vertical Francis
Number's	3
POWER BENEFITS	
90% Dependable Energy (MU)	1267.38

(*Source*: Pre Feasibility Report by NHPC Ltd.)

Table 2.5: Salient Features of Etalin (3097 MW)

LOCATION		
District	Dibang Valley	
Name of River	Dri	Tangon
Coordinates - Diversion Site	N28^{0}42'24" E95^{0}51'52"	N28^{0}39'18" E96^{0}00'07"
Coordinates - Powerhouse Site	N28^{0}36'40" E95^{0}51'51"	
Type	Run-of-the river with pondage	Run-of-the river with pondage
HYDROLOGY		
Catchment area at diversion site (Sq km)	3,685	2,573
Design Flood (PMF) (m^3/s)	11,811	10,218
LAND REQUIREMENT (Ha)		
Total	**1160.73**	
DIVERSION STRUCTURE		
Type	Concrete Gravity	Concrete Gravity
Height from deepest foundation level (m)	101.5	80
Top of Structure (m)	1047	1052
FRL (m)	1045	1050
MDDL (m)	1039	1040
Deepest foundation level (m)	945.5	972
Live Storage (MCM)	4.6	2.94
HEADRACE TUNNEL		
Shape	Circular	Circular
Diameter (m)	11.3	9.7
Length (m)	10722	13045
Number	1	1
SURGE SHAFT		
Type	Restricted orifice	Restricted orifice
Number	1	1
Diameter (m)	26	21
Height (m)	132	137
PRESSURE SHAFT		
Type	Steel Lined	Steel Lined
Number	3	2
Diameter (m)	5.6	5.6
Length (m)	49.2, 26.6, 49.2	46 each
POWERHOUSE		
Type	Underground	
Installed Capacity (MW)	3070	
Rated Net Head (m)	420	
Tail water level (m)	605.6	
TURBINE		
Type	Vertical Axis Francis	
Number's	10	
Rated Output	311.68 MW each	
POWER BENEFITS		
90% Dependable Energy (MU)	12,848	
POWERHOUSE (Dam-toe)		
Type	Surface	Surface
Installed Capacity (MW)	19.6	7.4
Rated Head (m)	72.5	43
Tail water level (m)	968	1001.5
TURBINE		
Type	Vertical Axis Francis	Vertical Axis Francis
Number's	1	1
Rated Output	20 MW	7.55 MW
POWER BENEFITS		
90% Dependable Energy (MU)	172	65

(*Source*: Project Developer)

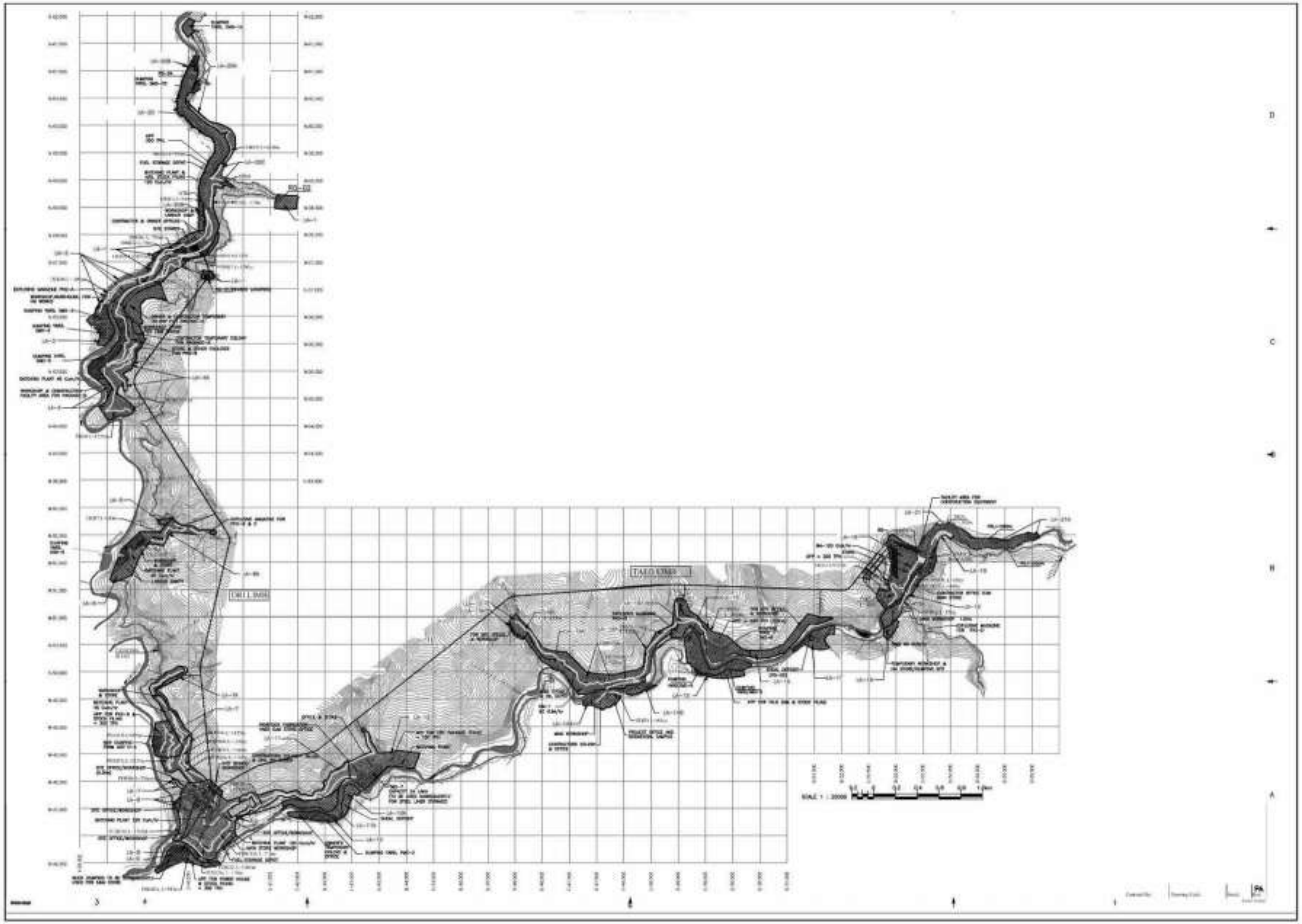


Figure 2.4: Layout Map of Etalin HEP (as per Project Developer)

Table 2.6: Salient Features of Dibang Multipurpose Project (2880 MW)

LOCATION	
District	Lower Dibang Valley
Name of River	Dibang
Coordinates - Diversion Site	N28^{0}20'7" E95^{0}46'38"
Type	Storage Project
HYDROLOGY	
Catchment area at diversion site (Sq km)	11,276
Probable Maximum Flood (PMF) (cumec)	26,230
LAND REQUIREMENT (Ha)	
Total	**4577.84**
DIVERSION STRUCTURE	
Type	Concrete Gravity
Height from river bed level (m)	248
Top of Structure (masl)	540
FRL (masl)	530.3
MDDL (masl)	489.2
River Bed Level (m)	292
Gross Storage at FRL (Mcum)	3,248
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	9
Length (m)	300 to 600
Number	6
PRESSURE SHAFT	
Shape	Circular
Number	6
Diameter (m)	7.5
Height (m)	184.8
PENSTOCK	
Shape	Circular
Number	12
Diameter (m)	5.2
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	2880
Net Head (m)	233
Tail water level (masl)	286.72
TURBINE	
Type	Francis
Number's	12
Rated Output	240 MW each
POWER BENEFITS	
90% Dependable Energy with Flood Moderation (MU)	11330
90% Dependable Energy without Flood Moderation (MU)	12210.12

(*Source*: Project Developer)

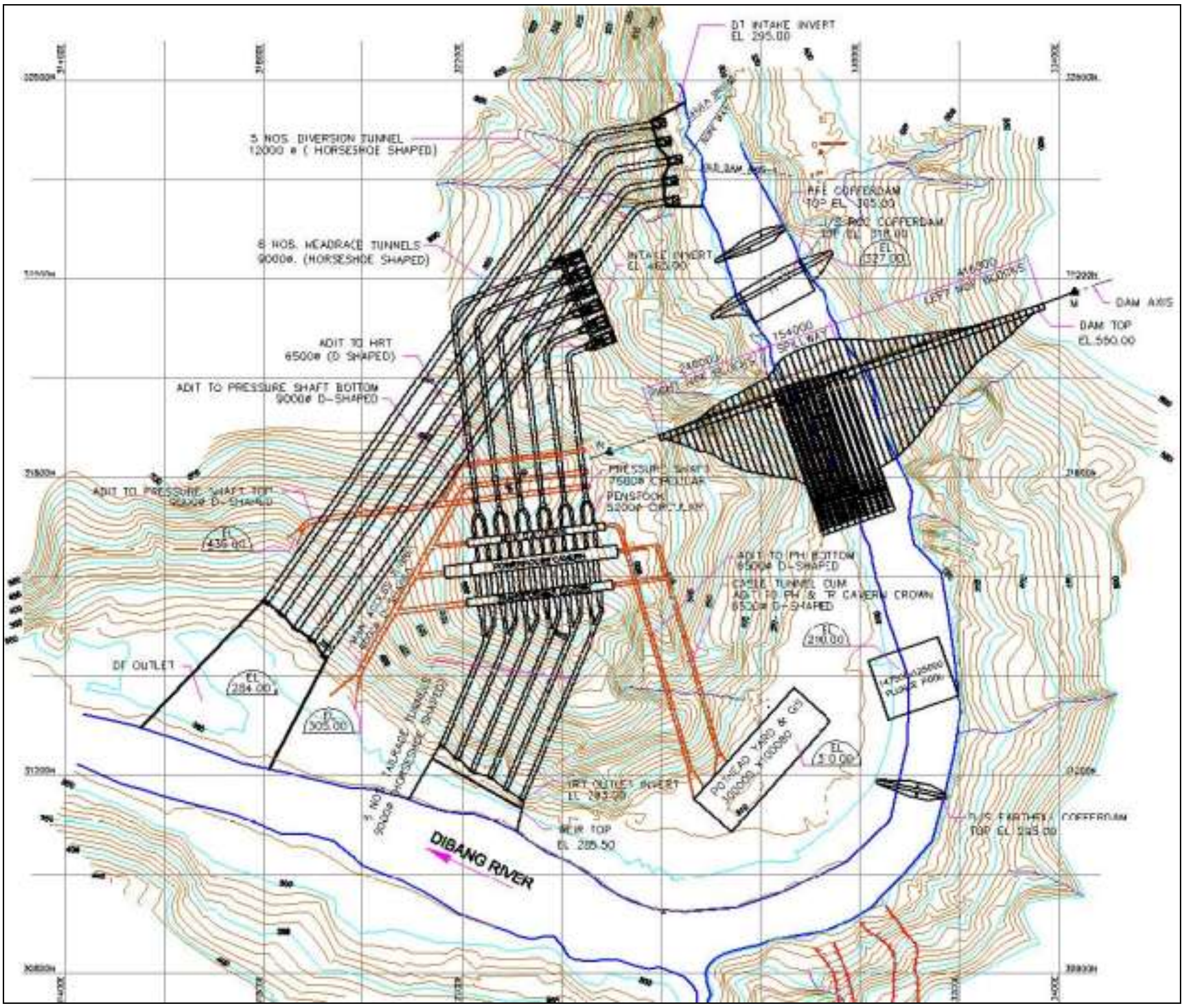


Figure 2.5: Layout Map of Dibang MPP (as per Project Developer)

Table 2.7: Salient Features of Amulin HEP (420 MW)

LOCATION	
District	Dibang Valley
Name of River	Mathun
Diversion Site	Near Mipidon
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	2,175
LAND REQUIREMENT (Ha)	
Total	**1102**
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from deepest foundation level (m)	75
Top of Structure (m)	1445
FRL (m)	1440
MDDL (m)	1430
River Bed level (m)	1390
Gross Storage at FRL (MCM)	15.98
Gross Storage at MDDL (MCM)	10.07
HEADRACE TUNNEL	
Shape	Horse Shoe
Length (m)	7000
Number	1
SURGE SHAFT	
Number	1
Diameter (m)	28
Height (m)	85
PRESSURE SHAFT	
Type	Steel Lined
Number	1
Diameter (m)	8
Vertical Height (m)	104
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	420
Tail water level (m)	1290 (max)
TURBINE	
Type	Vertical Francis
Number’s	3
POWER BENEFITS	
90% Dependable Energy (MU)	1716.40

(*Source*: Pre Feasibility Report by NHPC Ltd.)

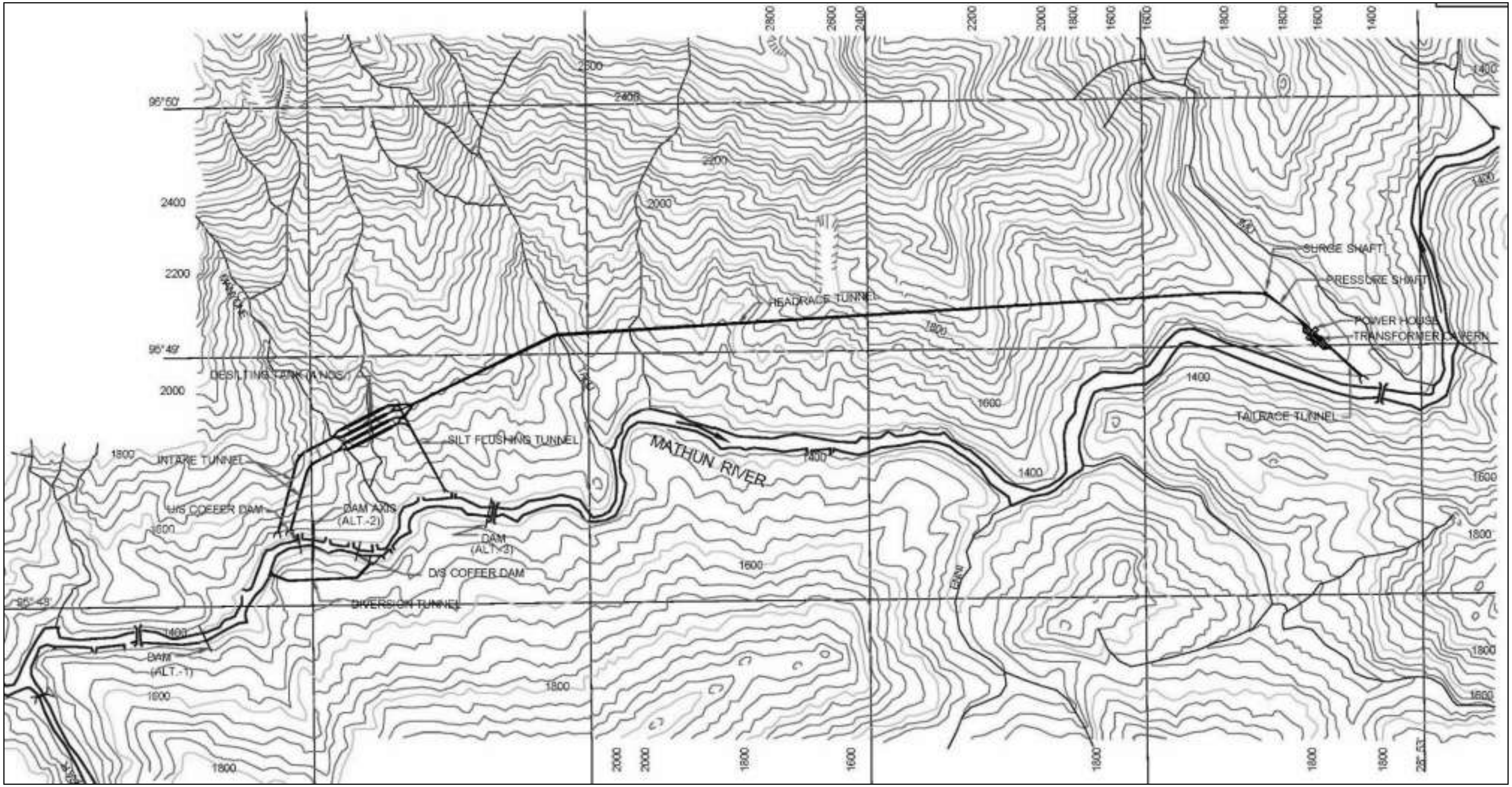


Figure 2.6: Layout Map of Amulin HEP (as per PFR by NHPC Ltd.)

Table 2.8: Salient Features of Emini HEP (500 MW)

LOCATION	
District	Dibang Valley
Name of River	Mathun
Diversion Site	D/S of confluence of Kanji rivulet with Mathun river
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	2,600
LAND REQUIREMENT (Ha)	
Total	**1251**
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from deepest foundation level (m)	85
Top of Structure (m)	1275
FRL (m)	1270
MDDL (m)	1260
Average Bed level (m)	1200
Gross Storage at FRL (MCM)	46.555
Gross Storage at MDDL (MCM)	34.060
HEADRACE TUNNEL	
Shape	Horse Shoe
Length (m)	5000
Number	2
SURGE SHAFT	
Number	2
Diameter (m)	25
Height (m)	75
PRESSURE SHAFT	
Type	Steel Lined
Number	2
Diameter (m)	7
Vertical Height (m)	115
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	500
Tail water level (m)	1128 (max)
TURBINE	
Type	Vertical Francis
Number's	4
POWER BENEFITS	
90% Dependable Energy (MU)	1695.45

(*Source*: Pre-Feasibility Report by NHPC Ltd.)

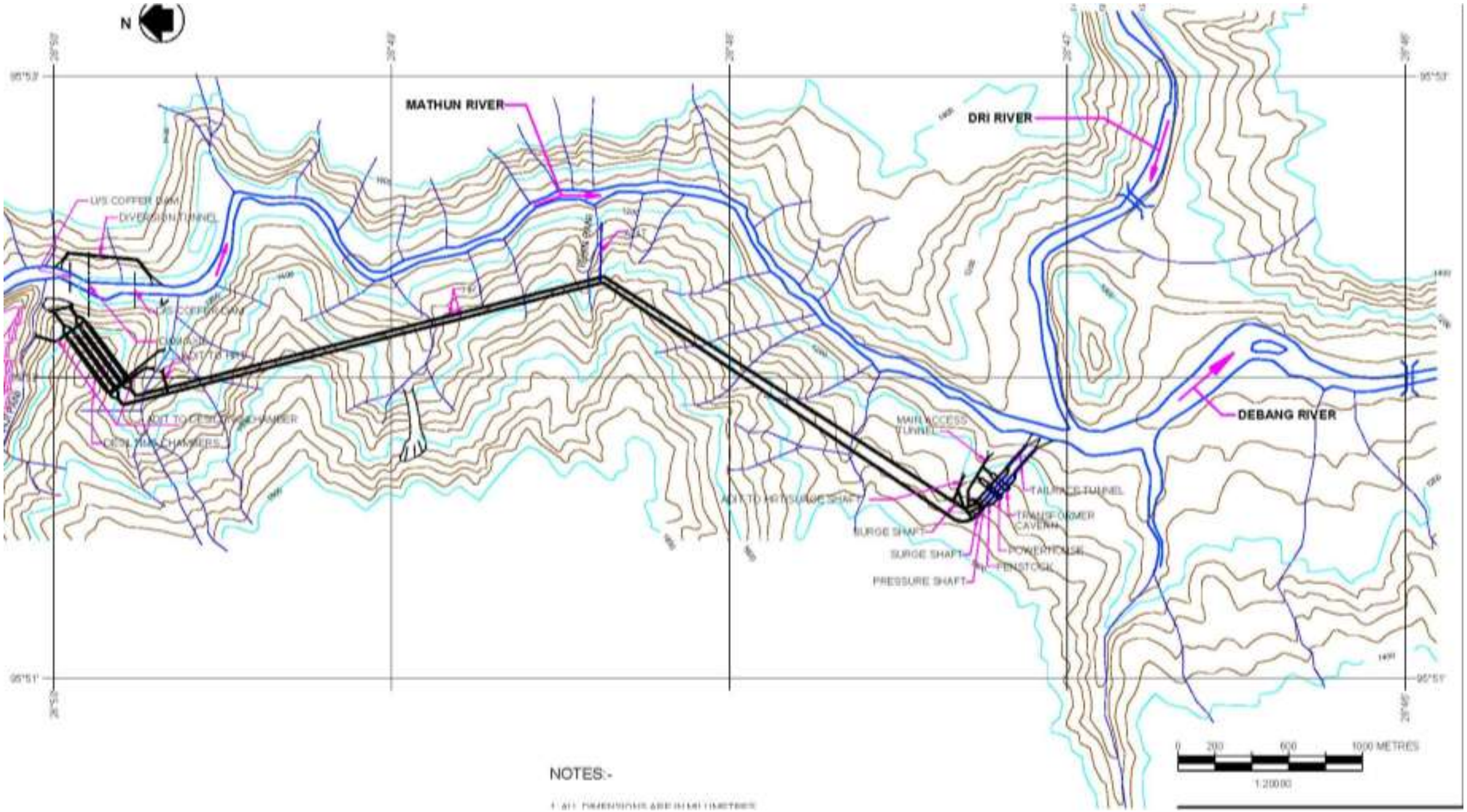


Figure 2.7: Layout Map of Emini HEP (as per PFR by NHPC Ltd.)

Table 2.9: Salient Features of Attunli HEP (680 MW)

LOCATION	
District	Dibang Valley
Name of River	Talo (Tangon)
Coordinates - Diversion Site	
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	2,358
Design Flood (m^3/s)	9,927
LAND REQUIREMENT (Ha)	
Total	**250**
DIVERSION STRUCTURE	
Type	Concrete Gravity
Height from deepest foundation level (m)	90
Top of Structure (m)	1362
FRL (m)	1360
MDDL (m)	1349
River Bed Level (m)	1289
Live Storage at FRL (Mcum)	2.71
HEADRACE TUNNEL	
Type	Circular
Diameter (m)	9.4
Length (m)	7915
Number	1
SURGE SHAFT	
Type	Restricted Orifice & Open to Sky
Number	1
Diameter (m)	22.5
Height (m)	89
PRESSURE TUNNEL	
Type	Underground
Number	4
Diameter (m)	3.7
Length (m)	35 each
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	680
Gross Head (m)	282.6
Tail water level (m)	1070.6
TURBINE	
Type	Vertical Francis
Number's	4
POWER BENEFITS	
90% Dependable Energy (MU)	2903

(*Source*: Project Developer)

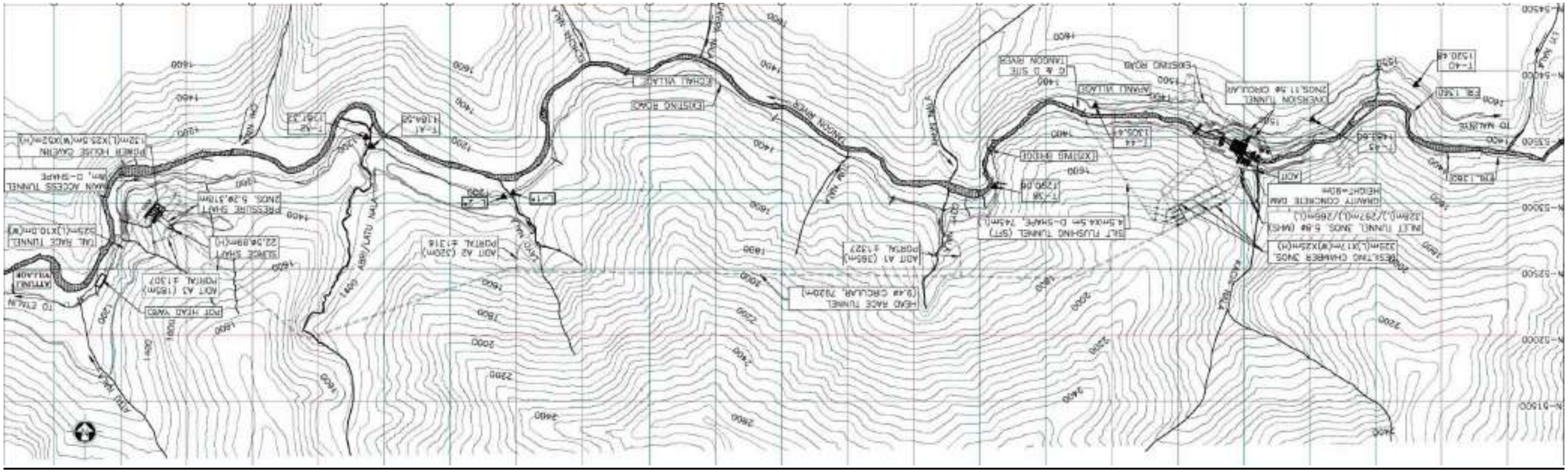


Figure 2.8: Layout Map of Attunli HEP (as per Project Developer)

Table 2.10: Salient Features of Anonpani SHEP (22 MW)

LOCATION	
District	Dibang Valley
Name of Stream	Anon Pani
Coordinates - Diversion Site	N28^{0}38'04" E96^{0}00'35.36"
Coordinates - Powerhouse Site	N28^{0}38'34.97" E95^{0}59'09.56"
HYDROLOGY	
Catchment area at diversion site (Sq km)	147
Design Discharge (m^3/s)	18
LAND REQUIREMENT (Ha)	
Total	**29.76**
DIVERSION WORK	
Type	Trench Weir
Weir Elevation (m)	1160
Width (m)	2.50
Depth (m)	0.5 to 3.80
Length (m)	25
HEADRACE TUNNEL	
Type	Modified D-Shape
Size (m)	3.0 (W) x 3.2 (H)
Length (m)	2515
FOREBAY	
Full Supply Level (m)	1156
Minimum Drawdown Level (m)	1152
Length (m)	49
Width (m)	5.0 to 7.0
Height (m)	6.0 to 12.5
PENSTOCK	
Number	1 (main), 4 (units)
Diameter (m)	2 (main), 1.7 (unit)
Length (m)	293 (main), 13.5 each (unit)
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	22
Rated Net Head from forebay (m)	206.0
Tail water level (masl)	946.5
TURBINE	
Type	Horizontal Francis
Number's	4
POWER BENEFITS	
75% Dependable Energy (MU)	118.15

(*Source*: Project Developer)

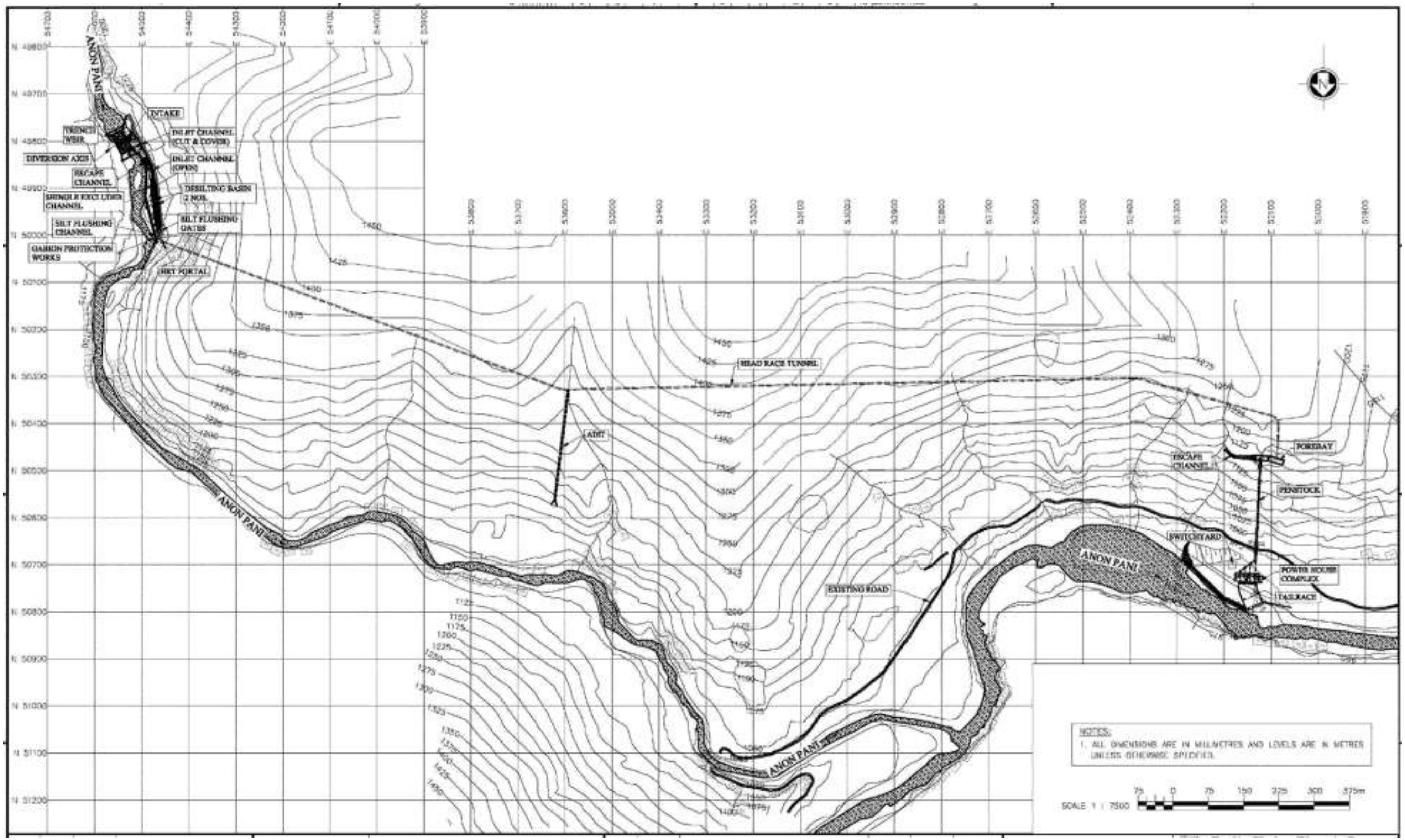


Figure 2.9: Layout Map of Anonpani SHEP (as per Project Developer)

Table 2.11: Salient Features of Emra I HEP (600 MW)

LOCATION	
District	Dibang Valley
Name of River	Emra
Coordinates - Diversion Site	N28^{0}48'16" E95^{0}52'25"
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	1,668
Design Flood (PMF) (cumec)	6,550
DIVERSION STRUCTURE	
Type	Barrage
Height from average bed level (m)	25
Top of Structure (m)	1,145
Average River Bed level (m)	1,120
RESERVOIR	
FRL (m)	1,140
MDDL (m)	1,135
Submergence Area at FRL (ha)	45
HEADRACE TUNNEL	
Shape	Concrete Lined
Numbers	01
Length (m)	10200
Diameter (m)	08
PRESSURE SHAFT	
Length (m)	735
Diameter after bifurcation (m)	05
Length after bifurcation (3 nos.) (m)	50
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	600
Tail water level (m)	720
Gross Head (m)	420
TURBINE	
Type	Vertical Francis
Number's	4

(*Source*: Present Features were provided by Project Developer)

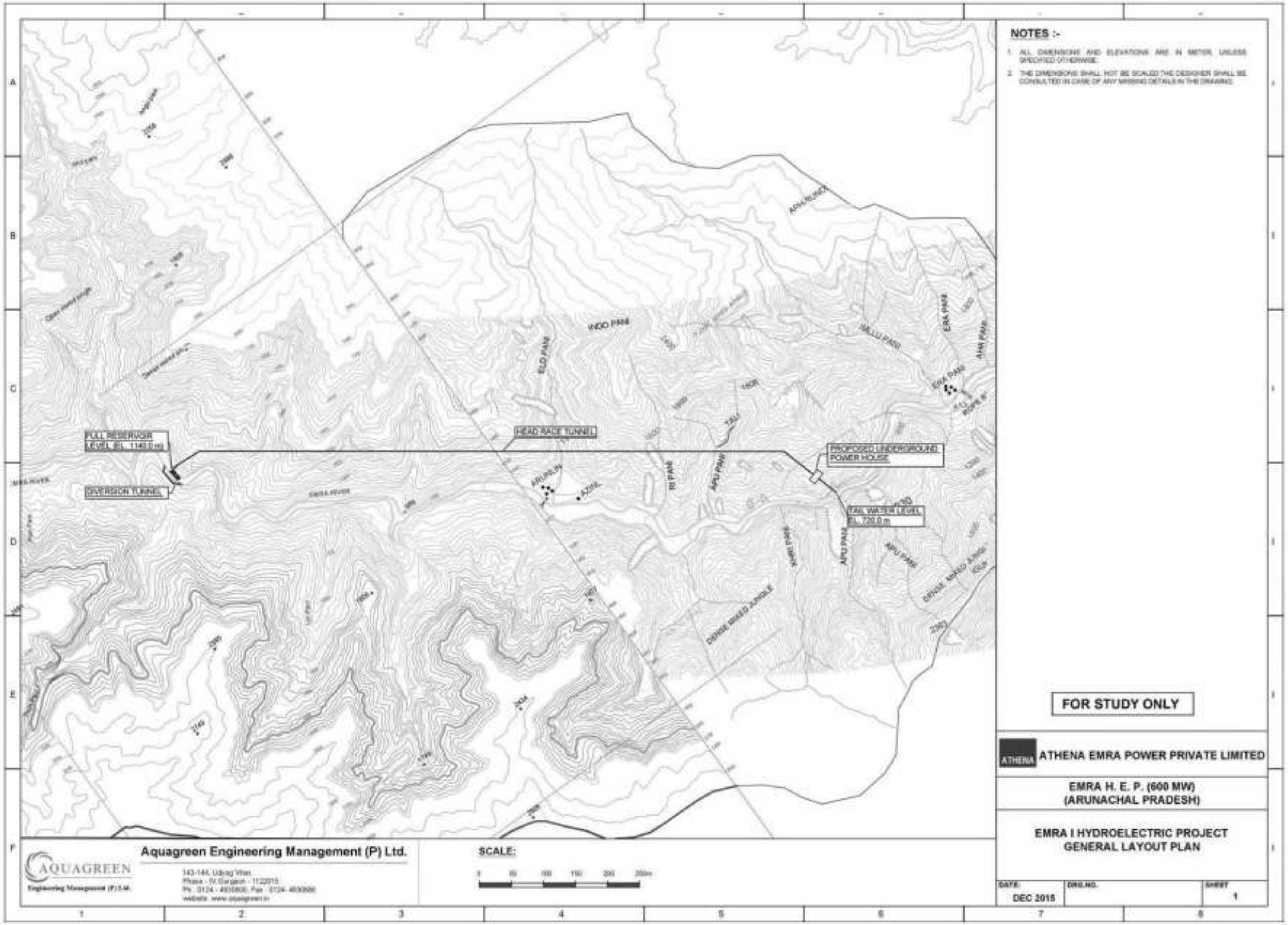


Figure 2.10: Layout Map of Emra-I HEP (as per Project Developer)

Table 2.12: Salient Features of Emra-II HEP (315 MW)

LOCATION	
District	Dibang Valley
Name of River	Emra
Coordinates - Diversion Site	N28^{0}34'42.3" E95^{0}49'28.1"
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	1,756
Design Flood (PMF) (cumec)	6,895
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from average bed level (m)	113
Top of Structure (m)	707
Average River Bed level (m)	594
RESERVOIR	
FRL (m)	705
MDDL (m)	695
Submergence Area at FRL (ha)	130.30
Live Storage (MCM)	12.10
PRESSURE TUNNEL/ SHAFT	
Numbers	01
Type	Steel Lined
Diameter (m)	6.75
Top horizontal length (m)	525.23
Vertical length (m)	144.00
Bottom length (m)	41.95
Diameter after bifurcation (m)	04
Length after bifurcation (3 nos.) (m)	42.48
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	315
Tail water level (m)	530
Gross Head (m)	175
TURBINE	
Type	Vertical Francis
Number's	3

(*Source*: Present Features were provided by Project Developer)

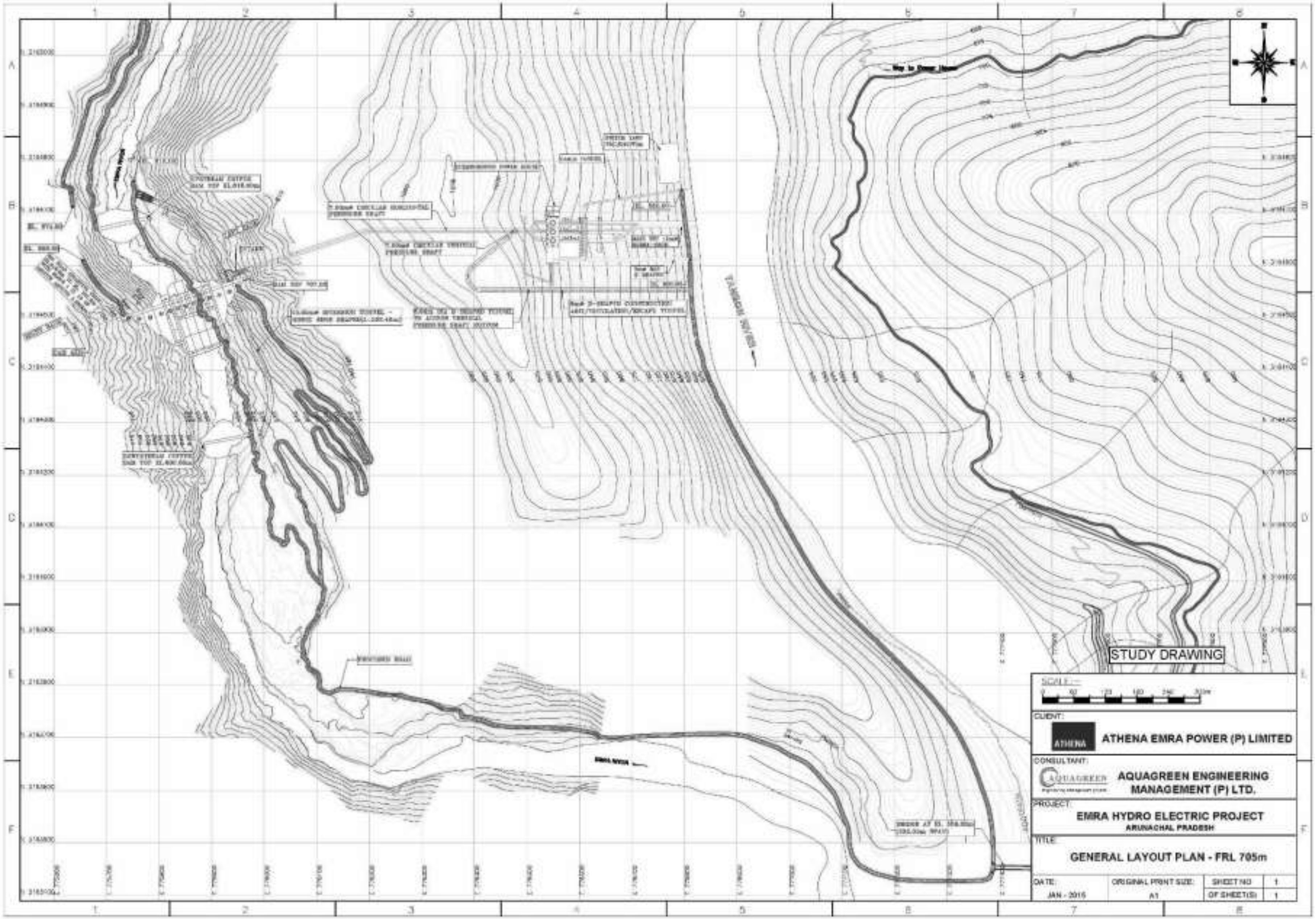


Figure 2.11: Layout Map of Emra-II HEP (as per Project Developer)

Table 2.13: Salient Features of Ithun-I HEP (86 MW)

LOCATION	
District	Lower Dibang Valley
Name of River	Ithun
Coordinates - Diversion Site	N28⁰18'7" E96⁰00'30"
Type	Run-of-the river
HYDROLOGY	
Catchment area at diversion site (Sq km)	841
Design Discharge (m^3/s)	96.94
LAND REQUIREMENT (Ha)	
Total	**76**
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed level (m)	25
Top of Structure (m)	669
FRL (m)	667
MDDL (m)	663
Average Bed level (m)	644
HEADRACE TUNNEL	
Shape	Modified Horse Shoe
Length (m)	5650
Diameter (m)	6
SURGE SHAFT	
Type	Restricted Orifice, Open to Sky
Diameter (m)	18.5
Height (m)	62
PENSTOCK	
Type	Underground & Surface
Number	2
Diameter (m)	3.2
Length (m)	81 Underground & 132 Surface
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	86
Net Head (m)	98.17
Tail water level (m)	558
TURBINE	
Type	Vertical Axis Francis
Number's	2
Rated Output (MW)	43.88
POWER BENEFITS	
90% Dependable Energy (MU)	408

(*Source*: Project Developer)

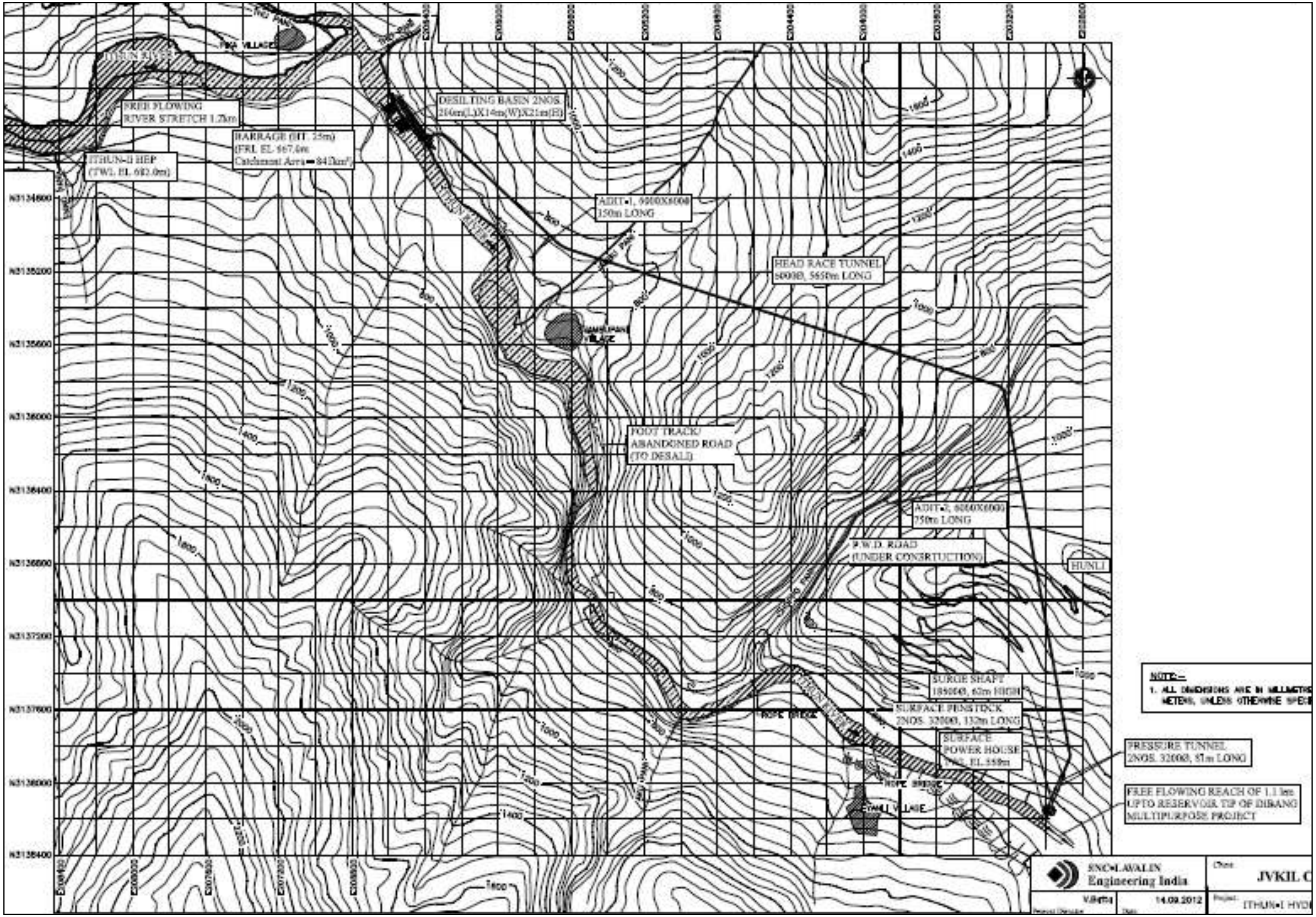


Figure 2.12: Layout Map of Ithun-I HEP (as per Project Developer)

Table 2.14: Salient Features of Ithun-II HEP (48 MW)

LOCATION	
District	Lower Dibang Valley
Name of River	Ithun
Coordinates - Diversion Site	N28^{0}18'42" E96^{0}04'06"
Type	Run-of-the river
HYDROLOGY	
Catchment area of Ithun river and Chuyyu Nallah at diversion site (Sq km)	708 (540 + 168)
Design Discharge of Ithun river and Chuyyu Nallah (m^3/s)	72.65 (55.41 + 17.24)
LAND REQUIREMENT (Ha)	
Total	**58**
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	19 (Tail race development)
Top of Structure (m)	769
FRL (m)	767
MDDL (m)	761
Average Bed level (m)	750
TRENCH WEIR AT CHUYYU NALLAH	
FRL (m)	773.5
Width (m)	2.50
Depth (Right/Left) (m)	1.0/ 2.5
Length (m)	25
DIVERSION TUNNEL FROM CHUYYU NALLAH	
Shape	D-shape
Diameter (m)	3.5
Length (m)	2300
HEADRACE TUNNEL	
Type	Modified Horse Shoe
Diameter (m)	5.2
Length (m)	3350
SURGE SHAFT	
Type	Restricted Orifice, Open to Sky
Diameter (m)	17
Height (m)	47
PENSTOCK	
Type	Underground & Surface
Number	2
Diameter (m)	2.7
Length (m)	66 Underground, 134 Surface
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	48
Net Head (m)	74
Tail water level (masl)	682
TURBINE	
Type	Vertical Axis Francis
Number's	2
Rated Output	24.49 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	231.3

(*Source*: Project Developer)

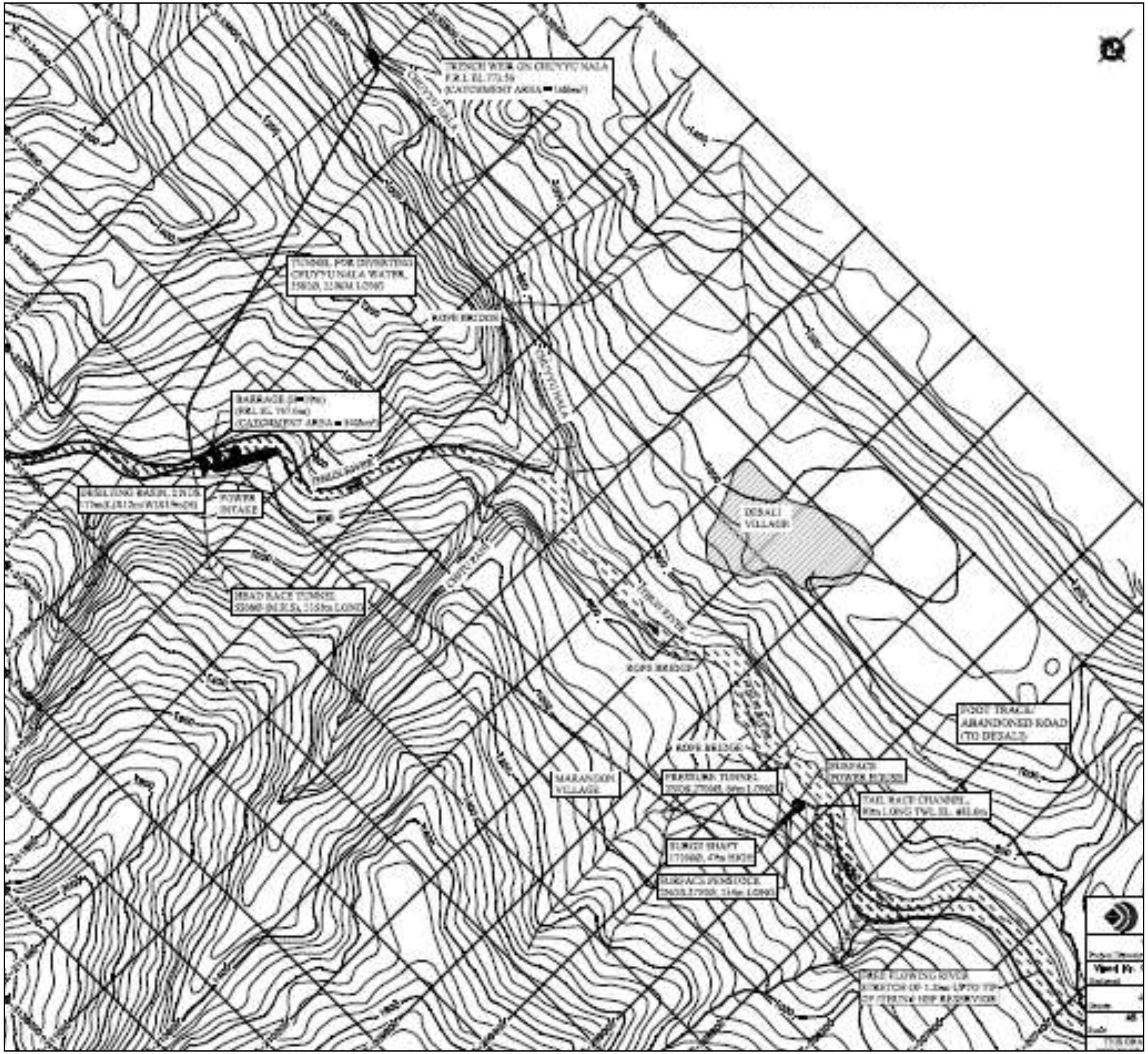


Figure 2.13: Layout Map of Ithun-II HEP (as per Project Developer)

Table 2.15: Salient Features of Ithi Pani SHEP (22 MW)

LOCATION	
District	Lower Dibang Valley
Name of Stream	Ithi Pani
Coordinates - Diversion Site	N28^{0}23'25" E95^{0}58'08"
Coordinates - Powerhouse Site	N28^{0}23'01" E95^{0}56'31"
HYDROLOGY	
Catchment area at diversion site (Sq km)	235
Design Discharge (m^3/s)	23.3
LAND REQUIREMENT (Ha)	
Total	**21.7**
DIVERSION WORK	
Type	Overflow Weir
Height from riverbed (m)	8.0
Top of Weir (m)	675.0
FRL (m)	675.0
MDDL (m)	673.0
Average Bed Level	667.0
HEADRACE TUNNEL	
Type	D-Shape
Diameter (m)	3.1
Length (km)	2.1
SURGE SHAFT	
Type	Restricted Orifice, Open to Sky
Diameter (m)	6.0
Height (m)	36.0
PRESSURE TUNNEL/ PENSTOCK	
Type	Underground (1)/ Surface (1)
Diameter (m)	2.4
Length (m)	30 (underground), 190 (surface)
UNIT PENSTOCK	
Type	Surface
Number	2
Diameter (m)	1.7
Length (m)	17
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	22
Net Head	113.3
Tail water level (masl)	555.0
TURBINE	
Type	Vertical Axis Francis
Number's	2
Rated Output (MW)	11.22 each
POWER BENEFITS	
75% Dependable Energy (MU)	122.8

(*Source*: Project Developer)

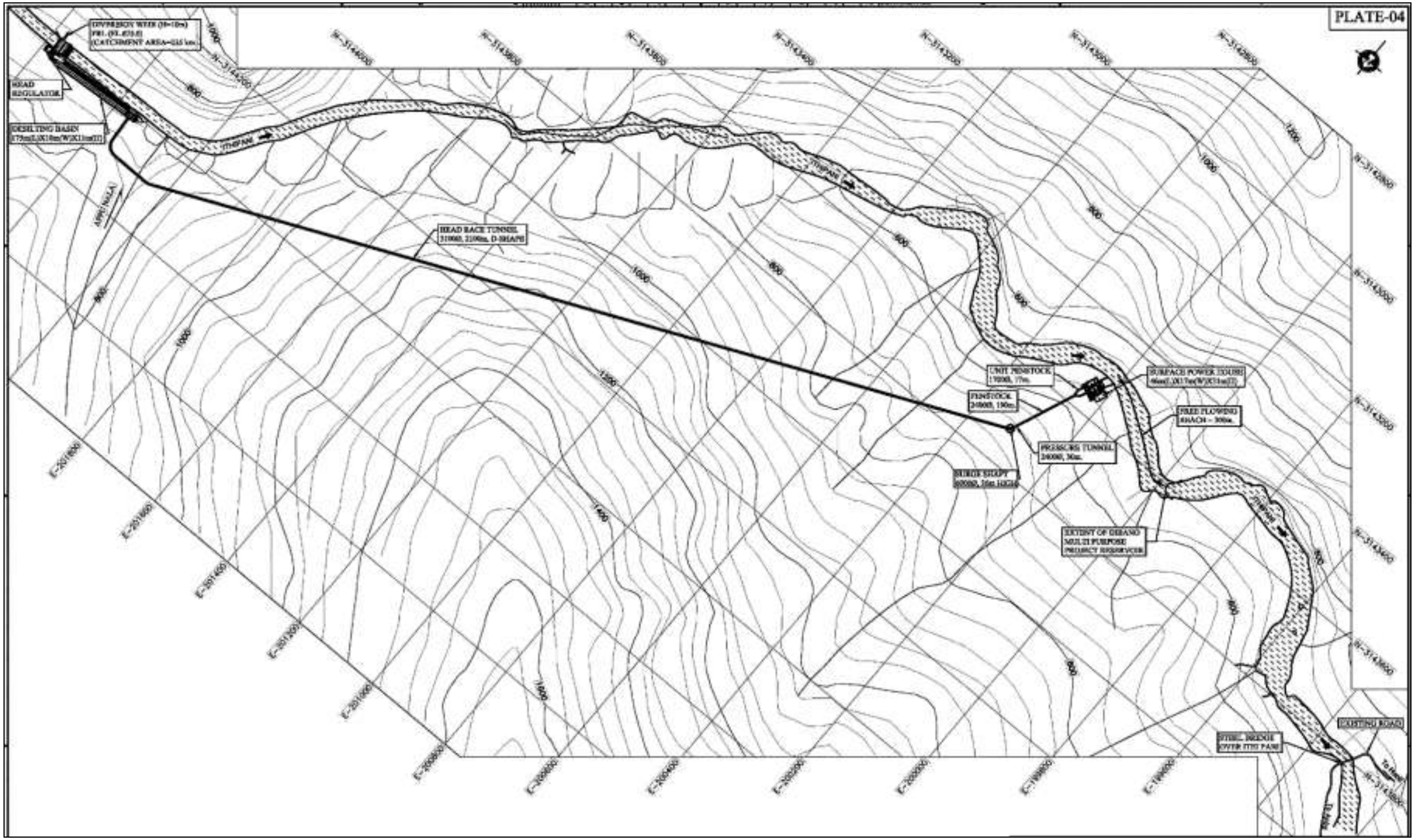


Figure 2.14: Layout Map of Ithi Pani SHEP (as per Project Developer)

Table 2.16: Salient Features of Ashupani HEP (30 MW)

LOCATION	
District	Lower Dibang Valley
Name of River	Ashu Pani
Diversion Site	Across Ashu Pani river about 10 km from Tiwari Gaon
Type	Run-of-the river with storage
HYDROLOGY	
Catchment area at diversion site (Sq km)	67
LAND REQUIREMENT (Ha)	
Total	**226**
DIVERSION STRUCTURE	
Type	Earth core rock fill dam
Height from bed level (m)	25
Top of Structure (m)	645
FRL (m)	640
MDDL (m)	637
Average Bed level (m)	620
Gross Storage at FRL (MCM)	1.71
Gross Storage at MDDL (MCM)	0.625
HEADRACE TUNNEL	
Shape	Horse Shoe
Number	1
Length (m)	1800
Diameter (m)	3.3
SURGE SHAFT	
Number	1
Diameter (m)	5
Height (m)	50
PRESSURE SHAFT	
Type	Inclined
Number	1
Diameter (m)	1.50
Vertical drop (m)	410
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	30
Tail water level (m)	220 (max.)
TURBINE	
Type	Vertical Pelton
Number’s	2
POWER BENEFITS	
90% Dependable Energy (MU)	126.65

(*Source*: Pre Feasibility by NHPC Ltd.)

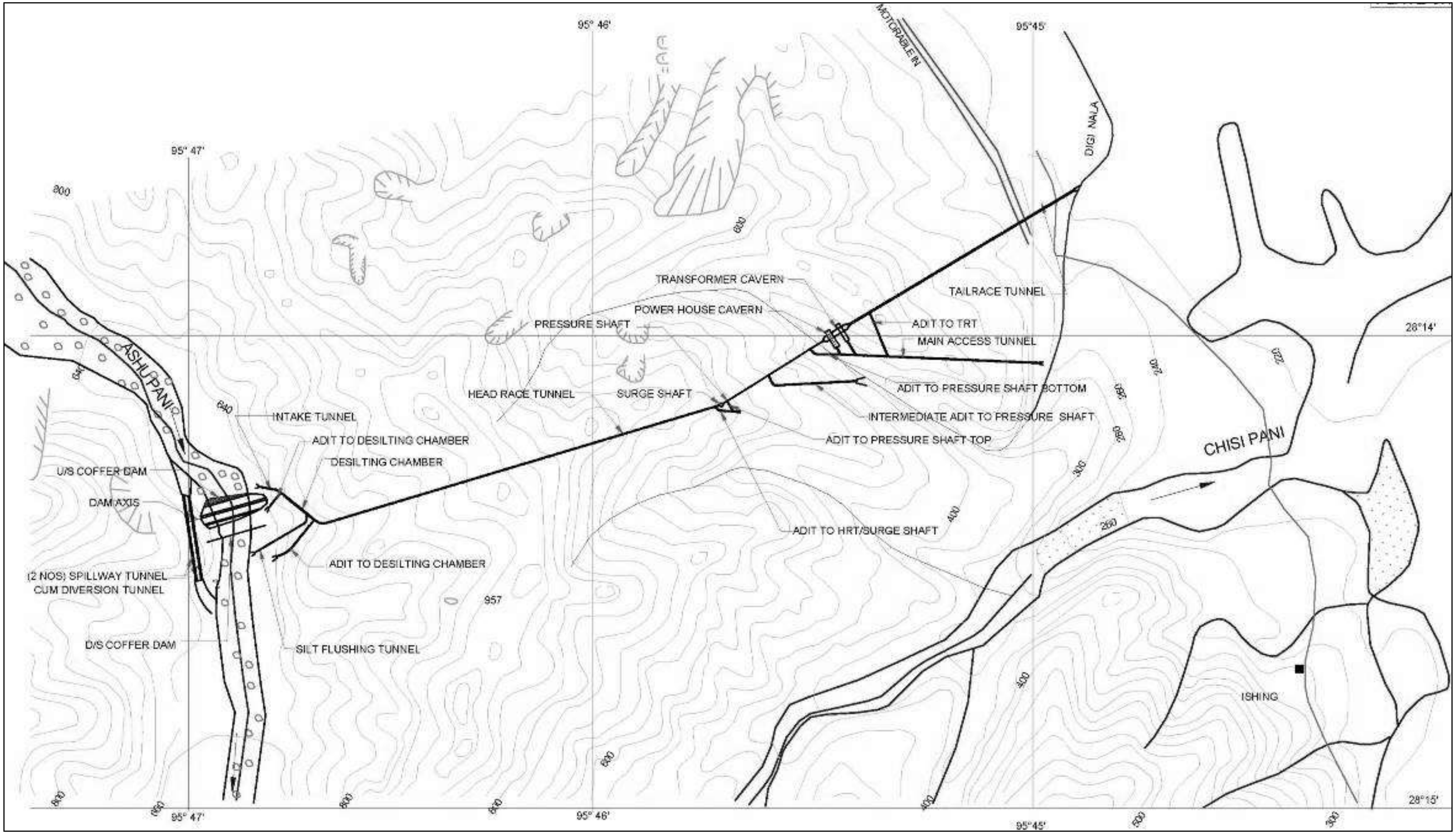


Figure 2.15: Layout Map of Ashupani (as per PFR by NHPC Ltd)

Table 2.17: Salient Features of Sissiri HEP (100 MW)

LOCATION	
District	Lower Dibang Valley
Name of River	Sissiri
Type	Dam-toe Storage
HYDROLOGY	
Catchment area at diversion site (Sq km)	610
DIVERSION STRUCTURE	
Type	Dam
Height from deepest foundation level (m)	142.5
Top of Structure (m)	512.5
FRL (m)	510
MDDL (m)	482
Deepest foundation level (m)	370
Gross Storage (Million m^3)	177.4
RIVER DIVERSION ARRANGEMENT	
River Diversion Location	Left Bank
Type	Modified Horse Shoe
Length including bellmouth entrance (m)	478 (approx.)
Diameter (m)	6
SPILLWAY	
Type	Central Ogee Suppressed
Crest Elevation (m)	484
Maximum Outflow (cumec)	4390
Radial Gates (Nos.)	4
Size (m)	8.5 (W) x 12 (H)
Tail water level at spillway discharge (m)	398.19 (max.)
SLUICE OUTLET	
Type	Rectangular
Size (m)	1 (W) x 2 (H)
Centreline Level (m)	452
Invert Level (m)	451
PENSTOCK	
Type	Circular
Number	1 Nos. bifurcating into 2
Diameter (m)	5.2/ 2.9
Length (m)	200 (aprox.)
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	100
Rated & Designed Net Head (m)	107.63
Maximum Tail water level (m)	392 (all turbines running)
TURBINE	
Type	Vertical Shaft Francis
Number's	2
POWER BENEFITS	
90% Dependable Energy (GWh)	301.57

(*Source*: Project Developer)

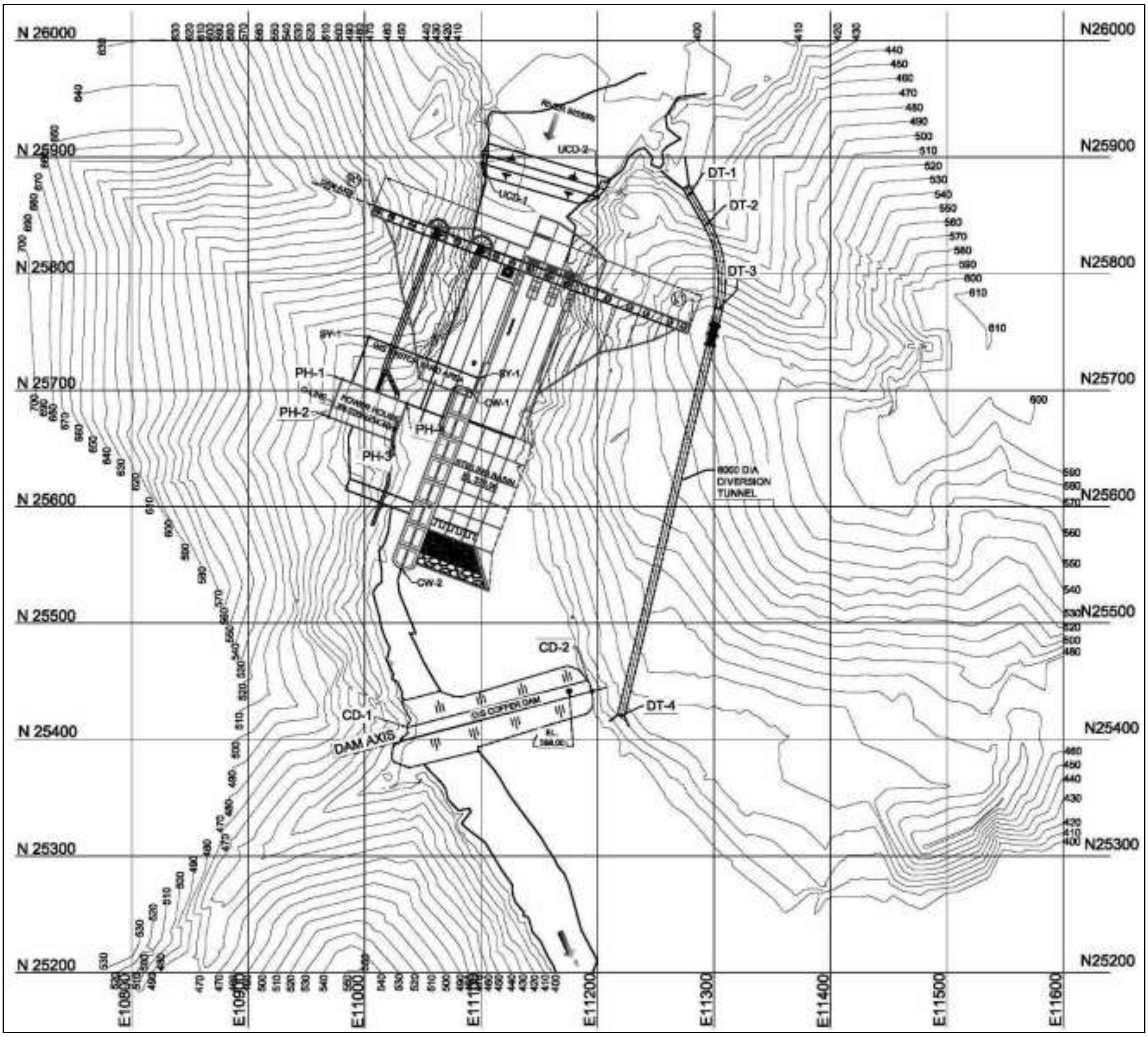


Figure 2.16: Layout Map of Sissiri HEP (as per Developer)

CHAPTER-3
METHODOLOGY

In order to undertake Cumulative Environment Impact Assessment (CEIA) study of Dibang river basin, present environmental baseline setting of different components was assessed primarily through documentation, collection, compilation of data available with different Central Government agencies like Botanical Survey of India (BSI), Kolkata, Zoological Survey of India (ZSI), Kolkata, Forest Survey of India (FSI), Dehradun, Indian Institute of Remote Sensing (IIRS), Dehradun and Department of Environment & Forests, Itanagar, Government of Arunachal Pradesh (GoAP). In addition data/ information was also collected from published reports, research articles, trip reports, etc. The data on terrestrial ecology and aquatic ecology was further supplemented with one season (monsoon) field surveys and sampling undertaken at various locations spread over the entire Dibang basin essentially covering sites nearby the proposed hydropower projects as mandated by EAC at MoEF&CC, GoI. Salient features of all the proposed hydropower projects were obtained from Department of Hydropower Development, GoAP. In this chapter, methodology for the collection of data on different environmental baseline parameters has been given.

3.1 LAND USE/ LAND COVER MAPPING

Land use and land cover map of the basin was prepared from the data of 2013 was procured from Forest Survey of India (FSI). It was further refined by ground checks carried out during the field surveys. For this purpose FCC of the entire study area was generated from digital satellite data of LISS-III, IRS-P6.

False Color Composite (FCC) covering the entire Dibang basin was prepared using enhanced data of Bands 2, 3 and 4 of LISS III, IRS-P6 as well from LANDSAT ETM+ data. The image was interpreted digitally using various digital image-processing techniques. The data procured from FSI was downloaded and further processed to generate mosaic of entire Dibang basin (see **Figure 3.1**).

3.1.1 Classification Scheme

In order to understand the extent of forest cover in particular, the classification scheme suggested by Forest Survey of India, Dehradun was adopted for the preparation of land use/land cover map of the basin. Three forest density classes were interpreted for the forest cover mapping. The forests with >70% canopy cover has been demarcated as Very Dense Forest, between 40% and 70% canopy cover was delineated as Moderately Dense Forest and between 10% and 40% crown density as Open Forest. Furthermore, degraded forests, grass covered slopes with canopy density <10% were delineated as Scrubs. The area not included in any of the above classes is delineated as Non-forest land cover.

Data Set Used

Forest Surveys of India	:	The Status of Forest Survey of India (2013)
Projection and Datum	:	UTM and WGS 84; 46 North
Satellite Data	:	IRS P6 LISS 3 and LANDSAT ETM+

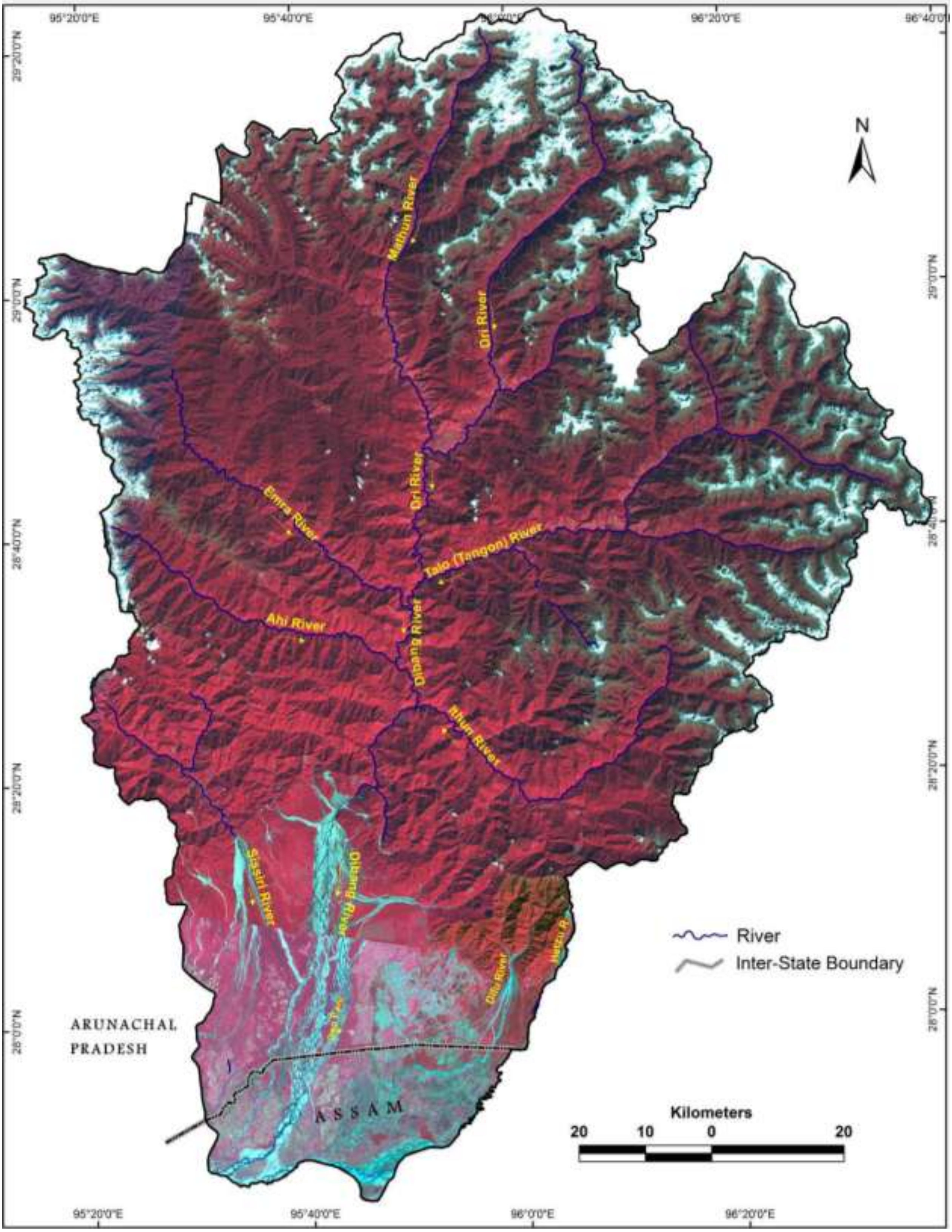


Figure 3.1: False Color Composite (FCC) of Dibang basin prepared from LISS-III IRS- P6 Data

3.2 FOREST TYPES

The forests in Dibang basin fall under East Circle with headquarters at Tezu whereas the Protected Areas in the basin are under the administrative control of Additional PCCF (Wildlife & Biodiversity), Itanagar.

The details of forest types in the basin has been referenced from Working Plans of the Forest Divisions and Management Plans of Mehao Wildlife Sanctuary, Dibang Wildlife Sanctuary at

Roing and Anini social forestry division headquarter at Anini, information provided by the Department of Environment & Forests, Government of Arunachal Pradesh. However the forest type classification of Champion and Seth (1968) has been followed in the report.

3.3 COMMUNITY STRUCTURE

The objectives of the phytosociological surveys to study community structure are as follows:

- To prepare an inventory of various groups plants (Angiosperms, Gymnosperms, Pteridophytes, Bryophytes and Lichens) in the basin
- To assess the plant species composition and other ecological parameters like frequency, density, basal area, and
- Diversity and dominance indices like Shannon Wiener Diversity Index, Evenness Index and Importance value Index

In order to understand the community structure/species composition, vegetation sampling was done at 21 different locations in the Dibang basin during monsoon in September, 2015 covering forests in and around locations of structures like dam site and submergence area, power house site of the proposed hydropower projects. The list of sampling locations is given in **Table 3.1** their location on the map of Dibang basin has been marked and is shown in **Figure 3.2**.

3.4 SAMPLING LOCATIONS AND METHODOLOGY

The size and number of quadrats needed were determined using the species-area curve (Misra, 1968). The data on vegetation were quantitatively analyzed for abundance, density, frequency as per the methodology given in Curtis & McIntosh (1950). The Importance Value Index (IVI) for trees was determined as the sum of relative density, relative frequency and relative dominance (Curtis, 1959).

Sampling Site Selection

The sampling locations were selected on the basis of the area located in the vicinity of proposed projects and its components. Entire Dibang basin has been covered i.e. 21 sampling location were selected for the study. Sampling locations were identified to capture the baseline status and depending upon the anticipated changes in the topography, vegetation, forest types, water quality, aquatic ecology, etc. so as to capture the representative baseline of the area. Proposed project locations were also kept in mind while identifying the sampling locations, as these locations will be direct impact areas during project construction and operation. Hydropower projects can spread over several km along river stretches and cannot be represented by a single point sampling locations. Reach of project is considered from tip of the FRL to the tail water outfall point. Therefore, for projects in cascade each sampling location can represent more than one project also. Moreover, sampling locations vegetation as well as aquatic ecology wherein sampling sites sometimes extend over a distance of 2-3 km for the collection of composite water sample while terrestrial ecology sampling sites were invariably spread over an area of 4-5 sq km over which 10-14 number of 10mx10m quadrats were laid to capture the vegetation structure.

A good representation of baseline has been done focusing more on the locations where changes are expected in vegetation profile. Sampling locations were selected keeping in mind the project locations and their accessibility also.

Twenty one sampling sites located within the basin were selected for carrying out phyto-sociological surveys of the vegetation and in addition an inventory of various floristic elements was also prepared by walking along different transects around these sampling sites. In order to understand the composition of the vegetation, most of the plant species were identified in the field itself whereas the species that could not be identified, the photographs of different plant parts were taken for identification later with the help of available published literature, herbaria and floras of the region.

Standard methodology of vegetation sampling i.e. nested quadrat sampling method was used for the study of community structure of the vegetation. Each sampling unit consisted of randomly placed quadrats of 10 x 10 m^2 for trees, 5 x 5m^2 for shrubs and 1 x 1m^2 for herbs (**Table 3.2**). For sampling of vegetation, number of quadrats to be laid varied from minimum of 10 quadrats to 14 quadrats for trees, 10 quadrats to 20 quadrats for shrubs and 13 quadrats to 21 quadrats for herbs at a particular sampling site/ area depending upon the heterogeneity/ homogeneity of the vegetation encountered at a particular site/ area (**see Table 3.2**). At each site the quadrats were laid along the altitudinal gradient beginning from the vegetation along the river bank/riverine vegetation and further up along the slope ensuring maximum possible representative coverage of the vegetation of a particular sampling location. Each sampling location/ area was divided into grids vertically as well as horizontally along the slopes thereby capturing the maximum diversity of vegetation. In case of trees total basal area/cover per unit area was calculated by measuring the '*cbh*' (circumference at breast height) of each individual tree belonging to different species, which was then converted into basal area using the formula given in the following paragraph. However in case of herbs and shrubs the circumference of at least 10-20 was measured by bunching them together which was then converted into circumference of total number of individuals which was then further used to calculate basal area of herbs and shrubs per unit area. As already mentioned the number of individuals of herbs and shrubs to be bunched together depends upon the thickness of their stems.

<u>**Calculation of Dominance & Diversity Indices**</u>

Based on the quadrat data, frequency, density and cover (basal area) of each species were calculated. The data on density and basal cover are presented on per ha basis.

The **Importance Value Index (IVI)** for different tree species was determined by adding up the Relative Density, Relative Frequency and Relative Dominance/ Cover values. The Relative Density and Relative Frequency values were used to calculate the IVI of shrubs and herbs.

For the calculation of dominance, the basal area was determined by using following formula.
Basal area = πr^2

The index of diversity was computed by using Shannon Wiener Diversity Index (Shannon Wiener, 1963) as:

$H = - \Sigma (ni/n) \times \ln (ni/n)$
Where, ni is individual density of a species and n is total density of all the species

The Evenness Index (E) is calculated by using Shannon's Evenness formula (Magurran, 2004).
Evenness Index (E) = $H / \ln(S)$

Where, H is Shannon Wiener Diversity index; S is number of species

Table 3.1: Sampling sites and their locations for vegetation sampling in Dibang basin

Site Code	Name of Sampling Sites
V1	Upstream of Amulin HEP project area- Mathun Valley
V2	Near Emini HEP project area- Mathun Valley
V3	Near Mihumdon HEP project area- Dri Valley
V4	Angepani –Dri river Confluence- Dri Valley
V5	Near Etabue HEP project area- Dri Valley
V6	Dr i- Mathun river Confluence

Site Code	Name of Sampling Sites
V7	Etalin HEP Dam Site- Dri Limb
V8	Malinye Village- Talo (Tangon) River
V9	Edzon- Talo river Confluence near Attunli HEP
V10	Anonpani Nala (Left bank tributary of Talo (Tangon) river)
V11	Etalin HEP Dam Site- Tangon Limb
V12	Etalin HEP Power House Site: near Dri - Talo (Tangon) river Confluence
V13	Left bank of Emra river: near Emra- Dibang river Confluence
V14	Left bank of Ahi river: near Elango HEP Project area
V15	Left bank of Dibang River near Ryali Village
V16	Near Desali village (Ithun II HE project area): Ithun River
V17	Near Hunli (Ithun I HE project area): Ithun River
V18	Near Proposed Dam site of Dibang Multipurpose HE Project
V19	Left bank of Ashupani Nala (left bank tributary of Dibang river): Near Ashupani HE project area
V20	Downstream area of Dibang HE multipurpose Project PH Site
V21	Left bank of Sissiri river near Sissiri HE project area

Table 3.2: No. of quadrats studied for each vegetation component

Sampling Site	Trees (10x10) m^2	Shrubs (5x5) m^2	Herbs (1x1) m^2
V1	14	20	21
V2	14	20	17
V3	14	20	14
V4	14	20	15
V5	14	20	15
V6	14	20	15
V7	14	20	15
V8	14	20	15
V9	14	20	13
V10	14	20	15
V11	14	20	17
V12	14	20	18
V13	14	20	20
V14	10	10	15
V15	10	10	15
V16	10	10	15
V17	10	10	15
V18	10	10	15
V19	10	10	15
V20	10	10	15
V21	14		15

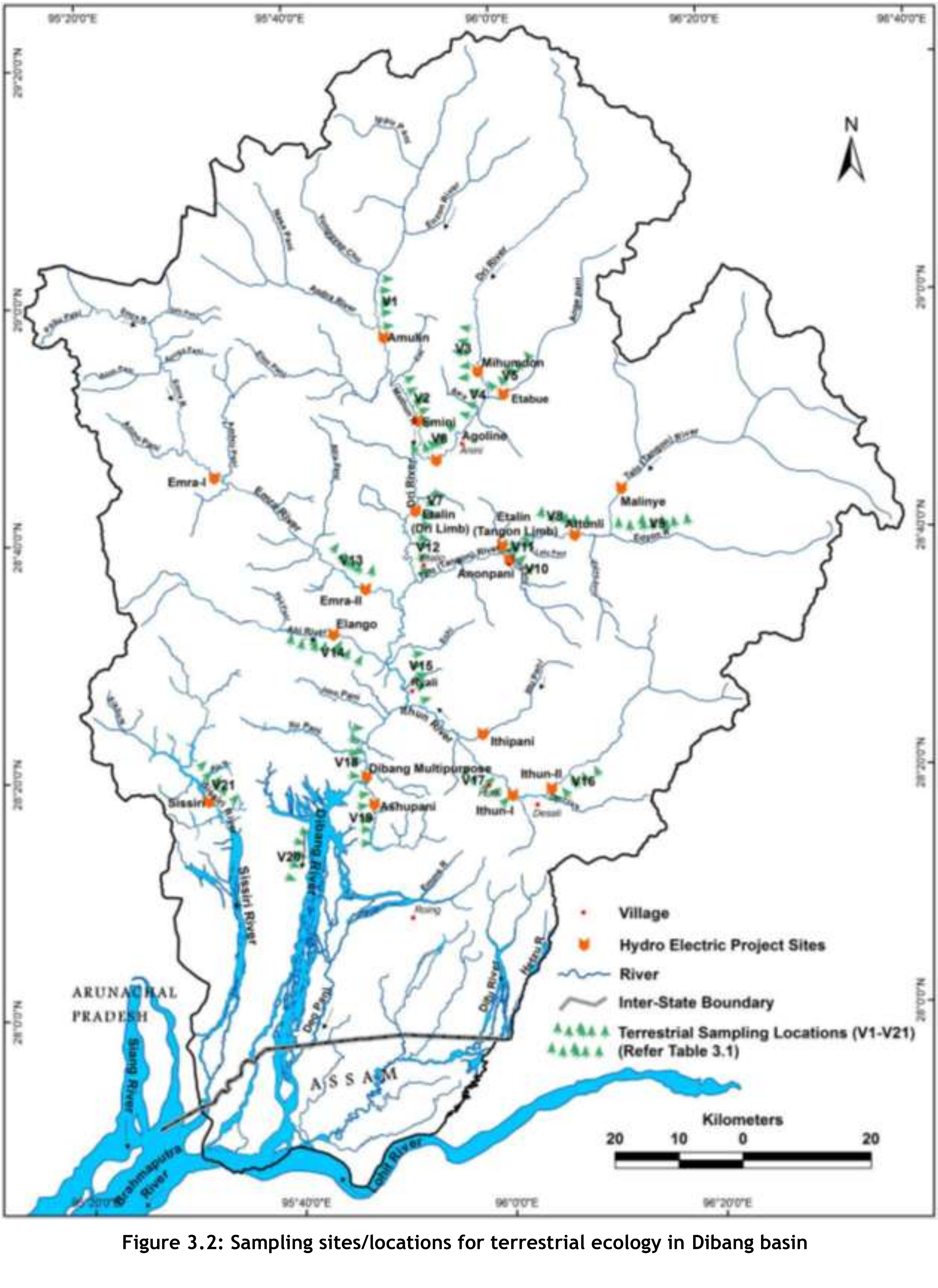


Figure 3.2: Sampling sites/locations for terrestrial ecology in Dibang basin

3.5 FAUNAL ELEMENTS

The data on faunal elements of the basin has been compiled with the help of secondary sources supplemented with information provided by local people during field surveys conducted in different areas of the basin as discussed in previous section.

For the preparation of checklist of animals, Forest Working Plan of Dibang Forest Division, Anini Social Forestry Division, as well as Management Plans of Mehao Wildlife Sanctuary and Dibang

Wildlife Sanctuary were consulted. In addition data was compiled from published literature like Fauna of Arunachal Pradesh, Vol.-1 & 2 (2006), Arunachal Forest News Journal, Vol. 19 (2001), Ali & Ripley (1983), Grimmett *et al*. (1998, 2011), Fleming (2006).

The study area was divided into different strata based on vegetation and topography. Sampling for habitat and animals was done in each strata. As the normal systematic transects for mammals and birds were not possible in this study area due to difficult terrain, therefore trails were used for faunal sampling. In addition to the field sampling the data/ information was also collected as follows.

- Direct sighting and indirect evidences such as calls, signs and trophies of mammals were recorded along the survey routes taking aid from Prater (1980).
- Interviews of local villagers for the presence and relative abundance of various animal species within each locality.
- Data collection on habitat condition, animal presence by direct sighting and indirect evidences by forest personnel and villagers.

The checklist of mammalian fauna of the basin has been compiled with the help of data provided by Zoological Survey of India (ZSI) supplemented with information provided by local people during field surveys.

For the compilation of checklist of birds, butterflies and herpetofauna found in the Dibang basin, published literature was consulted along with Management Plans of Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary and working plans of forest divisions. In addition published research papers by Gogoi (2012), Singh *et al*. (2003), Choudhury *et al*. (2003), Pawar and Birand (2001), and Daniel Mize (2014) were also consulted.

3.6 AQUATIC ECOLOGY

Data on physico-chemical water quality, and aquatic biodiversity i.e. Plankton (phytoplankton and zooplankton), benthic macro-invertebrates, aquatic plants and fish was collected through water sampling in major rivers/steams at different locations in the basin.

3.7 SAMPLING LOCATIONS & SITE DESCRIPTION

Selection of Sampling Sites

Sampling was carried out at 20 different locations and their details and locations are given at **Table 3.3 & Figure 3.3**, respectively. The sampling sites were located near the area where major project components are proposed like dam site, powerhouse site, working area, near the confluence of major tributaries with the main channel and near settlements.

The sampling was carried out in Dibang river and its major tributaries like Mathun, Dri, Talo (Tangon), Anonpani, Emra, Ahi, Ithun and Sissiri in the basin. Water samples were collected and analyzed for physico-chemical and biological parameters. The sampling location with site description are given below:

Mathun River

The topography of the Mathun Valley is undulating which is the part of Mishmi hills. In this valley, 2 water samples were collected from Mathun river (right bank tributary of Dri river), i) near dam site of proposed Amulin HEP and ii) Power house site of proposed Emini HEP.

Dri River

Dri river is the right bank tributary of Dibang river, the area is completely undulating covering thick forest in the surroundings. In this area, 4 water samples were collected at various locations viz. Upstream of proposed Mihumdon HE project (Dri River), Agolin HEP near Anini, proposed Etalin dam site, and proposed Etalin Power house site.

Ange Pani Nala

This nala is the right bank tributary of Dri river, water sample was collected near the upstream of the confluence point of Dri and Ange Pani Nala.

Talo (Tangon) River

In Talo river (also known as Tangon river) water samples were collected from i) Talo (Tangon) river: Near proposed Malinye HEP ii) upstream of proposed Attulni HEP, iii) near proposed Attunli Dam site and iv) at Anonpani- Talo confluence.

Anonpani Nala

One water sample was collected at proposed dam site of Anonpani SHEP.

Dibang River

Dibang river formed after the confluence of two major river called as Dri river and Talo rivers. Here, one water sample was collected near proposed Etalin Power house site.

Emra River

Emra is the right bank tributary of Dibang river. Two sampling sites were selected, one near Dam site and another one near power house site of Emra II HEP.

Ahi River

One sample was taken from the Ahi river which is the right bank tributary of Dibang river.

Ithun River

Ithun river is the left bank tributary of Dibang river. Two sampling sites were selected one near Desali village and other near Hunli village.

Ashupani Nala

One sampling site was selected near dam site of proposed Ashupani HEP.

Sissiri River

One sampling site was located near dam site of proposed Sissiri HEP.

3.8 METHODOLOGY

The composite water samples from the river were taken in triplicates at each site and average values were computed for the results. The details of sampling sites and their location along with coordinates are given in **Table 3.3** and locations of sampling sites are marked on map is given in **Figure 3.3.**

3.8.1 Physico-chemical Parameters

The analysis of physico-chemical parameters include pH, temperature, electrical conductivity, TSS, whereas the chemical parameters includes alkalinity, hardness, DO, BOD, COD, nitrite, phosphate, chloride, sulphate, sodium, potassium, calcium, magnesium, silica, oil and grease, phenolic compounds, residual sodium carbonate. Bacteriological parameters included Total Coliform and heavy metals included Pb, As, Hg, Cd, Cr-6, total Chromium, Cu, Zn, and Fe. The samples were taken in the replicates at each site of the river and composite samples were then analysed.

Table 3.3: Details of sampling locations for the water sampling

Sampling Code	Name of Sampling Site
Mathun River: Right Bank tributary of Dri river	
W1	Near proposed Amulin HEP
W2	Near proposed Emini HEP
Dri River	
W3	Dri river: Upstream of proposed Mihumdon HE project
W4	Downstream of Ange Pani- Dri river Confluence
W5	Near proposed Dam Site of Etalin HEP (Dri Limb)

Sampling Code	Name of Sampling Site
W6	Near proposed Power House Site of Etalin HEP
Talo (Tangon) River	
W7	Talo (Tangon) river: Near proposed Malinye HEP
W8	Attunli HEP dam site: near Tangon - Edzon River Confluence
W9	Anonpani Nala: left bank tributary of Tangon river
W10	Near proposed Dam Site of Etalin HEP (Tangon Limb)
Emra river: Right bank tributary of Dibang river	
W11	Proposed Dam Site of Emra II HEP at Emra River
Dibang river	
W12	Dibang River D/S of Emra- Dibang Confluence
W13	Dibang River D/S of Dibang- Ithun Confluence
W14	Dibang Multipurpose Dam Site
W15	Dibang Multipurpose PH Site
Ahi river: Right Bank tributary of Dibang river	
W16	Ahi River
Ithun River: Left bank tributary of Dibang river	
W17	Ithun River near Desali village
W18	Ithun River Near Hunli village
Ashupani : Left bank tributary of Dibang river	
W18	Ashupani Nala
Sissiri River: Right Bank tributary of Dibang river	
W20	Sissiri River

Some of the physico-chemical parameters of water necessary for the ecological studies were measured in the field with the help of different instruments. The water temperature was measured with the help of graduated mercury thermometer. The hydrogen ion concentration (pH), electrical conductivity and total dissolved solids were recorded with the help of a pH, EC and TDS probes of Hanna instruments (Model HI 98130) in the field. Dissolved oxygen was measured with the help of Digital Dissolved Oxygen meter (Eutech ECDO 602K). Total coliforms were assessed by Presence/absence techniques using media method. For the analysis of rest of the parameters the water samples were collected in polypropylene bottles from the different sampling sites and brought to the laboratory for further analysis after adding formalin as preservative. The turbidity was measured with the help of Digital Turbidity meter and other parameters such as total alkalinity, total hardness, DO, BOD, COD, nitrite, phosphate, chloride, sulphate, sodium, potassium, calcium, magnesium, silica, oil and grease, phenolic compounds, residual sodium carbonate and heavy metals included Pb, As, Hg, Cd, Cr-6, total Chromium, Cu, Zn, and Fe were analyzed at the Hitech Labs Limited, Okhla, New Delhi. These parameters were analysed as per the standard procedures given by Adoni (1980) and APHA (1992) and Bureau of Indian Standards (BIS):IS 3025 (Indian Standard: methods of sampling and test (physical and chemical) for water used in industry).

3.8.2 Sampling of Phytoplankton & Periphyton - Benthic (Epilithic) Diatoms and Zooplankton

For the quantification of phytoplankton and zooplankton 50 liters of water for each community was filtered at each site by using plankton net made up of fine silk cloth (mesh size 25 μm). The study was repeated three times at each site and samples were pooled. The filtrate collected for phytoplankton was preserved in 1% Lugol's Iodine solution.

For periphyton the sampling was performed across width of stream at a depth of 15 - 30 cm. The samples were taken from the accessible banks only. The cobbles (64 -128 mm size) usually 4 - 5 in number, were picked from the riffle and pools, in apparently different flows such as stones above and below gushing waters, swift flow and slow flow conditions so as to obtain a representative sample. Benthic diatom samples were collected by scratching the pebbles with a brush of hard bristles in order to dislodge benthos from crevices and minute cavities on the boulder surface from an area of 3 x 3 cm^2, using a sharp edged razor. The scrapings from each cobble were collected in 25µ mesh and transferred to storage vials. The samples were preserved in 1% Lugol's iodine solution.

Acid treatment according to Reimer (1962) method, adopted also by Nautiyal & Nautiyal (1999, 2002), was followed to process the samples for light microscopy. The treated samples were washed repeatedly to remove traces of acid. Samples with high organic content were treated with hydrogen peroxide (H_2O_2) to clean the diatom frustules. The permanent mounts were prepared in Naphrax for further analysis. They were examined using a BX-40 Trinocular Olympus microscope (x10 and x15 wide field eyepiece) fitted with Universal condenser and PLANAPO x100 oil immersion objective under bright field using appropriate filters to identify the species.

For preparing permanent mounts from the treated samples, the slide was first smeared with Mayer's albumen. The sample was then agitated to render it homogeneous. Quickly a drop of known volume (0.04 ml) of processed material was placed on the slide and heated gently till it dried. It was dehydrated using 95% and 100% alcohol, consecutively. The dehydrated material was transferred to Xylol twice before finally mounting in Euparol.

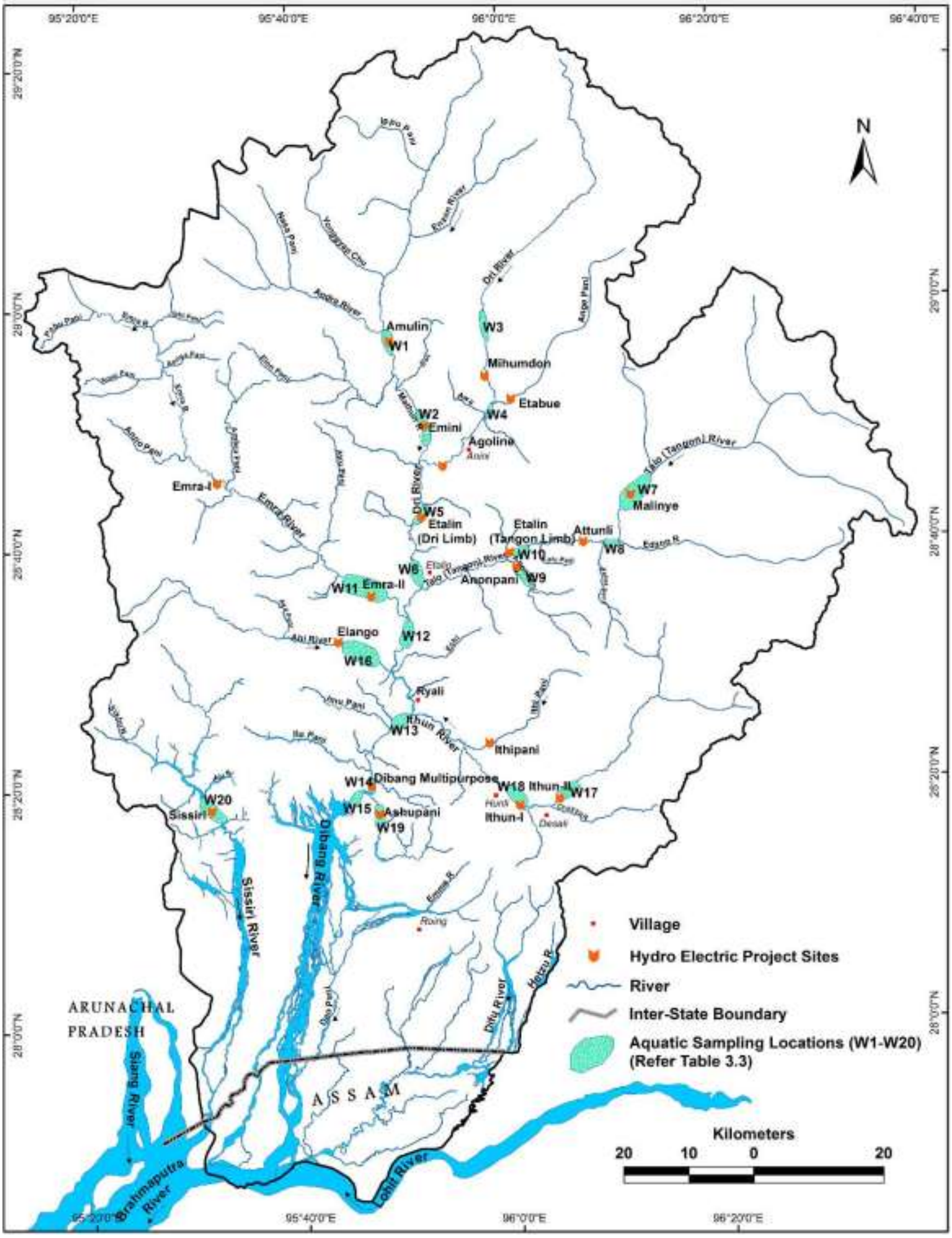


Figure 3.3: Location of sampling sites for aquatic ecology in Dibang basin

3.8.3 Identification of Benthic (Epilithic) Diatoms & Zooplankton

The permanent mounts were then subjected to analysis under a phase contrast binocular microscope using an oil immersion lens of x100 magnification. For identifying the various diatom species, varieties and forms, the morphological characteristics used included length, width (µm), number of striae, raphe, axial area, central area, terminal and central nodules. Identifications were made according to standard literature viz. Schmidt 1914 -1954, Hustedt 1943, Hustedt 1985, Krammer & Lange - Bertalot 1986, 1991, 1999, 2000 a & b, Lange - Bertalot, H. Krammer, K. 2002, Metzeltin & Lange - Bertalot 2002, Krammer 2000, 2003, Lange Bertalot *et al*., 2003, Werum & Lange - Bertalot 2004, Metzeltin *et al*., 2005. Sarode & Kamat (1984), Prasad (1992) and Gandhi (1998) were also consulted for the oriental species.

The identification of zooplankton was made with the help of Ward and Whipple (1959) and Battish (1992).

3.8.4 Sampling & Identification of Macro-invertebrates

For Macro-invertebrate samples were collected from 1 sq ft area by lifting of stones and sieving of substratum from the wadeable portion of the river. The material was sieved through 125 µm sieve and preserved in 70% ethyl alcohol. Samples were collected in three replicates and pooled for further analysis. The organisms obtained were then counted after identifying them up to family level. Standard keys were used for the identification of macro invertebrate samples (Pennek 1953; Edmondson 1959; Macan 1979; Edington and Hildrew 1995).

3.9 PHYSICO-CHEMICAL WATER QUALITY

The water quality objectives for freshwaters focus on a core indicator set that reflects their importance along a river stretch in a valley/basin. The core indicators pH, turbidity, electrical conductivity and dissolved oxygen are addressed in this report.

In order to assess the water quality of Dibang river and its tributary streams a Water Quality Index was used which has been developed at Washington State Department of Ecology, Environmental assessment Programme. The Water Quality Index (WQI) used in the report is a unitless number ranging from 1 to 100. A higher number is indicative of better water quality. For temperature, pH, faecal coliform bacteria and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses (based on criteria in Washington's Water Quality Standards, WAC 173-201A).

Water quality index is a 100 point scale that summarizes results from a total of nine different measurements viz.

- pH,
- Dissolved Oxygen
- Turbidity
- Faecal Coliform
- Biochemical Oxygen Demand
- Total Phosphates
- Nitrates, and
- Total Suspended Solids

During the Water Quality analysis number of other parameters were also analysed from the water samples collected from different locations during the field surveys. These are as follows:

Electrical conductivity (EC)	Magnesium
Total Dissolved Solids (TDS)	Silica
Total Alkalinity	Oil & Grease
Total Hardness	Phenolic Compounds
Dissolved Oxygen (DO)	Residual Sodium Carbonate

Biochemical Oxygen Demand (BOD)	Lead
Chemical Oxygen Demand (COD)	Arsenic
Nitrite	Mercury
Phosphate	Cadmium
Chlorides	Cr-6
Sulphates	Total Chromium
Sodium	Copper
Potassium	Zinc
Calcium	Iron

The analysis of water quality therefore has been based upon 9 parameters as defined for WQI above.

Water Quality Index Legend	
Range	**Quality**
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

3.10 BIOLOGICAL WATER QUALITY INDEX

For the assessment and analysis of Biological Water Quality an index named **Biological Monitoring Working Party (BMWP)** procedure was employed using species of macro-invertebrates as biological indicators (http://www.nethan-valley.co.uk/insectgroups.doc). The method is based on the principle that different aquatic invertebrates have different tolerances to pollutants. The presence of mayflies or stoneflies for instance indicates the cleanest water. The BMWP score equals the sum of the tolerance scores of all macroinvertebrate families in the sample. Therefore a higher BMWP score is considered to reflect a better water quality. The number of different macroinvertebrates is also an important factor, because a better water quality is assumed to result in a higher diversity. Alternatively, also the **Average Score Per Taxon (ASPT)** score is calculated. The ASPT equals the average of the tolerance scores of all macroinvertebrate families found, and ranges from 0 to 10. The main difference between both indices is that ASPT does not depend on the family richness.

For the present analysis of biological water quality, above indices have been calculated for each location in Dibang basin.

Lincoln Quality Index

It is similar to BMWP but also takes account of the average per family and habitat quality (either habitat rich or habitat poor). The BMWP score alone is insufficient due to variability of thereof the scores in relation to habitat diversity. By using a combination of BMWP score and the Average Score Per Taxon the influence of habitat diversity is reduced. It was found by experience that for small stream riffles with low habitat diversity an adjustment to the score levels was still found to be necessary to obtain comparable results. . For this reason a judgment on whether or not the riffle at a small stream site is "habitat rich" or "habitat poor" is required. Normally this judgment is only made once and is not to be changed unless a significant change in the habitat availability occurs due to river maintenance or flow alteration.

After the samples have been analysed and the BMWP Score and ASPT calculated, the LQI is assessed using the tables for X and Y values. The BMWP score is used to obtain rating of X and the ASPT is used to obtain rating Y from tables given below.

Standard BMWP Ratings for Habitat Rich Riffles

BMWP score	Rating X
151 +	7
121 - 150	6
91 - 120	5
61 - 90	4
31 - 60	3
15 - 30	2
0 - 1 4	1

Standard ASPT Ratings for Habitat Rich Riffles

ASPT score	Rating Y
6 +	7
5.5	6
5.1	5
4.6	4
3.6	3
2.6	2
0	1

The overall quality rating is obtained from the formula as follows:

$$\text{Overall Quality Rating} = \frac{X + Y}{2}$$

Overall Quality Ratings, Equivalent Lincoln Quality Index Values and Interpretation of results

Quality Rating	Index	Interpretation
6 or better	A++	Excellent Quality
5.5	A+	Excellent Quality
5.0	A	Excellent Quality
4.5	B	Good Quality
4.0	C	Good Quality
3.5	D	Moderate Quality
3.0	E	Moderate Quality
2.5	F	Poor Quality
2.0	G	Poor Quality
1.5	H	Very Poor Quality
1.0	I	Very Poor Quality

Using this system sites which support a very good fauna are classified as A, A+ or A++ (Excellent) and so on.
LQI ratings: 1-1.5(I-H) = very poor, 2-2.5(G-F) = poor, 3-3.5(E-D) = moderate, 4-4.5(C-B) = good, above 5(A, A++) excellent.

3.11 FISH AND FISHERIES

Freshwater is an important source of food for humans, in which fish play a significant role. Running water of Himalaya comprise many torrential rivers and streams providing a wide variety of ecological niches for freshwater fish. The fish species of Himalaya are well adapted to fast flowing water, low to medium water temperature, boulders on river bed, etc.

For collection of data on occurrence and distribution of fish species in the Dibang river and its tributaries, experimental fishing was done with the help of local fishermen's at various sites in the basin. Due to fast flow of rivers during monsoon period no fish landed during the experimental fishing. Interviews were conducted with locals regarding the probable presence of fishes in the river.

The data on fish species in Dibang basin was also collected from Fisheries Department of State Government and through published literature. An inventory of the fish species was prepared after consulting main sources like Nath & Dey (2000) and Bagra *et al.* (2009) and correct scientific names were checked and updated by following http://www.fishbase.org.

CHAPTER-4
BASIN CHARACTERISTICS

4.1 INTRODUCTION

The Dibang river basin is a part of Brahmaputra River System and is one of the major rivers traversing through Arunachal Pradesh. There are six major river basins in Arunachal Pradesh viz. Kameng, Subansiri, Siang (Dihang), Dibang, Lohit and Tawang with large number of their tributaries drain the waters of vast catchment area into the mighty Brahmaputra. The Dibang originates from the snow covered southern flank of the Himalaya/Trans Himalaya close to the Tibet border at an elevation of more than 5000 m. It cuts through deep gorges and difficult terrain in its upper reach through the Great Himalayan range in Dibang Valley and Lower Dibang Valley districts of Arunachal Pradesh and finally meets the river Lohit near Sadia in Assam. The total length of Dibang from its source to its confluence with Lohit river is about 223 km and the catchment area is about 13,933 sq km. The combined flow meets Brahmaputra near Kobo Chapori (**see Figure 4.1**).

The river emerges from hills and enters the sloping plain areas near Nizamghat in Arunachal Pradesh, from where the river flows for a distance of about 50 km to meet the river Lohit. Although there is no hill in between this reach, the river gradient is very steep for such a large river; in this 50 km reach, the river loses a height of about 160 m. In this portion, the river is highly braided and destructive in nature. It branches out into a number of channels, somewhere as many as 15 numbers and occupies a width of about 4 to 9 km. The river changes its course quite often destroying large tracts of jungle and cultivable land and floods occur in the low lying areas of Sadiya in Tinsukia District of Assam.

The boundary of Dibang river basin in Arunachal Pradesh in general coincides with boundaries of two districts viz. Lower Dibang Valley and Dibang Valley, however it includes entire catchment of Sissiri river, main right bank tributary of Dibang river in sloping plains and another left bank tributary i.e. Deopani. After entering state of Assam it is joined by off-shoots of Sissiri river on its right bank and those of Deopani and Kundli rivers like Emme and Difu rivers on left bank. Thereafter Dibang is joined by Lohit to form Brahmaputra river.

Total catchment area of Dibang river basin delineated as above is 13933 sq km with 13300 sq km in Arunachal Pradesh and 633 sq km in Assam. Approximate length of Dibang river in Arunachal Pradesh is 203.80 km while it traverses another 19.60 km in Assam to merge with Lohit river to form Brahmaputra river.

River	River length (km)
Dri river from source up to Mathun confluence	87.30
Dri river from Mathun confluence up to Etalin (confluence of Talo with DRi)	26.00
Dibang river (Dri + Talo) from Etalin up to confluence of Ithun river	27.50
Dibang river from confluence of Ithun up to confluence with Ashupani	16.50
Dibang river from confluence of Ashupani up to Assam border	46.50
Dibang river in Arunachal Pradesh	**203.80**
Dibang river in Assam up to confluence with Lohit river	**19.60**
Dibang river total	**223.40**

4.2 DRAINAGE

Dibang river drainage is comprised mainly of Dri and Talo (Tangon) rivers. Dri river originates at an altitude of 5355 m to 5375 m in the glacier ranges of the Greater Himalaya in the northern side of the basin. Talo (Tangon) river originates in the high hills of Himalaya near Kayapass in the eastern side of the basin. Both the rivers meets at Etalin to form Dibang river. As it flows down in southern direction of the basin several other tributaries like Emra river, Ahi river, Ithun river, Ilupani, Ashupani, Iphipani, Deopani, Sissiri, Kundli rivers, etc. join it along its course. The drainage of Dibang river basin has been described tributary wise upon which hydro-electric power projects are planned wherein description of major streams joining the main channel has been given. The drainage map of the Dibang basin is given as **Figure 4.2**.

4.2.1 Dri River

Dri river as already mentioned originates at an altitude of 5355 m to 5375 m in the glacial ranges of the Greater Himalaya. The river flows in southern direction. As it flows down meets Ange river at its left bank near Atoto village and Mathun river at its right bank near Mathuli. River Talo (Tangon) meets Dri river from the east at Etalin Township. After the confluence at Etalin the river is known as Dibang river. Total length of Dri river up to its confluence with Talo (Tangon) river is around 110 km. Total catchment area of Dri river up to its confluence with Talo (Tangon) river is around 3,750 sq km.

4.2.1.1 Dri River up to Mathun Confluence

Dri river after originating in the glacier ranges of the Greater Himalaya flows in southern direction. Total length of river is around 90 km up to confluence with Mathun river. Total catchment area of Dri river up to its confluence with Mathun river is around 1,450 sq km. Major tributaries/ streams joining Dri river at its right bank are Kama Pani, Chanye nala, Ketha Pani, Baso Pani, Mathu Pani, Thaha Pani, Ape Pani, Kanhi nala, Awa nala, Kaji nala, Sha nala and Kain nala. Major tributaries/ streams joining Dri river at its left bank are Kaho Pani, Mayini nala, Ichi nala, Ngra nala, Ange river, Chaya nala, Awa nala, Kaha nala, Mai nala and Ipih nala.

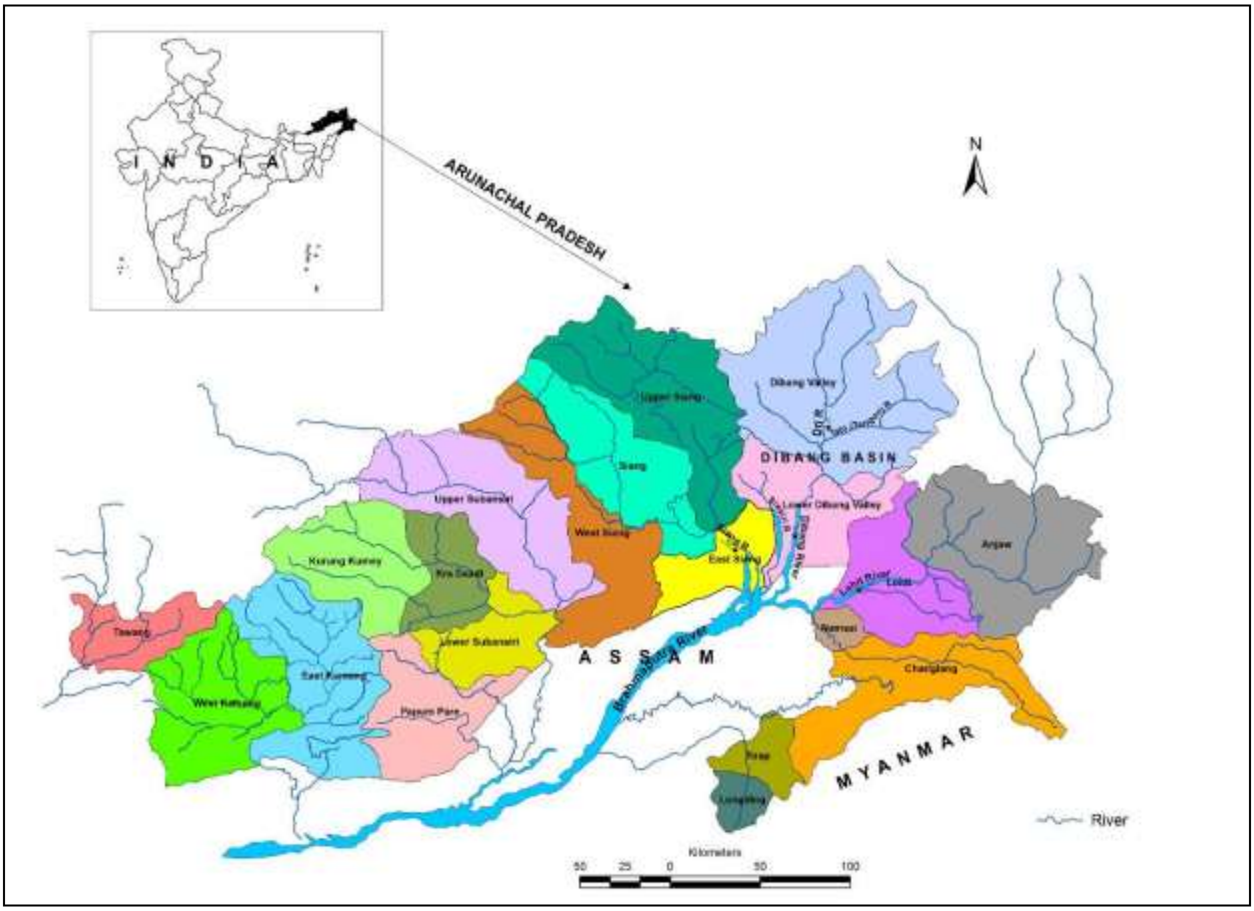


Figure 4.1: Location Map of Dibang Basin

4.2.1.2 Ange River

Ange river originates at an altitude more than 4000 m. It is a left bank tributary of Dri river and located in the eastern side of the basin. The river has a steep gradient throughout and flows through comparatively narrow valleys with occasional open valley. Total length of river is around 28 km up to confluence with Dri River. Total catchment area of Ange river up to its confluence with Dri river is around 380 sq km. Apeh, Thalon, Aron, Aronli, Aku, Chitu, Thason, Hanlon, Thauwe, Meku, and Ezha are some of the important tributaries of Ange river.

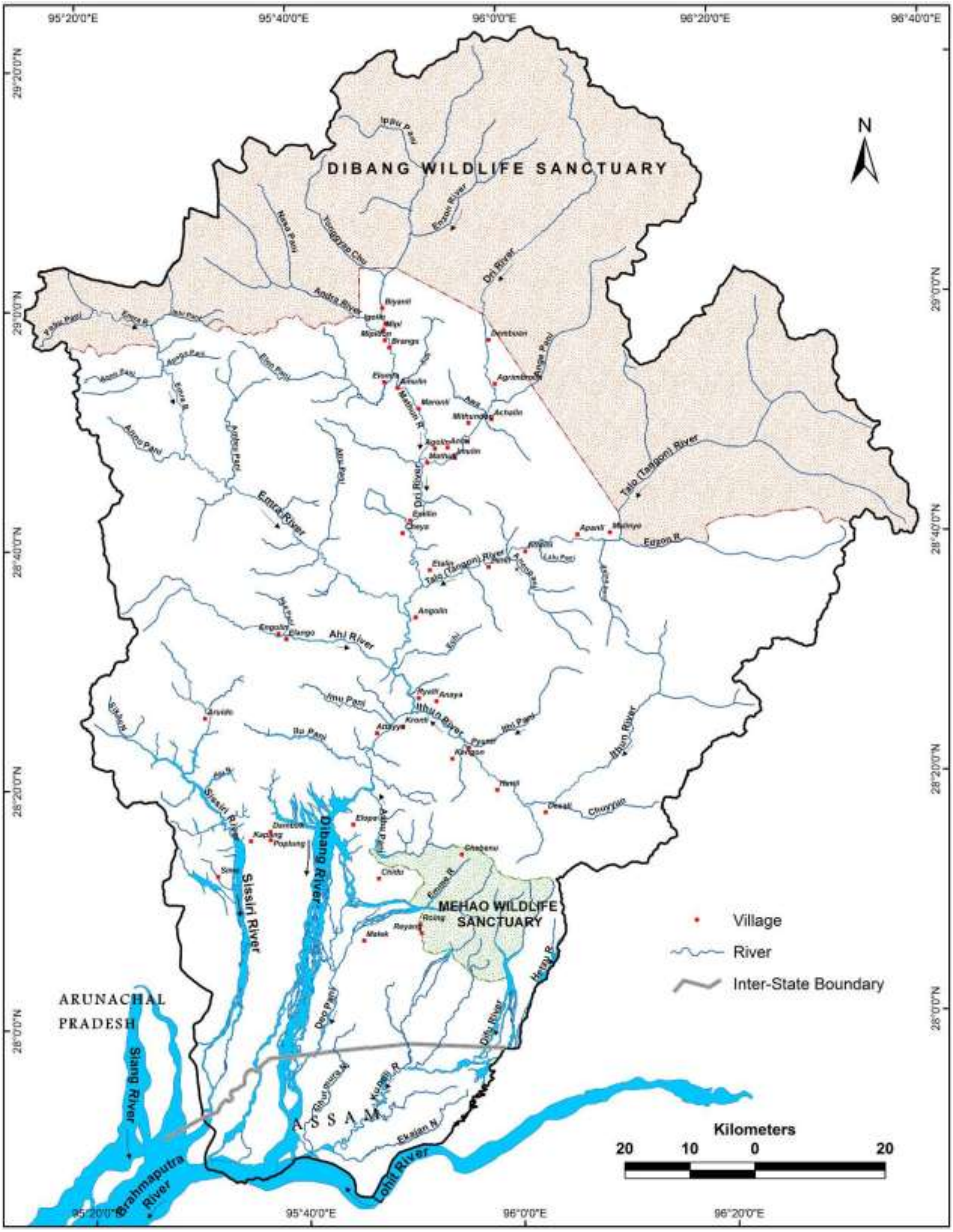


Figure 4.2: Drainage Map of Dibang Basin

4.2.1.3 Mathun River

Mathun river originates from high ranges of Himalaya and meets Dri river at its right bank near Mathuli. The river flows in southern direction. The gradient of the river is sufficiently steep and flows though narrow valley and is subjected to heavy rainfall. The total length of the river is about 80 km up to confluence with Dri River. Total catchment area of Mathun river up to its confluence with Dri river is around 2,000 sq km. In the upper reaches, Ippu Pani and Enzon river joins it at right bank and left bank respectively. As it flows down meets Yonggyap Chu, Andra river, Enni nala, Chingu nala, Elon Pani, Kanji nala and Issin nala at its right bank and Kamu nala, Chelu nala, Manyone nala, Talli nala, Tahu nala, Kathi nala, Imu nala, Bu nala, Malone nala, Maron nala at its left bank.

4.2.1.4 Dri River after Mathun Confluence

After the confluence of Dri river with Mathun river, the river continue to flow in south direction and meets Talo (Tangon) river near Etalin to form Dibang river. The elevation drops from around 1100m to below 600m between this stretch. During its course several big and small tributaries join the river at both the banks. Most of the settlement can be found on the left bank. Total length of Dri river from its confluence with Mathun and up to its confluence with Talo (Tangon) river is around 20 km. Total catchment area of Dri river from its confluence with Mathun and up to its confluence with Talo (Tangon) river is around 300 sq km. The major tributaries/ streams joining Dri river at its right bank are Igu nala, Imu Pani, Ei Pani, Duko Pani, Emi Pani, Ayu Pani, Api Pani, Chika Pani, Ano Pani and Nigi Pani. The major tributaries/ streams joining Dri river at its left bank are Tho Pani, Manu Pani, Kamba Pani, Kita Pani, Aiyo Pani, Inu Pani, Ari Pani, Kabo Pani, Ru Pani and Chambo Pani.

4.2.2 Talo (Tangon) River

Talo (Tangon) river as already mentioned originates in the high hills of Himalaya near Kayapass. The river flows from east to west from its source till Makhri river meets it at its right bank. From the confluence point with Makhri river till the confluence point with Edzon river near Maliney the river flows from north to south. From the confluence point with Edzon river the river takes a western turn and flows from east to west till it meets Dri river at Etalin. After the confluence at Etalin the river is known as Dibang river. The river flows in a sufficiently deep and narrow river basin. The total length of Talo river is about 91 km. Total catchment area of Talo (Tangon) river up to its confluence with Dri river is around 2,500 sq km. Major tributaries joining the river at its left bank are Aku nala, Awa nala, Andre nala, Davu nala, Eko nala, Chippu nala, Edzon river, Ela nala, Kachi nala, Achcha nala, Goye nala, Tum nala, Layo nala, Lalu Pani, Attu nala, Anon Pani, Chan nala, Non nala, Makri nala, Ahru nala, Noh nala and Aru nala while the major tributaries joining the river at its right bank are Makhri, Ipi Pani, Emo Pani, Emuni nala, Ahun nala, Chippa nala, Echcha nala, Chi nala, Dogon nala, Kun nala, Shu nala, Ron nala, Mir nala and Math nala.

4.2.2.1 Anon Pani Nala

Anonpani nala is a major left bank tributary of Talo (Tangon) river. This nala originates from El 4,785 m and flows in northwest direction. It joins Talo (Tangon) river at an elevation of around El 1,200 m near Awonli village. From its origin to its confluence with Talo (Tangon) river many unnamed streams joins the nala from the banks. The total length of the nala is about 21 km. Total catchment area of Anon Pani nala up to its confluence with Talo (Tangon) river is around 145 sq km.

4.2.3 Right Bank Tributaries of Dibang River

4.2.3.1 Emra River

Emra river originates at an altitude of around El 4000 m and meets Dibang river at its right bank near Agoline. The river is located in the western side of the basin. The total length of the river is about 93 km. Total catchment area of Emra river up to its confluence with Dibang river is around 1,500 sq km. The river flows from west to east direction. Chandro Pani, Iphi river, Yan Pani, Apoga Pani, Apogayaro Pani, Apili Pani, Au Pani, Si Pani, Li Pani, Arha Pani, Aoo Pani, Ehan Pani, Ara Pani, Arun Pani, Amu Pani, Inga Pani, Aru Pani, Su Pani, Elo Pani, Ri Pani, Apu Pani, Imliu Pani, Era Pani and Aha Pani are the important left bank tributaries of Emra river. Important right bank tributaries of Emra river are Pabu Pani, Chiciyakuni Pani, Maha Pani, Pubu Pani, Ekunji Pani, Apusu Pani, Anno Pani, Chichango Pani, Chichi Pani, Ekra Pani, Na Pani, Ri Pani, Amu Pani, Ithiu Pani, Mu Pani, Chan Pani, Poh Pani, Thun Pani, Un Pani, Inoin Pani, Imi Pani, Ema Pani, Aron Pani, Apu Pani and Igu Pani.

4.2.3.2 Ahi River

Ahi river originates at an altitude of around El. 3500m and meets Dibang river at its right bank just downstream of Anelih village. The river is located in the western side of the basin. The total length of the river is about 60 km. Total catchment area of Ahi river up to its confluence with Dibang river is around 640 sq km. The river flows from west to east direction Major tributaries joining the river at its left bank are Imni Pani, Ahuni Pani, Iri Pani, Ri Pani, Ya Pani, Alan Pani, Duni Pani, Dua Pani, Ashar Pani, Aha Pani, Amu Pani, Ayu Pani, Irhi Pani, Ichi Pani Payi Pani, Ruh Pani, Ingu Pani, Ane Pani, etc. while the major tributaries joining the river at its right bank are Abro Pani, Enzon Pani, Atani Pani, Ataya Pani, Iyu Pani, Apul Pani, Apru Pani, Thru Pani, Alo Pani, Yama Pani, Agi Pani, Bri Pani, Ni Pani, Na Pani, Yama Pani, Chhan Pani, Lohi Pani, Kru Pani, Kron Pani etc.

4.2.3.3 Sissiri River

The river Sissiri is one of the important right bank tributaries of Dibang river. The Sissiri catchment is sandwiched between Dibang basin in east and north and Siang basin in west. The main stem of the river known as Sissiri or Ihi Nadi originates from Ihimbon peak of Dimuin Hill at El.3694m in Lower Dibang Valley district of Arunachal Pradesh. From its origin it flows in a general south-westerly direction for a length of about 19 km up to its confluence with Senzen Nala from where it flows in a southern to south-westerly direction for a length of about 10 km up to its confluence with Sikhu Nala, its largest right bank tributary. It then takes a turn and flows in almost south-easterly direction for a length of about 14 km before entering the plains. The river then flows in an almost southerly direction for a length of about 26 km before bifurcating in two channels. The right channel flows in a south-westerly to almost westerly direction before joining the river Sibia. The left channel or the main channel continues to flow in southerly direction and is joined by a branch of Dibang River.

During its course, the river Sissiri is joined by number of small and large streams, the principal among them being Aphuru, Ewama, Sikhu, Riru, Yenga and Egadi Korong from the right and Bee, Ane, Senzen, Alu and Kambo from the left. The general flow direction of the tributaries is west to east on the right and east to west on the left. The river runs within narrow deep gorges in the hills with its gradients varying from 1:7 in upper part to 1:18 in middle portion to 1:80 just before entering the plains. The river meanders a lot after entering the plains. The river suddenly flares up after entering the plains and at places the bank to bank river width is more than 1500 m.

4.2.4 Left Bank Tributaries of Dibang River

4.2.4.1 Ithun River

Ithun river originates at an altitude of about El. 5000m and meets Dibang river on its left bank near Ipu village. The river is located in the eastern part of the basin. The total length of the river is about 77 km. Total catchment area of Ithun river up to its confluence with Dibang river is around 1,340 sq km. It travels westwards before it is joined by Mayi Pani at 2090m on its right bank, after its confluence with Mayi Pani and till its confluence with Chuyyu nala on its left bank the river flows from north to south. From its confluence with Chuyyu nala to confluence with Thu Pani on its left bank the river flows from east to west for a small distance of about 5 km. Further downstream, till it meets Dibang river the river flows in north west direction. Major right bank tributaries are Mayi Pani, Chemia Pani, Machisi Pani, Pikhari Pani, Pri Pani, Se Pani, Iphi Pani, Chitu Pani, Enno Pani, Aku Pani, Ithi Pani, Ni nala and Chilu nala. Major left bank tributaries are Mau Pani, Thri Nala, Ru Pani, Emme Pani, Asan Pani, Chuyyu nala, Thu Pani, Chuppu Machi, Era nala and Ithu nala.

4.2.4.2 Ashu Pani River

Ashu Pani river originates from Mayudia range of mountain at an elevation of 2500 m and meets Dibang river at its left bank. The river is located in the eastern side of the basin. The total length of the river is about 28 km and the total catchment area of the river is about 110 sq. km. Initially it moves from north to south and on the way numerous mountain streams join the river. After flowing for about 10 km, the river takes a right angle turn and flows towards west. The river has a wide valley at this portion. After flowing for another 9-10 km it takes another acute angle turn and flows backward towards high mountain ranges and after flowing further for about 10-12 km in this direction meets the river Dibang.

4.2.4.3 Deopani River

Deopani R. is formed by the confluence of Emme and Eje rivers which emerge nearby Mehao lake area. After this it travels mainly in plains joining Dibang near Loikhopurgaon.

4.2.4.4 Kundli River

It emerges as Difu river draining catchment of Mehao Wildlife Sanctuary. Thereafter it travels in plains as Kundli river near Kundli Bazar.

4.3 TOPOGRAPHY & RELIEF

Arunachal Pradesh could be divided into four distinct physiographic segments:

a) Arunachal Himalayan Ranges, that occurs as a "gigantic crescent",
b) Mishmi Hills, the northern continuation of the Proterozoic succession of Northern Myanmar,
c) Naga-Patkai Ranges, the eastern extension of Shillong Plateau, and
d) Brahmaputra Plains.

Further, the Arunachal Himalayan ranges extended from the eastern border of Bhutan to the Dibang and Lohit Valleys, abutting against Mishmi Hills, This part is sub-divided into four parallel linear zones:

a) Tethys or Tibetan Himalaya to the north,
b) Higher Himalaya,
c) Lesser Himalaya, and
d) Sub-Himalaya to the south.

The hills and mountains in the Tethys Himalaya and Higher Himalaya are made up of Palaeo Proterozoic and Meso Proterozoic rocks, where as those of Lesser Himalaya and Sub-Himalaya are made up of Palaeozoic, Mesozoic, Cenozoic rocks and Noozone - Early Quaternary sediments.

The Dibang Basin has a very severe and rigorous topographic feature. Its elevation ranges from 121 m in the outer Siwalik type hills rising from plains of Assam to as high as 5500 m in the Greater Himalaya, bordering China (see **Figure 4.3**). The upper catchment area is characterized by rugged physiography and can be delineated into Denude Structural Mountains (DSM) and Denudational Mountains (DM). The Piedment Zone is mostly located below El 400 m, is a stretch of alluvial plains occurring along the foot hills formed by coalescence of several alluvial fans consisting of boulders, stones, pebbles, sand and silt. The Flood Plains are strips of relatively smooth, adjacent to river channels, seasonally flooded, consisting of unconsolidated sediments. The width of the Piedmont Zone, together with Flood Plains, is mostly limit to 12 to 15 km. The Basin has a catchment area of 12,015 sq km. As per Agroclimatic Zone, the area falls within (i) Alpine Zone, and (ii) Mild Tropical Plain Zone.

In order to understand the terrain morphology Digital Elevation Model (DEM) of the basin has been prepared from Shuttle Radar Topography Mission (SRTM) 3 Arc-Second Global Digital Terrain Elevation Model (DTED) data. In order to understand the relief profile of the basin it has been divided into 500 m elevation zones. The relief maps thus prepared for Dibang Basin and have been given at **Figure 4.4.**

Around 60% of the basin area is below the elevation range of 3000m and around 28% of the area lies between 3000 and 4000m elevation range. Considerable amount of basin area i.e. around 15% lies below the elevation of 500m. Out of the 18 allotted/ planned hydro-electric power projects, 2 projects are located below 500m elevation, 7 projects are between 500 and 1000m elevation range, 6 projects are between 1000 and 1500m elevation range and the rest of the 3 projects are located between 1500 and 2000m elevation range.

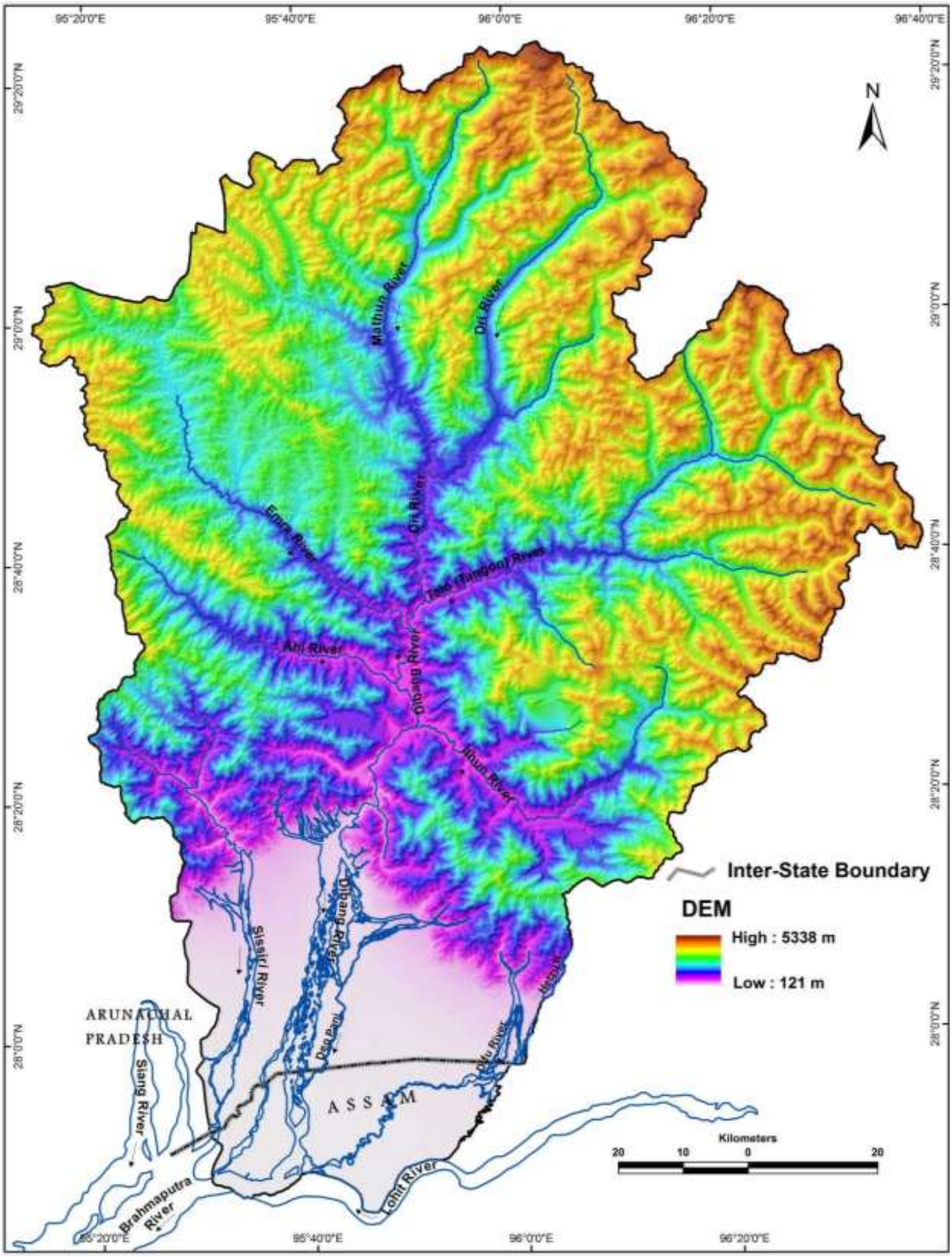


Figure 4.3: Elevation Map of Dibang Basin

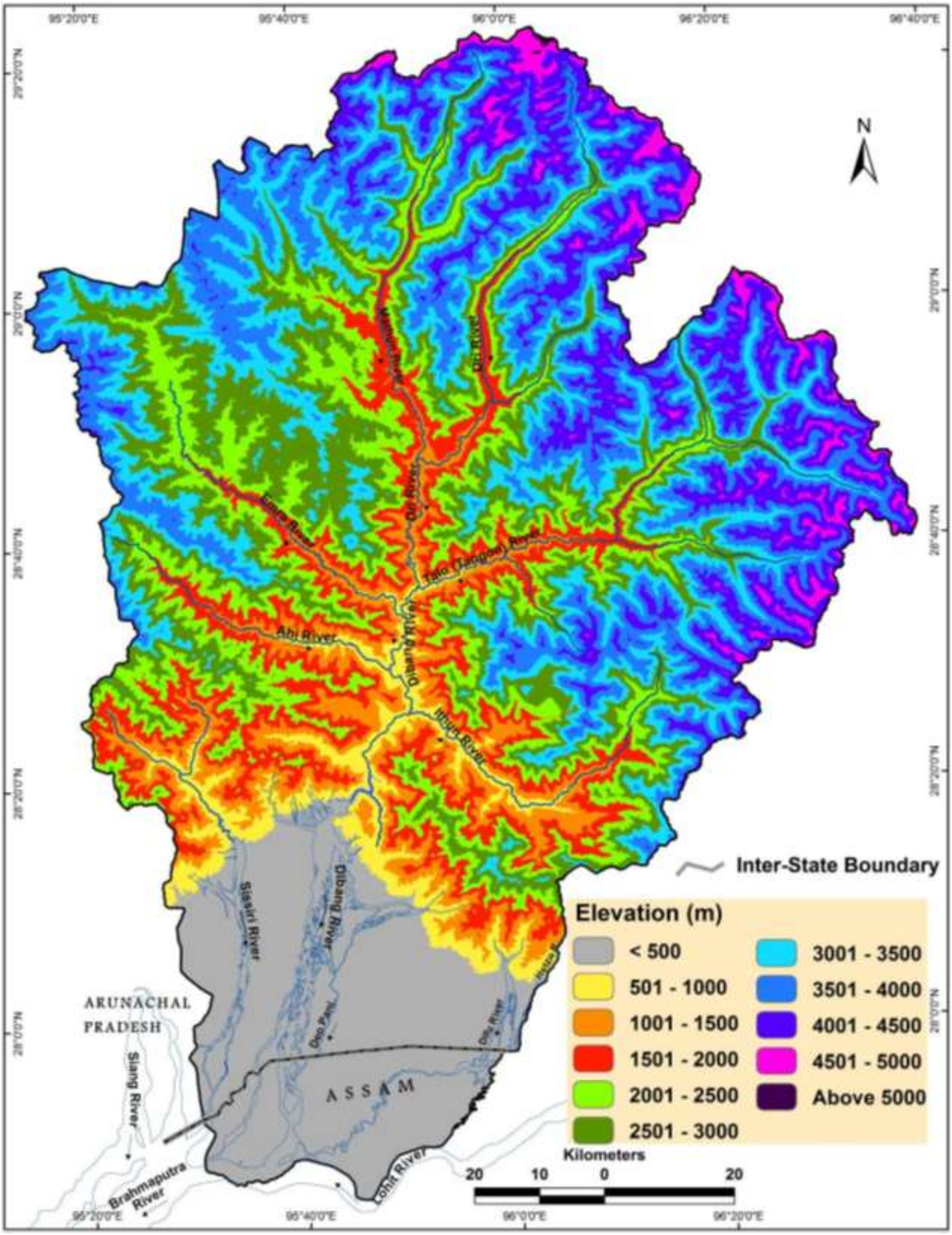


Figure 4.4: Relief Map of Dibang Basin

4.4 SLOPE

For the preparation of slope map of the basin Shuttle Radar Topography Mission (SRTM) 3 Arc-Second Global Digital Terrain Elevation Model (DTED) data has been used. The data was downloaded in Georeferenced Tagged Image File Format (GeoTIFF) format and using ArcGIS software a slope (in degrees) map was prepared. The degree slope was divided into different slope classes as per SLUSI. The slope prepared as above has been given at **Figure 4.5**. The following slope classes and ranges have been used for the study (**Table 4.1**).

Table 4.1: Description and Area under different Slope Categories in Dibang Basin

Slope in Degrees	Description	Area (sq km)	Area (%)
0 - 2	Gently sloping	1993.45	14.31
2 - 8	Moderately sloping	609.99	4.38
8 - 15	Strongly sloping	827.98	5.94
15 - 30	Moderately steep	4734.58	33.98
30 - 45	Steep	5246.66	37.66
45- 60	Very steep	514.49	3.69
60-70	Extremely Steep	3.85	0.03
Above 70	Escarpments	2.09	0.02
Total		**13933.09**	**100.00**

Around 38% of the basin area is characterized by steep slopes while around 34% area is having moderately steep slopes. Around 14% of the basin area falls in gently sloping slope category i.e. up to 2 degree slope.

4.5 GEOLOGY & GEO-MORPHOLOGY

The area in and around Dibang valley located on the eastern limb of Eastern Syntaxial Bend in eastern part of the Arunachal state is characterized by four distinct physiographic units. These are:

i) Himalayan ranges (referred to as the Arunachal Himalaya or NEFA)
ii) Mishmi Hills of Trans – Himalaya
iii) Brahmaputra Plain and
iv) Naga Patkoi Ranges of the Arakan Youma Mountains.

These four physiographic units in and around Dibang valley have developed and evolved at different times in response to various major events related to plate tectonic and therefore, the stratigraphy and geological history of each unit differs from each other.

The Arunachal Himalaya forms the eastern most part of the Himalaya and is considered to be the northern fringe of the Indian Plate abutting against the Tibetan Plate along the Indus - Tsangpo Suture in the north and the Indo – Burmese Plate along the Tidding Suture in the east. To its south lies the Brahmaputra Plain and to its east lies a chain of NW – SE trending mountains known as Mishmi Hills. The Arunachal Himalaya is made up of rocks ranging in age from Proterozoic to Holocene. The Brahmaputra plain is made up of post Siwalik Quaternary sediments. The Mishmi hill comprises meta-sediments of Precambrian age with younger mafic and acidic intrusive. To the south of Brahmaputra plain lie the Naga-Patkoi ranges which are the northern extensions of the Arakan – Youma fold – thrust belt. The ranges comprise essentially flyschoid sediments with tectonic slices of older rocks which also abut against the Mishmi hills. After their junction with the Mishmi hills along the Mishmi Thrust, the Naga - Patkoi ranges assume an E-W to NW – SE trend.

The highest peak in the Upper Dibang district along the international border with China ranges in height from 5000m to 7000m above m.s.l. Over an average aerial distance of 160km towards the Brahmaputra plain in the south, the height drops down to nearly 100m above m.s.l. (Chakrabarti *et. al.*, 1987).

Geomorphologically the area consists of (i) glaciated region, (ii) highly dissected hills, (iii) narrow ridge & valley province and (iv) floodplain and piedmont zone (Chakrabarti *et al.*, 1987). The highly dissected hills in the north are snow covered and some of the valleys just below the permanent snowline are U-shaped due to glacial and / or seasonal ice action. In Dri River well preserved moraines are seen at various places upstream of Anini with main terminal moraine at Anini. According to Kumar and Kumar (1998), the Mathun valley seems to be hanging valley with respect to the main Dri valley. The remnants of lateral moraines have been observed in areas between north of Anini and south of Acholin and in between Anini and Agoline in Dri valley.

According to Dasgupta *et. al.,* (1997), Dri River can be considered a captured stream. Glacio – fluvial deposits in Dibang valley are well exposed around 3km west of Avali (Kumar and Kumar, 1998), exhibiting perfect fining upward graded bedding. They also observed glacio – lacustrine features in Etabue – Ahrulin area, which exposes 1.5m thick sequence of varvites. An orographic bend is very conspicuous across the Siang River course within the highly dissected hills. The narrow ridge and valley province in the foothills of Arunachal Himalaya show a general ENE –WSW trend, while in the upper reaches of Siang River shows arcuate nature due to folding showing NE-SW and NW-SE trends. The composite present flood plain of the Brahmaputra River and its tributaries has been demarcated by fluvial geomorphic features such as cut off meanders, levees, back swamps and related elements. The present flood plain is wider in the upper reaches of the Brahmaputra due to coalescing of individual flood plains of Lohit, Dibang and Buri Dihing, etc. South of the Brahmaputra, the older flood plain is easily recognizable.

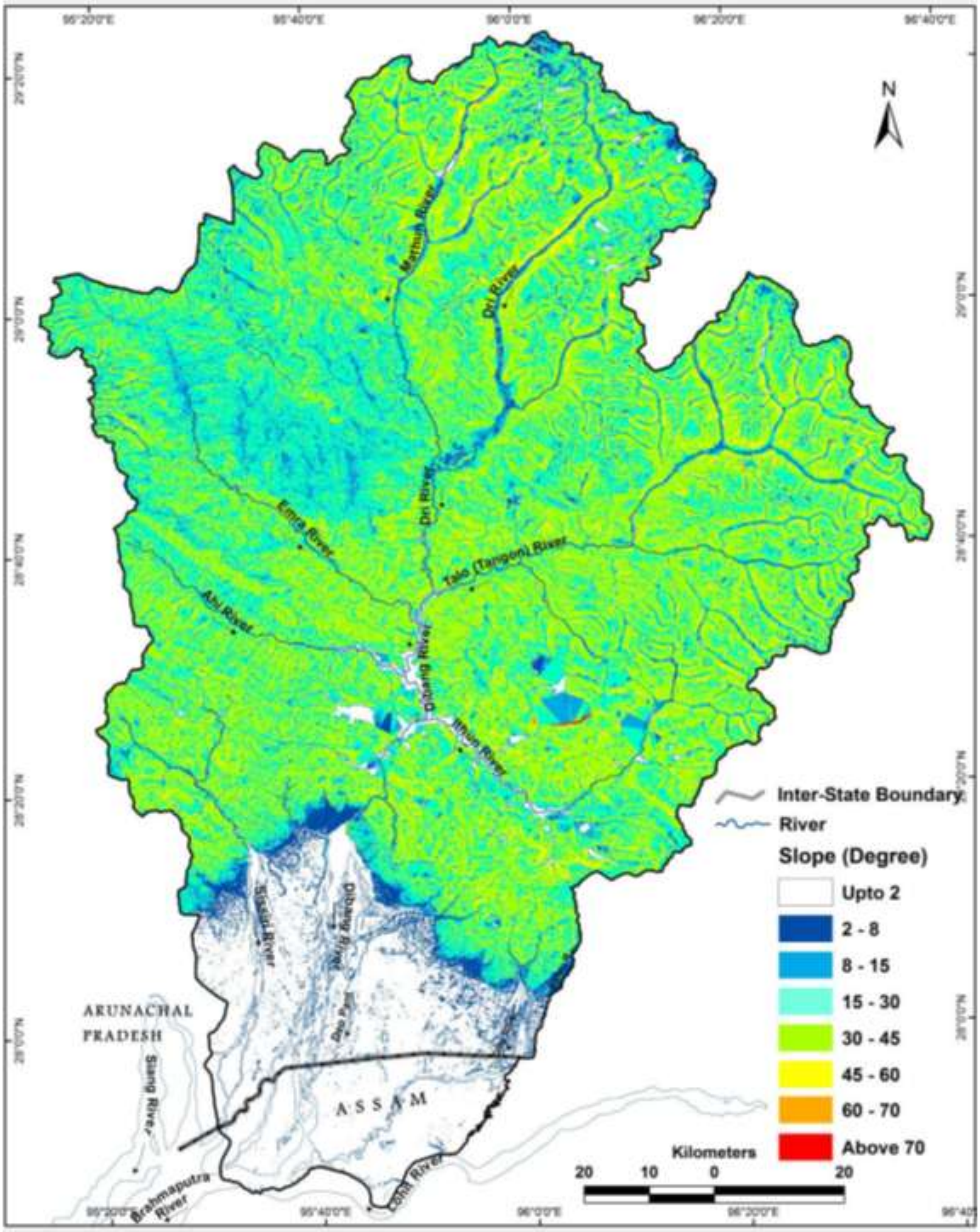


Figure 4.5: Slope Map of Dibang Basin

Table 4.2: Litho-Tectonic succession in Dibang Basin from north to south

	Erathem	Group	Formation	Lithology	
TRANS HIMALAYA	**Mesozoic** (Cretaceous – Tertiary)	**Mishmi**	Ithun (3000 - 3500m)	Granite – Granodiorite	Biotite Granite. Granodiorite Gneiss with crystalline limestone as xenoliths. Granite gneiss. Granodiorite Gneiss with garnetiferous mica - kyanite schist
	Proterozoic (unclassified)			Biotite gneiss with intercalation of amphibolite, quartzite, calcareous quartzite, garnetiferous mica schist, carbonate rock and sillimanite, kyanite bearing garnetiferous mica schist.	
			Hunli	Mainly chlorite schist and quartz chlorite schist with inter bands of green quartzite, carbon phyllite and carbon rock.	
	Lohit Thrust				
	Mesozoic (Cretaceous) Proterozoic (unclassified)		Yang Sang Chu /Tidding	Grey slate with marble bands. Graphite schist and calcschist, occasionally garnetiferous and highly puckered. Staurolite – garnet graphitic schist. Kyanite – sillimanite – garnet graphite schist.	Dyke and sills of serpentine. Green chlorite – quartz phyllite, actinolite schist (metavolcanic, crystalline limestone, graphite, phyllite, granodiorite.
	Tidding suture				
	Palaeo-proterozoic	**Sela**			Mylonitic augen gneisses with amphibolite boudins graphitic schists with marble bands and quartzite, phyllonite, platy mylonite
	Thrust				
	Palaeo-proterozoic	**Bomdila**	Tenga		Biotite Granite gneisses Quartzite, basic metavolcanic, limestone
	Paleozoic (Lr. Permian)	**Lower Gondwana**			Quartzite, shale, oligomicticconglomerate, slate, chert and greywacke
	Main Boundary Thrust				
	Cenozoic (Mid Miocene – Pleistocene)	**Siwalik**	Dafla (Lower Siwaliks)		Sandstone, shale clay with plant fossils
	Cenozoic (Pleistocene to Recent)				Alluvium (Riverine deposit)

4.6 SEISMO-TECTONICS

The North Eastern Region of India and its environment are both tectonically as well as seismically very dynamic and active. This region has been a source of two of the greatest earthquakes in the world with magnitude greater than 8.5, besides which, several earthquakes of magnitude 7.0 and more occurred in the region. Some of the modern day destructive earthquakes that have occurred in this region are of 1869 (M-7.5), 1875, 1897 (M=8.7), 1918 (M=7.6), 1930 (M=7.1), 1943 (M=7.2), 1950 (M=8.7), 1957 (M= 7.2), 1984 (M=5.5), 1988 (M= 7.3) and 1997 (M=5.3). On the basis of past recorded earthquakes, various scientists have predicted a due for high magnitude earthquake from this region (M>7.0). Whatever may be the time and place for such predicted high magnitude earthquake, yet, intermittent release of energy through micro to macro earthquake from this region are taking place throughout the year.

4.6.1 Tectono-Stratigraphic Set up

Regional tectonics and seismic history of the North Eastern Region is highly significant. It constitutes active, unparallel relief, complex geological set up and anomalous crustal structure, which are attributed to the direct collision between Indian plate (Himalaya) and China / Tibet plate in the north and Indo- Burma subduction plate tectonics in the south east. This continent collision and subduction tectonics has developed juxtaposition of three tectonic blocks, viz N.E. projection of Indian shield with Himalayan thrust front, Eastern syntaxis of Mishmi block and the thrust imbricated Indo-Burmese block as well as the intervening Brahmaputra and Surma Valley.

In the Himalayan belt, a few well defined techno geologic domains extend over a distance of 2500 km from Nanga Parbat in the west to Namcha-Barwa in the east. In the north of Arunachal Himalaya, the southern margin of Eurasian plate is marked by Indus Tsangpo Suture Zone (ITZ). The 15 to 20 km wide Tsangpo ophiolite melange occurs along the Tsangpo river course and extends beyond the Siang fracture and the serpentinites of Mishmi block occurring in association with actinolite tremolite schists as well as crystalline limestone. The diorite-granodiorite complex of Mishmi block is thrusted over the frontal metamorphics, consisting of high to low grade metamorphic rocks with serpentinites along the NW Lohit thrust. The metamorphics in turn over ride the Neogene folded rocks of the Burmese arc by the Mishmi thrust in Noa Dihing Valley.

The highest axial zone of Himalaya is occupied by the Proterozoic crystalline rocks delimited to the south by the Main Central Thrust (MCT). The Neogene granites are common along the contact of the crystallines and the Tethyan sediments. The well-defined Lesser Himalayan belt between MCT and MBT, in all probability, may represent the tectonised northern extension of the Indian shield with both fresh water and marine sediments and ortho-quartzite dolomite sequence. South of the MBT, all along the foot hills, occur the folded and thrusted belt of Upper Tertiary molassic Siwalik sediments with slices of Gondwana and Eocene rocks at some places. South of the Siwalik belt is the Brahmaputra alluvial plain.

The Meghalaya plateau and Mikir hills consisting mostly of Archean gneissic complex and Proterozoic intercratonic sediments of Shillong Group intruded by Upper Proterozoic granite batholith and basic igneous rocks, represents a positive shield element. This block occupies a crucial position between the Himalaya in the north and North West and Burmese arc in the east and south east. The Dauki fault at the southern margin of the plateau separates it from the Sylhet plain of Surma Basin. Cretaceous Tertiary shelf sediments occur along the southern margin of the plateau. The Upper Assam Valley forms a fore deep for the Himalaya and the Burmese arc.

The Naga Patkoi belt is composed of thick sediments of Eocene flysh, coal bearing Barails, uncomfortably overlain by middle and upper Tertiary rocks consisting of sandstone, clay shale and pebble beds. The ultra-basic ophiolites occur along Indo- Burmese border. The belt of schuppen consists of several thrust slices, viz. Haflong thrust, Disang thrust, Margherita thrust, Naga thrust, are some prominent features, which are mostly over thrust with some overlap.

4.6.2 Tectonic Setting

The East West structural trend of the Himalaya has- taken a sharp bend towards North East - North in the Siang Valley, Arunachal Pradesh The available geological information do not indicate physical continuity of the Himalayan rock units across the Siang fracture (Nandy, 1980) into the Mishmi block, rather the north east trending elements of Arunachal Himalaya with its thrust sheets abut against the north-west trending structural grain of the Mishmi block. The MGT and the MBT are the two major crustal discontinuity extending west to east throughout Himalaya, but these do not represent single dislocation plane. The MBT is well exposed all along the southern margin of Arunachal Himalaya up to Siang river, while MCT is yet doubtful about its extension. Thrusting along the MBT is a late event involving the youngest Siwalik rocks of Pliocene to Pleistocene age. Besides these longitudinal thrusts / faults, many oblique to transverse faults lineaments cut across the Himalaya, some of which are regionally extensive and traverse from fore deep to ITZ through Himalaya. Few of these caused noticeable off sets on MBT & MCT in the Siang fracture zone.

The most prominent and significant tectonic feature around the project site are apparently parallel NW trending Mishmi thrust and Lohit Thrust. This tectonic block over rides the NW and SE dipping thrust packets of Himalaya and Burmese arc, respectively. The northern boundary of this block is Po Chu Fault. The frontal Mishmi thrust in this zone show late Neogene thrusting over the Upper Assam alluvial plain while recent seismic activity indicates predominant right lateral shear.

Amongst the N-S trending fault, Bame fault has affected other tectonic features in Arunachal Himalaya. Bame fault is connected with the Eastern syntaxis and appears to be related to the refolding of rocks due to collision of Burmese plate with the Indian plate during Post Lower Eocene time. The Great Assam Earthquake of 1950 (M=8.7), originating from this domain, illustrates similar right lateral sense of displacement (Ben-Menahem *et. al.,* 1974). The southern corner of this domain is at present most active where ENE thrust sheets of Burmese arc intersects the NW Mishmi and Lohit thrust.

In addition to the above tectonic lineaments of Arunachal Pradesh, other regionally extended prominent tectonic features of the region are:

a) Dauki fault in the south of Shillong plateau separating Shillong massif from the Surma basin of Bangladesh.
b) NE trending Sylhet fault extending from Bangladesh and merging with Haflong Disang fault.
c) N-S trending Jamuna fault demarcating western boundary of Shillong plateau from the Rajmahal gap.
d) Hidden, conjugate Brahmaputra lineament.
e) N-S trending Chidrang, Oudhnai, Krishnai, Kulsi, Kopili fault.

4.6.3 Seismicity of the Region

Tile study of distribution of all available earthquake epicenters of the region shows that the dispersion is not uniform in space. However, close view reveals that some of the epicenters do not follow major lineaments in true sense. But considering cut off magnitude and accuracy of data acquisition, some correlation can be made with probable source. In a very generalized way epicenter clustering can be visualized around (1) Western part of Shillong Plateau, (2) Central Assam & Western Arunachal Pradesh, (3) Indo Burma Border, and (4) North Eastern part of Arunachal Pradesh. The Upper Assam Valley area shows less epicenter distribution, which was designated as Assam Gap area by Khattri (1987). Further, in this gap area only a few small magnitudes of earthquakes have generated. But it is established that this area is in fact a seismic and not a seismic gap area.

Dibang basin falls in Seismic Zone-V as per Seismic zoning map of India.

The epicenter map considering ISC data source and 84 reliable shallow events of M > or = 4.9 for a period of 1963-84 along with recorded events (M>or = 7.0) of pre 1963, when superimposed on a tectonic map revealed the following.

a) In the north of Suture Zone only a few seismic events are located.
b) Seismic events are mostly located between MBT & MCT in the lesser Himalaya domain.
c) Earthquakes occurring between MBT & MCT are evenly distributed along the Himalayan front and tend to concentrate in areas traversed by fractures/ faults across the strike of the Himalaya.

d) The Upper Assam Valley in between the Himalayan front and the belt of Schuppen is largely aseismic up to the Mishmi thrust.
e) The Mikir Hills & Meghalaya Massif has witnessed a few moderate events.
f) The Sylhet plains, south of Dauki fault and the Mishmi block are more active relative to their immediate surroundings.
g) The Assam earthquakes (M> or = 7.0) of 1897, 1930 (Dhubri) and 1943 (Kopili) are all located south of the Himalayan thrust front.
h) The Great Assam earthquake of 1950 (M=8.7) located within Mishmi tectonic block that has been caused by the displacement along an inclined fault lying across the Assam axial belt trending NE-SW direction (Ray, 1953).

4.7 SOILS

Soil map of Dibang basin has been produced using soil maps collected from National Bureau of Soil Survey & Land Use Planning (NBSS & LUP), Nagpur. The soil map thus prepared has been shown as **Figure 4.6**. Area distribution of various soil units has been shown in **Table 4.3**. Predominant soil type is Lithic Udorthents (31.74%) which is found at middle slopes characterized by shallow, excessively drained, loamy-skeletal soils on very steeply sloping hill summit having loamy surface with very severe erosion hazard. Second predominant soil type (23.90%) is found near the ridge slopes and is characterized by Rocky Mountains covered with perpetual snow and glaciers soil type. Valley floor is comprised of Entic Haplumbrepts (9.56%) and Lithic Udorthents characterized by deep to shallow, somewhat excessively drained, loamy-skeletal soils on moderately steeply to very steeply sloping summits having loamy surface with severe erosion hazard. Flood plain is comprised of Coarse-Silty Aeric Fluvaquents (5.28%) characterized by deep, imperfectly drained, coarse-silty soils on very gently sloping active flood plain having loamy, surface with severe erosion and severe flooding hazards. The river and river bed in flood plain is comprised by Coated, Typic Udipsam (2.08%) characterized by moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards.

Table 4.3: Description and Area under different Soil Units in Dibang Basin

Soil Unit	Type	Area (sq km)	Area (%)
1	**Loamy-skeletal, Lithic Udorthents** Shallow, excessively drained, loamy-skeletal soils on very steeply sloping hill summit having loamy surface with very severe erosion hazard and moderate stoniness; *associated with*: **Loamy-skeletal, Typic Udorthents** Moderately deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slopes with severe erosion hazard and moderate stoniness	4422.06	31.74
2	**Loamy-skeletal, Entic Haplumbrepts** Deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping summits having loamy surface with severe erosion hazard and moderate stoniness; *associated with*: **Sandy-skeletal, Typic Udorthents** Moderately shallow, excessively drained, sandy-skeletal soils on steeply sloping summits with very severe erosion hazard and slight stoniness.	1332.30	9.56
3	**Loamy-skeletal, Lithic Udorthents** Shallow, excessively drained, loamy-skeletal soils on steeply sloping summits having loamy surface with severe erosion hazard and slight stoniness; *associated with*: **Loamy-skeletal, Dystric Eutrochrepts** Moderately deep. Somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slopes and slight stoniness	930.74	6.68
4	**Loamy-skeletal, Lithic Udorthents** Shallow, excessively drained, loamy-skeletal soils on very steeply sloping summits having loamy surface with severe erosion hazard and strong stoniness; *associated with*:	683.94	4.91

Soil Unit	Type	Area (sq km)	Area (%)
	Sandy-skeletal Typic Udorthents Moderately deep, somewhat excessively drained, sandy-skeletal soils with very severe erosion hazard and moderate stoniness		
7	**Fine Typic Palehumults** Very deep, somewhat excessively drained, fine soils on moderately steeply sloping side slope of hills having loamy surface with moderate erosion hazard; *associated with*: **Fine Typic Haplumbrepts** Moderately shallow, excessively drained, clayey soils on steeply sloping side slope of hills with severe erosion hazard	148.95	1.07
9	**Fine, Typic Kanhaplohumults** Deep, well drained, fine soils on moderately side slope of hills having clayey surface with moderate erosion hazard; *associated with*: **Fine-loamy, Pachic Haplumbrepts** Very deep, well drained, fine-loamy soils with moderate erosion hazard	297.74	2.14
10	**Fine-loamy, Umbric Dystrochrepts** Very deep, Somewhat excessively drained, fine loamy soils on moderately steeply sloping side slope of hill having loamy surface with moderate erosion hazard and slight stoniness; *associated with*: **Fine-loamy, pachic Haplumbrepts** Very deep, well drained, fine loamy soils with moderate erosion hazard	110.62	0.79
11	**Fine loamy Pachic Haplumbrepts** Very deep, well drained, fine-loamy, soils on moderately sloping side slope of hills having loamy surface with moderate erosion hazard and slight stoniness; *associated with*: **Fine, Typic Palehumults** Very deep, well drained, fine soils with moderate erosion hazard	464.71	3.34
12	**Fine Typic Kandihumults** Very deep, well drained, fine soils on moderately steeply sloping side slope of hills having clayey surface with moderate erosion hazard; *associated with*:; **Fine Pachic Haplumbrepts** Deep , somewhat excessively drained, fine soils with erosion hazard	1.24	0.01
36	**Loamy-skeletal, Typic Udorthent** Moderately shallow, well drained, loamy-skeletal soils on very gently sloping upper piedmonts having loamy surface with severe erosion and slight flooding hazard; *associated with*: **Coarse-loamy, Entic Haplumbrepts** Moderately deep, well drained, coarse-loamy soils with moderate erosion hazard and slight stoniness	128.90	0.93
37	**Coarse-loamy, Umbric Dystrochrepts** Very deep, well drained, coarse-loamy soils on very gently sloping upper piedmonts having loamy surface with moderate erosion hazard and slight stoniness; *associated with*: **Coarse-loamy, Dystric Eutrochrepts** Deep well drained, coarse-loamy soils with severe erosion and slight flooding hazards	367.06	2.63
40	**Fine-loamy, Typic Dystrocrepts** Very deep, well drained, fine-loamy soils on very gently sloping plain having loamy surface with moderate erosion hazard; *associated with:* **Fine-loamy Fluventic Dystrochrepts** Very deep, moderately well drained, fine-loamy soils with moderate erosion and slight flooding hazard	118.20	0.85
41	**Coarse-loamy, Aeric Haplaguents** Very deep, imperfectly drained, coarse-loamy soils on level to nearly level plain having loamy surface with slight erosion and moderate flooding hazards; *associated with*: **Fine-silty Typic Haplaguents** Very deep, imperfectly drained, fine-silty soils with slight erosion and moderate flooding hazards	548.37	3.94
43	**Coarse-loamy, Typic Udifluven** Deep, well drained, coarse-loamy soils on very gently sloping active flood plain having sandy surface with very severe erosion and very severe flooding hazards; *associated with:* **Coated Aquic Udipsam** Moderately deep, somewhat excessively drained, sandy soils with moderate erosion and severe flooding hazards	23.64	0.17

Soil Unit	Type	Area (sq km)	Area (%)
44	**Coarse-Silty Aeric Fluvaquents** Deep, imperfectly drained, coarse-silty soils on very gently sloping active flood plain having loamy, surface with severe erosion and severe flooding hazards; *associated with*: **Coarse-loamy fluventic-Dystrochrepts** Very deep, moderately we;; drained, coarse-loamy soils with moderate erosion and flooding hazards	735.30	5.28
45	**Coated, Typic Udipsam** Moderately shallow, somewhat excessively drained, sandy soils on very gently sloping bar lands having sandy surface with very severe erosion and flooding hazards	289.58	2.08
46	Rocky mountains covered with perpetual snow and glaciers	3329.74	23.90
	Total	**13933.09**	**100.00**

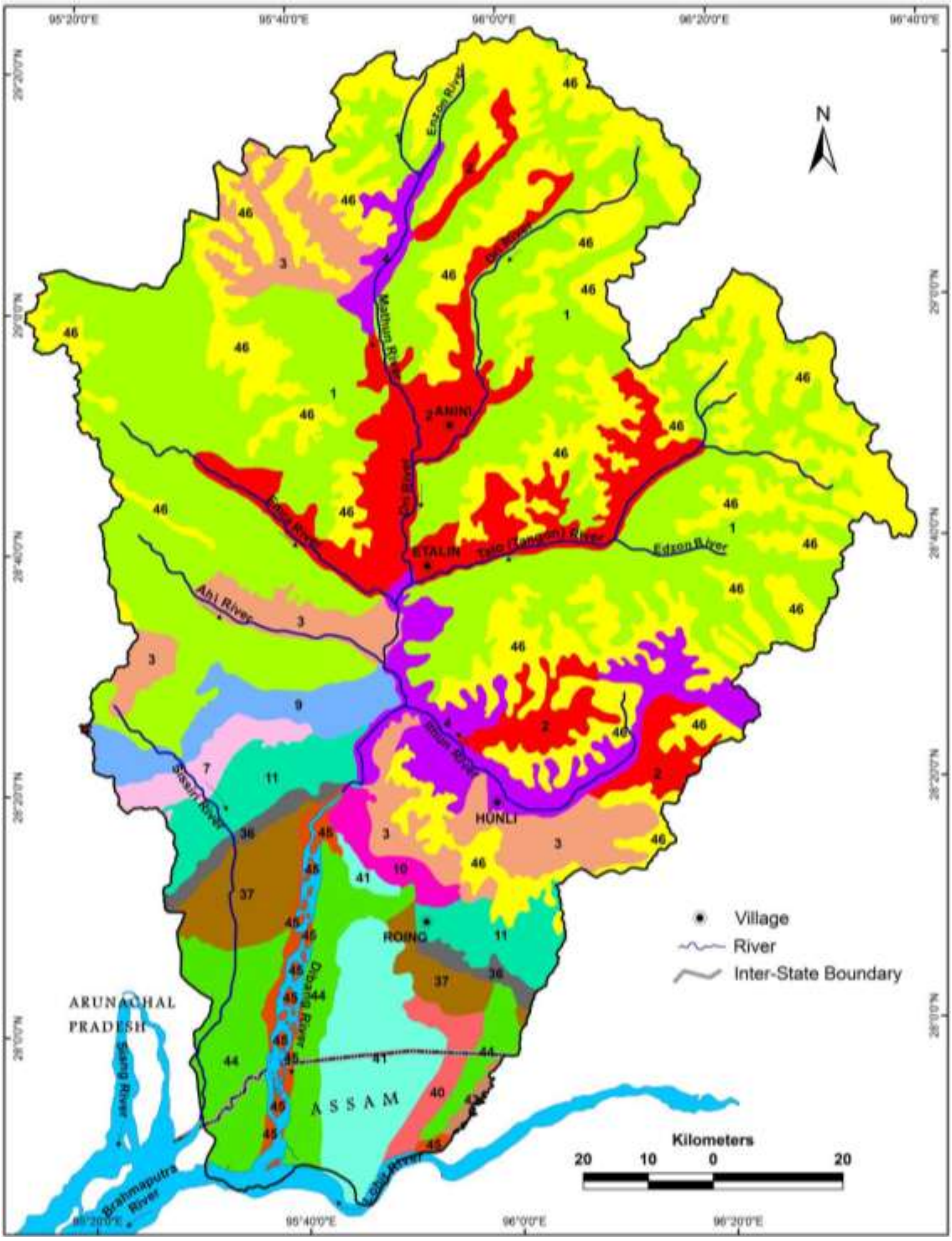


Figure 4.6: Soil Map of Dibang Basin (refer Table 4.3 for Soil Legend)

CHAPTER-5
HYDRO-METEOROLOGY

5.1 METEOROLOGY

Two distinct climatic conditions prevail over the entire Dibang Catchment. The upper reach starts from the Indo-Tibet border up to Mayudiya Hill Range and the lower reach starts from Mayudiya Hill range to the confluence of Lohit. In the upper catchment, rainfall is comparatively less and the region is very cool during winter and comfortable during summer. The lower part maintains tropical climate. Rainfall is very high and the climate remains very humid.

5.1.1 Precipitation Characteristics

Annual rainfall in the Lower Dibang Valley district varies from 3500 mm to 5000 mm. The normal annual rainfall in Roing area is 3990 mm. Most of the rainfall is received during the monsoon period (June to September). Heavy rainfall is received during summer and occasional rainfall during winter and Pre-monsoon period. January and February are the driest months. The rainfall received during summer is under the spell of South - West monsoon. The onset of South-West monsoon occurs by the end of May or the first week of June and withdraws by late September or early October.

The Dibang Valley district falls under heavy rainfall belt, which varies from 3000 mm to 5000 mm. In 2004, the district HQ Anini recorded average annual rainfall of 3281.33 mm. Generally, the monsoon starts from March and continues up to last part of September, but winter rains are not infrequent. However, period from January to February may be considered as pre-monsoon period and October to December as post-monsoon period.

The rainfall in the basin is mainly influenced by the mountain system and occurs due to the Southwest monsoon, which sets in by the second week of May and continues upto the middle of October. On the basis of the available data, average rainfall in the basin has been estimated to be 4405 mm. However, the major portion of the rainfall occurs during the period from June to August.

The status of rain gauge stations in Dibang basin and rainfall stations established by NHPC is given in **Table 5.1.** The average monthly rainfall data from the year 1998 to 2001 at various stations in Dibang basin is given in **Table 5.2**. The average annual rainfall data at various stations in Dibang basin for different years is given in **Table 5.3**. In addition to that, arithmatic averages of annual rainfall at stations in the Dibang Valley and Lower Dibang Valley districts from the year 2009 to 2013 are given in **Table 5.4**.

In addition, the rainfall scenario of Dibang basin has been studied and analyzed using TRMM data which is shown in **Figure 5.1**. The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to measure rainfall for weather and climate research. TRMM is designed to measure tropical precipitation and its variation from a low-inclination orbit combining a suite of sensors to overcome many of the limitations of remote sensors previously used for such measurements from space. TRMM is a comprehensive and systematic program designed to increase the extent and accuracy of tropical rainfall measurement. The TRMM science program consists of a broad research effort which includes development of cloud models, rain retrieval algorithms for the space sensors, use of TRMM measurements with other satellite data to improve sampling, a surface-based verification system, and a TRMM science data and information system (TSDIS).

The average annual rainfall for the period 1998-2009 is available for the tropic region in Geotiff format which gives a fairly good assessment of hypsometric variation in rainfall in Himalayan region and same has been presented as **Figure 5.1**, which shows that in Dibang basin area, rainfall varies from < 500 mm per year in most upstream catchment to > 4000 mm per year in most downstream reaches. This rainfall data shall be assessed for comparative estimation of yields during environment flow assessment.

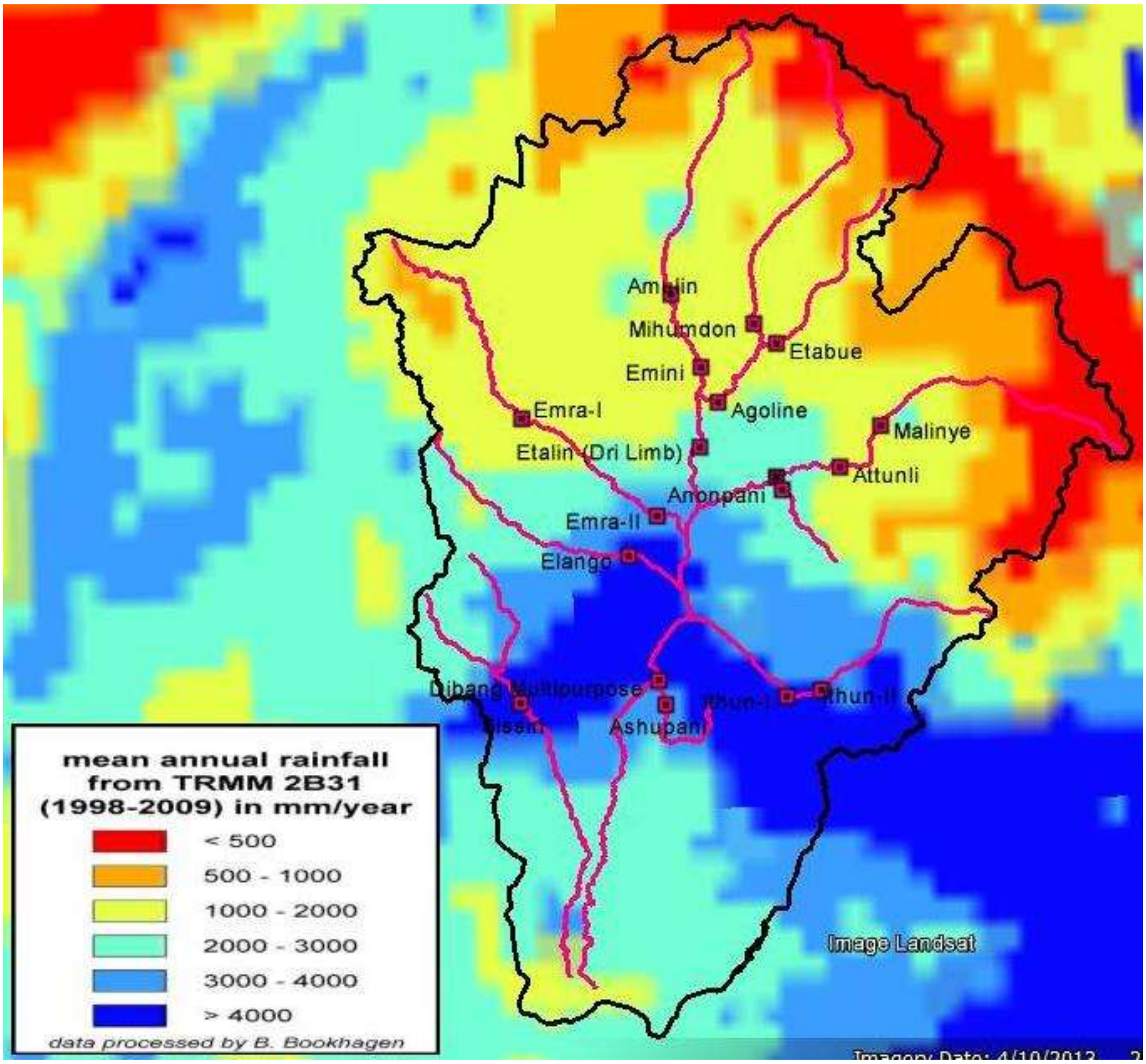


Figure 5.1: Rainfall Scenario of Dibang Basin

5.1.2 Precipitation Data Network

Brahmaputra Board has installed twenty rain-gauge stations in the entire Dibang basin, out of which three stations have Self Recording Rain-gauge in addition to the ordinary type. Although a few stations have data w.e.f. 1985-86, most of the stations have data only from 1997 onwards. NHPC has installed ordinary/SRRG rain-gauge stations in Dibang basin. One ordinary and one SRRG station has been installed at Munli village near Dibang dam site and installation procedure of more rain-gauge stations in Dibang basin has also been undertaken. The rainfall data availability status is given in **Table 5.1** and the available rainfall data is given in **Tables 5.2** to **5.4**.

Table 5.1: Status of Precipitation Data

S. No.	Type of Data	Name of Station	Data available in NHPC	Source
1	Daily Rainfall	Ahralin	Jun 98 to May 2003	Brahmaputra Board
2	Daily Rainfall	Jiagaon	Aug 85 to Sep 87, Jan 89 to Dec 90, July 92 to Aug 93, Jan 94 to Dec 01, Apr 02 to Aug 02	Brahmaputra Board
3	Daily Rainfall	Elopa	Jun 97 to Jan 01, Mar, Apr, Aug to Dec 01, Apr 02 to Aug 02	Brahmaputra Board

S. No.	Type of Data	Name of Station	Data available in NHPC	Source
4	Daily Rainfall	Ipingu	Apr 98 to Feb 01, Aug 01 to Dec 01, Jan 03 to May 03	Brahmaputra Board
5	Daily Rainfall	Anelih	Aug 97 to Aug 02	Brahmaputra Board
6	Daily Rainfall	Dunli	Sept 97 to Aug 03	Brahmaputra Board
7	Daily Rainfall	Mipidam	Apr 98 to July 01	Brahmaputra Board
8	Daily Rainfall	Kronli	Oct 85 to Dec 85	Brahmaputra Board
9	Daily Rainfall	Amarpur	Nil	Brahmaputra Board
10	Daily Rainfall	Anini	1979 to 1985, Feb 92 to Jun 95, 1999 to Aug 2003	Brahmaputra Board
11	Daily Rainfall	Agoline	Sept 85 to Apr 86	Brahmaputra Board
12	Daily Rainfall	Tangon	Sept 85 to Apr 86	Brahmaputra Board
13	Daily Rainfall	Epipani	Oct 85 to Oct 87, Jan 88 to Feb 88, Aug 88 to Jan 89, Sept 89 to Jun 90, Jan 91, Mar 94 to Nov 94, Jan 95 to Nov 95, Jan, Feb, May to Aug, Dec 96	Brahmaputra Board
14	Daily Rainfall	Chapakhowa	Sept 85 to Jul 86, Feb 87 to Nov 87, Jan 89 to Aug 90, Jan 91 to July 96	Brahmaputra Board
15	Daily Rainfall	Etalin	Aug 97 to May 03	Brahmaputra Board
16	Daily Rainfall	Roing	1976 to 1981, 1985, Nov 84 to Aug 96, Jan 97 to Jun 00, Oct 00 to Mar 01, Aug to Dec 01	Brahmaputra Board
17	Daily Rainfall	Hunli	Sep 98 to Jul 00, Nov 00 to Dec 00, Feb, Mar, Jun to Sep, Nov, Dec 01	Brahmaputra Board
18	Daily Rainfall	Christian Basti	Nil	Brahmaputra Board
19	Daily Rainfall	Nizamghat	Nil	Brahmaputra Board
20	Daily Rainfall	Munli	Jan-May 05	NHPC
21	SRRG	Hunli	Nil	Brahmaputra Board
22	SRRG	Roing	Nil	Brahmaputra Board
23	SRRG	Desali	Nil	Brahmaputra Board
24	SRRG	Munli	Mar 2005 to May 2005	NHPC

Table 5.2: Average Monthly Rainfall (mm) at different locations in Dibang Basin from 1998-2001

Month	Dunli	Anelih	Elopa	Etalin	Mipidon	Ipingo	Average
January	157.03	113.28	46.43	107.60	19.67	119.40	**93.90**
February	164.25	161.10	78.53	243.13	183.40	179.93	**168.39**
March	205.95	203.23	201.36	374.88	163.40	122.20	**211.84**
April	406.18	401.08	385.31	609.85	411.47	419.60	**438.92**
May	489.98	434.03	633.46	479.96	363.53	447.60	**474.76**
June	855.82	843.90	850.25	779.45	757.33	1535.33	**937.01**
July	791.00	822.75	1014.99	806.85	764.65	901.40	**850.27**
August	707.00	868.89	681.29	789.15	737.02	889.93	**778.88**
September	311.11	372.81	556.10	437.75	294.20	337.54	**384.92**
October	260.28	313.79	264.40	252.23	259.90	310.33	**276.82**
November	64.53	57.31	30.13	64.98	54.80	56.80	**54.76**
December	34.88	22.56	27.80	32.83	13.90	29.30	**26.88**
Total	**4448.01**	**4614.73**	**4770.05**	**4978.66**	**4023.27**	**5349.36**	**4697.35**

Table 5.3: Average Annual Rainfall (mm) at different locations in Dibang Basin

Rain Gauge Station	Elevation (m)	Avg. annual rainfall (mm)	Avg. Annual Rainfall over elevation range			Source
			Elevation Range (m)	Mean Elevation (m)	Avg. Annual Rainfall (mm)	
Roing	400	4258	400-800	600	4746	Daily Data -1985-09 (Etalin DPR)
Epipani	440	5366				Daily Data -1985-92, 94-96, 99 (Etalin DPR)
Elopa	460	4770				1997-02 (Etalin DPR)
Annelih	700	4362				1997-02 (Etalin DPR)

Rain Gauge Station	Elevation (m)	Avg. annual rainfall (mm)	Avg. Annual Rainfall over elevation range			Source
			Elevation Range (m)	Mean Elevation (m)	Avg. Annual Rainfall (mm)	
Etalin	600	4978				1997-01 (Etalin DPR)
Hunli	1200	3690	800-1200	1000	3690	Daily Data -1986-96 (Etalin DPR)
Dunli	1300	4119	1200-1600	1400	4119	1997-02 (Etalin DPR)
Mipidon	2000	4023	1600-2000	1800	3835	1998-01 (Etalin DPR)
Ahralin	2000	3645				Daily Data -1997-05 (Etalin DPR)
Anini	2440	2576	2000-2400	2200	3205	Daily Data -1993-95, 98-04, Monthly Data-2005-09 (Etalin DPR)
Ipingo	2950	5349				1998-01 (Etalin DPR)

Table 5.4: Average Annual Rainfall (mm) at different locations in Dibang Basin from 2009-2013

Month	2009		2010		2011		2012		2013	
	D.V.	L.D.V.	D.V.	L.D.V.	D.V.	L.D.V.	D.V.	L.D.V.	D.V.	L.D.V.
January					0		113	0	57	30.9
February	114.3					0	181	58	81	26
March	82			0	0		459	98	185	149.3
April	289.5				0	0	429		233	241
May	80				0		214	311.6	471	450.4
June	535.5		0				651	1160.2	127	634.7
July	591						264	1251.3	123	
August							202	430.5	64	507.9
September							383	1794.8	293	387.4
October				56.1			113		295	313.9
November	40.5			0			3.3	4.1	22	8.7
December			0		0	0	90		8.5	6.6

D.V.: Dibang Valley District, L.D.V.: Lower Dibang Valley District

Blank Spaces show non-availability of Data

Source: Arithmetic averages of Rainfall of Stations under the Districts, IMD

5.1.3 Temperature

The climate of the Dibang basin is mainly influenced by orography. It is sub-tropical, wet and highly humid in the foothills and cold in higher elevations. The temperature falls below freezing point during extremely cold period.

As per Brahmaputra Board, the meteorological observatory center in the Dibang basin is located in Hunli and Elopa. Temperature and Relative humidity data are collected here since 1998. The monthly maximum and minimum temperature and humidity recorded since September 1998 to June 2000 are given in **Tables 5.5 and 5.6**.

Table 5.5: Observed Temperature and Humidity Data at Hunli

Month/ Year	Maximum Temperature (°C)	Minimum Temperature (°C)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)
September 98	26	10	92	81
October 98	24	6	91	80
November 98	19	4	90	76
December 98	17	3	88	68
January 99	16	2	88	66
February 99	14	2	89	75
March 99	18	7	89	75
April 99	19	9	89	75
May 99	25	12	91	89
June 99	27	16	91	81
July 99	30	17	92	74

Month/ Year	Maximum Temperature (˚C)	Minimum Temperature (˚C)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)
August 99	29	16	92	82
September 99	27	11	91	61
October 99	22	11	89	64
November 99	16	8	88	52
December 99	12	7	87	71
January 00	14	7	88	71
February 00	19	8	89	49
March 00	20	12	90	59
April 00	33	14	92	34
May 00	30	19	92	82
June 00	31	18	92	78

Table 5.6: Observed Temperature and Humidity Data at Elopa

Month/ Year	Maximum Temperature (˚C)	Minimum Temperature (˚C)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)
June 98			92	76
July 98			92	84
August 98			92	92
September 98			92	85
October 98			93	83
November 98			92	76
December 98			92	65
January 99			91	71
February 99	30	19	92	41
March 99	37	17	92	42
April 99	32	17	91	44
May 99	39	20	92	49
June 99	39	22	92	52
July 99	39	20	92	52
August 99	37	22	92	70
September 99	37	23	92	70
October 99	36	20	92	61
November 99	32	17	92	53
December 99	28	13	89	19
January 00	26	13	92	20
February 00	28	14	89	34
March 00	35	16	85	51
April 00	35	16	85	51
May 00	37	21	92	53
June 00	39	23	92	49
July 00	31	18	92	48

NHPC has established Automatic Weather Station (AWS) and Maximum Minimum temperature recording stations in Dibang basin. One AWS/Maximum Minimum temperature recording station has been established at Munli w.e.f. March 2005.

In addition to above, Maximum and Minimum temperature data is available at Anini near confluence of Mathun River with Dri River, for the period Dec 2000 to Aug 2003. The maximum temperature and minimum temperature observed at this station is 41˚C and -3˚C respectively. The monthly temperature recorded since Jan 2001 to Aug 2003 is given in the **Table 5.7.**

Table 5.7: Maximum & Minimum Temperature (˚C) at Anini

Month/Year	2001		2002		2003	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
January	16	-2	16	-3	18	0
February	20	-1	21	-2	20	-1
March	21	6	25	2	23	3
April	26	7	28	7	22	9
May	31	11	32	10	26	10
June	32	9	34	16	40	14

Month/Year	2001		2002		2003	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
July	33	17	35	15	41	14
August	37	10	33	16	32	18
September	29	18	26	12		
October	27	10	25	6		
November	22	5	21	1		
December	18	0				

5.1.4 Humidity

The relative humidity in the study area is high throughout the year. However, winter months are slightly less humid. The relative humidity ranges from a minimum of 19 % to a maximum of 92%.

5.1.5 Cloud Cover

Clear or lightly clouded sky is common during the post-monsoon months. During winter season, the morning sky often remains overcast mainly due to lifted fog which gets cleared as the day advances. In the pre-monsoon months sky is generally moderately clouded. Heavily clouded to overcast sky prevails in the monsoon months, when hills and ridges are enveloped in cloud.

5.1.6 Wind

Winds are generally light during the south-west monsoon season. In rest of the year, winds are moderate, becoming strong at times in association with thunder storms. Strong winds down the valleys are experienced. The direction of wind is highly influenced by the local conditions.

5.1.7 Special Weather Phenomena

Thunder storms mainly occur during the months from February to September. The frequency is maximum in April and minimum in the month of December. During the pre-monsoon months, thunder storms are often violent and from December to April they are occasionally accompanied by hail. Fog is frequent in the valleys during the winter months.

5.2 WATER DISCHARGE AND AVAILABILITY

Most of the rainfall and G&D data of Dibang basin has been collected by Brahmaputra Board. Data for Munli dam has been collected by NHPC, while the rainfall data at Roing is sourced locally. Rain-gauge data intermittently available for Chapakhowa, Epipani, Aharline, Anini, Hunli, Roing and Jiagaon while G & D data is intermittently available for Elopa, Munli, Ashupani and Christian Basti.

As discussed above, there are 18 identified projects in Dibang basin and they are at different stages of survey and investigation. Using the above data, projects proponents have developed long term discharge data for their projects as part of water availability studies. So far Central Water Commission (CWC) has approved water availability series for four projects (Etalin, Attunli, Sissiri HEPs and Dibang MPP) and same data has been procured for modeling exercise. For remaining 12 project locations, series have been taken from PFRs. For rest 2 projects no data is available as they are neither allotted to anyone not any PFR has been prepared for them so far by any agency.

From the long term flow series, 90% dependable year for different projects have been derived as the year with over 90% dependability and shall be used in the modeling exercise as input flow data. Discharge data for all these projects for 90% dependable year has been shown in **Tables 5.8 to 5.11**. For Anon Pani and Ithi Pani Projects, 75% dependable year series shall be used as projects are designed for same being small projects of less than 25 MW.

Table 5.8: 90% Dependable Year Discharge Data for Etalin, Attunli HEPs and Dibang Multipurpose Project

		Etalin HEP		Attunli HEP	Dibang Multipurpose Project
		Dri Limb	Talo (Tangon) Limb	Talo river	Dibang river
		CA: 3685 sq km	CA: 2358 sq km	CA: 2573 sq km	CA: 11276 sq km
		2001-02	2001-02	2001-02	2001-02
		Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec
Jun	I	376.90	216.48	240.07	1337.50
	II	399.70	229.58	254.59	1418.42
	III	348.20	199.99	221.78	1235.61
Jul	I	375.70	215.79	239.29	1333.20
	II	364.90	209.59	232.42	1294.91
	III	551.40	316.72	351.22	1956.79
Aug	I	454.60	261.15	289.60	1613.49
	II	452.20	259.74	288.04	1604.78
	III	531.30	305.20	338.45	1885.62
Sep	I	464.70	266.93	296.01	1649.19
	II	353.60	203.13	225.26	1254.99
	III	256.10	147.10	163.13	908.86
Oct	I	327.00	187.83	208.29	1160.45
	II	234.40	134.65	149.32	831.92
	III	144.70	83.11	92.17	513.51
Nov	I	200.80	115.35	127.92	712.68
	II	208.10	119.52	132.54	738.45
	III	186.30	107.02	118.68	661.22
Dec	I	173.30	99.58	110.42	615.21
	II	185.80	106.73	118.36	659.43
	III	168.50	96.76	107.31	597.84
Jan	I	153.60	88.24	97.85	545.15
	II	137.40	78.92	87.51	487.57
	III	173.20	99.51	110.36	614.83
Feb	I	131.30	75.43	83.65	466.03
	II	142.80	82.04	90.97	506.84
	III	140.10	80.47	89.24	497.18
Mar	I	122.60	70.42	78.10	435.10
	II	136.00	78.13	86.64	482.70
	III	173.80	99.86	110.74	616.98
Apr	I	165.10	94.84	105.17	585.96
	II	354.70	203.78	225.98	1259.01
	III	257.60	148.00	164.12	914.39
May	I	212.70	122.16	135.47	754.77
	II	246.20	141.44	156.85	873.87
	III	220.30	126.53	140.31	781.74

Table 5.9: 90% Dependable Year Discharge Data for Amulin, Emini, Mihumdon, Etabue & Agoline projects

		Amulin HEP	Emini HEP	Mihumdon HEP	Etabue HEP	Agoline HEP
		Mathun river	Mathun river	Dri river	Ange Pani	Dri River
		CA: 2175 sq km	CA: 2600 sq km	CA: 968 sq km	CA: 443 sq km	CA: 1550 sq km
		1994-95	1994-95	1994-95	1994-95	1994-95
		Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec
Jun	I	340.56	407.11	151.57	48.56	242.70
	II	399.83	477.96	177.95	57.01	284.94
	III	399.49	477.55	177.80	56.94	284.69
Jul	I	155.53	185.92	69.22	22.17	110.84
	II	150.07	179.40	66.79	21.40	106.95

		Amulin HEP	Emini HEP	Mihumdon HEP	Etabue HEP	Agoline HEP
	III	139.27	166.48	61.98	19.86	99.25
Aug	I	238.48	285.07	106.14	34.00	169.95
	II	300.78	359.55	133.86	42.88	214.35
	III	278.28	332.65	123.85	39.68	198.31
Sep	I	179.14	214.15	79.73	25.54	127.66
	II	101.04	120.79	44.97	14.41	72.01
	III	76.10	90.97	33.87	10.85	54.23
Oct	I	216.08	258.30	96.17	30.81	153.99
	II	177.64	212.35	79.06	25.33	126.60
	III	194.94	233.03	86.76	27.79	138.92
Nov	I	118.34	141.46	52.67	16.87	84.33
	II	114.39	136.74	50.91	16.31	81.52
	III	107.81	128.88	47.98	15.37	76.83
Dec	I	77.53	92.68	34.51	11.05	55.25
	II	78.67	94.04	35.01	11.22	56.06
	III	72.63	86.82	32.32	10.36	51.76
Jan	I	87.64	104.76	39.00	12.50	62.45
	II	87.37	104.44	38.88	12.46	62.26
	III	84.27	100.74	37.50	12.01	60.05
Feb	I	92.04	110.03	40.96	13.12	65.59
	II	91.86	109.81	40.88	13.10	65.46
	III	100.26	119.85	44.62	14.30	71.45
Mar	I	120.68	144.26	53.71	17.21	86.00
	II	113.34	135.49	50.44	16.16	80.77
	III	134.65	160.96	59.93	19.20	95.96
Apr	I	140.69	168.18	62.62	20.06	100.26
	II	219.61	262.52	97.74	31.31	156.50
	III	241.20	288.33	107.35	34.39	171.89
May	I	202.66	242.26	90.19	28.89	144.42
	II	176.13	210.55	78.39	25.11	125.52
	III	235.37	281.36	104.75	33.56	167.73

Table 5.10: 90% Dependable Year Discharge Data for Emra I, Emra II, Ithun I, Ithun II, Ashu Pani projects and 75% Dependable Year Discharge Data for Anon Pani and Ithi Pani Projects

		Emra I	Emra II	Ithun II	Ithun I	Ashu Pani	Anon Pani (75%)	Ithi Pani (75%)
		Emra river	Emra river	Ithun river	Ithun river	Ashu Pani	Anon Pani	Ithi Pani
		CA: 1708 sq km	CA: 1756 sq km	CA: 708 sq km	CA: 841 sq km	CA: 67 sq km	CA: 147 sq km	CA: 235 sq km
		2001-02	2001-02	2001-02	2001-02	1994-95	1999-2000	1994-1995
		Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec	Flow in cumec
Jun	I	179.41	184.45	66.10	86.30	8.64	18.68	26.10
	II	190.44	195.79	70.10	91.50	10.14	21.62	34.90
	III	165.52	170.17	61.00	79.70	10.13	27.81	33.80
Jul	I	178.82	183.85	65.80	86.00	3.95	36.87	35.50
	II	173.60	178.48	64.00	83.60	3.81	15.51	29.20
	III	263.84	271.25	96.60	126.30	3.53	9.78	29.50
Aug	I	217.03	223.13	79.70	104.10	6.05	13.93	24.80
	II	215.84	221.91	79.30	103.60	7.63	17.73	32.10
	III	254.13	261.27	93.10	121.70	7.06	19.88	26.40
Sep	I	221.89	228.13	81.50	106.40	4.54	10.72	24.50
	II	168.15	172.88	62.00	81.00	2.56	10.84	22.10
	III	120.97	124.37	44.90	58.70	1.93	6.36	15.10
Oct	I	155.27	159.63	57.30	74.90	5.48	5.59	34.00
	II	110.49	113.59	41.10	53.70	4.51	5.45	14.20
	III	67.07	68.96	25.40	33.10	4.95	5.43	11.80
Nov	I	97.16	99.89	35.20	46.00	3.00	5.12	8.60
	II	100.67	103.50	36.50	47.70	2.90	4.94	8.40
	III	90.14	92.67	32.70	42.70	2.74	4.81	7.30
Dec	I	83.87	86.23	30.40	39.70	1.97	4.63	6.40

		Emra I	Emra II	Ithun II	Ithun I	Ashu Pani	Anon Pani (75%)	Ithi Pani (75%)
	II	89.89	92.42	32.60	42.60	2.00	4.51	6.20
	III	81.50	83.79	29.50	38.60	1.84	4.31	5.80
Jan	I	74.32	76.41	26.90	35.20	2.22	4.21	6.00
	II	66.47	68.34	24.10	31.50	2.22	4.23	5.90
	III	83.81	86.17	30.40	39.70	2.14	4.26	6.10
Feb	I	63.53	65.32	23.00	30.10	2.33	4.80	6.20
	II	69.10	71.04	25.00	32.70	2.33	4.67	7.00
	III	67.78	69.68	24.60	32.10	2.54	4.68	8.30
Mar	I	59.31	60.98	21.50	28.10	3.06	5.27	8.80
	II	65.80	67.65	23.80	31.20	2.88	5.40	10.60
	III	84.11	86.47	30.50	39.80	3.42	5.73	15.50
Apr	I	79.88	82.13	28.90	37.80	3.57	11.78	17.20
	II	171.64	176.46	62.20	81.20	5.57	20.42	24.50
	III	124.66	128.16	45.20	59.00	6.12	22.19	26.60
May	I	99.97	102.78	37.30	48.70	5.14	17.57	23.30
	II	116.20	119.47	43.20	56.40	4.47	15.96	24.20
	III	103.65	106.56	38.60	50.40	5.97	20.98	21.50

Table 5.11: 90% Dependable Year Discharge Data for Sissiri HE Project

		Sissiri (90%)
		Sissiri
		CA: 610 sq km
		1992-1993
		Flow in cumec
May	I	30.938
	II	37.604
	III	34.238
June	I	42.025
	II	43.183
	III	60.995
July	I	78.993
	II	100.868
	III	44.371
Aug	I	42.072
	II	30.347
	III	36.921
Sept	I	27.407
	II	39.456
	III	37.234
Oct	I	43.935
	II	34.850
	III	32.260
Nov	I	22.292
	II	18.900
	III	16.169
Dec	I	16.204
	II	14.560
	III	14.320
Jan	I	18.819
	II	21.586
	III	15.541
Feb	I	13.935
	II	27.060
	III	32.624
March	I	18.449
	II	18.981
	III	37.037
April	I	27.778
	II	32.824
	III	29.606

CHAPTER-6
TERRESTRIAL ECOLOGY

6.1 LAND USE/ LAND COVER

Arunachal Pradesh is one of the Himalayan biodiversity hot spots and is endowed with rich diversity of terrestrial and aquatic species. The diversity of topographical and climatic condition has favoured the growth of luxuriant forests, which are home to myriad plant and animal species.

The Recorded Forest Area in the state is 51540 sq km which is 61.55% of its geographic area. Reserved Forests, Protected Forests and Unclassified State Forests (USF) constitute 20.46%, 18.49% and 61.05% of the total Recorded Forest area, respectively (**refer Table 6.1**). The Protected Areas constitute 11.68% of the geographic area of the state.

Table 6.1: Area under different forest classes in Arunachal Pradesh

S. No.	Legal Classification	Area (Sq km)	% of Recorded Forest	% of Geographic Area
1	Reserved Forest	9722.69	18.86	11.61
2	Protected Forest	694.30	1.35	0.82
3	Anchal Reserve Forest	329.38	0.64	0.39
4	Village Reserve Forest	300.24	0.58	0.36
5	National Parks	2468.24	4.79	2.94
6	Wildlife Sanctuaries	7059.75	13.70	8.43
7	Unclassified State Forest (USF)	30965.39	60.08	36.90
	Total	**51540.00**	**100.00**	**61.55**

(*Source: Department of Environment & Forests, Government of Arunachal Pradesh*)

Major part of Dibang river basin is comprised of the Dibang river system travesing the Dibang Valley and Lower Dibang Valley districts of Arunachal Pardesh.

6.2 FOREST COVER IN STATE, DIBANG VALLEY & DIBANG VALLEY DISTRICTS

The state of Arunachal Pradesh occupies the largest area (83,743 sq km) in the northeastern region of India. It is uniquely situated in the transition zone between the Himalayan and Indo-Burmese regions (Mani, 1974; Rodgers and Panwar, 1988). According to Indian State of Forest Report (ISFR), 2015 (Forest Survey of India, Dehradun), 80.30% (67,417 sq km) of area is under forest which shows a slight decrease of 73 sq km from forest cover data given in Indian State of Forest Report, 2013 as some of forest cover has degraded and has been included in scrub which shows an increase of 143 sq km from 121 sq km in ISFR, 2013. However the area under non-forest has decreased by 70 sq km.

About one fourth (24.22%) of Very Dense forests of the country exist in this state (FSI, 2015). Major portion of the area in the state is still covered with primary forests. Several forest types and subtypes with characteristic floristic composition occur in Arunachal Pradesh. The forests vegetation comprises a variety of medicinal and other commercially useful plants.

Total forest cover (FSI, 2015) in part of Dibang basin covering only two districts Dibang Valley and Lower Dibang Valley is 9321 sq km (71.54%) as compared to state's average forest cover of 80.30% (**see Table 6.2**).

Total forest cover in Dibang basin comprising only of two districts viz. Lower Dibang Valley and Dibang Valley has decreased very little from according to FSI forest cover data of 2013 to 2015;

slightly by 1 sq km, the area under Moderately Dense forest has decreased by 6 sq km while area under Open forest cover has increased by 5 sq km.

Table 6.2: Area under different forest cover classes as per FSI data of 2013 & 2015) in two districts covering Dibang basin in Arunachal Pradesh

District	Forest Cover (Sq km)					Total Geographic area (Sq km)	Scrub	Non-forest
	Very Dense	Moderately Dense	Open	Total (Sq km)	% of Geographic Area			
Total (2013)	1696	4979	2647	9322	71.55	13029	5	-
Total (2015)	1696	4973	2652	9321	71.54	13029	9	-
STATE	20804	31301	15079	15143	80.30	83743	264	16422

(*Source: Indian State of Forest Report, 2013 & 2015, Forest Survey of India*)

6.2.1 Forest Cover in Dibang Basin

The Dibang basin area delineated in GIS domain covering two districts of Arunachal Pradesh, entire catchment of Sissiri river and basins part in Assam.

Land use/ Land cover map was prepared for the entire basin delineated as described above from the Indian Forest Survey of India Report data of 2013 procured from FSI, Dehradun is given at **Figure 6.1** and area under different classes is given in **Table 6.3.** As seen from the **Table 6.3** and **Figures 6.1** forest constitutes main land use in the basin and account for more than 68% of the entire basin area. Very Dense forests constitute 12.33% while Moderately Dense forests cover 37.06% of the total area. Most of the forest cover in the basin lies in Arunachal Pradesh while most of the non-forest comprising mainly of floodplains of Dibang river lies in Assam part of the basin.

Table 6.3: Area under different land use/ land cover categories in Dibang basin (FSI data, 2013)

S. No.	Land use/ land cover	Area (sq km)	(%)
1	Very Dense Forest	1718.06	12.33
2	Medium Dense Forest	5164.06	37.06
3	Open Forest	2665.94	19.13
4	Scrub	5.38	0.04
5	Non-Forest	4291.21	30.80
6	Water	88.45	0.63
	Total	**13933.09**	**100.00**

Bio-geographically Dibang basin is situated in the Eastern Himalayan province, the richest Bio-geographical province of the Himalayan zone. The entire territory forms a complex hill system with varying elevations ranging from 121m in the foot-hills and gradually ascending to about 5338m, traversed throughout by a number of rivers and rivulets.

6.3 FOREST TYPES

The forests in Dibang basin fall under Eastern Circle with headquarters at Teju whereas the Protected Areas in the basin are under the administrative control of Addl. Principal Chief Conservator Forests (Wildlife & Biodiversity), Itanagar. The two Protected Areas in the basin are Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary. The details of forest types in the basin are primarily based upon Working Plans of the Roing Forest Division and Anini Social Forest Division, Management Plans of Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary and

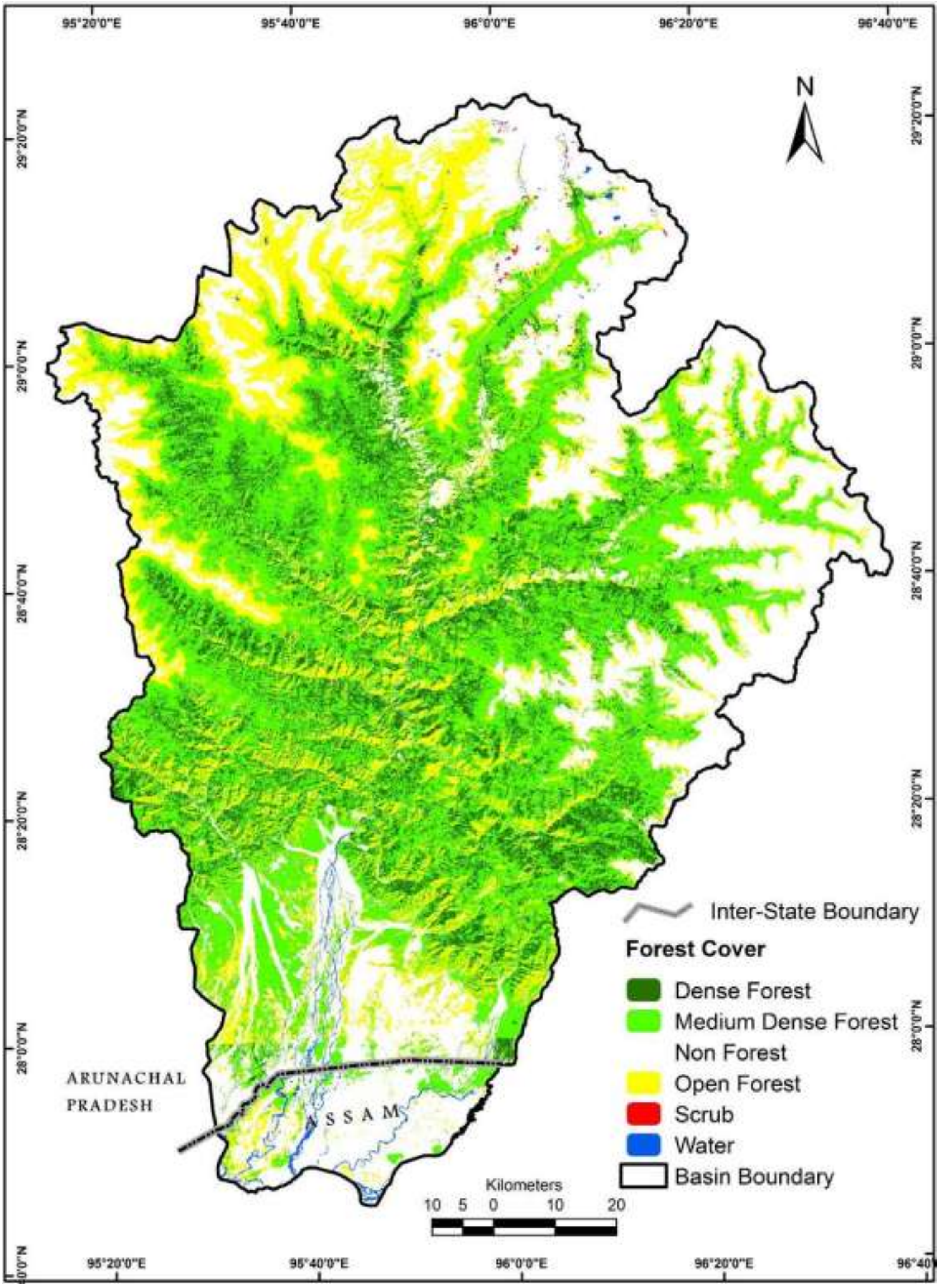


Figure 6.1: Forest cover map of Dibang basin based upon FSI data (2013)

information provided by the Department of Environment and Forests, Government of Arunachal Pradesh. Their distribution in the basin is also described as per Forest Working Plans as well as supplemented with information gathered during field surveys in the area. The major forest types encountered in the area have been described based on the classification of Champion and Seth (1968).

6.3.1 Upper Assam Valley Tropical Evergreen Forest (Tropical Evergreen Forest) (1B/C2)

The species composition is classified into top storey representing tall trees like *Altingia excelsa*, *Castanopsis indica, Duabanga grandiflora* and *Terminalia myriocarpa*. Trees are heavily covered with lichens and climbers and epiphytes of the numerous lianas like *Pericamphylus glaucus, Stephania elegans, Parabaena sagitata* and species of *Bauhinia, Derris, Entada, Gnetum, Hodgsonia, Piper* and *Raphidophora*. The second storey mainly consists of medium to small trees and shrubs viz. *Actiphila excelsa, Ardisia crispa, Bauhinia pupurea, Grewia disperma, Gynocardia odorata, Leea robusta, Michelia doltsopa,* and *Mussaenda roxburghii*. *Salacca secunda* and *Wallichia densiflora* are found on the drier hill slopes, whereas *Angiopteris evecta, Cyathea spinulosa,* and *Pandanus nepalensis* are found along the shaded gorges. *Calamus erectus, Calamus leptospadix* and various other species of similar plants occur along the swampy areas and form extensive thickets. *Arenga pinnata, Caryota obtusa, Livistona jenkinsiana,* and *Phoenix rupicola* are the palms that occur in these forests. The epiphytic flora is very rich, some of the common epiphytes are the species of *Aerides, Cymbidium, Eria* and *Pholidota*.

Along the hills slopes wild species of *Musa* comprising *Musa acuminata, M. balbisiana* and *M. rosacea* is prominent feature of the vegetation.

6.3.2 Eastern sub-montane Semi-evergreen Forest (Tropical Semi-evergreen forest) – (2B/C1b)

These types of forests occur on slopes in the vicinity of dam as well as powerhouse area and also on foothills and river bank. The upper storey consists of deciduous trees as well as evergreen trees. The shrubs, climbers and lianas constitute the rest. Depending on its species contents Tropical Semi-evergreen forests are further divided into two subtypes.

i) Low hills and plains semievergreen forest

In this forest the upper storey is dominated by tall trees like *Altingia excelsa, Bombax ceiba, Canarium strictum, Elaeocarpus rugosus, Phoebe lanceolata* and *Terminalia myriocarpa* followed by small trees and shrubs. The ground flora is dominated by species of *Colocacia, Costus* and *Phrynium*. Among the climbers and lianas *Disocorea alata, Thunbergia coccinea* and *Thunbergia grandiflora* are common. There are number of epiphytic species of orchids like *Dendrobium, Pholidota, Eria*, and *Hoya balaensis* and several species of ferns in these forests.

ii) Riverine semi-evergreen forest

The top storey is dominated by *Bombax ceiba, Bischofia javanica, Canarium strictum, Dalbergia sissoo, Duabanga grandiflora,* and *Lagerstroemia parviflora*. The next storey is represented by the species of *Calamus, Ficus, Meliosma, Murraya* and *Randia*. These species are closely associated with species of *Phragmitis, Saccharum* and *Hedychium*.

6.3.3 East Himalayan moist mixed deciduous forests (Sub tropical Broadleaved Forests) – (3/C3b)

The subtropical broadleaved forests occur between 900 and 1200 m and are basically are of evergreen and dense in nature. The canopy layer consists of *Castanopsis indica*, *Quercus spicata*, *Q. lemellosa*, *Alnus nepalensis*, *Ulmus lancifolia*, *Engelhardtia spicata*, and *Schima khasiana*. The middle storey is comprised mainly of *Schefflera*, *Turpinia*, *Rhus*, *Hydrangea* sp., *Vernonia arborea, Eurya acuminata*, *Symplocos racemosa*, and *Viburnum foetidum*. Shrub and herb layers include number of species of *Ardisia humilis*, *Oxyspora paniculata, Chasalia curviflora, Rubus ellipticus, Lobelia rhynchopetalum, Begonia palmata* and *Potentilla nepalensis*. Lianas are not very frequent but climbers are represented by *Clematis gauriana*, *Senecio densiflorus*, *Crawfurdia speciosa*, *Jasminum officinale* and *Holboelia latifolia*. Epiphytes are found growing luxuriantly and comprised mainly of orchids and ferns.

6.3.4 Assam Sub-tropical Pine Forests – (9/C2)

These forests occur between 1200 and 1800 m, the Pine forest is common in catchment area of Dri and Talo (Tangon) Rivers. The dominant species is *Pinus merkusii*. There is no middle storey. However, the shrub and herb layer is gregarious. The main species in this layer is *Imperata cylindrica*, *Rubus ellipticus*, *Artemisia nilagirica*, *Pteridium aquilinum, Polygonum amplexicaule, Osbeckia stellata,* and *Desmodium laxiflorum*. A few broad-leaved species found associated are *Lyonia ovalifoila*, *Rhododendron arboreum*, *Quercus lemellosa*, *Rhus javanica*, and *Albizia mollis*.

6.3.5 East Himalayan Wet Temperate Forests (Temperate Broadleaved Forests) – (11B/C1)

They are found in elevation of 1800 – 2800 m and are generally dense in nature. These forests are dominated by members of Fagaceae and Lauraceae families. Canopy trees are represented by *Qurecus lamellosa*, *Michelia doltstopa*, *Acer laevigatum*, *Populus ciliata*, *Exbucklandia populnea*, *Carpinus viminea*, *Rhododendron* spp., *Tetracentron sinensis*, *Magnolia campbellii*, and *Amentotaxus assamica*. Middle canopy is composed of *Lyonia ovalifolia*, *Vaccinium donianum*, *Corylopsis himalayana*, *Rhododendron arboreum*, *Myrsine semiserrata*, *Spiraea callosa*, *Berberis wallichii*, and *Mahonia nepalensis*. Herbaceous layer is usually gregarious and abundant. The shrub layer is represented by *Potentilla polyphylla*, *Fragaria nubicola*, *Sedum* spp., *Desmodium caudatum* and *Rubus ellipticus*. Herbs are comprised of *Anaphalis busua*, *Daphne papyracea* and *Ranunculus sceleratus*. Epiphytes are represented by *Vaccinium chaetothrix*, *Aeschynanthus bracteatus* and *Hoya parasitica*. Lichens and ferns are few. These types of forests occur over Mithumna-Mailang ridge, Chaglagam area and Malinja-Simbi area.

6.3.6 East Himalayan Mixed Coniferous Forest (Temperate Conifer Forests) – (12/C3a)

These forests are seen above the elevation of temperate broadleaved forests. Among the conifers *Abies densa, Abies spectabilis* are more extensive than other species. The shrubs are represented by different species of *Berberis*, *Viburnum*, *Lonicera*, *Gaultheria*, *Rosa*, *Rubus*, and *Hydrangea*. The herb layer consists of species of *Anaphalis*, *Hypericum*, *Podophyllum*, *Primula*, *Polygonum*, *Rumex*, *Rheum*, *Pilea*, *Potentilla*, *Plectranthus*, and *Ranunculus*. Climbers are scanty and epiphytic flora is comprised of lichens.

6.3.7 Alpine Pastures (Alpine Forests) – 15/C3)

These forests occupy the highest altitude, 3500 - 5500m and lack tree cover. The main feature here is that the area is under snow cover for a longer period resulting in a very brief growing season. Even the occasional trees seen here are stunted in growth and are bushy or crooked in appearance. They include *Rhododendron* spp., *Juniperus* spp., *Betula alnoides* and *Acer oblongum*. The shrubs include *Berberis wallichiana*, *Rubus niveus*, and *Lonicera angustifolia*. The herbs include various species of *Pedicularis*, *Rheum*, *Rumex*, *Polygonum*, *Anaphalis*, *Cypripedium*, *Hypericum*, *Ranunculus*, *Sedum*, *Saxifraga*, *Delphinium*, and *Selinum*.

6.3.8 Secondary Forests (1B/2S)

The primary forest due to impact of various adverse biotic and abiotic factors like shifting cultivation or "*Jhumming*", development activities and urbanization, landslides, fires, etc., are destroyed and develop into secondary forests. The secondary forests divided into the three following types.

6.3.8.1 Degraded Forests

As compared to the original primary forest these degraded ones have very low species diversity and generally dominated by shrubs and small trees. Among the predominant trees are the species of *Bauhinia, Callicarpa, Glochidium* and *Mallotus* whereas species of *Capparis, Clerodendrum, Eurya* and *Randia* are the commonly occurring shrubs along with species of weeds like *Ageratum, Eupatorium* and *Mikania.*

6.3.8.2 Bamboo and Musa Forests

This type of secondary forests mostly occurs in the areas which are abandoned after '*jhum*' cultivation. The common bamboo species are *Arundina graminifolia, Bambusa pallida, Bambusa tulda, Chimonobambusa callosa, Dendrocalamus hamiltonia, Dendrocalamus hookeri* and *Dendrocalamus strictus*. *Musa* comprising *Musa acuminata, Musa balbisiana* and *Musa rosacea* are commonly found.

6.3.8.3 Grasslands

Generally formed due to practice of '*jhum*' cultivation or sometimes due to fires or over-grazing and also on sun facing slopes on the hill tops. The more common species of grasses are *Arundinella bengalensis, Chrysopogon aciculatus, Imperata cylindrica, Saccharum spontaneum, Themeda villosa, Thysanolaena maxima* with sedges like *Cyperus brevifolius* and *Fimbristylis bisumbellata*.

6.4 FLORISTICS

The varied climate and the altitude have greatly influenced the rich diversity of vegetation in this region. The state is known for its verdant rainforest and rich vegetation with unique ecosystem ranging from tropical belt to the snow clad alpine mountains. The vegetation of the state is rich and diverse abounding in spectacular flora including some of the tallest trees in India, ferns, orchids, primulas and a variety of colourful rhododendrons.

Arunachal Pradesh falls in the richest Botanical Province with nearly 50% ofthe flora of the Indian Subcontinent. Chowhdery *et al.* (1996) have enumerated 4117 species of flowering plants belonging to 1295 genera and 192 families of flowering plants from the state. The Dibang basin area has good vegetation with predominant subtropical evergreen, bamboo mixed, temperate mixed broad leaved and coniferous forests at higher elevations.

6.4.1 Taxonomic Diversity

For the documentation of floristics of Dibang basin data was collected during the field surveys as well as secondary data made available by Botanical Survey of India (BSI) through MoEF&CC and also collected from other secondary sources like published reports, research articles and literature. An inventory of different plant groups was prepared based upon the data collected as above. According to this 1548 species of higher plants have been documented so far from the study area. A brief overview of number of plant species in various taxonomic groups is given in **Table 6.4** and discussed in following paragraphs.

Table 6.4: Summary of number plants species in Dibang basin

HIGHER PLANTS				
Group	**Angiosperms**	**Gymnosperms**	**Pteridophytes**	**Total**
Species	1329	17	202	**1548**
Genus	635	14	86	**735**
Families	153	5	28	**186**
LOWER PLANTS				
Group	**Bryophytes**	**Lichens**		
Species	21	16		
Genus	18	16		
Families	13	15		

6.4.1.1 Angiosperms

In all total 1329 species of angiosperms were recorded. These angiosperm species belong to 635 genera and 153 families. Dominant family in the basin is Orchidaceae with 199 species followed by Poaceae with 85 species, Asteraceae with 53 species, Ericaceae 42 species, Lamiaceae with 40 species and Fabaceae with 34 species. The plant names and families are based upon http://www.theplantlist.org. Detail list of angiosperms are given in **Annexure - II, Volume II.**

6.4.1.2 Gymnosperms

The gymnosperms are represented by 17 species belonging to 5 families dominated by Pinaceae. A detailed list of the same is given in **Table 6.5**.

Table 6.5: List of Gymnosperms reported from Dibang basin

S.No.	Family	Name of Species
1	Cupressaceae	*Juniperus recurva*
2	Cupressaceae	*Cupressus torulosa*
3	Gnetaceae	*Gnetum gnemon*
4	Gnetaceae	*Gnetum montanum*
5	Pinaceae	*Abies delavayi*
6	Pinaceae	*Abies spectabilis*
7	Pinaceae	*Larix griffithii* (Syn. *Larix griffithiana*)
8	Pinaceae	*Pinus armandii*
9	Pinaceae	*Pinus merkusii*
10	Pinaceae	*Picea spinulosa* (Syn. *Pinus spinulosa*)
11	Pinaceae	*Pinus wallichiana*
12	Pinaceae	*Tsuga dumosa*
13	Pinaceae	*Abies densa*
14	Podocarpaceae	*Podocarpus neriifolius*
15	Taxaceae	*Amentotaxus assamica*
16	Taxaceae	*Cephalotaxus mannii* (Syn. *Cephalotaxus griffithii*)
17	Taxaceae	*Taxus wallichiana*

6.4.1.3 Pteridophytes

The study area was found to be rich in distribution of Pteridophytes. This group is represented by 201 species belonging to 28 families with Polypodiaceae, Pteridaceae, Dryopteridaceae and Athyriaceae being the largest family. A detailed list of the same is given in **Table 6.6**.

Table 6.6: List of Pteridophytes reported from Dibang basin

S.No.	Family	Name of Species
1	Aspleniaceae	*Asplenium cheilosorum*
2	Aspleniaceae	*Asplenium crinicaule*
3	Aspleniaceae	*Asplenium gueinzianum*
4	Aspleniaceae	*Asplenium nidus*
5	Aspleniaceae	*Asplenium nitidum*
6	Aspleniaceae	*Asplenium prolongatum*
7	Aspleniaceae	*Asplenium tenuifolium*
8	Aspleniaceae	*Asplenium unilaterale* (Syn. *Asplenium excisum*)
9	Aspleniaceae	*Asplenium ensiforme*
10	Athyriaceae	*Allantodia griffithii* (Syn. *Diplazium grifithii*)
11	Athyriaceae	*Allantodia sikkimensis* (Syn. *Diplazium sikkimense*)
12	Athyriaceae	*Athyrium atkinsonii*
13	Athyriaceae	*Athyrium distans*
14	Athyriaceae	*Athyrium drepanopterum*
15	Athyriaceae	*Athyrium falcatum*
16	Athyriaceae	*Athyrium foliolosum* (Syn. *Athyrium fimbriatum*)
17	Athyriaceae	*Athyrium himalaicum*
18	Athyriaceae	*Athyrium praetermissum*
19	Athyriaceae	*Athyrium rubricaule*
20	Athyriaceae	*Athyrium rupicola*
21	Athyriaceae	*Athyrium schimperi* (Syn. *Athyrium solenopteris*)
22	Athyriaceae	*Cornopteris opaca*
23	Athyriaceae	*Deparia boryana* (Syn. *Dryoathyrium boryanum*)
24	Athyriaceae	*Deparia petersenii*
25	Athyriaceae	*Diplazium apicisorum*
26	Athyriaceae	*Diplazium axillare*
27	Athyriaceae	*Diplazium dilatatum*

S.No.	Family	Name of Species
28	Athyriaceae	*Diplazium dolichosorum*
29	Athyriaceae	*Diplazium esculentum*
30	Athyriaceae	*Diplazium subsinuatum* (Syn. *Athyrium lanceum*)
31	Athyriaceae	*Pseudocystopteris davidii* (Syn. *Athyrium davidii*)
32	Blechnaceae	*Blechnum orientale*
33	Blechnaceae	*Woodwardia unigemmata*
34	Cibotiaceae	*Cibotium assamicum*
35	Cibotiaceae	*Cibotium barometz*
36	Cytheaceae	*Alsophila andersoni*
37	Cytheaceae	*Alsophila khasyana*
38	Cytheaceae	*Cyathea gigantea*
39	Cytheaceae	*Cyathea spinulosa*
40	Cytheaceae	*Cythea spinulosa* (Syn. *Alsophila spinulosa*)
41	Davalliaceae	*Araiostegia divaricata* (Syn. *Davallia divaricata*)
42	Davalliaceae	*Araiostegia pseudocystopteris*
43	Davalliaceae	*Araiostegia pulchra*
44	Davalliaceae	*Davallia assamica* (Syn. *Humata assamica*)
45	Davalliaceae	*Davallia griffithiana*
46	Davalliaceae	*Davallia trichomanoides*
47	Davalliaceae	*Humata repens*
48	Dennsataedtiaceae	*Hypolepis punctata*
49	Dennsataedtiaceae	*Microlepia hallbergii*
50	Dennsataedtiaceae	*Microlepia hookeriana*
51	Dennsataedtiaceae	*Microlepia pilosiuscula*
52	Dennsataedtiaceae	*Microlepia speluncae*
53	Dennsataedtiaceae	*Pteridium aquilinum*
54	Dipteridaceae	*Dipteris wallichii*
55	Dryopteridaceae	*Arachniodes aristata*
56	Dryopteridaceae	*Arachniodes assamica*
57	Dryopteridaceae	*Ctenitis subglandulosa*
58	Dryopteridaceae	*Cyrtomium hookerianum*
59	Dryopteridaceae	*Dryopteris assamensis*
60	Dryopteridaceae	*Dryopteris chrysocoma*
61	Dryopteridaceae	*Dryopteris conjugata*
62	Dryopteridaceae	*Dryopteris rosthornii* (Syn. *Dryopteris xanthomelas*)
63	Dryopteridaceae	*Dryopteris sparsa*
64	Dryopteridaceae	*Dryopteris splendens*
65	Dryopteridaceae	*Dryopteris stenolepis* (Syn. *Dryopteris gamblei*)
66	Dryopteridaceae	*Dryopteris tuberculifera* (Syn. *Pseudocyclosorus tuberculifer*)
67	Dryopteridaceae	*Dryopteris yoroii*
68	Dryopteridaceae	*Peranema cyatheoides*
69	Dryopteridaceae	*Polystichum discretum*
70	Dryopteridaceae	*Polystichum lentum*
71	Dryopteridaceae	*Polystichum longipaleatum*
72	Dryopteridaceae	*Polystichum luctuosum*
73	Dryopteridaceae	*Polystichum neolobatum*
74	Dryopteridaceae	*Polystichum nepalense*
75	Dryopteridaceae	*Polystichum obliquum*
76	Dryopteridaceae	*Polystichum squarrosum*
77	Dryopteridaceae	*Thelypteris xylodes* (Syn. *Pseudocyclosorus tylodes*)
78	Equisetaceae	*Equisetum ramosissimum*
79	Equisetaceae	*Equisetumdiffusum*
80	Gleicheniaceae	*Dicranopteris linearis*
81	Gleicheniaceae	*Dicranopteris montana*
82	Hymenophyllaceae	*Crepidomanes auriculatum* (Syn. *Lacosteopsis auriculata*)
83	Hymenophyllaceae	*Crepidomanes bilabiatum*
84	Hymenophyllaceae	*Hymenophyllum badium* (Syn. *Mecodium badium*)
85	Hymenophyllaceae	*Hymenophyllum denticulatum*
86	Hypodematiaceae	*Leucostegia immersa*

S.No.	Family	Name of Species
87	Lindsaeaceae	*Lindsaea ensifolia*
88	Lindsaeaceae	*Lindsaea himalaica*
89	Lindsaeaceae	*Lindsaea odorata*
90	Lindsaeaceae	*Odontosoria chinensis*
91	Lycopodaceae	*Huperzia dixitiana*
92	Lycopodaceae	*Huperzia pulcherrima* (Syn. *Phlegmariurus pulcherrimus*)
93	Lycopodaceae	*Huperzia hamiltonii* (Syn. *Phlegmariurus hamiltonii*)
94	Lycopodaceae	*Huperzia herteriana*
95	Lycopodaceae	*Lycopodiella cernua* (Syn. *Palhinhaea cernua*)
96	Lycopodaceae	*Lycopodium japonicum*
97	Lycopodaceae	*Lycopodium obscurum*
98	Lycopodaceae	*Lycopodium pseudoclavatum*
99	Lycopodaceae	*Phlegmariurus cryptomerianus*
100	Lygodiaceae	*Lygodium japonicum*
101	Marattiaceae	*Angiopteris evecta*
102	Marsiliaceae	*Marsilea minuta*
103	Nephrolepidaceae	*Nephrolepis auriculata*
104	Nephrolepidaceae	*Nephrolepis biserrata*
105	Oleandraceae	*Oleandra musifolia*
106	Oleandraceae	*Oleandra wallichii*
107	Onocleaceae	*Onoclea orientalis* (Syn. *Matteuccia orientalis*)
108	Ophioglossaceae	*Botrychium lanuginosum*
109	Plagiogyriaceae	*Plagiogyria glauca* (Syn. *Plagiogyria glaucescens*)
110	Polypodiaceae	*Arthromeris lehmannii*
111	Polypodiaceae	*Arthromeris lungtauensis*
112	Polypodiaceae	*Arthromeris wallichiana*
113	Polypodiaceae	*Belvisia mucronata*
114	Polypodiaceae	*Colysis decurrens*
115	Polypodiaceae	*Colysis elliptica*
116	Polypodiaceae	*Colysis hemionitidea*
117	Polypodiaceae	*Drynaria propinqua*
118	Polypodiaceae	*Goniophlebium wattii*
119	Polypodiaceae	*Lepisorus bicolor* (Syn. *Pleopeltis bicolor*)
120	Polypodiaceae	*Lepisorus loriformis* (Syn. *Pleopeltis loriformis*)
121	Polypodiaceae	*Lepisorus nudus* (Syn. *Pleopeltis nuda*)
122	Polypodiaceae	*Lepisorus subconfluens* (Syn. *Pleopeltis subconfluens*)
123	Polypodiaceae	*Leptochilus axillaris*
124	Polypodiaceae	*Loxogramme involuta*
125	Polypodiaceae	*Microsorum dilatatum*
126	Polypodiaceae	*Microsorum punctatum*
127	Polypodiaceae	*Neocheiropteris zippelii* (Syn. *Microsorum zippelii*)
128	Polypodiaceae	*Phymatopteris chrysotricha*
129	Polypodiaceae	*Phymatopteris griffithiana*
130	Polypodiaceae	*Phymatopteris oxyloba*
131	Polypodiaceae	*Phymatosorus cuspidatus*
132	Polypodiaceae	*Polypodiastrum argutum*
133	Polypodiaceae	*Polypodiodes amoena* (Syn. *Goniophlebium amoenum*)
134	Polypodiaceae	*Polypodiodes microrhizoma* (Syn. *Goniophlebium microrhizoma*)
135	Polypodiaceae	*Pyrrosia adnascens*
136	Polypodiaceae	*Pyrrosia costata*
137	Polypodiaceae	*Pyrrosia flocculosa*
138	Polypodiaceae	*Pyrrosia lanceolata* (Syn. *Pyrrosia varia*)
139	Polypodiaceae	*Pyrrosia lingua*
140	Polypodiaceae	*Pyrrosia lingua* var. *heteractis*
141	Polypodiaceae	*Pyrrosia porosa* var. *stenophylla*
142	Polypodiaceae	*Pyrrosia subfurfuracea*
143	Polypodiaceae	*Selliguea rhynchophylla* (Syn. *Phymatopteris rhynchophylla*)
144	Polypodiaceae	*Tricholepidium normale* (Syn. *Neocheiropteris normalis*)
145	Psilotaceae	*Psilotum nudum*

S.No.	Family	Name of Species
146	Pteridaceae	*Adiantum lunulatum* (Syn. *Adiantum philippense*)
147	Pteridaceae	*Adiantum capillus-veneris*
148	Pteridaceae	*Adiantum edgeworthii*
149	Pteridaceae	*Aleuritopteris farinosa* (Syn. *Aleuritopteris flava*)
150	Pteridaceae	*Antrophyum callifolium*
151	Pteridaceae	*Antrophyum formosanum*
152	Pteridaceae	*Antrophyum reticulatum*
153	Pteridaceae	*Cheilanthes albomarginata* (Syn. *Aleuritopteris albomarginata*)
154	Pteridaceae	*Cheilanthes grisea* (Syn. *Aleuritopteris grisea*)
155	Pteridaceae	*Coniogramme falcata*
156	Pteridaceae	*Coniogramme fraxinea*
157	Pteridaceae	*Coniogramme procera*
158	Pteridaceae	*Onychium japonicum*
159	Pteridaceae	*Onychium siliculosum*
160	Pteridaceae	*Paraceterach vestita* (Syn. *Gymnopteris vestita*)
161	Pteridaceae	*Pityrogramma calomelanos*
162	Pteridaceae	*Pteris aspericaulis*
163	Pteridaceae	*Pteris biaurita*
164	Pteridaceae	*Pteris cretica*
165	Pteridaceae	*Pteris linearis*
166	Pteridaceae	*Pteris longipinnula*
167	Pteridaceae	*Pteris vittata*
168	Pteridaceae	*Pteris wallichiana*
169	Pteridaceae	*Vittaria elongata*
170	Pteridaceae	*Vittaria flexuosa*
171	Pteridaceae	*Vittaria ophiopogonoides*
172	Pteridaceae	*Vittaria wattii*
173	Pteridaceae	*Vittaria zosterifolia*
174	Selaginellaceae	*Selaginella involvens*
175	Selaginellaceae	*Selaginella monospora*
176	Selaginellaceae	*Selaginella pentagona*
177	Selaginellaceae	*Selaginella picta*
178	Selaginellaceae	*Selaginella semicordata*
179	Selaginellaceae	*Selaginella tenuifolia*
180	Selaginellaceae	*Selaginella wallichii*
181	Tectariaceae	*Tectaria decurrens*
182	Tectariaceae	*Tectaria gemmifera* (Syn. *Tectaria coadunata*)
183	Tectariaceae	*Tectaria heterocaroa*
184	Tectariaceae	*Tectaria Polymorpha*
185	Tectariaceae	*Tectaria vasta*
186	Thelypteridaceae	*Amblovenatum opulentum* (*Amphineuron opulentum*)
187	Thelypteridaceae	*Christella assamica* (Syn. *Cyclosorus assamicus*)
188	Thelypteridaceae	*Christella dentata* (Syn. *Cyclosorus dentatus*)
189	Thelypteridaceae	*Cyclosorus aridus*
190	Thelypteridaceae	*Cyclosorus crinipes*
191	Thelypteridaceae	*Cyclosorus evolutus*
192	Thelypteridaceae	*Cyclosorus subpubescens*
193	Thelypteridaceae	*Macrothelypteris ornata*
194	Thelypteridaceae	*Pneumatopteris truncata*
195	Thelypteridaceae	*Pronephrium articulatum*
196	Thelypteridaceae	*Pseudocyclosorus canus*
197	Thelypteridaceae	*Pseudocyclosorus falcilobus*
198	Thelypteridaceae	*Pseudocyclosorus ornatipes*
199	Thelypteridaceae	*Pseudophegopteris aurita*
200	Thelypteridaceae	*Thelypteris nudata* (Syn. *Pronephrium nudatum*)
201	Thelypteridaceae	*Trigonospora caudipinna*
202	Thelypteridaceae	*Trigonospora ciliata*

6.4.1.4 Bryophytes

A list of 21 species of bryophytes belonging to 13 families reported from Dibang basin was prepared from the published data and field surveys and the same is given at **Table 6.7**.

Table 6.7: List of Bryophytes reported from Dibang basin

S. No.	Family	Botanical Names
1	Anthocerotaceae	*Anthoceros* sp.
2	Aytoniaceae	*Asterella angusta*
3	Aytoniaceae	*Plagiochalma cordatum*
4	Funariaceae	*Funaria calcarea*
5	Hypnaceae	*Hypnum imponens*
6	Leucodontaceae	*Leucodon* sp.
7	Marchantiaceae	*Marchantia palmata*
8	Marchantiaceae	*Marchantia polymorpha*
9	Pelliaceae	*Pellia* sp.
10	Politrichaceae	*Polytrichum* sp.
11	Polytrichaceae	*Atrichum undulatum*
12	Polytrichaceae	*Dawsonia grandis*
13	Polytrichaceae	*Pogonatum aloides*
14	Polytrichaceae	*Pogonatum inflexum*
15	Polytrichaceae	*Polytrichum commune*
16	Polytrichaceae	*Polytrichum juniperinum*
17	Ricciaceae	*Riccia fluitans*
18	Ricciaceae	*Ricciocarpus natans*
19	Sphagnaceae	*Sphagnum strictum*
20	Targioniaceae	*Targionia hypophylla*
21	Thuidiaceae	*Thuidium delicatum*

6.4.1.5 Lichens

Lichens in Dibang basin are represented by 16 species belonging to 15 families (**Table 6.8**).

Table 6.8: List of lichens reported from Dibang basin

S.No.	Family	Name of Species
1	Buelliaceae	*Buellia* sp.
2	Cladoniaceae	*Cladonia* sp.
3	Collemataceae	*Leptogium* sp.
4	Cryptotheciaceae	*Cyptothecia* sp.
5	Lecanoraceae	*Lecanora* sp.
6	Lobariaceae	*Lobaria* sp.
7	Parmeliaceae	*Parmelia* sp.
8	Peltigeraceae	*Peltigera* sp.
9	Pyrenulaceae	*Anthracothecium* sp.
10	Ramaliaceae	*Ramalina* sp.
11	Rhizocarpaceae	*Rhizocarpon* sp.
12	Stereocaulaceae	*Stereocaulon* sp.
13	Teloschistaceae	*Brigantiaea* sp.
14	Thelotremataceae	*Diplochistes* sp.
15	Usneaceae	*Bryonia* sp.
16	Usneaceae	*Usnea* sp.

6.4.2 Predominant Plant Groups in the Basin

As discussed in previous secton amongst all flowering plant families Orchidaceae is the most dominant family in the basin being represented by 199 species followed by Poaceae with 85 species, Asteraceae with 53 species, Ericaceae 42 species, Lamiaceae with 40 species and Fabaceae with 34 species. The key plant groups like orchids and rhododendrons, bamboos, canes and rattans have been discussed in the following paragraphs.

6.4.2.1 Orchids

Arunachal Pradesh is known as an 'orchid paradise' as it is home to more than 40% of orchid species occurring in India as out of more than 1300 species of orchids found in India and 558 species are from Arunachal Pradesh (Rao, 2010). High species richness of orchids in Arunachal Pradesh is attributed mainly to the favourable eco-climatic conditions like high rainfall, high atmospheric relative humidity, and dense forest cover with diverse vegetation at different ecozones ranging from tropical to alpine regions. The orchid flora Arunachal Pradesh is unique in the sense that it harbours 38 species which are endemic only to the state.

In order to assess the orchid species richness in the basin an inventory of orchid species was prepared based upon field surveys as well as available secondary data collected from different sources like published reports mainly sourced from BSI, research papers and handbooks. A list of orchid species reported from Dibang basin is given at **Table 6.9**. According to this 199 species are reportedly found in the basin. However according to a list prepared by Rao (2010) there are 234 orchid species are found in central zone of Arunachal Pradesh. This zone also includes Siang basin also lying adjacent to Dibang basin which is also known as Abor Hills. However Dibang basin harbours more diversity of orchids than Siang basin as here 199 species are found as compared to 102 only in Siang basin. More than 50% of the species are found in the subtropical region whereas 30% are in tropical region, 16% in temperate and about 4% are reported from alpine region. Out of 199 species documented in this report, 150 are epiphytes and 46 are terrestrial orchids while there are three species which have mycotrophic habit (living in association with mycorrhiza).

Gastrochilus calceolaris and *Paphiopedilum fairrieanum* are listed under Critically Endangered Category as per IUCN Redlist while *Bulleyia yunnanensis* has been listed under Endangered category. Red Data Book by BSI has listed *Paphiopedilum fairrieanum* under Endangered category while *Galeola falconeri* and *Vanda coerulea* have been placed in Indeterminate and Rare categories.

Six orchid species reported from Dibang basin are endemic to Arunachal Paradesh viz. *Calanthe densiflora, Dendrobium cathcartii, Dendrobium hookerianum, Eria ferruginea, Galeola falconeri* and *Paphiopedilum fairrieanum.*

Table 6.9: Species of Orchids reported from Dibang basin

S.No.	Name of Species	Habit	Locality	Distribution Range (m)	Conservation Status	
					IUCN Redlist	BSI Red Data Book
1	*Acampe praemorsa* (Syn. *Acampe papillosa*)	E		700-1200		
2	*Acampe rigida*	E		300-1800		
3	*Acanthephippium sylhetense*	T		500-800		
4	*Aerides multiflorum*	E	Shantipur, Abango, Etalin	300-1000		
5	*Aerides rosea* (Syn. *Aerides williamsii*)	E		300-1700		
6	*Agrostophyllum brevipes*	E		Up to 1500		
7	*Anoectochilus brevilabris* (Syn. *Anoectochilus sikkimensis*)	T	Anini/Aleney	900-1500		
8	*Anoectochilus roxburghii*	T	Hunli	300-1800		
9	*Anthogonium gracile*	T	Roing to Mayudia	1200-2600		
10	*Aphyllorchis alpina*	T	Pasupani to Chitapani camp beyond	2000-2600		

S.No.	Name of Species	Habit	Locality	Distribution Range (m)	Conservation Status	
					IUCN Redlist	BSI Red Data Book
			Dambuen			
11	*Arundina graminifolia*	T	Through out the basin	Up to 1200		
12	*Biermannia bimaculata*	E		500-600		
13	*Bulbophyllum cauliflorum*	E		600-2000		
14	*Bulbophyllum affine*	E		Up to 600		
15	*Bulbophyllum apodum*	E		Up to 2000		
16	*Bulbophyllum capillipes*	E				
17	*Bulbophyllum careyanum*	E	Mehao WLS	200-2100		
18	*Bulbophyllum delitescens*	E	Desali	600-2500	LC	
19	*Bulbophyllum emarginatum*	E	Alenye	800-2200		
20	*Bulbophyllum guttulatum*	E	Etalin	600-2500		
21	*Bulbophyllum gymnopus*	E	Emuli	600-2000		
22	*Bulbophyllum hirtum*	E		800-2700		
23	*Bulbophyllum hymenanthum*	E	Chaipani camp	1300-2600		
24	*Bulbophyllum leopardinum*	E		1300-3300	LC	
25	*Bulbophyllum odoratissimum*	E	Desali to Hunli	800-2500		
26	*Bulbophyllum penicillium*	E		Around 2000		
27	*Bulbophyllum reptans*	E	Mayudia	1000-2800		
28	*Bulbophyllum rolfei*	E	Chaipani camp	2000-2800		
29	*Bulbophyllum roxburghii* (Syn. *Bulbophyllum sikkimense*)	E		Up to 300		
30	*Bulbophyllum scabratum*	E	Punli	1000-2000		
31	*Bulleyia yunnanensis*	E	Ahunli	700-2700	EN	
32	*Calanthe alpina*	T	Thaupani camp from Pasupani	1500-3500		
33	*Calanthe biloba*	T		1200-1800		
34	*Calanthe densiflora*	T		1000-3000		
35	*Calanthe griffithii*	T	Amboli, Atunli	1060-1300		
36	*Calanthe herbacea*	T	Dara to Chitapani camp beyond Mipi	1300-2600		
37	*Calanthe keshabii*	T	Mayudia	2000-2600		
38	*Calanthe mannii*	T		600-2400		
39	*Calanthe masuca*	T	Desali , Rheyanlie	900-1000		
40	*Calanthe ovalis*	T				
41	*Calanthe ovata*	T		around 1200		
42	*Calanthe plantaginea*	T	Dambuen, Chaipani camp	1600-2500		
43	*Cattleya labiata*	E		600-900		
44	*Ceratostylis himalaica*	E	Mehao Lake, Mipi	900-1700		
45	*Ceratostylis teres*	E		200-1700		
46	*Cheirostylis chinensis var. glabra*	T	Bejari	Up to 1500		
47	*Chiloschista lunifera*	E		150-600		
48	*Chusua nana*	T	Andra to Thupani camp beyond Mipi	500-3500		
49	*Cleisocentron trichromum*	E		300-2000		
50	*Cleisostoma filiforme*	E		400-1000		
51	*Cleisostoma racemiferum*	E		500-1800		
52	*Cleisostoma subulatum*	E	Desali	Up to 500		
53	*Coelogyne arunachalensis*	E		Up to 1500		
54	*Coelogyne barbata*	E	Mehao lake	1000-1800		
55	*Coelogyne corymbosa*	E	Bruinii	1500-3500		

S.No.	Name of Species	Habit	Locality	Distribution Range (m)	Conservation Status	
					IUCN Redlist	BSI Red Data Book
56	*Coelogyne flaccida*	E		900-2000		
57	*Coelogyne flavida*	E		900-2300		
58	*Coelogyne griffithii*	E		1200-1600		
59	*Coelogyne longipes*	E	Lenka village	1300-2300		
60	*Coelogyne nitida*	E		1300-2600		
61	*Coelogyne occultata*	E	Mipi, Dara to Kamulin camp	1400-2300		
62	*Coelogyne ovalis*	E	Alenye	600-2100		
63	*Coelogyne prolifera*	E	Suiyan	900-2300		
64	*Coelogyne punctulata*	E	Mayudia pass	around 2500		
65	*Coelogyne raizadae*	E	Deshali, Kamulin camp	1300-1750		
66	*Coelogyne schultesii*	E	Amboli	500-2000		
67	*Cryptochilus sanguineus*	E		1800-2300		
68	*Cymbidium aloifolium*	E	Bejari, Etalin	Up to 650		
69	*Cymbidium cochleare*	E	Mayudia area	1800-2400		
70	*Cymbidium cyperifolium*	T		600-1600		
71	*Cymbidium dayanum*	E	Punli	200-1800		
72	*Cymbidium eburneum*	E		300-2000		
73	*Cymbidium elegans*	E	Mayudia pass	1500-2800		
74	*Cymbidium hookerianum*	E	Mayudia pass	1600-2650		
75	*Cymbidium iridioides*	E	Etalin	500-2800		
76	*Cymbidium lancifolium*	T	Mipi river side	1000-2500		
77	*Cymbidium longifolium*	E	Alenye	1500-2800		
78	*Cymbidium sinense*	T	Punli	Up to 2000m		
79	*Dendrobium acinaciforme*	E		500-2200		
80	*Dendrobium amoenum*	E	Abango	500-2000		
81	*Dendrobium aphyllum*	E	Dambuk, Bejari	Up to 1800	LC	
82	*Dendrobium candidum*	E	Chitapani, Pasupani	2000-3000		
83	*Dendrobium cathcartii*	E		300-1000		
84	*Dendrobium chrysanthum*	E	Punli, Erone	300-2200		
85	*Dendrobium cumulatum*	E		300-1500		
86	*Dendrobium densiflorum*	E		1000-1800		
87	*Dendrobium devonianum*	E	Emuli, Arzoo, Anini, Aleney	500-2000		
88	*Dendrobium falconeri*	E		800-2000		
89	*Dendrobium fimbriatum var. oculatum*	E	Emuli	800-2500		
90	*Dendrobium hookerianum*	E	Lanka village, Aleney	1000-2000		
91	*Dendrobium jenkinsii*	E		500-1500		
92	*Dendrobium lituiflorum*	E	Attunli	Up to 1000		
93	*Dendrobium longicornu*	E		1200-3000		
94	*Dendrobium moschatum*	E		300-1000		
95	*Dendrobium nobile*	E		500-2000		
96	*Dendrobium numaldeorii*	E	Mehao WLS	Up to 500		
97	*Dendrobium pendulum*	E		500-1600		
98	*Dendrobium porphyrochilum*	E		1800-2500		
99	*Dendrobium wardianum*	E	Attunli	1000-2000		
100	*Diplomeris hirsuta*	E		200-1000		
101	*Epigeneium amplum*	E		500-2000		
102	*Epigeneium rotundatum*	E	Mayudia	1500-2500		
103	*Epipogium roseum*	M	Mehao lake	Up to 2000		
104	*Eria acervata*	E		1000-3000		

S.No.	Name of Species	Habit	Locality	Distribution Range (m)	Conservation Status	
					IUCN Redlist	BSI Red Data Book
105	*Eria amica*	E	Apali, Deshali	500-2000		
106	*Eria coronaria*	E	Achiso	500-2500		
107	*Eria discolor*	E		Up to 1500		
108	*Eria ferruginea*	E		800-2000		
109	*Eria flava*	E		1000-2000		
110	*Eria floribunda*	E		500-2500		
111	*Eria graminifolia*	E		2000-3200		
112	*Eria javanica*	E	Bejari	Up to 1000		
113	*Eria jenggingensis*	E		Up to 1000		
114	*Eria lasiopetala*	E	Bejari	Up to 1500		
115	*Eria pannea*	E	Deshali	1300		
116	*Eria stricta*	E	Dambuk	300-2000		
117	*Esmeralda clarkei* (Syn. *Arachnis clarkei*)	E		1500-2000		
118	*Galeola falconeri*	M		1000-2500		I
119	*Galeola lindleyana*	M	Thewarygaon, Kamulin from Dara	1200-2500		
120	*Gastrochilus calceolaris*	E		500-2500	CE	
121	*Gastrochilus dasypogon*	E		300-1000		
122	*Gastrochilus distichus*	E	Mayudia area	1500-2700		
123	*Gastrochilus inconspicuus*	E	Malo village	Up to 500		
124	*Geodorum pulchellum*	T		1000-1500		
125	*Goodyera procera*	T	Athunli, Bejari, Roing	100-1500		
126	*Goodyera recurva*	T		2000-2500		
127	*Habenaria malleifera*	T	Shaley lake	500-1800		
128	*Herminium lanceum*	T	Mayudia area, Mipi	1000-3200		
129	*Ione candida*	E	Chaipani camp beyond Dambuen	1500-2500		
130	*Kingidium deliciosum*	E		Up to 600		
131	*Lepanthes pedunculata*					
132	*Liparis plantaginea*	E		300-600		
133	*Liparis bistriata*	E	Dambuen, Deshali, Maruli	800-1800		
134	*Liparis bootanensis*	E	Anini, Alenye	1000-2500		
135	*Liparis caespitosa*	E	Chitapani camp	400-2500		
136	*Liparis cathcartii*	T	Desali	1000-2000		
137	*Liparis delicatula*	E	Etalin	500-3000		
138	*Liparis dongchenii*	T		1000-2000		
139	*Liparis elliptica*	E	Desali	1000-2000		
140	*Liparis gamblei*	T	Chitapani camp beyond Mipi	around 2000		
141	*Liparis resupinata*	E	Hunli from Mayudia, Pasupani beyond Mipi	1800-2100		
142	*Liparis stricklandiana*	E	Desali	500-1800		
143	*Liparis viridiflora*	E	Dambuk, Bejari	300-2000		
144	*Luisia filiformis*	E	Bomjir	Up to 300		
145	*Luisia tenuifolia*	E		Up to 500		
146	*Luisia trichorrhiza*	E	Epipani	1000-1500		
147	*Luisia zeylanica*	E	Malo village	Up to 1000		
148	*Malaxis latifolia*	T		500-1500		

S.No.	Name of Species	Habit	Locality	Distribution Range (m)	Conservation Status	
					IUCN Redlist	BSI Red Data Book
149	*Malaxis sp*	T				
150	*Micropera mannii*	E		Up to 1000		
151	*Myrmechis pumila*	T	Way to Dara camp beyond Mipi	1500-3500		
152	*Neogyna gardneriana*	E	Mehao lake	500-2500		
153	*Neottia alternifolia*	T	Andra Omkar camp beyond Mipi	around 2550		
154	*Neottia divaricata*	T	Andra Omkar camp beyond Mipi	2000-3500		
155	*Neottianthe secundiflora*	T	Mayudia	2500-4000		
156	*Nervilia gammieana*	T		around 1000		
157	*Oberonia acaulis*	E	Lenka village near Anini, Alenye, Punli	1000-2500		
158	*Oberonia angustifolia*	E	Kornu	Up to 500		
159	*Oberonia emarginata*	E	Lenka village near Anini	500-2000		
160	*Oberonia falcata*	E	Mehao lake	1000-1800		
161	*Oberonia helferi*	E	Way to Deshali from Hunli	Up to 600		
162	*Oberonia mannii*	E	Kamulin camp beyond Mipi	1000-2000		
163	*Oberonia maxima*	E		700-1500		
164	*Oberonia obcordata*	E	Mehao lake	1000-3000		
165	*Oberonia pyrulifera*	E	Bruinii	500-2000		
166	*Oberonia ritaii*	E	Hunli	Up to 2500		
167	*Oreorchis micrantha*	T		1500-3000		
168	*Ornithochilus difformis*	E	Shaley lake, Roing	500-2000		
169	*Otochilus fuscus*	E	Mehao Lake	1000-2500		
170	*Otochilus lancilabius*	E	Hunli, Mehao WLS	800-3000		
171	*Paphiopedilum fairrieanum*	T		1300-2200	CE	EN
172	*Papilionanthe teres*	E		500-1000		
173	*Phaius flavus*	T	Attunli	Up to 2000		
174	*Phaius mishmensis*	T	Way to Malini	500-2000		
175	*Phaius tankervilleae*	T	Deopani	Up to 1300		
176	*Phalaenopsis parishii*	E	Bejari	Up to 500		
177	*Pholidota articulata*	E	Mehao lake	300-2000		
178	*Pholidota imbricata*	E	Roing, Etalin	Up to 1700		
179	*Phreatia elegans* (Syn. *Eria elegans*)	E		around 2000		
180	*Pinalia spicata* (Syn. *Eria spicata*)	E		800-2800		
181	*Platanthera cumminsiana*	T		around 3000		
182	*Pleione hookeriana*	E	Mayudia Pass	1600-3000		
183	*Pleione praecox*	E	Mayudia Pass	1200-3000		
184	*Pleione saxicola*	E	Mayudia Pass	2300-2900		
185	*Pomatocalpa armigerum*	E		Up to 500		
186	*Pteroceras teres*	E	Diffu nalah, Shaley lake	500-1500		
187	*Renanthera indica*	E				
188	*Rhynchostylis retusa*	E	Attunli	300-1500		
189	*Saccolabiopsis pusilla*	E	Bejari	Up to 500		
190	*Schoenorchis gemmata*	E	Alenye, Mipi	1500-1640		

S.No.	Name of Species	Habit	Locality	Distribution Range (m)	Conservation Status	
					IUCN Redlist	BSI Red Data Book
191	*Smitinandia micrantha*	E	Roing, Bomjir	Up to 1300		
192	*Spiranthes sinensis*	T	Malini, Mayudia	1500-3000	LC	
193	*Stereochilus hirtus*	E	Alenye	Up to 1600		
194	*Thelasis longifolia*	E		Up to 1000		
195	*Thelasis pygmaea*	E		500-2600		
196	*Vanda alpina*	E		1200-2000		
197	*Vanda bicolor*	E		700-2000		
198	*Vanda coerulea*	E	Bejari	Up to 1700		R
199	*Zeuxine strateumatica*	T	Roing	Up to 1000	LC	

E= Epiphyte; T= Terrestrial; M= Mycotrophic

CE =Critically Endangered; EN= Endangered; R=Rare; I=Indeterminate

6.4.2.2 Rhododendrons

In Arunachal Pradesh rhododendrons are one of the important dominant plant taxa. Out of the total 111 species of rhododendrons which known from Indian sub-continent, 90 species are found in Arunachal Pradesh i.e. about 81% of the Indian Rhododendron species are found in Arunachal (Mao *el al*. 2001). The species of rhododendrons exhibit great variation in form and habitat and height of species ranges from 2.5 cm alpine plants to 30 m tall trees which are either evergreen, semi-deciduous or deciduous (Hora, 1981). They are known to occupy every possible habitat such as the forest floor, stream sides, marshes, ridges, glades, cliffs, rocks and boulders, open meadows and thickets, scree and mountain tops and even trees, where many species grow as epiphytes in the moss and debris at all levels from trunks to the topmost branches. Majoity of Rhododendron species are reported from the Kameng and Tawang districts of Arunachal Pradesh where 47 species have been recorded (Paul *et al*. 2010). In Dibang basin 27 species are reportedly found (**refer Table 6.10**). Out of these 10 are trees and rest of them are shrubs. Majority of the species occur at elevations between 2000 and 3000m and majority of them are found in and around Mayudia Pass. Three species *Rhododendron falconeri, Rhododendron megacalyx* and *Rhododendron pruniflorum* are endemic to Arunachal Pradesh.

Table 6.10: Species of Rhododendrons reported from Dibang basin

S.No.	Name of Species	Habit	Locality	Distribution Range (m)
1	*Rhododendron arboreum*	Tree	Mehao WLS, Mayudia, Mathun Valley	1500-3000
2	*Rhododendron arizelum*	Shrub	DDBR	2400-3000
3	*Rhododendron barbatum*	Tree	DDBR	2400-3000
4	*Rhododendron boothii*	Shrub	DDBR	1800-2500
5	*Rhododendron campanulatum*	Shrub	DDBR	Above 3200
6	*Rhododendron coxianum*	Shrub	Mayudia	2200-2400
7	*Rhododendron edgeworthii*	Shrub	Mayudia	Above 2000
8	*Rhododendron falconeri*	Tree	Mayudia	3000-3500
9	*Rhododendron grande*	Tree	Mayudia	2400-2600
10	*Rhododendron griffithianum*	Shrub	DDBR	2000-3000
11	*Rhododendron hodgsonii*	Shrub	DDBR	3000-4000
12	*Rhododendron hylaeum*	Tree	Mayudia	2600-3000
13	*Rhododendron johnstoneanum*	Shrub	DDBR	1200-3000
14	*Rhododendron kendrickii*	Tree	DDBR	2300-2800
15	*Rhododendron keysii*	Shrub	Mayudia	2400-3500
16	*Rhododendron lindleyi*	Shrub	Mayudia	2400-2600
17	*Rhododendron maddenii*	Shrub	Mayudia	2400-3500
18	*Rhododendron megacalyx*	Tree	Mayudia	2100-2700
19	*Rhododendron neriiflorum*	Tree	Mayudia	2000-3500
20	*Rhododendron pruniflorum*	Shrub	Mayudia	3000

S.No.	Name of Species	Habit	Locality	Distribution Range (m)
21	*Rhododendron sidereum*	Tree	Mayudia	2400-2500
22	*Rhododendron sinogrande*	Tree	Mayudia	2500-2700
23	*Rhododendron triflorum*	Shrub	Mayudia	3000
24	*Rhododendron vaccinioides*	Shrub	Mayudia	2500
25	*Rhododendron virgatum*	Shrub	Mayudia	2300-2600
26	*Rhododendron wightii*	Shrub	Mathun Valley, Dri Valley	Above 3000
27	*Rhododendron xanthostephanum*	Shrub	Mayudia	2300-2700

DDBR = Dibang Dihang Biosphere Reserve

6.4.2.3 Bamboos & Canes

Bamboo forms a major constituent of the forest vegetation of Arunachal Pradesh. Tropical, sub-tropical and temperate species are found well distributed in the State.

The state harbours nearly 46 species of bamboos which are found up to an elevation of 2000 m or even more. In Dibang basin 23 species of bamboos are found of which 6 belong to genera *Bambusa* & *Dendrocalamus* each, 2 each belong to *Cephalostachyum* and *Thamnocalamus*.

Canes also form important resource of Arunachal Pradesh. Canes (Rattans – climbing palms) belong to genus *Calamus* of family Arecaceae. Out of 20 species of canes found in the state, 12 species have been reported from Dibang basin. *Calamus leptospadix* is an endemic species (refer **Table 6.11**).

Table 6.11: Species of bamboos and canes reported from Dibang basin

S. No.	Name of Species
BAMBOOS: Family - Poaceae	
1	*Arundinaria falcata*
2	*Bambusa balcooa*
3	*Bambusa barpatharica*
4	*Bambusa nutans*
5	*Bambusa pallida*
6	*Bambusa rangaensis*
7	*Bambusa tulda*
8	*Cephalostachyum latifolium* (Syn. *Schizostachyum fuchsianum*)
9	*Cephalostachyum pergracile* (Syn. *Schizostachyum pergracile*)
10	*Chimonobambusa callosa*
11	*Dendrocalamus brandsii*
12	*Dendrocalamus giganteus*
13	*Dendrocalamus hamiltonii*
14	*Dendrocalamus hookeri*
15	*Dendrocalamus sikkimensis*
16	*Dendrocalamus strictus*
17	*Melocalamus compactiflorus*
18	*Neohouzeaua helferi* (Syn. *Schizostachyum helferi*)
19	*Phyllostachys bambusoides*
20	*Pseudostachyum polymorphum* (Syn. *Schizostachyum polymorphum*)
21	*Schizostachyum seshagirianum*
22	*Thamnocalamus aristatus*
23	*Thamnocalamus spathiflorus*
	CANES : Family - Arecaceae
1	*Calamus acanthospathus*
2	*Calamus erectus*
3	*Calamus flagellum*
4	*Calamus floribundus*
5	*Calamus guruba*
6	*Calamus inermis*
7	*Calamus latifolius*
8	*Calamus leptospadix*
9	*Calamus nambariensis*
10	*Calamus rotang*

S. No.	Name of Species
11	*Calamus tenuis*
12	*Calamus viminalis*

6.4.3 Threatened & Endemic Plant Species

Nayar and Sastry (1987-1990) have reported 35 species of rare and endangered plant species from Arunachal Pradesh. In Dibang basin all there are 30 plant species that are either under different threat categories as per IUCN or under Red Data Book categories.

List of some of the plant species found in the basin and are listed under different conservation status categories of IUCN Redlist is given in **Table 6.9**. According to this four species i.e. *Dipterocarpus gracilis, Gastrochilus calceolaris, Paphiopedilum fairrieanum* and *Saurauia punduana* has been categorized as Critically Endangered (CE). Eight species reported from the Dibang basin are under Endangered (EN) category, five species are under Vulnerable (VU) and three species are under Near Threatened (NT) category of IUCN ver 3.1.

According to Red Data Book of published by Botanical Survey of India (BSI), out of 33 species reported from Arunachal Praedsh under various categories, twelve species are reported from Dibang basin. *Acer oblongum*, *Paphiopedilum fairrieanum*, *Livistona jenkinsiana* has been categoreis under Endangered (EN) category, *Coptis teeta* and *Diplomeris hirsuta* are categories under Vulnerable (VU) category, six species are under rare category (**Table 6.12**).

Table 6.12: RET plant species reported from Dibang basin

S.No.	Family	Name of Species	IUCN	BSI Red Data List
1	Aceraceae	*Acer oblongum*	NA	Endangered
2	Actinidiaceae	*Saurauia punduana*	CE	-
3	Arecaceae	*Livistona jenkinsiana*	NA	Endangered
4	Balanophoraceae	*Rhopalocnemis phalloides*	NA	Rare
5	Begoniaceae	*Begonia aborensis*	NA	Rare
6	Begoniaceae	*Begonia scintillans*	NA	Indeterminate
7	Cactaceae	*Opuntia aciculata*	DD	-
8	Cyperaceae	*Rhynchospora modesti-lucennoi* (Syn. *Rhynchospora rugosa*)	EN	-
9	Dipterocarpaceae	*Dipterocarpus gracilis*	CE	-
10	Dipterocarpaceae	*Hopea parviflora*	EN	-
11	Fabaceae	*Indigofera sokotrana* (Syn. *Indigofera gerardiana*)	VU	-
12	Fabaceae	*Pterocarpus marsupium*	VU	-
13	Gesneriaceae	*Rhynchoglossum lazulinum*	NA	Rare
14	Illiciaceae	*Illicium griffithii*	EN	-
15	Juglandaceae	*Juglans regia*	NT	-
16	Lythraceae	*Lagerstroemia minuticarpa*	EN	-
17	Myricaceae	*Nageia nagi* (Syn. *Myrica nagi*)	NT	-
18	Orchidaceae	*Calanthe mannii*	NT	Rare
19	Orchidaceae	*Diplomeris hirsuta*	NA	Vulnerable
20	Orchidaceae	*Gastrochilus calceolaris*	CE	-
21	Orchidaceae	*Paphiopedilum fairrieanum*	CE	Endangered
22	Orchidaceae	*Vanda coerulea*	NA	Rare
23	Pinaceae	*Abies spectabilis*	NT	-
24	Pinaceae	*Pinus merkusii*	VU	-
25	Piperaceae	*Piper pedicellatum*	VU	-
26	Rafflesiaceae	*Sapria himalayana*	NA	Rare
27	Ranunculaceae	*Coptis teeta*	EN	Vulnerable
28	Taxaceae	*Amentotaxus assamica*	EN	-
29	Taxaceae	*Cephalotaxus mannii* (Syn. *Cephalotaxus griffithii*)	VU	-

S.No.	Family	Name of Species	IUCN	BSI Red Data List
30	Taxaceae	*Taxus wallichiana*	EN	-

CE =Critically Endangered; EN= Endangered; NT= NearThreatened; R=Rare; VU=Vulnerable; I=Indeterminate

6.4.4 Endemic Plant Species

Endemism is one of the important criteria for making an assessment of biodiversity uniqueness of biodiversity existing in a particular area. The endemic species are entirely dependent on a single area for their survival, and by virtue of their more restricted ranges, are often the most vulnerable (Myers, 1988). Endemic taxa are essentially restricted to a specified geographical area. In terms of spatial distribution, endemics may occupy limited geographical ranges – i.e., have a limited 'extent of occurrence' – and also have a limited 'area of occupation' within their geographical range (Gaston, 1991).

The Dibang basin falls in the eastern Himalayan biogeographic zone and owes its high floral and faunal diversity to its strategic location – at the junction of three biogeographic realms viz. the palaearctic, the Indo-Malayan and the Indo-Chinese. According to the biogeographic classification, the area resides in the Himalaya–east-Himalaya biogeographic region (Rodgers and Panwar, 1988).

Fifty three plant species that are endemic to Arunachal Pradesh have been recorded from Dibang basin (**Table 6.13**). These belong to 28 families and 42 genera. These species predominantly attributed to six plant families (i.e., Orchidaceae – 6 species; Gesneriaceae – 5 species, Balsaminaceae - 4 species; and Ericaceae, Rubiaceae, Begoniaceae and Acanthaceae represented by 3 species each). Three of these species viz. *Acer oblongum, Livistona jenkinsiana* and *Paphiopedilum fairrieanum* are under Endangered category according to BSI Red Data Book while *Begonia scintillans* and *Sapria himalayana* are under Rare category. IUCN has placed *Coptis teeta* and *Paphiopedilum fairrieanum* under Endangered and Critically Endangered categories.

Table 6.13: Plant species endemic to Arunachal Pradesh reported from Dibang basin

S. No.	Family	Name of Species	Conservation Status	
			IUCN Red List	BSI Red Data Book
1	Acanthaceae	*Phlogacanthus gracilis*	NA	
2	Acanthaceae	*Phlogacanthus parviflorus*	NA	
3	Acanthaceae	*Phlogacanthus tubiflorus*	NA	
4	Aceraceae	*Acer oblongum*	NA	Endangered
5	Araceae	*Rhaphidophora hookeri*	NA	
6	Arecaceae	*Calamus leptospadix*	NA	
7	Arecaceae	*Livistona jenkinsiana*	NA	Endangered
8	*Asteraceae*	*Senecio mishmi*	NA	
9	Asteraceae	*Prenanthes scandens*	NA	
10	Balsaminaceae	*Impatiens bracteolata*	NA	
11	Balsaminaceae	*Impatiens laevigata*	NA	
12	*Balsaminaceae*	*Impatiens mishmiensis*	NA	
13	Balsaminaceae	*Impatiens porrecta*	NA	
14	Begoniaceae	*Begonia aborensis*	NA	Rare
15	Begoniaceae	*Begonia scintillans*	NA	Indeterminate
16	Begoniaceae	*Begonia silhetensis*	NA	
17	*Caprifoliaceae*	*Leycesteria dibangvalliensis*	NA	
18	Caprifoliaceae	*Viburnum corylifolium*	NA	
19	Ericaceae	*Rhododendron falconeri*	NA	
20	Ericaceae	*Rhododendron megacalyx*	NA	
21	Ericaceae	*Rhododendron pruniflorum*	NA	
22	Euphorbiaceae	*Baliospermum calycinum*	NA	

S. No.	Family	Name of Species	Conservation Status	
			IUCN Red List	BSI Red Data Book
23	Fabaceae	*Dumasia villosa*	NA	
24	Gesneriaceae	*Aeschynanthus parasiticus*	NA	
25	Gesneriaceae	*Chirita macrophylla*	NA	
26	Gesneriaceae	*Chirita mishmiensis*	NA	
27	Gesneriaceae	*Loxostigma griffithii*	NA	
28	Gesneriaceae	*Wallichia nana* (Syn. *Didymosperma nanum*)	NA	
29	Lamiaceae	*Clerodendrum chinense* (Syn. *Clerodendrum lasiocephalum*)	NA	
30	*Lauraceae*	*Litsea mishmiensis*	NA	
31	Magnoliaceae	*Magnoila griffithii*	NA	
32	Meliaceae	*Aglaia edulis*	NA	
33	Musaceae	*Musa velutina*	NA	
34	*Myrtaceae*	*Syzygium mishmiense*	NA	
35	Orchidaceae	*Calanthe densiflora*	NA	
36	Orchidaceae	*Dendrobium cathcartii*	NA	
37	Orchidaceae	*Dendrobium hookerianum*	NA	
38	Orchidaceae	*Eria ferruginea*	NA	
39	Orchidaceae	*Galeola falconeri*	NA	
40	Orchidaceae	*Paphiopedilum fairrieanum*	CE	Endangered
41	*Primulaceae*	*Primula mishmiensis*	NA	
42	Rafflesiaceae	*Sapria himalayana*	NA	Rare
43	Ranunculaceae	*Aconitum lethale*	NA	
44	Ranunculaceae	*Coptis teeta*	EN	Vulnerable
45	Rosaceae	*Rubus burkillii*	NA	
46	Rubiaceae	*Luculia pinceana*	NA	
47	Rubiaceae	*Ophiorrhiza calcarata*	NA	
48	Rubiaceae	*Polyura geminata*	NA	
49	Theaceae	*Camellia siangensis*	NA	
50	Urticaceae	*Pilea insolens*	NA	
51	Vitaceae	*Tetrastigma planicaule* (Syn. *Vitis planicaulis*)	NA	
52	Zingiberaceae	*Globba multiflora*	NA	
53	Zingiberaceae	*Hedychium longipedunculatum*	NA	

6.4.5 Medicinal Plants

This region harbours a wide range of medicinal plants used in Ayurvedic, Homoeopathic and Unani medicines or used by the local people. An inventory of medicinal plant species used by local tribal people was prepared from data collected through literature survey (Rehty *et al.*, 2010; Nimasow *et al.*, 2012) Some of the medicinal plants of Dibang basin like *Acorus calamus, Adiantum capillus-veneris, Ageratum conyzoides, Artemisia nilagirica, Angiopteris evecta, Bauhinia purpurea, Breonia chinensis, Calamus* spp., *Cannabis sativa, Cinnamomum* spp., *Curcuma* spp., are quite common in the tropical and sub-tropical parts of Dibang basin. *Hedychium spicatum, Coptis teeta, Phyllanthus amarus, Rhus chinensis, Senna alata, Solanum* spp., *Tamarindus indica* and *Zanthoxylum* spp., are some other important medicinal plants of the region used by local populace in their daily life. These plants are used internally for treating stomachic diarrhea, dysentery, cough, cold, fever and asthma and externally for rheumatism, skin diseases, cuts, boils and injuries. The list of some of the medicinally important plants species used for medicinal purposes is given in **Table 6.14**.

Table 6.14: Locally used plants, plant parts for medicinal purposes

Name of Species	Local Name	Part used/ Disease
Abroma augusta	Yadukh, Pishach Karpasa, Ulatkambal	Leaf, root and stem, Cut and wounds, dysentery and vomiting, leucorrhoea
Achyranthes bidentata	Apamarga	Plant is diuretic and astringent
Acmella paniculata	Marsang, Cult	Flower and fruits

Name of Species	Local Name	Part used/ Disease
Acorus calamus	Vacha	Rhizome, tubers: Brain tonic, coolant and respiratory disorders
Adiantum capillus-veneris	Hansaj	Plant is used in cough
Aegle marmelos	Bilva	Fruit is used in diarrhoea and dysentery
Ageratum conyzoides	Namying-ling, Yemmang, Wild	Leaves
Allium sativum	Jilpa	Bulb: Infusion of *Zanthoxylum armatum* seeds with its bulb for stomach bloating
Alpinia allughas		Fruit and seeds: Rheumatism and fish poison
Alpinia malaccensis	Pupere	Rhizome, dry shoot
Alstonia scholaris	Saptaparna, Singar, Wild	Stem bark is used in malaria and inflammation
Amomum subulatum	Sthula ela	Fruit is used in cough and stomachic disorders
Andrographis paniculata		Leaf and whole plant; Diarrhoea, malaria and stomach trouble
Angiopteris evecta	Taba	Rhizome: Antidysenteric and antidiarrhoeic
Argyreia nervosa	Vastantri, Vradh daru, Riiko, wild	Rope of plant is used as bandage with bamboo strips on joints pain. Leaves are used as poultice on boil.
Aristolochia macrophylla	Rimom	Root
Artemisia nilagirica		Leaves; Wound healing, nose bleeding and muscular pain
Artemisia vulgaris	Damanak	Root: is used as tonic; plant is used as anthelmintic
Bauhinia purpurea	Kanchanar	Stem bark is used in throat disorder, worm infestation
Begonia josephi	Sis baying	Shoot, leaves
Berberis aristata	Daruharidra, Rasanjana	Root bark is used in diabetes, jaundice and leucodema
Bombax ceiba	Salmili	Root and stem bark are aphrodisiac, stimulant
Breonia chinensis (Syn. *Breonia chinensis*)	Kadamba	Plant is used as tonic in dysentery and spleen disorders
Bryophyllum pinnatum (Syn. *Bryophyllum calycinum*)	Nebinelum, Asthibhaksha, Yapong	Leaf juice is used in kidney stone and urinary disorders
Buddleja asiatica	Bana	Root is abortifacient. Leaf is used in skin diseases
Calamus erectus	Tara	Seeds, leaf: Indigestion and stomach problem
Calamus inermis (Syn. *Calamus nambariensis*)	Geying, Wild	Leaves buds and soft core (pith)
Calamus rotang	Tara	Tender shoot
Callicarpa macrophylla	Priyangu	Fruit is used in blood dysentery and skin diseases
Calotropis gigantea	Arka	Flowers are used in cough; root as Rasayana
Cannabis sativa	Vijaya	Plant leaf is used in digestion and dysentery
Carica papaya	Omri	Root
Cascabela thevetia (Syn. *Thevetia peruviana*)	Karvera	Bark is bitter, used in intermittent fever; seeds to kill lice
Cassia fistula	Aragvadha, Suvarnaka	Leaves and seeds are laxative. Leaf juice is used in skin diseases
Centella asiatica	Mandookaparni, Kipum, Brahmi	Plant is used in arthritis, diabetes, blood disorders and brain tonic
Cheilocostus speciosus (Syn. *Costus speciosus*)	Kebuk	Rhizome is used as worm repellant and blood purifier
Cinnamomum camphora	Karpura	Leaf is useful in diarrhoea, and skin diseases
Cinnamomum tamala	Tamala	Leaf is used in cough, digestion and diabetes
Cinnamomum verum (Syn. *Cinnamomum zeylanicum*)	Hitipori	Dry stem, bark
Cissampelos pareira	Ambastha, Patha, Tonbi	Root is bitter, diuretic, useful in fever and dysentery
Citrus limon	Nimbu	Fruit is digestive; useful in dysentery, dehydration and stomachic trouble
Citrus maxima	Madhu arkati	Fruit is digestive and cardiotonic
Citrus reticulata	Airavata	Fruit juice is used in rheumatism, fever, blood disorder and digestion
Clerodendrum glandulosum (Syn. *Clerodendrum*	Ongiin, Wild	Leaves

Name of Species	Local Name	Part used/ Disease
colebrookianum)		
Coffea benghalensis	Wansho	Fresh young shoots
Coptis teeta	Riingko, Mamiri, Wild	Root/Rhizome is used in fever, liver diseases hypertension and diabetes
Cordia myxa	Mowphaman	Leaves
Crotalaria juncea	Sana	Seeds, leaves are used in insanity, fever with Catarrhal
Curcuma caesia	Yakane Keloti	Fresh rhizome
Curcuma longa	Keloti	Rhizome: Body pain
Curcuma montana		
Datura stramonium	Dhattura	Leaves are used as narcotic, sedative and diuretic
Dendrocalamus strictus	Eng, Wild	Soft hearth between bark and inner core
Dillenia indica	Sompa, Bhavya	Fruit is used to improve appetite, heart fever, cough and mouth disease
Dioscorea bulbifera	Vidari kand; Kham Alu	Root is aphrodisiac and tonic
Dioscorea pentaphylla	Vidari kand; Kham Alu	Root is aphrodisiac and tonic
Diplazium esculentum	Takang	Young fronds
Drymaria cordata (Syn. *Drymaria diandra*)	Avijol, Tayi taor	Plant juice is laxative and ant febrile
Elaeocarpus floribundus	Jalpai	Bark and leaf infusion is used as mouth wash for inflamed gums, Fruit is rich source of vitamin C, digestive
Embelia ribes	Vai bidang	Fruit and root used in worm infestation, liver disorders and as tonic
Engelhardtia spicata		Bark: Skin diseases, fish poison
Entada gigas (Syn. *Entada scandens*)	Gilgachh	Seeds are used as tonic and in worm infestation
Eryngium foetidum	Ori	Stem, Leaf
Euphorbia hirta	Pusitoa/ Dugdhika bheda	Plant is used in dysentery and colic; decoction is useful in asthma and bronchial affection
Euphorbia royleana	Snuhi, Sehun	Milky juice is anthelmintic used in Kshar sutra for fistula
Euphorbia scordiifolia (Syn. *Euphorbia thymifolia*)	Dugdhika	Plant juice is used in ring worm, other skin diseases. Plant is diuretic, astringent, useful in bowel complaints
Ficus carica	Falgu/ Bhadroudambara	Fruit is demulcent; fruit juice is acrid used for cough, and skin diseases
Ficus racemosa	Udambara tree	Root is used in dysentery, diabetes; bark is astringent
Ficus relegiosa		Bark: Ulcer
Ficus sp.	Takuk, Wild	Roots
Garcinia pedunculata	Tabing	Dry pericarp
Girardinia diversifolia		Leaves: Diabetes
Gmelina arborea	Gambhari	Root bark and leaves are used in gonorrhoea
Hedychium sp.	Ali tang	Ripened fruits, Rhizome: Joint pain, injury and wound healing
Hedyotis scandens	Piyak kili/Bangkadsing	Root
Houttuynia cordata	Roram, Wild/Cult	Shoot, leaves
Hypodematium crenatum	Bhutkeshar	Rhizome is used in dysentery
Ixora sp.	Namle-riiyong, Wild	Leaves
Lagerstroemia speciosa	Ajar	Stem bark
Leucas lavandulaefolia	Dronapushpi, Droni	Leaf extract is poured into nostrils to check sinusitis.
Lygodium flexuosum	Rudrajata	Plant is used in cough, arthritis and skin disease
Marsilea minuta	Sunisannka	Plant is used in epilepsy and stomach disease
Melastoma malabathricum	Kechi-Yaying	Root, leaves
Mikania micrantha	Japani lota	Leaves
Mimosa pudica	Lajjalu	Root and leaves are used in piles and fistula
Moringa pterygosperma	Shigru Shwet	Seed is used in indigestion, worm repellant, antibacterial and jaundice
Morus alba	Talu/Tuda	Fruit is used as remedy for throat sour and fever
Morus macroura (Syn. *Morus*	Eyum	Stem

Name of Species	Local Name	Part used/ Disease
laevigata)		
Musa balbisiana	Paksum, Wild	Hearth (inner core
Musa paradisiaca	Kolung, Wild	Fruits
Nyctanthes arbor-tristis	Sephalika, Mokya, Hewali	Stem bark and root decoction is taken orally
Oroxylum indicum	Shyonaka, Domiir-etkung, Wild	Leaves, Root bark is astringent, tonic; useful in dysentery. Stem bark is bitter, tonic, useful in chronic rheumatism
Oxalis corniculata	Phakep, Chageri	Plant for burning sensation, digestion and hyperacidity
Paederia foetida	Prasarini, Bungka-Solut, Yepetare	Leaves, Plant used in tonic, arthritis, stomach pain and diarrhoea
Pandanus tectorius	Ketaki	Leaves bitter and aromatic; used in leucoderma and fever, bark oil in rheumatism.
Phlogacanthus thyrsiflorus	Teeta vasa	Leaves are used in cough and fever
Phyllanthus amarus (Syn. *Phyllanthus niruri*)	Bhumyamlak	Plant is useful in jaundice
Physalis minima	Bodopati	Fruit
Piper betle		Fruits: Various ailments
Piper longum	Pippali	Fruit is used in digestion, cough and joint pain including arthritis.
Piper mullesua	Pippali	Fruit: Used in cough, rheumatism, as appetizer
Piper nigrum	Kali Maricha	Fruit used in cough, digestion and diabetes
Plantago asiatica subsp. *erosa*	Eranda	Seeds used as substitute to Aswagola
Plantago major		Whole plant: Wound healing
Portulaca oleracea	Gubar oying	Stem and leaves
Pouzolzia viminea	Oyik or Yiktak, Wild	Leaves and stems
Psidium guajava	Mudurang	Tender leaves, Stem, Dysentery
Rauvolfia serpentina	Sarpagandha	Root is used in hypertension
Rhus chinensis (Syn. *Rhus semialata*)	Tangmo	Fruit
Ricinus communis	Eranda	Seed oil is useful in constipation, rheumatism
Rohdea nepalensis (Syn. *Campylandra aurantiaca*)	Dipo-Talo, Kelong, Wild	Whole part
Rotheca serrata (Syn. *Clerodendrum serratum*)	Bharangi	Root is useful in malaria
Rungia pectinata (Syn. *Rungia parviflora*)	Parpata	Plant is diuretic, bitter, cooling, used as blood purifier and leucoderma
Senna alata (Syn. *Cassia alata*)	Dadmardan	Leaf is used in ring worm; leaf decoction is used in bronchitis and asthma.
Senna occidentalis (Syn.*Cassia occidentalis*)	Kasamarda	Plant is digestive; used in skin diseases, fever and cough
Senna tora (Syn. *Cassia tora*)	Chakramarda	Leaf paste and oil is used in skin diseases
Sida acuta	Bala Bariar, Swet Barela	Root used in urinary disorder, aphrodisiac, liver tonic
Smilax perfoliata (Syn. *Smilax prolifera*)	Chob chini	Root used as tonic, arthritis, aphrodisiac and tonic
Smilax rhombifolia	Bala, Bariar	Root used in urinary disorders, aphrodisiac, as liver tonic
Smilax zeylanica (Syn. *Smilax ovalifolia*)	Maitri	Root used as tonic, arthritis, aphrodisiac and tonic
Solanum aculeatissimum (Syn.*Solanum khasianum*)	Kantakari Pratinidhi	Berries used in cough, asthma, fever
Solanum americanum (Syn. *Solanum nigrum*)	Kakamachi, Makoi, Okobang;	Plant used in liver diseases, dyspepsia, fever and diarrhoea
Solanum sp.	Kopi, Culti	Fruits
Solanum spirale	Bangko, Okobang; Culti	Fruits and leaves
Solanum torvum	Brihati, Brihat Kantkari	Whole Part, Berries used in intermittent fever and cough
Sonchus sp.	Ogen, Wild	Leaves
Stephania hernandiifolia	Rajpatha	
Tabernaemontana divaricata	Chandani	Bark is worm repellant, seed antidote to snakebite

Name of Species	Local Name	Part used/ Disease
Tacca integrifolia	Tagoon	Root
Tamarindus indica	Tentul	Paste prepared from tender leaves with local salt (Kou) is used for conjunctivitis.
Terminalia bellirica	Lokyo, Wild	Leaves and fruits
Toddalia asiatica	Kanchana	Berries are eaten raw, root/ bark as tonic, stimulant; used in malaria and dysentery
Trichosanthes cordata	Dongkyong riyong	Root
Urena lobata	Nagbala	Root is tonic, useful in liver dysfunction
Valeriana hardwickii	Tagar	Root is used in hypertension and asthma.
Vitex negundo	Nirgundi	Leaf is used in arthritis, sciatica and earache
Zanthoxylum armatum (Syn. *Zanthoxylum alatum*)	Onger, Tumburu	Seed and bark are used as tonic and in digestion
Zanthoxylum nitidum (Syn. *Zanthoxylum hamiltonianum*)	Ombe or Ombeng, Wild	Roots and barks
Zanthoxylum rhetsa	Onger, Wild/culti	Leaves
Zingiber officinale	Kakir	Rhizome
Zingiber zerumbet	Kekiir, Cult	Tubers including leaves
Ziziphus nummularia	Badari	Fruit is digestive, blood purifier. Root is used in fever, wound and ulcer.

Conservation Assessment and Management Plan (CAMP) workshop was held during March 2003 at Guwahati to assess the threat status of prioritized Medicinal plants of Arunachal Pradesh. During this process 44 medicinal plant species were assigned the Regional Level status of Near Threatened (NT) and above. Of these 44 species 19 are reported from Dibang basin. A list of these medicinal plants of concern is given at **Table 6.15**.

Table 6.15: Conservation Status Assessment of prioritused Medicinal plant species reported from Dibang basin based upon CAMP Workshop (2003) - FRLHT, Bangalore

S.No.	Family	Name of Species	Conservation Status
1	Apocynaceae	*Rauvolfia serpentina*	CR
2	Arecaceae	*Homalomena aromatica*	VU
3	Bignoniaceae	*Oroxylum indicum*	VU
4	Caprifoliaceae	*Valeriana hardwickii*	VU
5	Caprifoliaceae	*Valeriana jatamansi*	VU
6	Cibotiaceae	*Cibotium barometz*	NT
7	Clusiaceae	*Garcinia pedunculata*	NT
8	Illiciaceae	*Illicium griffithii*	NT
9	Lauraceae	*Cinnamomum tamala*	VU
10	Myrsinaceae	*Embelia ribes*	NT
11	Orchidaceae	*Dendrobium nobile*	VU
12	Piperaceae	*Piper pedicellatum*	VU
13	Piperaceae	*Piper peepuloides*	VU
14	Ranunculaceae	*Coptis teeta*	EN
15	Saxifragaceae	*Bergenia ciliata*	VU
16	Smilacaceae	*Smilax glabra*	CR
17	Taxaceae	*Amentotaxus assamica*	CR
18	Taxaceae	*Cephalotaxus mannii*	EN
19	Taxaceae	*Taxus wallichiana*	EN

CR=Critically Endangered; EN= Endangered; T=Threatened; VU=Vulnerable; NT= Near Threatened

6.4.6 Community Structure

In order to understand the community structure, vegetation sampling was done at 21 locations in the Dibang basin during monsoon season (September, 2015) covering forested areas around proposed locations of proposed hydropower project especially structures like dam/barrage site, submergence area, power house site in Dibang basin. Details of the same have already been given in Chapter 3 - Methodology. In all 288 species of plants were recorded during the field surveys conducted at different locations covered during the studies and the same has been at **Annexure-III, Volume II.**

Site-wise description of floristic composition at different sampling locations is given in the following paragraphs.

Site V1: Upstream of Amulin HEP - Mathun Valley

Sampling Site is located in the project area of proposed Amulin HEP. The area is predominantly under forests like Sub-tropical and Pine forest at lower slopes while slopes at higher elevations forests are temperate broadleaved and temperate conifer forests.

The tree layer at this site is mainly represented by *Pinus merkusii, Pinus wallichiana, Eurya acuminata, Xylosma longifolium and Castanopsis hystrix. Pinus wallichiana was* dominant tree at higher elevations (**Table 6.16**). The shrub layer is dominated by the species of bamboo and grasses. The shrub species compromises by *Bambusa pallida, Dendrocalamus giganteus, Dendrocalamus hamiltonii, Arundinaria falcata, Phragmites karka* and *Saccharum spontaneum* with other species like *Oxyspora paniculata* and *Rhus wallichi* (**Table 6.16**).

Arundina graminifolia, Pratia nummularia, Ageratum conyzoides, Thysanolaena maxima, Cyperus rotundus and *Chirita bifolia* are the common herbs in the catchment area of Mathun River. In addition, fern species like *Pteridium* and *Selaginella* are also found at this site (**Table 6.17**).

Table 6.16: Community structure -Site-V1 (Trees & Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Acer caudatum*	14	21	42	16
2	*Castanopsis hystrix*	36	36	34	26
3	*Eurya acuminata*	36	50	135	44
4	*Exbucklandia populnea*	21	29	45	21
5	*Macaranga denticulata*	21	43	111	33
6	*Pinus wallichiana*	43	57	121	46
7	*Pinus merkusii*	21	43	173	42
8	*Quercus serrata*	21	29	17	17
9	*Schefflera impressa*	14	14	24	12
10	*Toona ciliata*	29	43	23	24
11	*Xylosma longifolium*	14	43	19	18
			408		
Shrubs					
1	*Acacia pennata*	10	80	0.32	8
2	*Arundinaria falcata*	15	240	0.43	15
3	*Bambusa pallida*	20	560	37.92	59
4	*Dendrocalamus giganteus*	20	280	66.66	72
5	*Dendrocalamus hamiltonii*	15	200	17.13	27
6	*Oxyspora paniculata*	10	360	0.28	17
7	*Phragmites karka*	25	420	0.40	26
8	*Rhus wallichi*	20	160	0.16	15
9	*Rubus ellipticus*	15	120	0.09	11
10	*Rubus foliolosus*	15	80	0.11	10
11	*Saccharum spontaneum*	25	240	0.35	20
12	*Schizostachyum polymorphum*	20	100	0.09	13
13	*Solanum ciliatum*	10	100	0.05	8

Table 6.17: Community structure -Site-V1 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	24	10000	13
2	*Anaphalis contorta*	14	2381	5
3	*Artemisia maritima*	24	7143	11
4	*Arundina graminifolia*	19	10476	12

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
5	*Chirita bifolia*	24	8571	12
6	*Commelina benghalensis*	14	4286	7
7	*Cynodon dactylon*	10	7143	7
8	*Cyperus rotundus*	14	8571	9
9	*Dicranopteris linearis*	5	2857	3
10	*Dryoathyrium boryanum*	14	3333	6
11	*Fragaria indica*	14	5714	8
12	*Impatiens acuminata*	19	8095	10
13	*Leucas ciliata*	10	4762	6
14	*Microsorum punctatum*	19	5238	9
15	*Persicaria chinensis*	19	6667	9
16	*Pilea scripta*	14	7619	9
17	*Plantago erosa*	5	3810	4
18	*Poa annua*	10	7619	8
19	*Pratia nummularia*	19	10000	12
20	*Pteridium aquilinum*	10	2381	4
21	*Selaginella picta*	10	5238	6
22	*Solanum indicum*	14	2857	6
23	*Spilanthes paniculata*	14	5714	8
24	*Strobilanthes elongata*	19	4762	8
25	*Thysanolaena maxima*	14	9048	10

Site V2: Near Proposed Emini HE Project area - Mathun Valley

On left bank of the Mathun river near proposed Emini HE project, trees cover is sparse and is comprised mainly of *Pinus merkusii* in upper reaches, along the river bank *Castanopsis indica*, *Alnus nepalensis* and *Ficus semicordata* were dominant tree species in these forests and are found in association with *Aralia armata*, *Brassaiopsis glomerulata* and *Cyathea spinulosa*. *Dendrocalamus giganteus*, *Musa acuminata*, *Bambusa pallida*, *Rubus ellipticus*, *Musa balbisiana* and *Saccharum spontaneum* are the dominant shrub species observed at this sampling site. Amongst the herbs *Cyperus rotundus*, *Cynodon dactylon*, *Arundina graminifolia*, *Thysanolaena maxima*, *Fragaria indica* and *Bidens pilosa* were the dominant species. Ferns in the area were represented by *Dicranopteris linearis*, *Pteridium aquilinum*, *Angiopteris evecta*, *Adiantum caudatum*, *Equisetum diffusum* and *Lycopodium clavatum*. Frequency, density and Importance Value Index (IVI) of the species reported at the site are given in **Tables 6.18** and **6.19**.

Table 6.18: Community structure -Site-V2 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Albizia procera*	29	36	304.78	41
2	*Alnus nepalensis*	14	43	18.87	18
3	*Aralia armata*	21	36	153.70	28
4	*Brassaiopsis glomerulata*	29	29	10.52	19
5	*Castanopsis indica*	29	57	65.97	30
6	*Cyathea spinulosa*	21	21	13.10	15
7	*Engelhardtia spicata*	14	14	64.75	14
8	*Ficus semicordata*	29	50	347.24	48
9	*Macaranga denticulata*	14	21	43.44	14
10	*Macropanax dispermus*	7	7	4.72	5
11	*Pinus merkusii*	29	57	366.90	51
12	*Terminalia chebula*	14	14	45.05	12
13	*Toona hexandra*	7	7	6.97	5
			393		
Shrubs					
1	*Acacia pennata*	10	40	2.29	5
2	*Agapetes forrestii*	10	60	1.53	6
3	*Angiopteris evecta*	15	100	0.32	8
4	*Bambusa pallida*	10	360	47.12	32
5	*Bambusa tulda*	20	580	74.06	53

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
6	*Costus speciosus*	10	80	0.28	6
7	*Dendrocalamus giganteus*	20	440	0.92	18
8	*Ficus heterophylla*	15	100	7.50	11
9	*Hydrangea robusta*	10	100	0.48	6
10	*Jasminum amplexicaule*	15	140	1.86	9
11	*Luculia pinceana*	5	40	0.50	3
12	*Musa acuminata*	20	360	1.53	17
13	*Musa balbisiana*	10	120	7.78	10
14	*Myrsine semiserrata*	10	80	0.54	6
15	*Oxyspora paniculata*	10	240	75.37	41
16	*Phragmites karka*	15	160	9.79	13
17	*Piper clarkei*	15	160	0.74	9
18	*Rhaphidophora decursiva*	10	80	0.37	6
19	*Rubus ellipticus*	25	340	0.46	17
20	*Saccharum spontaneum*	20	260	1.12	14
21	*Trevesia palmata*	20	100	3.58	11

Table 6.19: Community structure –Site V2 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Adiantum caudatum*	18	5882	7
2	*Angiopteris evecta*	12	3529	4
3	*Arisaema jacquemontii*	12	1765	3
4	*Arisaema speciosum*	18	2941	5
5	*Artemisia maritima*	24	5882	8
6	*Arundina graminifolia*	29	10588	11
7	*Bidens pilosa*	24	8824	9
8	*Chirita bifolia*	29	7647	10
9	*Commelina benghalensis*	18	4706	6
10	*Cynodon dactylon*	24	12941	12
11	*Cyperus rotundus*	29	12353	12
12	*Dicranopteris linearis*	18	8235	8
13	*Equisetum diffusum*	24	6471	8
14	*Fagopyrum dibotrys*	18	8235	8
15	*Fragaria indica*	18	9412	9
16	*Hedychium densiflorum*	18	4706	6
17	*Hedychium spicatum*	24	2941	6
18	*Impatiens bicornuta*	24	6471	8
19	*Impatiens racemosa*	29	7647	10
20	*Lycopodium clavatum*	12	6471	6
21	*Microsorum punctatum*	18	2941	5
22	*Persicaria chinensis*	18	3529	5
23	*Plantago erosa*	12	1765	3
24	*Poa annua*	18	7059	7
25	*Pteridium aquilinum*	6	1765	2
26	*Selaginella picta*	6	2353	2
27	*Solanum indicum*	12	1176	3
28	*Strobilanthes rhombifolius*	18	4706	6
29	*Thysanolaena maxima*	29	9412	11

Site V3: Near Mihumdon HE Project area- Dri Valley

The sampling site V3 is located in upstream of the dam site of proposed Mihumdon HEP on Dri River on the right bank. *Pinus merkusii, Alnus nepalensis, Ficus semicordata, Engelhardtia spicata* and *Castanopsis indica* was the dominant tree species, *Bambusa tulda, Oxyspora paniculata, Oxyspora paniculata, Phragmites karka, Rubus ellipticus* and *Musa acuminata* was the shrub species dominating in the area. *Pratia nummularia, Fragaria indica* and *Polygonum capitatum* was the dominant herb species in these forest areas. Some other frequently distributed species in the area are *Hedychium densiflorum, Chirita bifolia*, *Ageratum conyzoides* and *Arundina graminifolia.* Fern species in the area was mainly represented by *Lycopodium clavatum, Pteris quadriaurita* and *Nephrolephis cordifolia* species. Frequency, density, basal cover and Importance Value Index (IVI) of the species reported at the site are given in **Tables 6.20** and **6.21**.

Table 6.20: Community structure -Site-V3 (Trees and Shrubs)

S.No	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Acrocarpus fraxinifolius*	14	29	10.4	19
2	*Albizia lucida*	29	36	14.62	29
3	*Albizia procera*	14	21	13.59	19
4	*Alnus nepalensis*	21	50	6.57	24
5	*Aralia armata*	14	14	2.51	10
6	*Brassaiopsis glomerulata*	14	21	4.75	13
7	*Canarium strictum*	7	7	6.73	8
8	*Caryota urens*	7	14	6.12	10
9	*Castanopsis indica*	21	36	21.48	30
10	*Cyathea spinulosa*	7	7	0.51	5
11	*Engelhardtia spicata*	29	36	13.63	28
12	*Ficus semicordata*	29	43	22.08	35
13	*Macaranga denticulata*	7	7	3.3	6
14	*Macropanax undulatus*	14	14	8.56	14
15	*Pandanus odoratissima*	7	7	0.36	5
16	*Pinus merkusii*	29	57	32.61	45
			399		
Shrubs					
1	*Angiopteris evecta*	10	60	0.52	6
2	*Bambusa pallida*	5	160	33.40	36
3	*Bambusa pallida*	25	540	7.43	30
4	*Dendrocalamus giganteus*	20	240	18.41	30
5	*Hydrangea macrophylla*	15	100	1.53	10
6	*Jasminum amplexicaule*	10	60	0.55	6
7	*Calamus leptospadix*	20	240	1.82	15
8	*Musa acuminata*	20	280	24.10	36
9	*Musa balbisiana*	15	180	9.95	19
10	*Myrsine semiserrata*	20	120	1.12	12
11	*Oxyspora paniculata*	30	480	1.69	25
12	*Phragmites karka*	20	400	1.41	19
13	*Piper clarkei*	20	460	1.35	21
14	*Rhaphidophora decursiva*	10	60	0.23	5
15	*Rubus ellipticus*	15	140	7.99	16
16	*Saccharum spontaneum*	20	180	1.86	14

Table 6.21: Community structure -Site-V3 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Adiantum caudatum*	14	3571	5
2	*Ageratum conyzoides*	21	7143	8
3	*Arisaema speciosum*	21	3571	6
4	*Arundina graminifolia*	29	6429	9
5	*Chirita bifolia*	36	7857	12
6	*Commelina benghalensis*	7	2143	3
7	*Equisetum diffusum*	14	5714	6
8	*Fagopyrum dibotrys*	29	12857	13
9	*Fragaria indica*	43	14286	17
10	*Gnaphalium affine*	21	3571	6
11	*Hedychium densiflorum*	36	8571	12
12	*Hedychium coccineum*	21	3571	6
13	*Hedychium spicatum*	21	5714	8
14	*Impatiens bicornuta*	14	4286	5
15	*Impatiens racemosa*	7	1429	2
16	*Lactuca virosa*	14	3571	5
17	*Lepisorus affinis*	7	6429	5

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
18	*Lycopodium clavatum*	21	9286	10
19	*Nephrolephis cordifolia*	29	5714	9
20	*Physalis minima*	14	2143	4
21	*Polygonum capitatum*	29	11429	12
22	*Pratia nummularia*	36	20000	19
23	*Pteris quadriaurita*	21	7143	8
24	*Selaginella picta*	14	5714	6
25	*Stellaria monosperma*	7	2857	3

Site V4: Near Dri Angepani Confluence- Dri Valley

The area near confluence of Angepani river with Dri river is composed of moderate hilly terrains with dense vegetation. During the sampling 16 tree species are recorded from area, from which *Castanopsis indica*, *Saurauia roxburghii*, *Macropanax dispermus* and *Ficus semicordata* are the dominant species. Shrub layer is dominated by *Bambusa pallida*, *Musa balbisiana, Myrsine semiserrata, Dendrocalamus giganteus* and *Acacia pennata*. The herb layer is represented by 16 species. Commonly recorded herbs are *Thysanolaena maxima, Pothos scandens, Poa annua, Plantago erosa, Hedychium spicatum, Physalis minima* and *Murdannia nudiflora*. Among ferns *Nephrolepis cordifolia* was the only species widely distributed in the shady and moist area. Frequency, density, and Importance Value Index (**IVI**) of the species reported at the site are given in **Tables 6.22** and **6.23**.

Table 6.22: Community structure -Site V4 (Trees and Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Ailanthus integrifolia*	21	29	140.18	20
2	*Albizia lucida*	21	43	380.31	38
3	*Albizia procera*	29	36	61.16	19
4	*Brassaiopsis glomerulata*	14	21	42.55	11
5	*Caryota urens*	14	14	26.45	8
6	*Castanopsis indica*	29	50	32.76	20
7	*Cyathea spinulosa*	14	21	4.05	8
8	*Engelhardtia spicata*	29	36	109.72	22
9	*Ficus semicordata*	29	43	195.69	29
10	*Lagerstroemia parviflora*	21	21	42.55	13
11	*Macaranga denticulata*	21	29	63.54	15
12	*Macropanax dispermus*	29	43	94.49	22
13	*Pandanus odoratissimus*	21	36	7.62	13
14	*Saurauia roxburghii*	29	43	77.72	21
15	*Terminalia chebula*	21	21	151.47	19
16	*Terminalia myriocarpa*	21	29	155.77	21
			515		
Shrubs					
1	*Clerodendrum viscosum*	20	80	10.9	12
2	*Agapetes forrestii*	20	90	1.12	8
3	*Angiopteris evecta*	15	100	0.54	7
4	*Calamus leptospadix*	10	100	0.34	5
5	*Trevesia palmata*	40	100	15.4	19
6	*Ficus heterophylla*	40	120	3.98	14
7	*Oxyspora paniculata*	50	120	5.75	17
8	*Rhamnus nepalensis*	15	120	10.83	12
9	*Solanum ciliatum*	30	120	11.86	16
10	*Artemisia indica*	40	130	2.07	14
11	*Rubus foliolosus*	20	130	10.67	13
12	*Calamus floribundus*	20	140	0.23	9
13	*Cassia occidentalis*	30	150	13.21	17
14	*Acacia pennata*	30	180	4.44	14
15	*Dendrocalamus giganteus*	30	260	31.11	29
16	*Myrsine semiserrata*	10	300	0.31	11

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
17	*Musa balbisiana*	30	410	33.99	35
18	*Bambusa pallida*	10	690	49.4	47

Table 6.23: Community structure -Site V4 (Herbs)

Sl. No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	20	13333	16
2	*Alpinia allughas*	13	4667	7
3	*Anaphalis contorta*	13	4000	7
4	*Begonia nepalensis*	18	7000	11
5	*Begonia palmata*	27	9333	15
6	*Bidens pilosa*	23	7500	12
7	*Elatostema sessile*	23	8000	13
8	*Fagopyrum dibotrys*	20	4000	9
9	*Hedychium spicatum*	20	14667	17
10	*Murdannia nudiflora*	20	8000	12
11	*Nephrolepis cordifolia*	27	19333	22
12	*Physalis minima*	20	6667	11
13	*Plantago erosa*	20	5333	10
14	*Poa annua*	27	14667	19
15	*Pothos scandens*	20	2667	8
16	*Thysanolaena maxima*	20	6667	11

Site V5: Near Etabue HE Project area - Dri Valley

The tree component of these open forest areas were dominated by *Pinus merkusii, Pterospermum acerifolium, Ficus semicordata* and *Engelhardtia spicata* were other dominant tree species. *Bambusa pallida, Musa balbisiana, Dendrocalamus giganteus* and *Acacia pennata* was the dominant shrub and *Hedychium coccineum, Poa annua, Physalis minima, Elatostema sessile* and *Bidens pilosa* was the dominant herb species. *Equisetum diffusum* and *Pteridium aquilinum* are the fern allies in the area. Frequency, density, basal cover, and Importance Value Index (IVI) of the species reported at the site are given in **Tables 6.24 and 6.25**.

Table 6.24: Community structure -Site V5 (Trees and Shrubs)

S. No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
TREES					
1	*Brassaiopsis glomerulata*	21	29	17.1	23
2	*Caryota urens*	7	7	3.8	7
3	*Cyathea spinulosa*	21	21	42.9	24
4	*Engelhardtia spicata*	21	29	90.0	34
5	*Ficus semicordata*	29	29	137.2	44
6	*Kydia calycina*	14	14	13.5	14
7	*Macropanax dispermus*	21	21	54.6	26
8	*Ostodes paniculata*	14	14	10.4	13
9	*Pandanus odoratissimus*	14	21	7.2	16
10	*Pinus merkusii*	29	57	237.8	69
11	*Pterospermum acerifolium*	21	29	72.4	31
			271		
SHRUBS					
1	*Acacia pennata*	30	180	4.44	12
2	*Agapetes forrestii*	20	90	1.12	8
3	*Angiopteris evecta*	15	100	0.54	7
4	*Artemisia indica*	40	130	2.07	5
5	*Bambusa pallida*	10	690	49.4	19
6	*Calamus floribundus*	20	140	0.23	14
7	*Calamus leptospadix*	10	100	0.34	17
8	*Cassia occidentalis*	30	150	13.21	12

S. No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
9	*Clerodendrum viscosum*	20	80	10.9	16
10	*Dendrocalamus giganteus*	30	260	31.11	14
11	*Ficus heterophylla*	40	120	3.98	13
12	*Musa balbisiana*	30	410	33.99	9
13	*Myrsine semiserrata*	10	300	0.31	17
14	*Oxyspora paniculata*	50	120	5.75	14
15	*Rhamnus nepalensis*	15	120	10.83	29
16	*Rubus foliolosus*	20	130	10.67	11
17	*Solanum ciliatum*	30	120	11.86	35
18	*Trevesia palmata*	40	100	15.4	47

Table 6.25: Community structure -Site V5 (Herbs)

S. No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Alpinia allughas*	18	7500	12
2	*Amaranthus viridis*	14	5000	9
3	*Arisaema speciosum*	14	4500	9
4	*Begonia nepalensis*	18	7000	12
5	*Begonia palmata*	14	4500	9
6	*Bidens pilosa*	23	7500	14
7	*Commelina benghalensis*	14	3500	8
8	*Elatostema sessile*	23	8000	15
9	*Equisetum diffusum*	5	31000	24
10	*Hedychium coccineum*	20	11000	16
11	*Impatiens racemosa*	9	4000	6
12	*Oxalis corniculata*	9	4000	6
13	*Physalis minima*	9	9500	10
14	*Poa annua*	14	10500	13
15	*Pogonatherum paniceum*	15	4000	9
16	*Pteridium aquilinum*	9	3500	6
17	*Senecio cappa*	9	5500	7
18	*Strobilanthes rhombifolius*	14	5000	9
19	*Urtica dioica*	9	3000	6

Site V6: Near Dri- Mathun Confluence

The sampling area near to the confluence of Mathun river with Dri is composed of sharp hills with patches of tree vegetation. *Saurauia roxburghii* was the dominant tree species assosited with *Castanopsis indica, Albizia procera, Engelhardtia spicata, Pandanus odoratissimus* and *Lagerstroemia parviflora*. Among the herb species *Bambusa pallida, Pseudostachyum polymorphum, Oxyspora paniculata, Murraya exotica* and *Chimonobambusa callosa* were the dominant shrubs. In the moist localities in the sampling area species like *Hedychium coccineum, Pteridium aquilinum* and *Equisetum diffusum* were widely distributed. In the slopes and open area species of grasses viz. *Poa annua, Digitaria ciliaris* and *Thysanolaena latifolia* was the dominant herbaceous species. Other herbs in the area are *Begonia palmata, Strobilanthes rhombifolius, Pilea scripta, Urtica dioica* and *Commelina benghalensis*. Frequency, density, basal cover, and Importance Value Index (IVI) of the species reported at the site left bank are given in **Tables 6.26 and 6.27**.

Table 6.26: Community structure -Site V6 (Trees and Shrubs)

S.No	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Albizia procera*	36	57	261.17	44
2	*Caryota urens*	14	21	41.77	7
3	*Castanopsis indica*	43	57	120.89	12

S.No	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
4	*Cyathea spinulosa*	21	29	16.71	33
5	*Engelhardtia spicata*	36	50	134.70	12
6	*Ficus semicordata*	21	43	111.15	31
7	*Lagerstroemia parviflora*	21	43	172.97	24
8	*Macaranga denticulata*	21	29	45.05	30
9	*Macropanax dispermus*	14	14	24.25	15
10	*Mallotus philippensis*	36	36	33.54	9
11	*Pandanus odoratissimus*	29	43	22.57	17
12	*Sarcosperma griffithii*	29	29	17.08	19
13	*Saurauia roxburghii*	43	57	19.53	14
14	*Brassaiopsis glomerulata*	14	14	11.93	23
15	*Toona hexandra*	14	14	32.85	9
			536		
Shrubs					
1	*Agapetes forrestii*	15	100	0.54	11
2	*Ardisia thyrsiflora*	20	120	10.58	16
3	*Bambusa pallida*	20	1360	345.9	115
4	*Boehmeria macrophylla*	10	80	12.31	10
5	*Chimonobambusa callosa*	15	240	21.47	19
6	*Debregeasia longifolia*	20	140	15.2	18
7	*Indigofera dosua*	10	40	3.66	7
8	*Murraya exotica*	10	280	25.12	18
9	*Oxyspora paniculata*	10	320	7.78	16
10	*Pentapanax leschenaultiana*	20	80	7.19	15
11	*Pseudostachyum polymorphum*	10	600	43.48	30
12	*Rhamnus nepalensis*	10	120	13.56	11
13	*Rubus ellipticus*	10	160	13.85	13

Table 6.27: Community structure -Site V6 (Herbs)

S. No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Achyranthes aspera*	40	5333	12
2	*Begonia palmata*	27	12000	15
3	*Commelina benghalensis*	27	5333	10
4	*Cyrtococcum accrescens*	20	4000	7
5	*Digitaria ciliaris*	33	8000	13
6	*Equisetum diffusum*	33	8000	13
7	*Hedychium coccineum*	53	4667	14
8	*Impatiens racemosa*	27	8667	12
9	*Oplismenus compositus*	20	4667	8
10	*Oxalis corniculata*	20	8000	10
11	*Pilea scripta*	27	9333	13
12	*Poa annua*	27	9333	13
13	*Pogonatherum paniceum*	20	6667	9
14	*Pteridium aquilinum*	33	6667	12
15	*Strobilanthes rhombifolius*	40	10667	17
16	*Thysanolaena latifolia*	25	5000	9
17	*Urtica dioica*	30	7500	12

Site V7: Etalin HEP Dam Site- Dri Limb

The sampling location is located in the upstream of the proposed Etalin HEP power house site near Dri and Talo river confluence in the left bank of Dri river. During the sampling 17 tree species are recorded from area, from which *Castanopsis indica, Saurauia roxburghii, Macropanax dispermus, Ficus semicordata, Albizia lucida* and *Pandanus odoratissimus* are the dominant species. Shrub layer is composed of 16 species dominated by *Dendrocalamus giganteus* in the upper slopes, *Musa balbisiana* was the dominating species in the forest area.

Other species distributed in the area are *Eupatorium odoramtum*, *Elatostema sessile*, *Rubus ellipticus*, *Trevesia palmata*, *Myrsine semiserrata* and *Ficus heterophylla*. The herb layer is represented by 17 species found nearby springs and dominating by fern species like *Pteridium aquilinum*, *Pteris quadriaurita* and *Nephrolephis cordifolia*. Commonly recorded herbs are *Ageratum conyzoides*, *Poa annua*, *Alpinia allughas*, *Cynodon dactylon* and *Aster himalaicus*. Frequency, density, basal cover and Importance Value Index (IVI) of the species reported at the site are given in **Tables 6.28 and 6.29**.

Table 6.28: Community structure -Site V7 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Ailanthus integrifolia*	21	29	140.18	19
2	*Albizia lucida*	21	43	380.31	36
3	*Albizia procera*	29	36	61.16	18
4	*Aralia armata*	21	36	93.61	18
5	*Brassaiopsis glomerulata*	14	21	42.55	10
6	*Caryota urens*	14	14	26.45	8
7	*Castanopsis indica*	29	50	32.76	18
8	*Cyathea spinulosa*	14	21	4.05	8
9	*Engelhardtia spicata*	29	36	109.72	20
10	*Ficus semicordata*	29	43	195.69	27
11	*Lagerstroemia parviflora*	21	21	42.55	12
12	*Macaranga denticulata*	21	29	63.54	15
13	*Macropanax dispermus*	29	43	94.49	21
14	*Pandanus odoratissimus*	21	36	7.62	13
15	*Saurauia roxburghii*	29	43	77.72	20
16	*Terminalia chebula*	21	21	151.47	18
17	*Terminalia myriocarpa*	21	29	155.77	20
			550		
Shrubs					
1	*Acacia pennata*	10	70	2.29	7
2	*Agapetes forrestii*	10	80	1.53	7
3	*Artemisia indica*	15	90	0.32	9
4	*Calamus flagellum*	20	150	3.58	14
5	*Costus speciosus*	20	90	0.34	10
6	*Dendrocalamus giganteus*	40	720	75.37	85
7	*Elatostema sessile*	20	220	0.92	15
8	*Eupatorium odoramtum*	10	580	47.12	52
9	*Ficus heterophylla*	20	90	7.5	15
10	*Hypericum hookerianum*	10	50	0.48	6
11	*Jasminum amplexicaulis*	20	80	1.86	11
12	*Musa balbisiana*	30	360	9.79	29
13	*Myrsine semiserrata*	10	120	0.54	8
14	*Ricinus communis*	10	60	0.37	6
15	*Rubus ellipticus*	20	170	0.74	13
16	*Trevesia palmata*	10	160	7.78	14

Table 6.29: Community structure -Site V7 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	20	17500	18
2	*Alpinia allughas*	27	10000	15
3	*Anaphalis contorta*	20	6000	10
4	*Aster himalaicus*	13	8500	10
5	*Begonia nepalensis*	27	7000	13
6	*Bidens pilosa*	20	7500	11
7	*Cynodon dactylon*	13	9500	10
8	*Fagopyrum dibotrys*	13	7000	9

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
9	*Hedychium spicatum*	20	2500	8
10	*Impatiens racemosa*	13	7000	9
11	*Pilea scripta*	27	7500	13
12	*Poa annua*	13	11500	12
13	*Pteridium aquilinum*	27	18000	20
14	*Pteris quadriaurita*	27	9000	14
15	*Nephrolephis cordifolia*	33	7333	15
16	*Thysanolaena maxima*	20	6000	10
17	*Urena lobata*	7	6000	6

Site V8: Malinye Village- Talo (Tangon) River

The tree component of these open forest areas were dominated by *Pinus merkusii* located near Malinye village, *Alnus nepalensis, Engelhardtia spicata, Ficus semicordata* and *Castanopsis indica* were the dominant tree species. Among the shrub species *Bambusa pallida* and *Dendrocalamus giganteus* were the dominant bamboo species recorded from the area. *Saccharum spontaneum, Phragmites karka* and *Arundinella nepalensis* are the other shrub species recorded from the area. *Bidens pilosa, Ageratum conyzoides, Artemisia maritima and Fragaria indica* was the dominant herb species in these open forest areas. Fern allies were represented by *Dryoathyrium boryanum, Nephrolepis cordifolia, Pteridium aquilinum* and *Pteris subindivisa*. Frequency, density, basal cover and Importance Value Index (IVI) of the species reported at the site right bank are given in **Tables 6.30 and 6.31**.

Table 6.30: Community structure -Site V8 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Acrocarpus fraxinifolius*	14	29	10.4	19
2	*Albizia lucida*	29	36	14.62	29
3	*Albizia procera*	14	21	13.59	19
4	*Alnus nepalensis*	21	50	6.57	24
5	*Aralia armata*	14	14	2.51	10
6	*Brassaiopsis glomerulata*	14	21	4.75	13
7	*Canarium strictum*	7	7	6.73	8
8	*Caryota urens*	7	14	6.12	10
9	*Castanopsis indica*	21	36	21.48	30
10	*Cyathea spinulosa*	7	7	0.51	5
11	*Engelhardtia spicata*	29	36	13.63	28
12	*Ficus semicordata*	29	43	22.08	35
13	*Macaranga denticulata*	7	7	3.3	6
14	*Macropanax undulatus*	14	14	8.56	14
15	*Pandanus odoratissima*	7	7	0.36	5
16	*Pinus merkusii*	29	57	32.61	45
			399		
Shrubs					
1	*Acacia pennata*	20	80	5.87	18
2	*Artemisia indica*	15	240	2.07	16
3	*Arundinella nepalensis*	20	280	1.41	18
4	*Bambusa pallida*	10	440	7.9	28
5	*Buddleja asiatica*	20	160	9.25	25
6	*Dendrocalamus giganteus*	10	400	7.77	26
7	*Hydrangea macrophylla*	20	100	7.02	20
8	*Luculia pinceana*	20	80	5.87	18
9	*Musa balbisiana*	10	120	7.43	17
10	*Opuntia aciculata*	5	100	3.83	10
11	*Oxyspora paniculata*	20	200	1.53	16
12	*Phragmites karka*	20	300	2.45	20

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
13	*Piper clarkei*	15	160	0.57	12
14	*Rubus ellipticus*	10	60	0.54	7
15	*Rubus foliolosus*	10	80	0.76	7
16	*Saccharum spontaneum*	20	500	13.76	41

Table 6.31: Community structure –Site 8 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Anaphalis contorta*	33	6667	13
2	*Aster himalaicus*	27	2667	8
3	*Bidens pilosa*	13	10000	12
4	*Dryoathyrium boryanum*	20	1333	5
5	*Eupatorium odoratum*	13	6667	9
6	*Fagopyrum dibotrys*	20	3333	7
7	*Pteris subindivisa*	20	5333	9
8	*Leucas ciliata*	27	2000	7
9	*Pteridium aquilinum*	20	4000	8
10	*Nephrolepis cordifolia*	33	3333	10
11	*Poa annua*	20	6667	10
12	*Pouzolzia fulgens*	13	4667	7
13	*Adiantum caudatum*	27	6000	11
14	*Thysanolaena maxima*	13	5333	7
15	*Urtica dioica*	13	4667	7
16	*Polygonum capitatum*	27	4000	9
17	*Pilea scripta*	27	6667	12
18	*Viola diffusa*	27	6000	11
19	*Artemisia maritima*	33	7333	13
20	*Ageratum conyzoides*	27	8000	13
21	*Fragaria indica*	33	6667	13

Site V9: Edzon- Talo Confluence near Attulni HEP

Sampling site is located near confluence of Edzon and Talo river composed of sharp hills. *Pinus merkusii*, *Pterospermum acerifolium*, *Albizia procera*, *Ficus semicordata*, *Engelhardtia spicata* and *Brassaiopsis glomerulata* was dominant tree species. Shrub layer was mainly constituted by *Oxyspora paniculata*, *Arundinella nepalensis*, *Bambusa pallida*, *Phragmites karka* and *Dendrocalamus giganteus*. Among the herbaceous flora *Urtica dioica*, *Equisetum diffusum*, *Hedychium coccineum*, *Elatostema sessile* and *Alpinia allughas* are the dominant herb species in the area. Frequency, density, basal cover, and Importance Value Index (IVI) of the species reported at the site right bank are given in **Table 6.32** and **6.33**.

Table 6.32: Community structure –Site V9 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Albizia procera*	29	43	63.30	32
2	*Aralia armata*	14	21	32.25	16
3	*Brassaiopsis glomerulata*	21	29	17.08	19
4	*Caryota urens*	7	7	3.84	5
5	*Cyathea spinulosa*	21	21	42.95	20
6	*Engelhardtia spicata*	21	29	90.00	28
7	*Ficus semicordata*	29	29	137.16	37
8	*Kydia calycina*	14	14	13.54	12
9	*Macropanax dispermus*	21	21	54.62	22
10	*Ostodes paniculata*	14	14	10.37	11
11	*Pandanus odoratissimus*	14	21	7.21	13
12	*Pinus merkusii*	29	57	237.83	59
13	*Pterospermum acerifolium*	21	29	72.36	26
			336		

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Shrubs					
1	*Artemisia indica*	10	140	0.50	8
2	*Arundinaria falcata*	15	240	0.41	12
3	*Bambusa pallida*	20	360	20.41	30
4	*Arundinella nepalensis*	35	400	4.49	27
5	*Musa balbisiana*	15	100	5.51	12
6	*Buddleja asiatica*	15	120	2.61	11
7	*Dendrocalamus giganteus*	10	340	120.53	87
8	*Hydrangea macrophylla*	10	100	0.83	7
9	*Oxyspora paniculata*	25	480	1.32	23
10	*Phragmites karka*	20	340	1.10	18
11	*Piper clarkei*	15	160	0.37	10
12	*Rhus wallichii*	10	100	0.92	7
13	*Rubus ellipticus*	20	160	0.35	12
14	*Rubus foliolosus*	20	200	1.26	14
15	*Saccharum spontaneum*	15	260	2.18	14
16	*Saxifraga aspera*	10	160	1.12	9

Table 6.33: Community structure -Site V9 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Abutilon indicum*	15	1538	5
2	*Adiantum caudatum*	8	4615	5
3	*Anaphalis contorta*	23	3846	8
4	*Artemisia maritima*	8	2308	4
5	*Arundina graminifolia*	23	9231	12
6	*Chirita bifolia*	31	11538	16
7	*Commelina benghalensis*	31	5385	11
8	*Cynodon dactylon*	23	18462	20
9	*Cynoglossum glochidiatum*	23	6154	10
10	*Cyperus rotundus*	15	7692	9
11	*Dicranopteris linearis*	15	2308	5
12	*Dioscorea belophylla*	23	3846	8
13	*Elsholtzia fruticosa*	15	4615	7
14	*Hedychium coronarium*	8	1538	3
15	*Hedychium spicatum*	15	2308	5
16	*Impatiens bicornuta*	15	3846	6
17	*Lecanthes peduncularis*	15	4615	7
18	*Lycopodium clavatum*	8	2308	4
19	*Pratia nummularia*	31	14615	18
20	*Rhaphidophora decursiva*	23	2308	7
21	*Selaginella picta*	8	3846	5
22	*Sida rhombifolia*	23	4615	9
23	*Solanum indicum*	15	3077	6
24	*Spilanthes paniculata*	8	769	2
25	*Strobilanthes elongata*	15	3846	6

Site V10: Anonpani Nala: Left bank tributary of Talo (Tangon) river

This site is comprised of area around the proposed Weir site of Anonpani HEP. At this site 16 tree species were recorded during the sampling. *Castanopsis indica, Alnus nepalensis, Ficus semicordata* and *Engelhardtia spicata* are the most dominant tree species with highest density. At this site total 21 shrub species were recorded during surveys. In the area most common shrub species are *Dendrocalamus giganteus, Bambusa tulda, Phragmites karka, Bambusa pallida* and *Piper clarkei*. *Actinidia callosa* are most dominant shrub species. The herbaceous layer at this site is represented by 23 species. *Thysanolaena maxima* and *Fagopyrum dibotrys* were the most dominant species followed by *Polygonum flaccidum, Strobilanthes* sp. *Bidens* *pilosa*. Some other ffern allies in the sampling site are *Dicranopteris linearis, Lycopodium clavatum, Nephrolephis cordifolia* and *Pteris vittata* Frequency, density, basal cover, and Importance Value Index (IVI) of the species reported at the site left bank are given in **Tables 6.34 and 6.35**.

Table 6.34: Community structure –Site V10 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Albizia lucida*	29	50	135.57	30
2	*Albizia procera*	21	36	94.05	22
3	*Alnus nepalensis*	36	57	55.51	26
4	*Acrocarpus fraxinifolius*	14	14	10.56	8
5	*Brassaiopsis glomerulata*	21	21	7.17	10
6	*Castanopsis indica*	29	64	66.70	26
7	*Cinnamomum obtusifolia*	29	29	31.99	16
8	*Cyathea spinulosa*	14	29	13.21	10
9	*Dalbergia pinnata*	14	21	42.75	12
10	*Engelhardtia spicata*	29	50	87.02	25
11	*Ficus semicordata*	29	50	229.99	40
12	*Itea macrophylla*	14	21	17.08	9
13	*Lagerstroemia parviflora*	14	29	62.94	15
14	*Macaranga denticulata*	21	36	82.30	20
15	*Saurauia roxburghii*	29	43	48.34	20
16	*Toona hexandra*	14	21	17.02	9
			571		
Shrubs					
1	*Acacia pennata*	10	60	1.35	5
2	*Ficus heterophylla*	10	80	0.37	5
3	*Rhaphidophora decursiva*	20	80	0.61	8
4	*Myrsine semiserrata*	20	100	0.71	9
5	*Rubus ellipticus*	15	100	0.67	7
6	*Cassia occidentalis*	15	120	0.38	8
7	*Hydrangea macrophylla*	20	120	11.44	13
8	*Rubus foliolosus*	10	120	0.83	6
9	*Eupatorium odoratum*	10	140	1.07	7
10	*Murraya paniculata*	15	140	1.15	8
11	*Rubus foliolosus*	20	140	1.12	10
12	*Calamus leptospadix*	20	160	1.02	10
13	*Girardinia diversifolia*	15	160	0.52	9
14	*Saccharum spontaneum*	15	200	1.86	10
15	*Musa rosea*	25	240	36.99	27
16	*Piper clarkei*	15	260	2.57	12
17	*Bambusa pallida*	10	280	38.23	23
18	*Phragmites karka*	20	280	0.65	13
19	*Oxyspora paniculata*	15	480	2.37	17
20	*Dendrocalamus giganteus*	10	540	154.81	71
21	*Bambusa tulda*	10	560	17.98	22

Table 6.35: Community structure –Site V10 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	20	3333	7
2	*Arisaema speciosum*	20	3333	7
3	*Arundina graminifolia*	13	5333	7
4	*Begonia megaptera*	20	5333	8
5	*Bidens pilosa*	27	7333	11
6	*Chirita bifolia*	27	6667	10
7	*Commelina benghalensis*	13	4667	6

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
8	*Dicranopteris linearis*	7	2667	3
9	*Equisetum diffusum*	13	5333	7
10	*Fagopyrum dibotrys*	27	12667	15
11	*Hedychium spicatum*	33	6667	12
12	*Impatiens racemosa*	20	6000	8
13	*Impatiens chinensis*	33	8000	13
14	*Lycopodium clavatum*	13	2667	5
15	*Nephrolephis cordifolia*	13	4000	6
16	*Polygonum flaccidum*	27	8667	12
17	*Polystichum aculeatum*	20	5333	8
18	*Pteris vittata*	20	6667	9
19	*Selaginella picta*	20	5333	8
20	*Smilax aspera*	13	4000	6
21	*Strobilanthes thomsonii*	27	9333	12
22	*Thysanolaena maxima*	27	14000	16
23	*Tinospora crispa*	20	3333	7

Site V11: Etalin HEP Dam Site- Talo (Tangon) Limb

Near the proposed Dam site of Etalin HEP in Talo limb, area is characterized by open canopy tree layer dominated by *Saurauia roxburghii, Castanopsis indica, Albizia procera, Engelhardtia spicata* and *Pandanus odoratissimus*.

Shrub layer is represented by 17 species at this location. *Dendrocalamus giganteus* was most dominant species followed by *Musa balbisiana* and *Saccharum spontaneum*. Other dominant shrub species were *Opuntia aciculata, Piper clarkei, Oxyspora paniculata* and *Acacia pennata*. Herbaceous flora is comprised of 23 species. *Thysanolaena maxima*, *Fragaria indica Bidens pilosa, Bidens pilosa* and *Cymbidium aloifolium* are the common herbs of this area. *Pteridium aquilinum* and *Fagopyrum dibotrys* are the fern species distributed in the area.

Frequency, density, basal cover, and Importance Value Index (IVI) of the species reported at the site are given in **Tables 6.36 and 6.37.**

Table 6.36: Community structure -Site V11 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Albizia procera*	36	57	261.17	44
2	*Caryota urens*	14	21	41.77	12
3	*Castanopsis indica*	43	57	120.89	33
4	*Cyathea spinulosa*	21	29	16.71	12
5	*Engelhardtia spicata*	36	50	134.70	31
6	*Ficus semicordata*	21	43	111.15	24
7	*Lagerstroemia parviflora*	21	43	172.97	30
8	*Macaranga denticulata*	21	29	45.05	15
9	*Macropanax dispermus*	14	14	24.25	9
10	*Mallotus philippensis*	36	36	33.54	19
11	*Pandanus odoratissimus*	29	43	22.57	17
12	*Sarcosperma griffithii*	29	29	17.08	14
13	*Saurauia roxburghii*	43	57	19.53	23
14	*Terminalia myriocarpa*	14	14	11.93	7
15	*Toona hexandra*	14	14	32.85	9
			536		
Shrubs					
1	*Acacia pennata*	10	280	24.47	26
2	*Angiopteris evecta*	15	160	3.30	12
3	*Bambusa pallida*	5	200	19.28	19

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
4	*Buddleja asiatica*	5	160	14.72	15
5	*Calamus leptospadix*	10	100	0.78	7
6	*Cassia occidentalis*	20	240	1.10	14
7	*Dendrocalamus giganteus*	30	680	11.78	35
8	*Hydrangea macrophylla*	20	80	3.93	12
9	*Musa balbisiana*	25	560	17.55	34
10	*Myrsine semiserrata*	10	60	0.46	5
11	*Opuntia aciculata*	20	320	0.65	16
12	*Oxyspora paniculata*	20	280	42.73	42
13	*Phragmites karka*	10	160	0.67	8
14	*Piper clarkei*	15	300	5.16	16
15	*Rubus ellipticus*	15	60	0.32	7
16	*Rubus foliolosus*	15	100	0.78	9
17	*Saccharum spontaneum*	20	500	6.05	23

Table 6.37: Community structure -Site 11 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)
1	*Ageratum conyzoides*	23.53	8235	11
2	*Arundina graminifolia*	5.88	1765	3
3	*Begonia nepalensis*	11.76	2941	5
4	*Bidens pilosa*	29.41	9412	14
5	*Centella asiatica*	17.65	7647	10
6	*Chirita bifolia*	23.53	5882	10
7	*Colocasia forniculata*	5.88	1176	2
8	*Commelina benghalensis*	17.65	7647	10
9	*Cymbidium aloifolium*	23.53	8824	12
10	*Dryoathyrium boryanum*	17.65	3529	7
11	*Erigeron bonariensis*	17.65	7059	9
12	*Fagopyrum dibotrys*	23.53	9412	12
13	*Fragaria indica*	29.41	11765	15
14	*Impatiens racemosa*	11.76	1765	4
15	*Hedychium spicatum*	23.53	2941	8
16	*Hypericum uralum*	17.65	2353	6
17	*Impatiens racemosa*	17.65	5882	8
18	*Phyrnium pubinerve*	17.65	4706	8
19	*Polygonum capitatum*	23.53	7059	11
20	*Pratia nummularia*	5.88	1765	3
21	*Pteridium aquilinum*	23.53	9412	12
22	*Stellaria monosperma*	11.76	2941	5
23	*Thysanolaena maxima*	29.41	12941	16

Site V12: Etalin HEP Power House site: Near Dri- Talo (Tangon) River Confluence

The tree component near the proposed power house area of Etalin HEP near Etalin town was dominated by *Saurauia roxburghii*. *Ficus semicordata, Engelhardtia spicata* and *Pterospermum acerifolium* were other co-dominant tree species. *Oxyspora paniculata*, *Dendrocalamus giganteus, Saccharum spontaneum* and *Phragmites karka* were the dominant shrubs. *Thysanolaena maxima, Polygonum capitatum* and *Ageratum conyzoides* were the dominant herb species associated with fern species like *Polystichum lentum*, *Woodwardia unigemmata* and *Selaginella picta* Frequency, density, basal cover and Importance Value Index (IVI) of the species reported at the site near Etalin town are given in **Tables 6.38 and 6.39.**

Table 6.38: Community structure -Site V12 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Albizia lucida*	21	29	93	28
2	*Artocarpus chaplasa*	14	21	52	17
3	*Caryota urens*	14	29	16	13
4	*Cinnamomum obtusifolia*	14	21	50	17

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
5	*Cyathea spinulosa*	14	14	17	10
6	*Duabanga grandiflora*	21	29	65	23
7	*Engelhardtia spicata*	29	43	72	30
8	*Ficus semicordata*	36	50	120	41
9	*Macropanax dispermus*	14	21	7	10
10	*Magnolia campbellii*	14	14	6	9
11	*Pandanus odoratissimus*	21	29	3	14
12	*Pterospermum acerifolium*	29	36	42	24
13	*Saurauia roxburghii*	36	57	52	32
14	*Terminalia myriocarpa*	21	21	24	15
15	*Vitex altissima*	21	29	15	15
			443		
Shrubs					
1	*Angiopteris evecta*	15	100	0.54	10
2	*Bambusa taluda*	5	120	6.63	12
3	*Callicarpa vestita*	10	100	0.34	8
4	*Cassia occidentalis*	15	240	1.47	15
5	*Clerodendrum colebrookianum*	10	160	0.57	10
6	*Dendrocalamus giganteus*	5	280	45.07	52
7	*Hydrangea macrophylla*	10	80	0.16	7
8	*Musa acuminata*	10	160	23.48	31
9	*Myrsine semiserrata*	5	100	0.31	5
10	*Oxyspora paniculata*	25	440	2.77	27
11	*Phragmites karka*	20	280	2.00	19
12	*Piper clarkei*	20	300	1.35	19
13	*Rubus ellipticus*	10	100	0.27	8
14	*Saccharum spontaneum*	15	280	2.18	17
15	*Saxifraga aspera*	10	160	3.30	12
16	*Ficus heterophylla*	25	140	12.84	27
17	*Trevesia palmata*	25	100	4.88	18
18	*Solanum viarum*	5	80	0.28	5

Table 6.39: Community structure –Site V12 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Abutilon indicum*	11	1667	4.22
2	*Ageratum conyzoides*	22	10000	14.21
3	*Begonia palmata*	17	3333	7.05
4	*Blumea procera*	11	2778	5.18
5	*Commelina benghalensis*	17	6111	9.46
6	*Cyanotis vaga*	22	2778	7.96
7	*Cynodon dactylon*	22	7222	11.81
8	*Cyperus rotundus*	17	2778	6.57
9	*Fragaria indica*	22	6111	10.84
10	*Impatiens acuminata*	11	2778	5.18
11	*Impatiens acuminata*	11	3333	5.66
12	*Iris domestica*	17	4444	8.01
13	*Justicia khasiana*	17	2778	6.57
14	*Lecanthes peduncularis*	6	4444	5.24
15	*Pogostemon amaranthoides*	17	5556	8.97
16	*Polygonum capitatum*	22	7778	12.29
17	*Polygonum flaccidum*	17	5556	8.97
18	*Polystichum lentum*	28	10000	15.60
19	*Selaginella picta*	11	2778	5.18
20	*Solanum indicum*	17	4444	8.01
21	*Strobilanthes thomsonii*	17	1667	5.61
22	*Thysanolaena maxima*	22	10000	14.21
23	*Woodwardia unigemmata*	28	7222	13.19

Site V13: Left bank of Emra River near proposed Emra-II HEP

To analyze the status of vegetation in the project area of proposed of Emra-II hydroelectric Power Project sampling was carried out near proposed dam site.

At this sampling site, 17 species of trees were recorded. Of these *Pandanus odoratissimus, Livistona jenkinsiana, Terminalia myriocarpa, Kydia calycina* and *Betula alnoides* are the most dominant (**Table 6.40**). *Osbeckia stellata* and *Oxyspora paniculata* was the most dominated species followed by *Gonostegia hirta* (**Table 6.40**). *Melastoma malabathricum, Piper clarkei, Cassia occidentalis* and *Saccharum spontaneum* were the other dominant species. Bamboo species recorded from the area *Bambusa taluda* and *Dendrocalamus giganteus*. The herbaceous layer is comprised of 20 species in this area. *Pratia nummularia, Thysanolaena maxima* and *Alocasia fornicata* were the most dominant. Other common species were *Bidens pilosa, Alocasia fornicata, Lycopodium clavatum* and *Polygonum flaccidum*. (**Table 6.41**)

Table 6.40: Community structure –Site V13 (Trees and Shrubs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	Basal Cover (sq m/ha)	IVI
Trees					
1	*Ailanthus integrifolia*	14	7	15	7
2	*Albizia lucida*	36	21	56	22
3	*Albizia procera*	36	29	27	19
4	*Breonia chinensis*	36	14	60	21
5	*Artocarpus chaplasa*	50	29	129	39
6	*Betula alnoides*	14	29	4	11
7	*Bhesa indica*	21	14	27	13
8	*Canarium strictum*	36	21	18	16
9	*Duabanga grandiflora*	14	14	22	10
10	*Ficus glomerata*	29	21	42	19
11	*Kydia calycina*	21	29	7	13
12	*Lagerstroemia speciosa*	29	14	31	15
13	*Livistona jenkinsiana*	29	36	12	17
14	*Pandanus odoratissimus*	36	57	6	23
15	*Saurauia roxburghii*	21	21	36	16
16	*Terminalia chebula*	14	14	15	9
17	*Terminalia myriocarpa*	21	29	99	28
			400		
Shrubs					
1	*Acacia pennata*	15	100	4.44	10
2	*Agapetes forrestii*	10	40	1.12	5
3	*Angiopteris evecta*	20	160	2.07	12
4	*Bambusa pallida*	5	300	49.40	32
5	*Osbeckia stellata*	15	520	31.11	32
6	*Callicarpa vestita*	10	80	0.23	5
7	*Cassia occidentalis*	15	300	13.21	18
8	*Clerodendrum colebrookianum*	10	160	0.90	8
9	*Dendrocalamus giganteus*	5	240	32.25	22
10	*Ficus heterophylla*	20	120	3.98	12
11	*Melastoma malabathricum*	20	360	3.21	17
12	*Luculia pinceana*	10	80	3.73	7
13	*Musa balbisiana*	15	220	33.99	26
14	*Oxyspora paniculata*	25	480	5.75	23
15	*Phragmites karka*	20	240	2.18	14
16	*Piper clarkei*	20	300	2.77	15
17	*Saccharum spontaneum*	20	240	6.63	16
18	*Solanum ciliatum*	15	160	1.86	10
19	*Trevesia palmata*	20	160	15.40	18

Table 6.41: Community structure –Site V13 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	20	11000	14
2	*Asplenium nidus*	15	5000	8
3	*Begonia palmata*	20	6000	10
4	*Bidens pilosa*	25	8000	13
5	*Chirita bifolia*	30	9000	15
6	*Commelina benghalensis*	15	7000	10

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
7	*Dryoathyrium boryanum*	15	2000	6
8	*Fragaria indica*	15	7000	10
9	*Hedychium spicatum*	15	2500	6
10	*Impatiens acuminata*	10	4000	6
11	*Imperata cylindrica*	20	6000	10
12	*Justicia khasiana*	15	4000	7
13	*Lycopodium clavatum*	20	7500	11
14	*Poa annua*	15	5000	8
15	*Pogostemon amaranthoides*	15	5500	8
16	*Polygonum flaccidum*	20	7000	11
17	*Pratia nummularia*	20	12500	15
18	*Solanum indicum*	15	3500	7
19	*Themeda arundinacea*	15	6000	9
20	*Thysanolaena maxima*	25	11000	15

Site V14: Left bank of Ahi river: Near Elango HE Project area

At left bank of Ahi river near proposed Elango HEP, tree stratum was dominated by *Gmelina arborea*, *Alstonia scholaris* and *Artocarpus chaplasa*. In the shrub layer the most dominant species was *Bambusa tulda*. Other competing species of the shrubs were *Melastoma malabathricum*, *Rubus elipticus*, *Medinilla himalayana* and *Sida acuta*.

The herbaceous layer is represented by 20 species, dominated by *Pogonatherum paniceum*, *Alocasia indica*, *Ageratum conyzoides*, *Imperata cylindrica*, *Bidens bipinnata and Commelina maculata species*. Frequency, density and Importance Value Index (IVI) of the species reported at the site are given in **Table 6.42** and **6.43**.

Table 6.42: Community structure – Site V14 (Trees and Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
Trees					
1	*Albizia procera*	70	26	177	33
2	*Alstonia scholaris*	60	32	333	36
3	*Artocarpus chaplasa*	80	28	171	23
4	*Artocarpus lakoocha*	60	18	70	30
5	*Bauhinia vahlii*	60	23	123	29
6	*Dalbergia assamica*	80	24	83	18
7	*Gmelina arborea*	90	39	171	44
8	*Melia azederach*	50	18	27	38
9	*Toona ciliata*	80	22	146	49
			230		
Shrubs					
1	*Anaphalis contorta*	30	260	2.474	9
2	*Bambusa tulda*	70	560	78.782	46
3	*Clematis gouriana*	40	130	0.002	6
4	*Dendrocalamus brandsii*	30	150	29.422	16
5	*Dendrocalamus giganteus*	50	180	123.096	51
6	*Desmodium floribundum*	40	170	21.052	14
7	*Eupatorium odoratum*	90	140	0.284	11
8	*Magnolia hodgsoni*	20	210	0.805	7
9	*Medinilla himalayana*	70	280	1.945	13
10	*Melastoma malabathricum*	80	340	0.457	15
11	*Osbeckia stellata*	90	240	1.258	13
12	*Polygonum capitatum*	70	190	0.290	10
13	*Polygonum chinense*	80	180	0.107	11
14	*Polygonum microcephalum*	50	220	20.859	16
15	*Rubus elipticus*	90	320	0.732	15
16	*Rubus lucens*	80	210	0.689	12
17	*Rubus moluccanus*	50	120	4.165	8
18	*Sida acuta*	40	260	0.074	9
19	*Solanum indicum*	50	190	2.614	9

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
20	*Urtica dioica*	40	190	0.562	8

Table 6.43: Community structure – Site V14 (Herbs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
1	*Acorus calamus*	27	8000	8
2	*Ageratum conyzoides*	47	30667	19
3	*Agrostis griffithiana*	27	22000	12
4	*Alocasia indica*	33	31333	17
5	*Begonia nepalensis*	40	12667	12
6	*Chirita mishmiensis*	40	10000	11
7	*Commelina maculata*	33	24667	14
8	*Cyperus brevifolius*	40	9333	11
9	*Drymaria diandra*	27	18000	11
10	*Globba multiflora*	13	2667	3
11	*Imperata cylindrica*	47	30000	19
12	*Mariscus sumatrensis*	27	18000	11
13	*Paspalum scorbiculatum*	20	16667	9
14	*Pogonatherum paniceum*	40	34667	19
15	*Pseudostachyum polymorphum*	13	2667	3
16	*Senecio wightianus*	20	6000	6
17	*Solanum nigrum*	20	4667	5
18	*Tacca laevis*	13	6667	5
19	*Viola canescens*	13	8667	5

Site 15: Left bank of Dibang River near Riyali village

On left bank of Diabang river near Riyali village the tree cover is sparse and is comprised mainly of *Terminalia myriocarpa, Bombax ceiba, Albizia procera* and *Duabanga grandiflora*. *Eupatorium odoratum* was the dominant shrub in the area followed by *Dendrocalamus hamiltonii* and *Eupatorium odoratum*. Other associate shrub species in the area are *Corchorus capsularis, Blumea lacinata, Polygonum microcephalum* and *Osbeckia stellata*.

Ageratum conyzoides, Mariscus sumatrensis, Fragaria indica, Thysanolaena maxima, Begonia nepalensis, Chrysopogon aciculatus, Pogonatherum paniceum and *Senecio wightianus* was the dominant herb species in the area. Frequency, density, basal cover and Importance Value Index (IVI) of the species reported from left bank of Dibang river near Riyali village are given in **Tables 6.44** and **6.45**.

Table 6.44: Community structure – Site V15 (Trees and Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
Trees					
1	*Albizia lucida*	50	15	27	22
2	*Albizia procera*	60	17	126	35
3	*Bauhinia vahlii*	70	15	18	25
4	*Bombax ceiba*	30	17	177	34
5	*Dalbergia assamica*	40	14	83	25
6	*Duabanga grandiflora*	30	16	70	23
7	*Gmelina arborea*	30	16	73	23
8	*Magnolia cambellii*	30	15	102	26
9	*Melia azederach*	20	13	27	15
10	*Terminalia myriocarpa*	50	17	123	33
11	*Toona ciliata*	70	15	146	38
			170		
Shrubs					
1	*Anaphalis contorta*	40	170	0.79	8
2	*Blumea lacinata*	60	270	15.75	15

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
3	*Corchorus capsularis*	80	290	4.41	15
4	*Dendrocalamus hamiltonii*	60	390	204.49	56
5	*Dendrocalamus sikkimensis*	40	160	107.23	29
6	*Eupatorium odoratum*	90	350	4.44	18
7	*Magnolia campbelli*	50	230	15.01	13
8	*Magnolia hodgsoni*	60	240	57.33	23
9	*Medinilla himalayana*	70	220	2.20	12
10	*Melastoma malabathricum*	50	150	70.27	22
11	*Osbeckia stellata*	90	240	2.47	15
12	*Polygonum capitatum*	30	170	0.23	7
13	*Polygonum chinense*	40	190	4.07	9
14	*Polygonum microcephalum*	50	260	8.87	13
15	*Rubus elipticus*	90	220	0.72	14
16	*Rubus lucens*	80	220	1.04	13
17	*Rubus niveus*	30	170	3.00	8
18	*Urtica dioica*	50	220	2.60	11

Table 6.45: Community structure – Site V15 (Herbs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
1	*Acorus calamus*	20	9333	8
2	*Ageratum conyzoides*	53	17333	17
3	*Agrostis griffithiana*	47	10667	13
4	*Alocasia indica*	33	5333	8
5	*Amomum subulatum*	33	10667	11
6	*Begonia nepalensis*	40	12000	12
7	*Carex baccans*	27	7333	8
8	*Chirita mishmiensis*	20	9333	8
9	*Chrysopogon aciculatus*	20	12000	9
10	*Cynodon dactylon*	7	10667	6
11	*Cyperus brevifolius*	33	11333	11
12	*Fragaria indica*	33	14000	12
13	*Globba multiflora*	27	10000	9
14	*Mariscus sumatrensis*	47	15333	15
15	*Panicum palmifolium*	47	5333	10
16	*Pogonatherum paniceum*	53	11333	14
17	*Senecio wightianus*	40	11333	12
18	*Tacca laevis*	20	10000	8
19	*Thysanolaena maxima*	13	12667	8

Site V16: Near Ithun II HEP Area; Desali Village (Ithun River)

The sampling location is located near the diversion site of proposed Ithun II HEP on the left bank near Desali. Tree component in the area was dominated by *Pterospermum acerifolium* and *Castanopsis indica* and *Alnus nepalensis*. *Dendrocalamus giganteus* was the most dominant shrub associated with *Oxyspora paniculata*, *Chimonobambusa callosa* and *Solanum cili*atum. Herbaceous species in the area were represented mainly by *Saccharum spontaneum*, *Hedychium coccineum*, *Poa annua*, *Physalis minima*, *Elatostema sessile*, *Bidens pilosa*, *Alpinia allughas*, *Begonia nepalensis* and *Senecio cappa*. Frequency, density, basal cover, and Importance Value Index (IVI) of the species reported in the area are given in **Tables 6.46** and **6.47**.

Table 6.46: Community structure – Site V16 (Tree and Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
Trees					
1	*Albizia procera*	40	50	304.78	41
2	*Alnus nepalensis*	20	60	18.87	18
3	*Aralia armata*	30	50	153.7	28

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
4	*Brassaiopsis glomerulata*	40	40	10.52	19
5	*Castanopsis indica*	40	80	65.97	30
6	*Chukrasia tabularis*	30	30	13.1	15
7	*Engelhardtia spicata*	20	20	64.75	14
8	*Ficus semicordata*	40	70	347.24	48
9	*Macaranga denticulata*	20	30	43.44	14
10	*Macropanax dispermus*	10	10	4.72	5
11	*Pterospermum acerifolium*	40	80	366.9	51
12	*Terminalia chebula*	20	20	45.05	12
13	*Tetrameles nudiflora*	10	10	6.97	5
			550		
Shrubs					
1	*Acacia pennata*	30	80	4.44	17
2	*Agapetes forrestii*	15	100	0.54	9
3	*Artemisia indica*	20	180	3.58	15
4	*Boehmeria macrophylla*	10	80	12.31	13
5	*Calamus floribundus*	20	140	0.23	12
6	*Cassia occidentalis*	5	160	0.31	7
7	*Rhamnus nepalensis*	15	240	21.47	24
8	*Chimonobambusa callosa*	10	290	49.4	37
9	*Clerodendrum viscosum*	10	180	0.16	10
10	*Debregeasia longifolia*	10	80	22.67	18
11	*Dendrocalamus giganteus*	10	600	43.48	44
12	*Musa balbisiana*	30	210	33.99	35
13	*Oxyspora paniculata*	10	320	7.78	18
14	*Rubus foliolosus*	20	130	0.67	12
15	*Solanum ciliatum*	20	280	0.92	17
16	*Trevesia palmata*	15	160	0.74	11

Table 6.47: Community structure – Site V16 (Herbs)

S. No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Urtica dioica*	9	3000	6
2	*Commelina benghalensis*	14	3500	8
3	*Pteridium aquilinum*	9	3500	6
4	*Impatiens racemosa*	9	4000	6
5	*Oxalis corniculata*	9	4000	6
6	*Pogonatherum paniceum*	15	4000	9
7	*Arisaema speciosum*	14	4500	9
8	*Begonia palmata*	14	4500	9
9	*Amaranthus viridis*	14	5000	9
10	*Strobilanthes rhombifolius*	14	5000	9
11	*Senecio cappa*	9	5500	7
12	*Begonia nepalensis*	18	7000	12
13	*Alpinia allughas*	18	7500	12
14	*Bidens pilosa*	23	7500	14
15	*Elatostema sessile*	23	8000	15
16	*Physalis minima*	9	9500	10
17	*Poa annua*	14	10500	13
18	*Hedychium coccineum*	20	11000	16
19	*Saccharum spontaneum*	5	31000	24

Site V17: Project area of Proposed Ithun I HEP near Hunli (Ithun River)

The sampling location is downstream of the diversion site of proposed Ithun I HEP on the left bank near Hunli. The area comes under shadow zone and dominated by Tropical evergreen, Tropical semi-evergreen and Subtropical forest types.

The site is comprised of 13 tree species (**Table 6.48**). The left bank slopes at this site are mainly comprised of *Breonia chinensis, Duabanga grandiflora and Canarium strictum* are the most dominant plants at slopes and Altingia excelsa, *Michelia baillonii, Dalbergia assamica* and *Ficus glomerata* are common near river bank and at lower elevations.

Shrub layer is represented by 15 species mainly comprised of the clumps of bamboo species viz: *Dendrocalamus giganteus*, *Dendrocalamus sikkimensis* and *Bambusa tulda*. On open places grasses like *Saccharum spontaneu, Colebrookea* sp. and *Clematis gouriana* are common. *Blumea lacinata, Rubus foliolosus, Urtica dioica, Rubus lucens,* etc are the other common shrubs recorded from the catchment area of left bank of Ithun river near Hunli.

Herb layer was represented by 25 species in monsoon (**Table 6.49**). The herbaceous layer mainly consists of *Ageratum conyzoides, Anaphalis contorta, Dryoathyrium boryanum, Eupatorium odoratum, Themeda nathera, Mariscus sumatrensis, Commelina maculata, Chrysopogon aciculatus, Agrostis griffithiana along* with fern species like *Nephrolephis cordifolia,* and *Lecanthes peduncularis.*

Table 6.48: Community structure – Site V17 (Tree and Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
1	*Betula alnoides*	30	8	9	11
2	*Breonia chinensis*	40	12	102	24
3	*Altingia excelsa*	30	14	74	20
4	*Dalbergia assamica*	80	34	83	41
5	*Sterculia villosa*	20	13	62	16
6	*Bhesa indica*	40	14	62	21
7	*Canarium strictum*	50	26	112	34
8	*Lagerstroemia speciosa*	40	14	102	25
9	*Pterospermum acerifolium*	20	12	38	14
10	*Duabanga grandiflora*	60	29	62	32
11	*Gmelina arborea*	20	14	118	22
12	*Ficus glomerata*	20	14	146	25
13	*Michelia baillonii*	10	17	36	13
			221		
Shrubs					
1	*Bambusa tulda*	70	460	170.75	51
2	*Blumea lacinata*	80	260	5.25	18
3	*Clematis gouriana*	50	270	8.36	15
4	*Colebrookea oppositifolia*	80	280	2.58	18
5	*Solanum indicum*	50	180	158.11	39
6	*Dendrocalamus sikkimensis*	40	140	66.20	20
7	*Desmodium floribundum*	60	210	9.36	15
8	*Eupatorium odoratum*	60	140	0.28	11
9	*Magnolia campbelli*	40	180	6.95	11
10	*Melastoma malabathricum*	70	340	5.28	19
11	*Polygonum chinense*	40	110	6.54	9
12	*Rubus lucens*	60	230	0.75	14
13	*Sida acuta*	50	190	5.41	12
14	*Dendrocalamus giganteus*	30	220	128.63	32
15	*Urtica dioica*	50	250	5.07	14

Table 6.49: Community structure – Site V17 (Herbs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	40	16000	11
2	*Agrostis griffithiana*	47	12667	10
3	*Alpinia nigra*	20	8000	5

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
4	*Amomum subulatum*	27	11333	7
5	*Carex baccans*	40	12000	9
6	*Chirita mishmiensis*	40	11333	9
7	*Chlorophytum tuberosum*	20	12000	7
8	*Chrysopogon aciculatus*	60	12667	12
9	*Commelina maculata*	40	12667	9
10	*Curcuma amada*	20	10667	6
11	*Themeda nathera*	53	13333	11
12	*Cyperus brevifolius*	47	10667	9
13	*Eleocharis tetraquetra*	20	12000	7
14	*Fragaria indica*	40	10667	9
15	*Globba multiflora*	33	12000	8
16	*Imperata cylindrica*	53	12000	11
17	*Mariscus sumatrensis*	33	12667	9
18	*Paspalum scorbiculatum*	40	6667	7
19	*Phragmites karka*	13	7333	4
20	*Pogonatherum paniceum*	53	10667	10
21	*Pseudostachyum polymorphum*	27	10000	7
22	*Sida acuta*	20	6667	5
23	*Tacca laevis*	27	10667	7
24	*Themeda villosa*	13	12000	6
25	*Thysanolaena maxima*	13	8667	5

Site VI8: Near Proposed Dam site of Dibang Multipurpose HE Project

Tree canopy is represented by 15 species with *Duabanga grandiflora*, *Bombax ceiba*, *Magnolia* sp., *Dalbergia assamica*, *Artocarpus chaplasa* and *Canarium strictum* as the dominant species (**Table 6.50**).

Bambusa tulda, *Eupatorium odoratum*, *Dendrocalamus hamiltonii*, *Naravelia zeylanica*, *Clematis gouriana* and *Anaphalis contorta* were the dominant shrubs (**Table 6.50**). The density and basal area of *Bambusa tulda* was the highest amongst 19 species recorded from this location.

The herb layer was represented by 18 species (**Table 6.51**). The herbaceous species dominant in the area are *Pogonatherum paniceum*, *Ageratum conyzoides*, *Alocasia indica* and *Saccharum arundinaceum* followed by *Begonia nepalensis*, *Mariscus sumatrensis*, *Paspalum scorbiculatum* and *Drymaria diandra*.

Table 6.50: Community structure – Site V18 (Tree and Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
Trees					
1	*Betula alnoides*	30	6	6	7
2	*Sterculia villosa*	20	7	112	14
3	*Bischofia javanica*	40	10	14	10
4	*Pterospermum acerifolium*	20	10	48	10
5	*Bhesa indica*	40	12	62	15
6	*Altingia excelsa*	30	14	74	15
7	*Bauhinia vahlii*	40	14	27	13
8	*Terminalia chebula*	30	15	55	14
9	*Toona ciliata*	50	24	146	27
10	*Canarium strictum*	50	26	171	29
11	*Artocarpus chaplasa*	70	28	171	33
12	*Dalbergia assamica*	80	34	83	29
13	*Magnolia oblonga*	50	34	102	26
14	*Bombax ceiba*	60	35	70	26
15	*Duabanga grandiflora*	70	39	123	33
			308		

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
Shrubs					
1	*Anaphalis contorta*	50	280	1.79	11
2	*Bambusa pallida*	50	150	128.63	32
3	*Bambusa tulda*	70	380	190.63	51
4	*Clematis gouriana*	70	280	3.12	13
5	*Clerodendrum colebrookeanum*	70	220	6.57	12
6	*Corchorus capsularis*	80	230	0.97	12
7	*Dendrocalamus hamiltonii*	60	320	97.26	31
8	*Dendrocalamus sikkimensis*	40	160	87.78	24
9	*Eupatorium odoratum*	50	320	1.79	12
10	*Medinilla himalayana*	40	190	1.32	8
11	*Naravelia zeylanica*	70	290	0.76	13
12	*Osbeckia stellata*	60	250	1.31	11
13	*Polygonum capitatum*	50	240	2.03	10
14	*Polygonum microcephalum*	40	190	1.03	8
15	*Rubus elipticus*	70	210	0.48	11
16	*Sida acuta*	70	210	1.37	11
17	*Solanum indicum*	60	180	0.15	9
18	*Tamarix dioica*	70	220	0.90	11
19	*Urtica dioica*	60	240	0.71	11

Table 6.51: Community structure – Site V18 (Herbs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
1	*Acorus calamus*	27	8000	8
2	*Ageratum conyzoides*	47	30667	20
3	*Alocasia indica*	33	31333	17
4	*Begonia nepalensis*	40	12667	12
5	*Chirita mishmiensis*	40	10000	11
6	*Commelina maculata*	33	24667	15
7	*Drymaria diandra*	27	18000	12
8	*Fragaria indica*	33	21333	14
9	*Globba multiflora*	13	2667	3
10	*Mariscus sumatrensis*	27	18000	12
11	*Paspalum scorbiculatum*	20	16667	10
12	*Pogonatherum paniceum*	40	34667	20
13	*Pseudostachyum polymorphum*	13	2667	3
14	*Saccharum arundinaceum*	47	30000	20
15	*Senecio wightianus*	20	6000	6
16	*Solanum nigrum*	20	4667	6
17	*Tacca laevis*	13	6667	5
18	*Viola canescens*	13	8667	6

Site V19: Left bank of Ashupani Nala: Near Ashupani HE project area

The tree canopy in the project area of proposed Ashupani HEP project area was represented by *Duabanga grandiflora*, *Breonia chinensis*, *Canarium strictum* and *Terminalia myriocarpa*, (**Table 6.52**).

Shrub layer is represented by 18 species in the area (**Table 6.52**) with *Bambusa tulda*, *Clerodendrum colebrookeanum*, *Polygonum chinense*, *Medinilla himalayana* and *Corchorus capsularis* as the dominant shrubs.

The herbaceous layer was represented by 20 species during monsoon surveys (**Table 6.53**). The herbaceous layer was dominated by species like *Pogonatherum paniceum*, *Alocasia indica*, *Ageratum conyzoides*, *Saccharum arundinaceum*, *Commelina maculata*, *Agrostis griffithiana*, *Fragaria indica*, *Mariscus sumatrensis* and *Drymaria diandra*.

Table 6.52: Community structure –Site V19 (Trees & Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
TREES					
1	*Bhesa indica*	20	40	91.17	28

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
2	*Lagerstroemia speciosa*	20	30	41.77	19
3	*Duabanga grandiflora*	30	60	82.89	34
4	*Albizia procera*	30	40	16.71	20
5	*Ficus glomerata*	10	20	94.7	21
6	*Arisaema rhizomatum*	10	20	65.62	17
7	*Terminalia myriocarpa*	30	50	87.97	32
8	*Mesua ferrea*	20	40	45.05	21
9	*Albizia lucida*	10	20	24.25	11
10	*Canarium strictum*	30	50	33.54	24
11	*Artocarpus chaplasa*	20	40	22.57	18
12	*Terminalia chebula*	20	40	17.08	17
13	*Breonia chinensis*	20	50	19.53	19
14	*Betula alnoides*	10	20	11.93	9
15	*Dalbergia assamica*	10	20	32.85	12
			540		
SHRUBS					
1	*Anaphalis contorta*	60	260	0.57	11
2	*Bambusa tulda*	70	560	168.66	74
3	*Blumea lacinata*	50	170	0.55	9
4	*Clerodendrum colebrookeanum*	60	450	1.37	15
5	*Corchorus capsularis*	80	340	1.10	15
6	*Dendrocalamus giganteus*	50	180	68.30	31
7	*Dendrocalamus sikkimensis*	40	160	55.91	26
8	*Desmodium floribundum*	50	210	0.63	9
9	*Eupatorium odoratum*	50	270	0.17	10
10	*Magnolia campbelli*	30	230	0.51	8
11	*Medinilla himalayana*	70	360	1.11	15
12	*Melastoma malabathricum*	60	240	0.21	11
13	*Osbeckia stellata*	60	200	0.11	10
14	*Polygonum chinense*	80	380	1.37	16
15	*Rubus elipticus*	70	210	0.08	11
16	*Rubus moluccanus*	50	250	0.50	10
17	*Rubus niveus*	40	280	0.58	10
18	*Solanum indicum*	40	210	0.46	8

Table 6.53: Community structure –Site V19 (Herbs)

S.No.	Scientific Name	Frequency (%)	Density (ind./ha)	IVI
1	*Acorus calamus*	27	8000	7
2	*Ageratum conyzoides*	47	30667	18
3	*Agrostis griffithiana*	27	22000	12
4	*Alocasia indica*	33	31333	16
5	*Begonia nepalensis*	40	12667	11
6	*Chirita mishmiensis*	40	10000	10
7	*Commelina maculata*	33	24667	14
8	*Cyperus brevifolius*	40	9333	10
9	*Drymaria diandra*	27	18000	10
10	*Fragaria indica*	33	21333	13
11	*Globba multiflora*	13	2667	3
12	*Mariscus sumatrensis*	27	18000	10
13	*Paspalum scorbiculatum*	20	16667	9
14	*Pogonatherum paniceum*	40	34667	18
15	*Pseudostachyum polymorphum*	13	2667	3
16	*Saccharum arundinaceum*	47	30000	18
17	*Senecio wightianus*	20	6000	5
18	*Solanum nigrum*	20	4667	5
19	*Tacca laevis*	13	6667	4
20	*Viola canescens*	13	8667	5

Site V20: Downstream of Proposed Dibang Multipurpose Project PH Site

The tree canopy at this location is dominated by *Duabanga grandiflora*, *Bombax ceiba*, *Magnolia* sp., *Dalbergia assamica* and *Artocarpus chaplasa* with 15 species recorded from this site (**Table 6.54**).

The shrub layer is represented by clumps of bamboos like *Bambusa tulda* and *Dendrocalamus hamiltonii*. Other common species are *Eupatorium odoratum, Naravelia zeylanica, Clematis gouriana, Anaphalis contorta* and *Osbeckia stellata* which are frequent all over the area (**Table 6.54**).

The number of herbaceous species found during monsoon surveys was 26 (**Table 6.55**). Commonly occurring herbs in this area are *Ageratum conyzoides, Cynodon dactylon, Mariscus sumatrensis, Frimbristylis acicularis, Commelina maculata, Chrysopogon aciculatus, Chrysopogon aciculatus, Agrostis griffithiana, Themeda villosa* and *Imperata cylindrica*.

Table 6.54: Community structure –Site V20 (Trees & Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
TREES					
1	*Albizia procera*	20	40	91.17	29
2	*Callicarpa macrophylla*	20	30	41.77	20
3	*Castanopsis indica*	10	40	82.89	24
4	*Chukrasia tabularis*	30	40	16.71	22
5	*Engelhardtia spicata*	10	20	94.7	22
6	*Ficus semicordata*	10	20	65.62	17
7	*Lagerstroemia parviflora*	30	50	87.97	34
8	*Macaranga denticulata*	20	40	45.05	22
9	*Macropanax dispermus*	10	20	24.25	11
10	*Mallotus philippensis*	10	40	33.54	17
11	*Pandanus odoratissima*	20	40	22.57	19
12	*Sarcosperma griffithii*	20	40	17.08	18
13	*Saurauia roxburghii*	20	60	19.53	22
14	*Terminalia myriocarpa*	10	20	11.93	10
15	*Toona hexandra*	10	20	32.85	13
			520		
SHRUB					
1	*Anaphalis contorta*	50	280	1.79	11
2	*Bambusa pallida*	50	150	128.63	32
3	*Bambusa tulda*	70	380	190.63	51
4	*Clematis gouriana*	70	280	3.12	13
5	*Clerodendrum colebrookeanum*	70	220	6.57	12
6	*Corchorus capsularis*	80	230	0.97	12
7	*Dendrocalamus hamiltonii*	60	320	97.26	31
8	*Dendrocalamus sikkimensis*	40	160	87.78	24
9	*Eupatorium odoratum*	50	320	1.79	12
10	*Medinilla himalayana*	40	190	1.32	8
11	*Naravelia zeylanica*	70	290	0.76	13
12	*Osbeckia stellata*	60	250	1.31	11
13	*Polygonum capitatum*	50	240	2.03	10
14	*Polygonum microcephalum*	40	190	1.03	8
15	*Rubus elipticus*	70	210	0.48	11
16	*Sida acuta*	70	210	1.37	11
17	*Solanum indicum*	60	180	0.15	9
18	*Tamarix dioica*	70	220	0.90	11
19	*Urtica dioica*	60	240	0.71	11

Table 6.55: Community structure –Site V20 (Herbs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
1	*Ageratum conyzoides*	40	16000	10
2	*Agrostis griffithiana*	47	12667	10
3	*Alpinia nigra*	20	8000	5
4	*Amomum subulatum*	27	11333	7
5	*Carex baccans*	40	12000	9
6	*Chirita mishmiensis*	40	11333	8
7	*Chlorophytum tuberosum*	20	12000	6
8	*Chrysopogon aciculatus*	60	12667	11
9	*Commelina maculata*	40	12667	9
10	*Curcuma amada*	20	10667	6
11	*Cynodon dactylon*	53	13333	11
12	*Cyperus brevifolius*	47	10667	9
13	*Eleocharis tetraquetra*	20	12000	6
14	*Fragaria indica*	40	10667	8
15	*Fimbristylis acicularis*	53	12667	10

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
16	*Globba multiflora*	33	12000	8
17	*Imperata cylindrica*	53	12000	10
18	*Mariscus sumatrensis*	33	12667	8
19	*Paspalum scorbiculatum*	40	6667	7
20	*Phragmites karka*	13	7333	4
21	*Pogonatherum paniceum*	53	10667	10
22	*Pseudostachyum polymorphum*	27	10000	6
23	*Sida acuta*	20	6667	5
24	*Tacca laevis*	27	10667	7
25	*Themeda villosa*	13	12000	6
26	*Thysanolaena maxima*	13	8667	5

Site V21: Left bank of Sissiri river near Sissiri HE project area

This sampling site is located in the vicinity of Sissiri Dam site and is comprised of tropical forest.

At this site 14 species of trees were recorded (**Table 6.56**). Most dominant and frequent trees are *Duabanga grandiflora, Artocarpus lakoocha, Pterospermum acerifolium, Ficus semicordata, Acacia* sp*, Erythrina variegate* and *Cinnamomum obtusifolia.*

Dendrocalamus hamiltonii, Calamus floribundus, Acacia gageana and *Musa paradisiaca* have highest density at this site (**Table 6.56**). Other dominant shrub species are *Calamus flagellum* and *Bambusa pallid*. Among the herbs *Persicaria virginiana, Colocasia forniculata* and *Thymus linearis* were the most adundant species (**Table 6.57**). *Impatiens chinensis*, *Cynodon dactylon, Thysanolaena maxima, Begonia tessaricarpa* and *Saccharum spontaneum* were dominant dominant herbs during monsoon. *Lygodium flexuosum, Pteridium aquilinum, Nephrolepis* sp. and *Adiantum philippense* are the fern species recorded from the area.

Table 6.56: Community structure –Site V21 (Trees & Shrubs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	Total Basal Area (sq m/ha)	IVI
Trees					
1	*Acacia pennata*	14	21	42	11
2	*Albizia procera*	43	57	121	32
3	*Artocarpus lakoocha*	21	29	17	13
4	*Bombax ceiba*	36	50	135	30
5	*Canarium strictum*	21	43	111	23
6	*Cinnamomum obtusifolia*	29	36	304.78	37
7	*Duabanga grandiflora*	14	43	18.87	14
8	*Dysoxylum gobarum*	21	36	153.70	24
9	*Erythrina variegate*	29	29	10.52	15
10	*Ficus semicordata*	29	57	65.97	24
11	*Macaranga denticulata*	29	50	347.24	42
12	*Morus macroura*	14	21	43.44	11
13	*Pterospermum acerifolium*	21	21	13.10	12
14	*Terminalia myriocarpa*	14	14	64.75	12
			507		
Shrubs					
1	*Abroma augusta*	10	120	6.5	16
2	*Acacia gageana*	25	340	1.36	38
3	*Dendrocalamus hamiltonii*	20	440	13.81	43
4	*Calamus flagellum*	15	160	0.39	21
5	*Calamus floribundus*	20	360	2.66	36
6	*Bambusa pallida*	10	80	383.51	107
7	*Ficus heteropleura*	10	100	3.59	14
8	*Musa paradisiacal*	15	160	0.74	21
9	*Trevesia palmata*	5	40	0.34	6

Table 6.57: Community structure –Site V21 (Herbs)

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
1	*Abutilon indicum*	4	1667	4
2	*Adiantum philippense*	8	3333	8
3	*Ageratum conyzoides*	8	2083	6

S.No.	Name of Species	Frequency (%)	Density (ind./ha)	IVI
4	*Amaranthus viridis*	4	1250	3
5	*Begonia tessaricarpa*	8	2917	7
6	*Bidens pilosa*	13	2500	9
7	*Cannabis sativa*	4	417	2
8	*Colocasia forniculata*	13	7500	15
9	*Commelina bengalensis*	4	1250	3
10	*Costus speciosus*	8	2083	6
11	*Cynodon dactylon*	8	5000	10
12	*Cyperus alternifolius*	4	1250	3
13	*Elatostema sesquifolium*	8	2083	6
14	*Fagopyrum esculentum*	17	3333	12
15	*Impatiens chinensis*	13	5833	13
16	*Lepidogramatis rostrata*	4	1667	4
17	*Lygodium flexuosum*	4	833	3
18	*Nephrolepis auriculata*	8	2500	7
19	*Osmunda regalis*	4	1667	4
20	*Persicaria virginiana*	21	7500	19
21	*Phragmites karka*	6	2222	5
22	*Pteridium aquilinum*	4	1250	3
23	*Saccharum spontaneum*	17	2500	10
24	*Solanum indicum*	4	417	2
25	*Strobilanthes perfoliatus*	8	1667	6
26	*Thymus linearis*	21	6250	17
27	*Thysanolaena maxima*	8	3333	8

6.4.5.1 Density, Diversity & Evenness

The data on density and dominance of various plant species recorded at each sampling site was analysed and the results of the same are discussed below.

a) Density

The density of trees varied from site to site. The overall tree density throughout the study area ranged from minimum of 170 number of trees/ha to maximum of 571 trees/ha (**Table 6.58**). Highest tree density was recorded at sampling site V10, located Along Anonpani nala (left bank of tributary of Talo river, followed by sampling site located Desali village (left bank of Ithun river) and lowest at sampling site V17, located in Reyali village (left bank of Diabng river).

In shrubs the highest species density was recorded at sampling site V19 located in the Ashupani nala with 4960 ind./ha followed by sampling site V20 (4560 ind./ha), located in the downstream of proposed Dibang Multipurpose Project Powerhouse and lowest at sampling site (V21) located near Dam site of proposed Sissiri HE project area (1800 ind./ha). The herbs show maximum species density at sampling site V19 (left bank of Ashupani nala) with 318667 ind./ha and minimum at sampling site V21 located located near Dam site of proposed Sissiri HE project area with 74305 ind./ha.

Table 6.58: Density of plant species (no. of individuals/ha) in Dibang basin

Sampling Site	Trees	Shrubs	Herbs
V 1	408	2940	154286
V 2	393	3940	172353
V 3	399	3700	165000
V 4	515	3340	135834
V 5	271	3340	138500
V 6	536	3640	123834
V 7	550	3090	147833
V 8	399	3300	111333
V 9	336	3660	129231
V 10	571	4360	140667
V 11	536	4240	137059

Sampling Site	Trees	Shrubs	Herbs
V 12	443	3220	115556
V 13	400	4260	129500
V 14	230	4540	297336
V 15	170	4160	206000
V 16	550	3230	131500
V 17	221	3460	275333
V 18	308	4560	287336
V 19	540	4960	318667
V 20	520	4560	288000
V 21	507	1800	74305

b) Species Diveristy

Shannon-Weiner Diversity index (H') of trees, shrubs and herbs were calculated for each sampling site in Dibang basins and results of the same are discussed here. Shannon-Weiner Diversity index (H') gives diversity pattern. The value of Shannon-Weiner Diversity index more than 2 is indicative higher species diversity while its value around 1 or less than 1 indicates low diversity. Amongst trees the diversity Index ranged from low of 2.17 at sampling site V14 located along Ahi river near proposed Elango HEP project area to highest at sampling site V7 at sampling site located at Dri river near proposed Dam site of Etalin HEP (**Table 6.59**).

Among shrubs, highest diversity Index was recorded at sampling site V14 located at located along Ahi river near proposed Elango HEP project area (2.92) and lowest at sampling site V21 located near Dam site of proposed Sissiri HE project area (1.98) (**Table 6.59**).

The species diversity in herbs was always higher during monsoon period and varied from 2.64 to 3.24 at different sampling locations. Highest herb diversity was recorded at sampling site V20 located in the downstream of proposed Dibang Multipurpose HEP and lowest at sampling site V4 located in Dri valley near Dri-Angepani confluence (**Table 6.59**).

Table 6.59: Shannon-Weiner Diversity Index (H') of plant species in Dibang basin

Sampling Site	Trees	Shrubs	Herbs
V 1	2.72	2.66	2.64
V 2	2.56	2.92	2.67
V 3	2.28	2.66	2.71
V 4	2.40	2.61	2.61
V 5	2.17	2.92	2.72
V 6	2.79	2.41	2.74
V 7	2.61	2.06	2.79
V 8	2.64	2.83	2.79
V 9	2.72	2.79	2.91
V 10	2.39	2.86	2.91
V 11	2.45	2.65	2.96
V 12	2.57	2.57	2.96
V 13	2.61	2.60	2.96
V 14	2.63	2.75	3.01
V 15	2.69	2.84	3.04
V 16	2.57	2.56	3.04
V 17	2.56	1.98	3.07
V 18	2.34	2.38	3.14
V 19	2.48	2.64	3.20
V 20	2.39	2.78	3.22
V 21	2.65	2.92	3.24

6.5 FAUNAL RESOURCES

6.5.1 Mammals

The description of various components of wildlife in the basin has been given in the preceeding paragraphs.

A list of 158 mammalian fauna reported from the dibang basin prepared from published literature (Chetry and Chetry, 2007; Chetry et al., 2007) and data provided by Zoological Survey of India (ZSI), Department of Environment and Forests, Government of Arunachal Pradesh i.e. Fauna of Arunachal Pradesh, State Fauna Series, 13 (2006) and the list is given at **Table 6.60**. Family Muridae is the largest family represented by 25 species while Vespertilionidae is represented by 19 species, Sciuridae by 13 species and Rhinolophidae, Mustelidae and Felidae is represented by 9 species each. The conservation status of the mammals reported from the basin was assessed based upon their listing in different lists published by agencies like International Union for Conservation of Nature (IUCN) Red List of Threatened Species 2015 and different Schedules notified under Wildlife (Protection) Act, 1972.

6.5.1.1 Primates

Order Primates is represented by 6 species belonging to 3 families (see **Table 6.60**). Slow loris inhabits tropical dense forest and is distributed up to 2400m. Slow loris is shy in nature and rarely observed around the settlements. Capped langur, Assamese macaque and Rhesus macaque inhabits open forest and are frequently seen near settlement areas. They are distributed up to 2000m elevation. Macaques are also found areas nearby the settlements. They are not considered as threatened species however, are ranked under the Schedule III (WPA, 1972). The Primates are hunted by the tribes mainly for food and their skins and fur is used as large knife case.

Hoolock gibbon (*Hoolock hoolock*) is one of the most important mammal found in the basin and is listed as Endangered species by IUCN.

6.5.1.2 Carnivora

Carnivora is one of the three the largest order in the basin, which comprises of 20 species belonging to 7 families (**Table 6.60**). Most of the species of cat and dog families (Common leopard, Clouded leopard, Leopard cat, Jungle cat, Fishing cat, Jackal, Wild dog) are widely distributed up to elevation of 1500 m. Snow leopard is restricted to higher elevations from 3200-5000m. Tiger is generally restricted to the lower reaches of the basin whereas bears inhabit the area above 1000 m elevation (ZSI, 2006) and has been reported from Dibang Wildlife Sanctuary. Gopi *et al*. (2014) have confirmed the occurrence of Tiger in Dibang Wildlife Sanctuary area. According to this report Dibang Wildlife Sanctuary has abundance of preys like Talin, Wild pig, Ghoral, Musk deer, Barking deer, Himalyan serow and Mithun which can sustain a good population of Tiger in the sanctuary. All civet species are found in the dense forest and are rarely sighted. Mongooses inhabit open forest areas; distributed up to 800 m elevation. They are very common around the proposed hydroproject areas. Common leopard, Fishing cat and Leopard cat are the most hunted animals. Tiger and Himalayan black bear are globally 'threatened' species, categorized as 'endangered' and 'vulnerable', respectively. Mammals like Tiger, Common leopard, Clouded leopard, Leopard cat, Fishing cat and Black bear have been included in 'threatened' category, in which Clouded leopard is 'endangered' and remaining are 'vulnerable' (ZSI. 1994). According to WPA (1972) 26 species are listed as Schedule I species (**Table 6.60).**

6.5.1.3 Proboscidae

Proboscidae is represented by Asian elephant, which inhabits foothill stretch (up to 300m elevation) of Dibang river in plains. Asian elephant is classified as 'vulnerable' and is under Schedule I.

6.5.1.4 Artiodactyla

Artiodactyla is comprised of 10 species belonging to 4 families Bovidae, Cervidae, Moschidae and Suidae (**Table 6.59**). Mithun (*Bos frontalis*), Goral, Barking deer, Serow, Hog deer and Wild boar inhabit the areas near settlements and its surroundings. Mithun is quite common, semi-domesticated cattle in the region. Wild buffalo is restricted in the lower reaches while Goral, Barking deer, Serow, Hog deer and Wild boar are distributed up to 1000 m elevation. Mishmi Takin and Musk deer are found in the high altitudes of the catchment; Takin inhabits the elevation range between 2100 m and 3000 m whereas Musk deer is found above 3000 m elevation range. All species of Artiodactyla are considered as game animals. The criterion used by Zoological Survey of India (ZSI) publication of 1994 for assessing conservation status includes Musk deer and Wild boar under the 'Endangered' category and Serow as 'vulnerable' (**Table 6.60**). Only Takin is considered as endemic to Eastern Himalaya. Asiatic buffalo (*Bubalus arnee*) and Hog deer (*Axis purnicus*) are found in the foothills in the wide riverbed area of Dibang river in plains.

6.5.1.5 Lagomorpha

Lagomorpha is represented by five species belonging to 2 families. Indian hare and Hispid hare are under Leporidae family. These inhabit scrubs forest and distributed from foothills to 1200 m. Hispid hare is a Schedule-I mammal while Indian hare is a game animal hunted by tribals for its skin. It is categorized under the Schedule IV. Family Ochotonidae is represented by 3 species *Ochotona roylei, O. thibetana* and *O. forresti*. All these are listed under Least Concern categories by IUCN.

6.5.1.6 Pholidota

This Order is represented by 2 species i.e. Chinese pangolin and Indian pangolin which are reported from the lower reaches of the basin. Both species belong to the family Manidae. They are found up to 300 m. Indian pangolin is locally 'vulnerable' species (ZSI, 1994) whereas Chinese pangolin has been placed under the Schedule I (WPA, 1972).

6.5.1.7 Rodentia

Rodentia is comprised of rats, porcupine, squirrels and shrews and is represented by 44 species belonging to 4 families. Rats are widely distributed and are quite common around the settlement areas. Indian porcupine is found up to 1000 m elevation and inhabits open areas. Squirrels (*Tamiops macClelland, Petaurista magnificus, Petaurista petaurista* and *Hylopetes alboniger*) and shrew (*Tupaia belangeri* and *Soriculus leucops*) inhabit dense forests. They are very common around the habitations. None of the rodent species is globally and locally threatened. Most of them have been placed under the Schedule V and considered as 'vermin' (pest).

6.5.1.8 Chiroptera

Order Chiroptera is represented by 39 species belonging to 7 families. All bat species are restricted to the lower reaches. They are nocturnal and invade citrus orchards in the region. They have been placed under the Schedule V.

6.5.1.9 Scandentia & Soricomorpha

These two Orders are represented by shrews where Scandentia covers tree shrews. They are represented by 9 species wherein Scandentia is represented by lone species i.e. Northern tree shrew.

6.5.1.10 Conservation Status

As already discussed in previous Sections the conservation status of the mammals reported from the basin was assessed based upon their listing in different lists published by agencies like IUCN Red List of Threatened Species 2015 and different Schedules notified under Wildlife (Protection) Act, 1972 and the same has been given in **Table 6.61**.

Twenty seven species of mammals have been included in Schedule-I according to WPA 1972, another 26 species in Schedule-II and rest of the species are either under Schedule- III, IV or V. According to IUCN Red List 12 species under Endangered category like *Manis pentadactyla, Cuon alpinus, Bubalus arnee, Axis pornicus* and *Caprolagus hispidus*. In addition there are 14 more species which are under Vulnerable category viz. *Capricornis sumatraensis, Budorcas taxicolor, Helarctos malayanus, Ursus thibetanus, Melursus ursinus* and *Trachypithecus* *pileatus* while 7 species are listed as Near Threatened category. One hundred and thirteen species of mammals reported from the basin are under Least Concern (LC) category of IUCN Red List (**refer Table 6.61**).

6.5.2 Avi-fauna

Arunachal Pradesh harbours a high richness of avian fauna. More than 700 species of birds are known to occur in Arunachal Pradesh (Choudhury, 2004; ZSI, 2006). Bird Life International (www.birdlife.org) has identified 28 Important Birding Areas (IBA) in the state. Dibang basin too is a good representative of avian diversity harbouring more than 650 species of birds. Three Birding areas have been identified in Dibang basin by IBA (**see Table 6.61**). International Birding Areas are achieved through the application of quantitative ornithological criteria, grounded in up-to-date knowledge of the sizes and trends of bird populations. The Global criteria are as follows:

A1. Globally threatened species
Criterion: The site is known or thought regularly to hold significant numbers of a globally threatened species, or other species of global conservation concern.

A2. Restricted-range species
Criterion: The site is known or thought to hold a significant component of a group of species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA).

Important birding areas identified by Birdlife International in Dibang basin are listed in **Table 6.60**.

Table 6.60: Important Birding areas in Dibang basin

IBA Code	IBA Site name	IBA Criteria
IN-AR-04	Dibang Reserve Forest and adjacent areas	A1, A2
IN-AR-05	Dibang Wildlife Sanctuary	A1, A2
IN-AR-14	Mehao Wildlife Sanctuary	A1, A2

Birds in Dibang Basin
Upper parts of Dibang basin comprise part of Mishmi Hills which also covers upper catchment of Lohit river comprising Anjaw district. Considering rich diversity of avi-fauna in Mishmi Hills IBA has listed 663 species of birds in Mishmi Hills itself.

For the compilation of checklist of birds found in the Dibang basin the documents and published literature consulted are the Management Plans of Mehao Wildlife Sanctuary and Dibang Wildlife Sanctuary, and also available data on Dibang Dihang Biosphere Reserve was also consulted. In addition published papers like Baker (1913), Katti *et al* (1992), Sen (2008), Choudhury (2010), Krishna *et al.* (2012), Birdlife International (2001), Rangini *et al* (2013) and Mize et al. (2014). Therefore inventory of the birds reportedly found in entire Dibang basin was prepared based upon IBA's checklist and the data provided by Zoological Survey of India (ZSI) i.e. Fauna of Arunachal Pradesh, State Fauna Series, 13 (2006). According to it **679 species** of birds belonging to **90 families** and the same has been given at **Annexure-IV, Volume II**.

Table 6.61: List of mammals reportedly found in Dibang basin

S.No.	Family	Name of species	Common Name	IUCN 3.1	WPA 1972	Distribution range (m)
	ORDER: ARTIODACTYLA					
	BOVIDAE					
1		*Bos frontalis*	Mithun	-	-	
2		*Bubalus arnee*	Asiatic wild buffalo	EN	I	Up to 900
3		*Budorcas taxicolor*	Mishmi Takin	VU	I	1500-4000
4		*Capricornis sumatraensis*	Serow	VU	I	200-3000
5		*Naemorhedus goral*	Himalayan goral	NT	III	900-2700
	CERVIDAE					
6		*Cervus unicolor*	Sambar deer	VU	III	2000-3000
7		*Muntiacus muntjak*	Common muntjac	LC	III	Up to 800
8		*Axis porcinus*	Hog deer	EN	III	Up to 400
	MOSCHIDAE					
9		*Moschus chrysogaster*	Alpine Musk Deer	EN	I	2000-5000
	SUIDAE					
10		*Sus scrofa*	Wild boar	LC	III	Up to 2400
	ORDER: CARNIVORA					
	AILURIDAE					
11		*Ailurus fulgens*	Red panda	VU	I	2800-3600
	CANIDAE					
12		*Canis aureus*	Golden jackal	LC	II	Up to 3800
13		*Canis lupus*	Gray wolf	LC	I	-
14		*Cuon alpinus*	Dhole	EN	II	-
15		*Vulpes bengalensis*	Bengal fox	LC	II	-
16		*Vulpes vulpes*	Red fox	LC	II	Up to 4500
	FELIDAE					
17		*Catopuma temminckii*	Asian golden cat	NT	I	Up to 3800
18		*Felis chaus*	Jungle cat	LC	II	1000-2400
19		*Neofelis nebulosa*	Clouded leopard	VU	I	2500-3000
20		*Panthera pardus*	Leopard	NT	I	Up to 4000
21		*Panthera tigris*	Tiger	EN	I	Up to 4000
22		*Pardofelis marmorata*	Marbled cat	VU	I	-
23		*Prionailurus bengalensis*	Leopard cat	LC	I	Up to 3000
24		*Prionailurus viverrinus*	Fishing cat	EN	I	Up to 1525
25		*Uncia uncia*	Snow leopard	EN	I	3000-4500
	HERPESTIDAE					
26		*Herpestes edwardsii*	Indian grey mongoose	LC	II	Up to 1500
27		*Herpestes urva*	Crab-eating mongoose	LC	II	Up to 1200
	MUSTELIDAE					
28		*Aonyx cinerea*	Oriental small-clawed otter	VU	-	-
29		*Arctonyx collaris*	Hog badger	NT	I	Up to 3500
30		*Lutrogale perspicillata*	Smooth-coated otter	VU	II	-
31		*Martes flavigula*	Yellow-throated marten	LC	II	Up to 3000

S.No.	Family	Name of species	Common Name	IUCN 3.1	WPA 1972	Distribution range (m)
32		*Mellivora capensis*	Honey badger	LC	I	2600-4000
33		*Melogale personata*	Burmese Ferret- badger	Data Deficient	II	50- 2000
34		*Mustela kathiah*	Yellow-bellied weasel	LC	II	1800-4000
35		*Mustela sibirica*	Siberian weasel	LC	II	1500-4800
36		*Mustela strigidorsa*	Back-striped weasel	LC	-	Up to2500
	URSIDAE					
37		*Helarctos malayanus*	Sun Bear	VU		
38		*Melursus ursinus*	Sloth bear	VU	I	1500-2000
39		*Ursus thibetanus*	Asian Black Bear	VU	I	-
	VIVERRIDAE					
40		*Arctictis binturong*	Binturong	VU	I	Up to 1100
41		*Arctogalidia trivirgata*	Small-toothed palm civet	LC	II	Up to 1500
42		*Paguma larvata*	Masked palm civet	LC	II	Up to 2500
43		*Paradoxurus hermaphroditus*	Asian palm civet	LC	II	Up to 2400
44		*Viverra zibetha*	Large Indian civet	NT	II	Up to 1600
45		*Viverricula indica*	Small Indian civet	LC	II	-
46	**ORDER: CHIROPTERA**					
	EMBALLONURIDAE					
47		*Taphozous longimanus*	Long-winged Tomb Bat	LC	-	Up to 1200
	HIPPOSIDERIDAE					
48		*Hipposideros armiger*	Great Himalayan Leaf-nosed Bat	LC	-	1000-2000
49		*Hipposideros cineraceus*	Least Leaf-nosed Bat	LC	-	62-1280
50		*Hipposideros fulvus*	Fulvus Leaf-nosed Bat	LC	-	Up to 2600
51		*Hipposideros galeritus*	Cantor's Leaf-nosed Bat	LC	-	Up to 1100
52		*Hipposideros larvatus*	Horsfield's Leaf-nosed Bat	LC	-	-
53		*Hipposideros pomona*	Andersen's Leaf-nosed Bat	LC	-	-
	MEGADERMATIDAE					
54		*Megaderma lyra*	Greater False Vampire Bat	LC	-	1000
55		*Megaderma spasma*	Lesser false vampire Bat	LC	-	Up to 1600
	PTEROPODIDAE					
56		*Cynopterus brachyotis*	Lesser short-nosed fruit bat	LC	IV	-
57		*Cynopterus sphinx*	Greater Shortnosed Fruit bat	LC	IV	Up to 400
58		*Eonycteris spelaea*	Dawn Bat	LC	IV	-
59		*Macroglossus sobrinus*	Long-tongued fruit bat	LC	IV	Up to 2000
60		*Megaerops niphanae*	Ratanaworabhan's Fruit Bat	LC	-	100-2100
61		*Pteropus giganteus*	Indian flying fox	LC	IV	Up to 2000
62		*Rousettus leschenaulti*	Leschenault's Rousette	LC	IV	Up to 1140
	RHINOLOPHIDAE					
63		*Rhinolophus affinis*	Intermediate Horseshoe Bat	LC	-	290-2000
64		*Rhinolophus ferrumequinum*	Greater horseshoe bat	LC	-	800-3000
65		*Rhinolophus lepidus*	Blyth's Horseshoe Bat	LC	-	Up to 2330
66		*Rhinolophus luctus*	Woolly Horseshoe Bat	LC	-	1600
67		*Rhinolophus pearsoni*	Pearson horseshoe bat	LC	-	610 -3070

S.No.	Family	Name of species	Common Name	IUCN 3.1	WPA 1972	Distribution range (m)
68		*Rhinolophus pusillus*	Least Horseshoe Bat	LC	-	-
69		*Rhinolophus rouxii*	Rufous Horseshoe Bat	LC	-	Up to 1370
70		*Rhinolophus trifoliatus*	Trefoil Horseshoe Bat	LC	-	Up to 1800
71		*Rhinolophus yunanensis*	Dobson horseshoe bat	LC	-	Up to 1231
	RHINOPOMATIDAE					
72		*Rhinopoma hardwickii*	Lesser mouse-tailed bats	LC	-	Up to 1100
	VESPERTILIONIDAE					
73		*Eptesicus serotinus*	serotine bat	LC	-	Up to 1440
74		*Kerivoula hardwickii*	Hardwicke's Woolly Bat	LC	-	60-2100
75		*Kerivoula picta*	Painted Bat	LC	-	Up to 1500
76		*Murina tubinaris*	Scully's Tube-Nosed Bat	LC	-	Up to1200-2600
77		*Myotis formosus*	Hodgson's bat	LC	-	Up to 3000
78		*Pipistrellus coromandra*	Coromandel Pipistrelle	LC	-	Up to1000-2700
79		*Pipistrellus kuhlii*	Kuhl's pipistrelle	LC	-	Up to 2000
80		*Pipistrellus paterculus*	Mount Popa pipistrelle	LC	-	Up to 1500
81		*Pipistrellus tenuis*	Least pipistrelle	LC	-	Up to 800
82		*Plecotus auritus*	Brown long-eared bat	LC	-	1900-2300
83		*Scotomanes ornatus*	Harlequin bat	LC	-	Up to1400
84		*Scotophilus kuhlii*	Lesser Asiatic Yellow House Bat	LC	-	Up to 1110
85		*Scotophilus* heathii	Greater Asiatic Yellow House Bat	LC	-	Up to1500
86		*Barbastella leucomelas*	Eastern Barbastelle	LC	-	Up to 2500
87		*Hesperoptenus tickelli*	Tickell's bat	LC	-	Up to 1000
88		*Myotis annectans*	Hairy-faced Bat	LC	-	Up to 1100
89		*Myotis longipes*	Kashmir Cave Bat	Data Deficient	-	300-2000
90		*Pipistrellus affinis*	Chocolate Pipistrelle	LC	-	Up to 2000
91		*Pipistrellus savii*	Savi's Pipistrelle	LC	-	Up to 3000
	ORDER: INSECTIVORA					
	TALPIDAE					
92		*Talpa micrura*	Indian Short-taile	#	-	1000-3000
	ORDER: LAGOMORPHA					
	LEPORIDAE					
93		*Caprolagus hispidus*	Hispid hare	EN	I	100-250
94		*Lepus nigricollis*	Indian hare	LC	IV	500-4500
	OCHOTONIDAE					
95		*Ochotona forresti*	Forrest's Pika	LC	-	2600-4400
96		*Ochotona roylei*	Royle's Pika	LC	IV	2400-4300
97		*Ochotona thibetana*	Moupin Pika	LC	-	2400-4100
	ORDER: PHOLIDOTA					
	MANIDAE					
98		*Manis crassicaudata*	Indianpangolin	EN	I	1100-2300
99		*Manis pentadactyla*	Chinese pangolin	EN	I	Up to 1500
	ORDER: PRIMATES					
	CERCOPITHECIDAE					

S.No.	Family	Name of species	Common Name	IUCN 3.1	WPA 1972	Distribution range (m)
100		*Macaca assamensis*	Assamese macaque	NT	II	2000-6000
101		*Macaca mulatta*	Rhesus macaque	LC	II	Up to 4000
102		*Nycticebus bengalensis*	Slow loris	VU	I	Up to 2400
103		*Trachypithecus pileatus*	Capped langur	VU	I	100-2000
	HYLOBATIDAE					
104		*Hoolock hoolock*	Hoolock Gibbon	EN	I	
	PRIONODONTIDAE					
105		*Prionodon pardicolor*	Spotted linsang	LC	I	150-2700
	ORDER: PROBOSCIDEA					
	ELEPHANTIDAE					
106		*Elephas maximus*	Asiatic elephant	EN	I	Up to 3000
	ORDER: RODENTIA					
	CRICETIDAE					
107		*Eothenomys melanogaster*	Père David's Vole	LC	-	
108		*Microtus sikimensis*	Sikkim Vole	LC	-	2100-2700
	HYSTRICIDAE					
109		*Atherurus macrourus*	Asiatic Brush-tailed Porcupine	LC	II	Up to 750
110		*Hystrix brachyura*	Himalayan porcupine	LC	II	Up to 1300
111		*Hystrix indica*	*Indian porcupine*	LC	IV	Up to 2400
	MURIDAE					
112		*Apodemus sylvaticus*	Wood mouse	LC	-	-
113		*Bandicota bengalensis*	Indian mole-rat	LC	IV	Up to 3500
114		*Bandicota indica*	Greater Bandicoot Rat	LC	V	Up to1500
115		*Dacnomys millardi*	Millard's Rat	Data Deficient	-	-
116		*Golunda ellioti*	Gulandi Bush Rats	LC	IV	-
117		*Micromys minutus*	Harvest mouse	LC	-	Up to 1700
118		*Mus boodunga*	Little Indian field mouse	#	-	-
119		*Mus cervicolor*	fawn-colored mouse	LC	-	Up to 2000
120		*Mus cookii*	Cook's mouse	LC	-	50-2500
121		*Mus musculus*	House mouse	LC	IV	-
122		*Mus pahari*	Gairdner's Shrewmouse	LC	-	200-2000
123		*Mus platythrix*	Flat-haired Mouse	LC	IV	Up to2000
124		*Mus saxicola*	Rock-loving Mouse	LC	-	Up to 1000
125		*Niviventer brahma*	Brahma White-bellied Rat	LC	-	2000-2800
126		*Niviventer eha*	Smoke-bellied Rat	LC	-	2000-3700
127		*Niviventer fulvescens*	Chestnut White-bellied Rat	LC	-	Up to2200
128		*Niviventer niviventer*	Anderson's white-bellied rat	LC	IV	Up to 3600
129		*Niviventer tenaster*	Tenasserim White-bellied Rat	LC	-	1300-2200
130		*Rattus nitidus*	Himalayan Field Rat	LC	IV	700-2700
131		*Rattus rattus*	Black rat	LC	IV	-
132		*Rattus turkestanicus*	Turkestan Rat	LC	-	1200-4250
133		*Vandeleuria oleracea*	Asiatic long-tailed climbing mouse	LC	-	200-1500
134		*Berylmys mackenziei*	Kenneth's White-toothed Rat	Data Deficient	-	1200-3000

S.No.	Family	Name of species	Common Name	IUCN 3.1	WPA 1972	Distribution range (m)
135		*Berylmys manipulus*	Manipur White-toothed Rat	Data Deficient	-	Up to 2000
		Leopoldamys edwardsi	Edwards's Long-tailed Giant Rat	LC	-	Up to 1400
	SCIURIDAE					
136		*Belomys pearsonii*	Hairy-footed flying squirrel	Data Deficient	II	
137		*Callosciurus erythraeus*	Pallas squirrel	LC	-	Above 3000
138		*Callosciurus pygerythrus*	Hoary-bellied Squirrel	LC	-	500-1560
139		*Dremomys rufigenis*	Asian Red-cheeked Squirrel	LC	-	Up to 1500
140		*Hylopetes alboniger*	Particolored Flying Squirrel	LC	II	1500-3400
141		*Petaurista candidatus*	Flying squirrel	#	-	
142		*Petaurista elegans*	Spotted Giant Flying Squirrel	LC	-	3000-4000
143		*Petaurista mechukaensis*	Mechuka Giany Flying squirrel	LC		
144		*Petaurista mishmiensis*	Mishmi hills Giany Flying squirrel			
145		*Petaurista petaurista*	Red Giant Flying Squirrel	LC	-	500-3100
146		*Pteromys magnificus*	Hodgson's Flying Squirrel	#	II	
147		*Ratufa bicolor*	Black giant squirrel	NT	II	500-2500
148		*Tamiops macclellandi*	Himalayan striped squirrel	LC	-	Up to 1500
	SPALACIDAE					
149		*Cannomys badius*	Lesser bamboo rat	LC	-	Up to 4000
	ORDER: SCANDENTIA					
	TUPAIIDAE					
150		*Tupaia belangeri*	Northern Treeshrew	LC	-	Up to 3000
	ORDER: SORICOMORPHA					
	SORICIDAE					
151		*Anourosorex squamipes*	Mole shrew	LC	-	-
152		*Chimarrogale himalayica*	Himalayan water shrew	LC	-	800-1500
153		*Crocidura attenuata*	Indochinese Shrew	LC	-	Up to 3000
154		*Episoriculus caudatus*	Hodgson's Brown-toothed Shrew	LC	-	Below 1000
155		*Soriculus leucops*	Long-tailed Brown-toothed Shrew	LC	-	2900-3500
156		*Soriculus nigrescens*	Sikkim Large-clawed Shrew	LC	-	1500-4300
157		*Suncus etruscus*	Etruscan shrew	LC	-	Up to 3000
158		*Suncus murinus*	Asian house shrew	LC	-	-

IUCN ver. 3.1: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern, NT = Near Threatened

According to this list, Muscicapidae with 63 species is the largest family in the basin followed by Sylviidae and Accipitridae with 32 species and Timaliidae with 30 species of birds. For the correct scientific names of bird species and their classification is based upon avibase portal http://avibase.bsc-eoc.org/avibase.jsp.

However during the survey only 113 species of birds could be sighted and the list of the same has been given at **Table 6.62**. An account the bird species sighted has been given below.

Family Muscicapidae of Order Passeriformes is the largest family represented by 17 species while families Leiothrichidae and Timaliidae of Passeriformes are represented by 8 and 5 species, respectively. Columbidae of Colubiformes is represented by 6 species.

6.5.2.1 Conservation Status

Out of 679 bird species reportedly found in Dibang basin of which checklist was prepared as many as 40 species belong to Schedule-I as per Wildlife (Protection) Act, 1972 (**refer Annexure-IV, Volume II**). However no species is under Schedules–II & III wheres 576 species are under Schedule-IV.

According to IUCN Red List ver 3.1 four species are under Critically Endangered category viz. Red-headed Vulture, Slender-billed Vulture, White-rumped Vulture and White-bellied Heron. Four species are under 'Endangered' category i.e. White-winged Duck, Yellow-breasted Bunting, Greater Adjutant and Black-bellied Tern. In addition 22 species have been listed under Vulnerable category.

Amongst the 113 species sighted during the survey 4 species viz. *Aceros nipalensis, Columba punicea, Pellorneum ruficeps* and *Spelaeornis badeigularis* are under Vulnerable category as per IUCN while 2 species i.e. *Psittacula alexandri* and *Sphenocichla humei* are of Near Threatened category. Three species - *Aceros nipalensis, Aceros undulates* and *Buceros bicornis* are Schedule I species (WPA, 1972). Majority of the species are resident in status.

6.5.3 Butterflies

The mountainous landscape and moist dense forest cover of Arunachal Pradesh provides conducive climatic conditions for the butterflies. Based upon the data compiled from field surveys and secondary sources, Forest Working Plans, Management Plans of Protected areas, etc. a list of butterflies was prepared. According to it total of 373 species of butterflies are found in the basin. These species belong to seven families – Hesperiidae, Lycaenidae, Hesperidae, Nymphalidae, Papilionidae, Pieridae, Riodinidae and Satyridae. Nymphalidae was most dominant family represented by 141 species. Great Mormon, De Nicéville's Windmill, Eastern Courtier, Broad-banded Sailer, Pale Hockeystick Sailer, Pale Hockeystick Sailer, Scarce White Commodore, Bamboo Treebrown, Autumn Leaf, Common Duffer, Khaki Silverline and Common Pierrot are categorised as Schedule I species (WPA, 1972). A check-list of species of butterflies found in the basin compiled through field surveys as well as published literature is given at **Annexure-V, Volume II.**

6.5.4 Herpetofauna

Herpetofauna comprise of amphibians that include frogs, toads, newts, salamanders, etc. and reptiles which include snakes, lizards, turtles, terrapins, tortoises, etc. An inventory of herpetofauna comprising reptiles and amphibians was prepared from the Forest Working Plans, management plans of Protected Area and Fauna of Arunachal Pradesh Vol. I and the same is given at **Table 6.63**. Total 23 species are reported from the Dibang basin of which 17 species are of reptiles and6 species are of amphibians.

Table 6.62: Avi-fauna recorded from Dibang basin during surveys

S. No.	Order	Family	Species name	Common name	IUCN 3.1	WPA Schedule	Status
1	Apodiformes	Apodidae	*Aerodramus brevirostris*	Himalayan Swiftlet	LC	Not Included	R
2	Bucerotiformes	Bucerotidae	*Aceros nipalensis*	Rufous necked hornbill	VU	I	Vr
3	Bucerotiformes	Bucerotidae	*Aceros undulatus*	Wreathed Hornbill	LC	I	r
4	Bucerotiformes	Bucerotidae	*Buceros bicornis*	Great pied Hornbill	LC	I	
5	Bucerotiformes	Upupidae	*Upupa epops*	Common Hoopoe	LC	Not Included	RW
6	Charadriiformes	Jacanidae	*Metopidius indicus*	Bronze-winged Jacana	LC	IV	R
7	Columbiformes	Columbidae	*Chalcophaps indica*	Emerald Dove	LC	IV	R
8	Columbiformes	Columbidae	*Columba hodgsonii*	Speckled Wood Pigeon	LC	IV	r
9	Columbiformes	Columbidae	*Columba livia*	Rock Pigeon	LC	IV	R
10	Columbiformes	Columbidae	*Columba punicea*	Pale-capped Pigeon	VU	IV	Vw
11	Columbiformes	Columbidae	*Streptopelia chinensis*	Spotted dove	LC	IV	R
12	Columbiformes	Columbidae	*Streptopelia orientalis*	Oriental turtle dove	LC	IV	RW
13	Coraciiformes	Cerylidae	*Megaceryle lugubris*	Crested Kingfisher	LC	IV	R
14	Coraciiformes	Coraciidae	*Ceyx erithacus*	Oriental Dwarf Kingfisher	LC	IV	r
15	Coraciiformes	Meropidae	*Merops leschenaulti*	Chestnut-headed Bee-eater	LC	Not Included	R
16	Cuculiformes	Cuculidae	*Centropus sinensis*	Greater Coucal	LC	IV	R
17	Cuculiformes	Cuculidae	*Eudynamys scolopacea*	Asian Koel	LC	IV	R
18	Galliformes	Phasianidae	*Gallus gallus*	Red jungle fowl	LC	IV	
19	Galliformes	Phasianidae	*Lophura leucomelana*	Kalij Pheasant	LC	IV	R
20	Gruiformes	Rallidae	*Amaurornis phoenicurus*	White-breasted Waterhen	LC	IV	R
21	Passeriformes	Campephagidae	*Pericrocotus ethologus*	Longtailed Minivet	LC	IV	
22	Passeriformes	Campephagidae	*Pericrocotus flammeus*	Scarlet Minivet	LC	IV	R
23	Passeriformes	Campephagidae	*Pericrocotus solaris*	Grey-chinned Minivet	LC	IV	r
24	Passeriformes	Cettiidae	*Cettia brunnifrons*	Grey-sided Bush Warbler	LC	IV	r
25	Passeriformes	Chloropseidae	*Chloropsis hardwickii*	Orange-bellied Leafbird	LC	IV	r
26	Passeriformes	Cinclidae	*Cinclus pallasii*	Brown Dipper	LC	Not Included	R
27	Passeriformes	Cisticolidae	*Orthotomus atrogularis*	Dark-necked Tailorbird	LC	IV	r
28	Passeriformes	Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	LC	IV	R
29	Passeriformes	Corvidae	*Corvus macrorhynchos*	Large billed crow	LC	IV	R
30	Passeriformes	Corvidae	*Dendrocitta formosae*	Grey Treepie	LC	IV	R
31	Passeriformes	Dicaeidae	*Dicaeum ignipectus*	Fire breasted flowerpecker	LC	IV	r
32	Passeriformes	Dicruridae	*Dicrurus aeneus*	Bronzed Drongo	LC	IV	r
33	Passeriformes	Dicruridae	*Dicrurus hottentottus*	Spangled Drongo	LC	IV	R
34	Passeriformes	Dicruridae	*Dicrurus leucophaeus*	Ashy Drongo	LC	IV	R
35	Passeriformes	Dicruridae	*Dicrurus macrocercus*	Black Drongo	LC	IV	R
36	Passeriformes	Dicruridae	*Dicrurus paradiseus*	Greater Racket-tailed Drongo	LC	IV	r
37	Passeriformes	Emberizidae	*Emberiza fucata*	Chestnut-eared Bunting	LC	IV	rw
38	Passeriformes	Emberizidae	*Emberiza leucocephalUs*	Pine Bunting	LC	IV	w

S. No.	Order	Family	Species name	Common name	IUCN 3.1	WPA Schedule	Status
39	Passeriformes	Emberizidae	*Emberiza pusilla*	Little Bunting	LC	IV	w
40	Passeriformes	Emberizidae	*Emberiza spodocephala*	Black-faced Bunting	LC	IV	w
41	Passeriformes	Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	LC	IV	R
42	Passeriformes	Hirundinidae	*Delichon nipalensis*	Nepal House Martin	LC	Not Included	r
43	Passeriformes	Laniidae	*Lanius schach*	Long-tailed Shrike	LC	Not Included	R
44	Passeriformes	Laniidae	*Lanius tephronotus*	Grey-backed Shrike	LC	Not Included	rW
45	Passeriformes	Leiothrichidae	*Cutia nipalensis*	Cutia	LC	IV	r
46	Passeriformes	Leiothrichidae	*Garrulax erythrocephalus*	Chestnut-crowned Laughingthrush	LC	IV	r
47	Passeriformes	Leiothrichidae	*Garrulax leucolophus*	White-crested Laughingthrush	LC	IV	R
48	Passeriformes	Leiothrichidae	*Garrulax monileger*	Lesser Necklaced Laughingthrush	LC	IV	r
49	Passeriformes	Leiothrichidae	*Garrulax striatus*	Striated Laughingthrush	LC	IV	r
50	Passeriformes	Leiothrichidae	*Leiothrix lutea*	Red-billed Leiothrix	LC	IV	r
51	Passeriformes	Leiothrichidae	*Liocichla phoenicea*	Red-faced Liocichla	LC	IV	r
52	Passeriformes	Leiothrichidae	*Turdoides striatus*	Jungle Babbler	LC	IV	
53	Passeriformes	Motacillidae	*Anthus hodgsoni*	Olive-backed Pipit	LC	IV	RW
54	Passeriformes	Motacillidae	*Motacilla alba*	White Wagtail	LC	IV	rW
55	Passeriformes	Motacillidae	*Motacilla cinerea*	Grey Wagtail	LC	IV	rW
56	Passeriformes	Muscicapidae	*Chaimarrornis leucocephalus*	White-capped Water Redstart	LC	IV	r
57	Passeriformes	Muscicapidae	*Cyornis unicolor*	Pale Blue Flycatcher	LC	IV	r
58	Passeriformes	Muscicapidae	*Enicurus schistaceus*	Slaty-backed Forktail	LC	IV	r
59	Passeriformes	Muscicapidae	*Eumyias thalassina*	Verditer Flycatcher	LC	IV	R
60	Passeriformes	Muscicapidae	*Ficedula hodgsonii*	Slaty-backed Flycatcher	LC	IV	r
61	Passeriformes	Muscicapidae	*Ficedula westermanni*	Little Pied Flycatcher	LC	IV	r
62	Passeriformes	Muscicapidae	*Luscinia pectoralis*	White-tailed Rubythroat	LC	IV	rW
63	Passeriformes	Muscicapidae	*Myophonus caeruleus*	Blue Whistling Thrush	LC	IV	R
64	Passeriformes	Muscicapidae	*Niltava grandis*	Large Niltava	LC	IV	r
65	Passeriformes	Muscicapidae	*Niltava sundara*	Rufous-bellied Niltava	LC	IV	r
66	Passeriformes	Muscicapidae	*Phoenicurus frontalis*	Blue-fronted Redstart	LC	IV	r
67	Passeriformes	Muscicapidae	*Phoenicurus hodgsoni*	Hodgson's Redstart	LC	IV	w
68	Passeriformes	Muscicapidae	*Phoenicurus ochruros*	Black Redstart	LC	IV	rW
69	Passeriformes	Muscicapidae	*Tarsiger cyanurus*	Orange-flanked Bush Robin	LC	IV	r
70	Passeriformes	Muscicapidae	*Enicurus maculatus*	Spotted forktail	LC	IV	r
71	Passeriformes	Muscicapidae	*Enicurus scouleri*	Little Forktail	LC	IV	r
72	Passeriformes	Muscicapidae	*Rhyacornis fuliginous*	Plumbeous redstart	LC	IV	
73	Passeriformes	Nectariniidae	*Aethopyga saturata*	Black-throated Sunbird	LC	IV	r
74	Passeriformes	Nectariniidae	*Arachnothera magna*	Streaked Spiderhunter	LC	IV	r
75	Passeriformes	Paridae	*Parus monticolus*	Green backed tit	LC	IV	R
76	Passeriformes	Paridae	*Parus spilonotus*	Yellow-cheeked Tit	LC	IV	r
77	Passeriformes	Passeridae	*Passer domesticus*	House sparrow	LC	IV	R

S. No.	Order	Family	Species name	Common name	IUCN 3.1	WPA Schedule	Status
78	Passeriformes	Passeridae	*Passer montanus*	Eurasian tree sparrow	LC	IV	R
79	Passeriformes	Pellorneidae	*Pellorneum albiventre*	Spot-throated Babbler	LC	IV	r
80	Passeriformes	Pellorneidae	*Pellorneum ruficeps*	Puff-throated Babbler	VU	IV	R
81	Passeriformes	Psittaculidae	*Psittacula alexandri*	Red-breasted Parakeet	NT	IV	R
82	Passeriformes	Pycnonotidae	*Hemixos flavala*	Ashy Bulbul	LC	IV	r
83	Passeriformes	Pycnonotidae	*Hypsipetes leucocephalus*	Black Bulbul	LC	IV	R
84	Passeriformes	Pycnonotidae	*Pycnonotus cafer*	Red-vented Bulbul	LC	IV	R
85	Passeriformes	Pycnonotidae	*Pycnonotus jocosus*	Red-whiskered Bulbul	LC	IV	R
86	Passeriformes	Pycnonotidae	*Pycnonotus striatus*	Striated Bulbul	LC	IV	r
87	Passeriformes	Rhipiduridae	*Rhipidura albicollis*	White-throated Fantail	LC	IV	R
88	Passeriformes	Sittidae	*Sitta castanea*	Chestnut-bellied Nuthatch	LC	Not Included	R
89	Passeriformes	Stenostiridae	*Rhipidura hypoxantha*	Yellow-bellied Fantail	LC	IV	R
90	Passeriformes	Sturnidae	*Acridotheres tristis*	Common Myna	LC	IV	R
91	Passeriformes	Sturnidae	*Gracula religiosa*	Common Hill Myna	LC	IV	r
92	Passeriformes	Sylviidae	*Phylloscopus chloronotus*	Lemon-rumped Warbler	LC	IV	rW
93	Passeriformes	Sylviidae	*Phylloscopus maculipennis*	Ashy-throated Warbler	LC	IV	r
94	Passeriformes	Sylviidae	*Seicercus affinis*	White-spectacled warbler	LC	IV	r
95	Passeriformes	Sylviidae	*Seicercus burkii*	Golden-spectacled Warbler	LC	IV	R
96	Passeriformes	Tichodromadidae	*Tichodroma muraria*	Wallcreeper	LC	Not Included	rw
97	Passeriformes	Timaliidae	*Pomatorhinus schisticeps*	White-browed Scimitar Babbler	LC	IV	r
98	Passeriformes	Timaliidae	*Pteruthius melanotis*	Black-eared Shrike Babbler	LC	IV	r
99	Passeriformes	Timaliidae	*Spelaeornis badeigularis*	Rusty-throated Wren Babbler	VU	IV	Vr
100	Passeriformes	Timaliidae	*Sphenocichla humei*	Wedge-billed Wren Babbler	NT	IV	r
101	Passeriformes	Timaliidae	*Stachyris nigriceps*	Grey-throated Babbler	LC	IV	r
102	Passeriformes	Turdidae	*Cochoa purpurea*	Purple Cochoa	LC	IV	r
103	Passeriformes	Turdidae	*Turdus albocinctus*	White-collared Blackbird	LC	IV	r
104	Passeriformes	Turdidae	*Zoothera dauma*	Scaly Thrush	LC	IV	r
105	Passeriformes	Zosteropidae	*Yuhina nigrimenta*	Black-chinned Yuhina	LC	IV	R
106	Passeriformes	Zosteropidae	*Yuhina occipitalis*	Rufous-vented Yuhina	LC	IV	r
107	Passeriformes	Zosteropidae	*Yuhina bakeri*	White-naped Yuhina	LC	IV	r
108	Piciformes	Megalaimidae	*Megalaima asiatica*	Blue-throated Barbet	LC	IV	R
109	Piciformes	Megalaimidae	*Megalaima virens*	Great Barbet	LC	IV	R
110	Piciformes	Picidae	*Dendrocopos macei*	Fulvous-breasted Woodpecker	LC	IV	R
111	Piciformes	Picidae	*Picus chlorolophus*	Lesser Yellownape	LC	IV	R
112	Piciformes	Picidae	*Picus flavinucha*	Greater Yellownape	LC	IV	R
113	Suliformes	Phalacrocoracidae	*Phalacrocorax carbo*	Great cormorant	LC	IV	RW

LC = Least concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, IK = Insufficiently Known; R = Widespread Resident, r = Sparse resident, W = Widespread winter visitor, w = Sparse winter visitor, s = sparse summer visitor

6.5.4.1 Reptiles

Reptilian fauna is comprised of 17 species belonging to 12 families (**Table 6.63**). Colubridae is the largest family represented by six species followed by Agamidae and Elapidae with 3 species each. IUCN Red List has kept Burmese Python (*Python molurus bivittatus*), King Cobra (*Ophiophagus hannah*) under Vulnerable category. Five species are under least concern category and rest of the species is not evaluated under IUCN Red List.

6.5.4.2 Amphibia

In Dibang basin 6 species of Amphibians are reportedly found which belong to 3 families, which comprises of toads and frogs. Ranidae is the largest family with 3 species followed by Bufonidae with 2 species (see **Table 6.63**). All species of frog falls in IUCN Red List Least Concern category.

Table 6.63: List of herpetofauna reported from Dibang basin

S. No.	Family	Scientific name	Common name	Status IUCN Ver. 3.1
Reptiles				
1	Elapidae	*Naja kaouthia*	Monocled cobra	LC
2	Elapidae	*Bungarus fasciatus*	Banded Krait	LC
3	Gekkonidae	*Hemidactylus frenatus*	Spiny tailed House Gecko	LC
4	Varanidae	*Varanus bengalensis*	Common Asian Monitor	LC
5	Viperidae	*Ovophis monticola*	Mountain Pit Viper	LC
6	Agamidae	*Calotes versicolor*	Common calotes	NA
7	Agamidae	*Ptyctolaemus gularis*	Blue throated Forest lizard	NA
8	Agamidae	*Calotes versicolor*	Garden lizard	NA
9	Colubridae	*Elaphe prasina*	Green Trinket Snake	NA
10	Colubridae	*Ptyas mucosa*	Rat Snake	NA
11	Colubridae	*Xenochrophis piscator*	Checkered Keelback	NA
12	Colubridae	*Boiga ocellata*	Eyed cat snake	NA
13	Colubridae	*Amphiesma stolatum*	Striped keelback	NA
14	Scincidae	*Mabuya macularia macularia*	Speckled little Sun skink	NA
15	Elapidae	*Ophiophagus hannah*	King Cobra	VU
16	Pythonidae	*Python molurus bivittatus*	Burmese Python	VU
17	Colubridae	*Trimeresurus* sp.	Pit Viper	
Amphibia				
18	Bufonidae	*Duttaphrynus himalayanus*	Himalayan Broad-skulled Toad	LC
19	Bufonidae	*Duttaphrynus melanostictus*	Common Indian Toad	LC
20	Dicroglossidae	*Fejervarya limnocharis* (Syn. *Rana limnocharis*)	Asian Grass frog	LC
21	Ranidae	*Amolops formosus*	Assam Sucker Frog	LC
22	Ranidae	*Euphlyctis cyanophlyctis* (Syn. *Rana cyanophlyctis*)	Indian Skipper Frog / Skittering Frog	LC
23	Ranidae	*Rana erythraea*	Common green frog	LC

LC = Least Concern, NA = Not Assessed, VU = Vulnerable

6.6 PROTECTED AREAS

Arunachal Pradesh is recognized as one of the 25 Biodiversity "Hot Spots" in the world. The state possesses myriad types of life forms co-existing in diverse ecological systems. There are eight Wildlife Sanctuaries, one Orchid Sanctuary and two National Parks in the state covering an area of 9,488.48 sq km. There are two Sanctuaries i.e. Dibang Wildlife Sanctuary and Mehao WLS in Dibang Basin. In addition Dibang Dihang Biosphere Reserve covers parts of Dibang Valley district.

Protected Area	Area (Sq km)
Dibang Wildlife Sanctuary	4149.00
Mehao Wildlife Sanctuary	281.50
Dibang Dihang Biosphere Reserve	5112.50 Core Area = 4094.80; Buffer Area = 1016.70

6.6.1 Dibang Wildlife Sanctuary

Dibang Wildlife Sanctuary is located in the Dibang Valley district of Arunachal Pradesh and administeratively under Divisional Forest officer, Mehao Wildlife Sanctuary Division with headquarters at Roing. It is spread over an area of 4149.00 sq km. The Sanctuary was notified under section 10 of the Wildlife (Protection) Act, 1972 vide Notification No. CWL/D/42/92/744-844 dt. 12/03/1998.

The area is located in the Himalaya at the junction of the eastern end of Arunachal Pradesh. The vegetation in the area varies from Sub-tropical broad leaf hill forest, Himalayan moist temperate Forest, Sub-alpine Forest and Alpine moist scrub. The altitude varies from 1800m to 5356m. Dri, Talo (Tangon), Edza and Edzon are main drainages of Dibang WLS.

The sanctuary is rich in wildlife. It is home to RET mammals such as Mishmi takin, Red goral, Musk deer, Red panda, Asiatic black bear, Snow leopard, Tiger (recently confirmed by WII, Dehradun) and Gongshan muntjac.

Recently a new species of flying squirrel has been discovered from the sanctuary named the Mishmi Hills Giant flying squirrel (*Petaurista mishmiensis*). Owing presence of tigers recently established Government of Arunachal Pradesh is proposing to convert Dibang WLS to Dibang Tiger Reserve (State Portal of Arunachal Pradesh, 2014).

Among birds there are the RET species like Sclater's monal and Blyth's tragopan. Four globally Vulnerable species have been recorded so far, the Red-breasted Hill-Partridge, and Beautiful Nuthatch (Singh 1994), Blyth's Tragopan and Sclater's Monal (Kaul *et al*. 1995). Ward's Trogon, a Near Threatened and Restricted Range species, was also recorded in the area (Singh 1994). Dibang WLS has been listed as one of the site of Important Bird and Biodiversity Areas (IBA) by Birdlife International. Six species identified by IBA are listed in the table below.

Common name	Species name	Season	IBA Criteria	IUCN Category
Sclater's Monal	*Lophophorus sclateri*	resident	A1, A2	Vulnerable
Chestnut-breasted Partridge	*Arborophila mandellii*	resident	A1, A2	Vulnerable
Blyth's Tragopan	*Tragopan blythii*	resident	A1, A2	Vulnerable
Ward's Trogon	*Harpactes wardi*	resident	A2	Near Threatened
Beautiful Sibia	*Heterophasia pulchella*	resident	A2	Least Concern
Beautiful Nuthatch	*Sitta formosa*	resident	A1	Vulnerable

The Common Crane (*Grus grus*) that migrate along the Dibang river (Choudhury 1994) eventually crosses Dibang WLS on the way to Tibet. Among other noteworthy species recorded are the Golden eagle (*Aquila chrysaetos*), Himalayan Monal (*Lophophorus impejanus*) and Himalayan Griffon (*Gyps himalayensis*).

Only one project i.e. part of Malinye HEP falls within Dibang Wildlife Sanctuary (**Figure 6.2**). However 4 projects fall within 10 radius of the sanctuary viz. Mihumdon, Etabue, Amulin and Attunli HEPs.

6.6.2 Mehao Wildlife Sanctuary

Mehao Wildlife Sanctuary is located in the Lower Dibang Valley district of Arunachal Pradesh named after Mehao lake and is spread over an area of 281.50 sq km. The Sanctuary was notified under section 10 of the Wildlife (Protection) Act, 1972 vide Notification No. FOR. 85/77/27-397-40 dt. 18/10/1980. Recently Draft Notification regarding demarcation of Eco Sensitive Zone (ESZ) of the sanctuary has been issued wherein area 100m from its northern boundary has been designated as ESZ.

The altitude of the sanctuary varies from 400m to 3560m. It is comprised three main lakes viz. Mehao lake, mini Mehao lake and Sally lake. It falls in Sub-tropical ecozone. Its area is drained by Difu Nala, Abha Nala, Jawe Nala, and tributaries of Deopani like Ezze and Emme Nalas. Due to altitudinal variation the WLS is comprised of three biomes i.e. Sino-Himalayan Temperate Forest, Sino-Himalayan Sub-tropical Forest, and Indo-Chinese Tropical Moist Forest.

More than 138 species of mammals are reported from the sanctuary (Management Plan, Mehao WLS, Management plan of Mehao WLS has listed 137 species of birds while 175 bird species have been recorded by Katti *et al.* (1992). It is home to number of RET species. Among the threatened birds, Spotbill Pelican was recorded just outside the Sanctuary in 1994 (Choudhury, 2000). White-winged Duck was also recorded from Mehao lake (Choudhury, 1995).

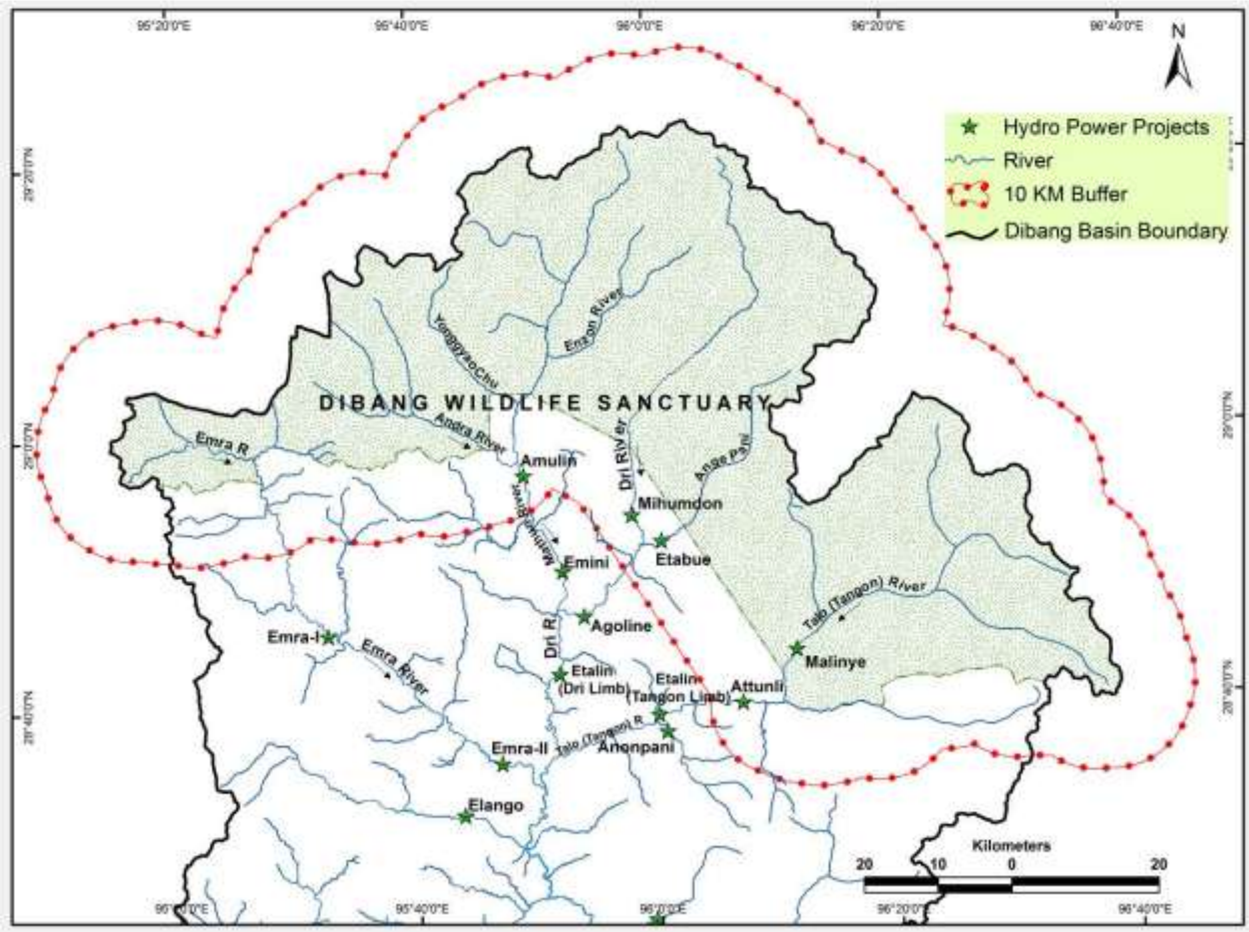


Figure 6.2: Map of Dibang Wildlife Sanctuary and proposed hydropower projects in its vicinity

Mehao WLS has been listed as one of the site of Important Bird and Biodiversity Areas (IBA) by Birdlife International. Twelve species identified by IBA are listed in the table below.

Common name	Species name	Status/Season	IBA Criteria	IUCN Category
Chestnut-breasted Partridge	*Arborophila mandellii*	resident	A1, A2	Vulnerable
Blyth's Tragopan	*Tragopan blythii*	resident	A1, A2	Vulnerable
White-winged Duck	*Asarcornis scutulata*	resident	A1	Endangered
Pale-capped Pigeon	*Columba punicea*	resident	A1	Vulnerable
Rufous-necked Hornbill	*Aceros nipalensis*	resident	A1	Vulnerable
Yellow-vented Warbler	*Phylloscopus cantator*	resident	A2	Least Concern
Broad-billed Warbler	*Tickellia hodgsoni*	resident	A2	Least Concern
Sphenocichla humei	*Sphenocichla humei*	resident	A2	Not Recognised
Streak-throated Barwing	*Actinodura waldeni*	resident	A2	Least Concern

Common name	Species name	Status/Season	IBA Criteria	IUCN Category
Ludlow's Fulvetta	*Alcippe ludlowi*	resident	A2	Least Concern
Beautiful Sibia	*Heterophasia pulchella*	resident	A2	Least Concern
White-naped Yuhina	*Yuhina bakeri*	resident	A2	Least Concern

The Wedge-billed Wren-Babbler, a Restricted Range species, and one of the least known Indian species, has been recorded from this Sanctuary (Katti *et al.* 1992). It has been collected only three times in the last century, in 1905 by Stevens (1914), in 1938 by Lightfoot (1940) and in 1988 by Ripley *et al.* (1991). It occurs in two races: humei and roberti. Rasmussen and Anderton (in press) have elevated these races to full species: *Sphenocichla humei* and *Sphenocichla roberti*. Ali and Ripley (1987) have also considered both subspecies as very rare residents.

Stattersfield *et al.* (1998) have identified endemic bird areas EBA) of the world and listed Restricted Range species found in each EBA. In the Eastern Himalayas EBA, 21 species are found in India, out of which 10 have been reported from this IBA. There are not many IBAs in this EBA where so many Restricted Range species are found.

Part of reservoir of Ashupani HEP falls within the Sanctuary. However Dibang Multipurpose Project, Ithun-I and Ithun-II are located outside the sanctuary i.e. at a distance of more than 10 km from the sanctuary.

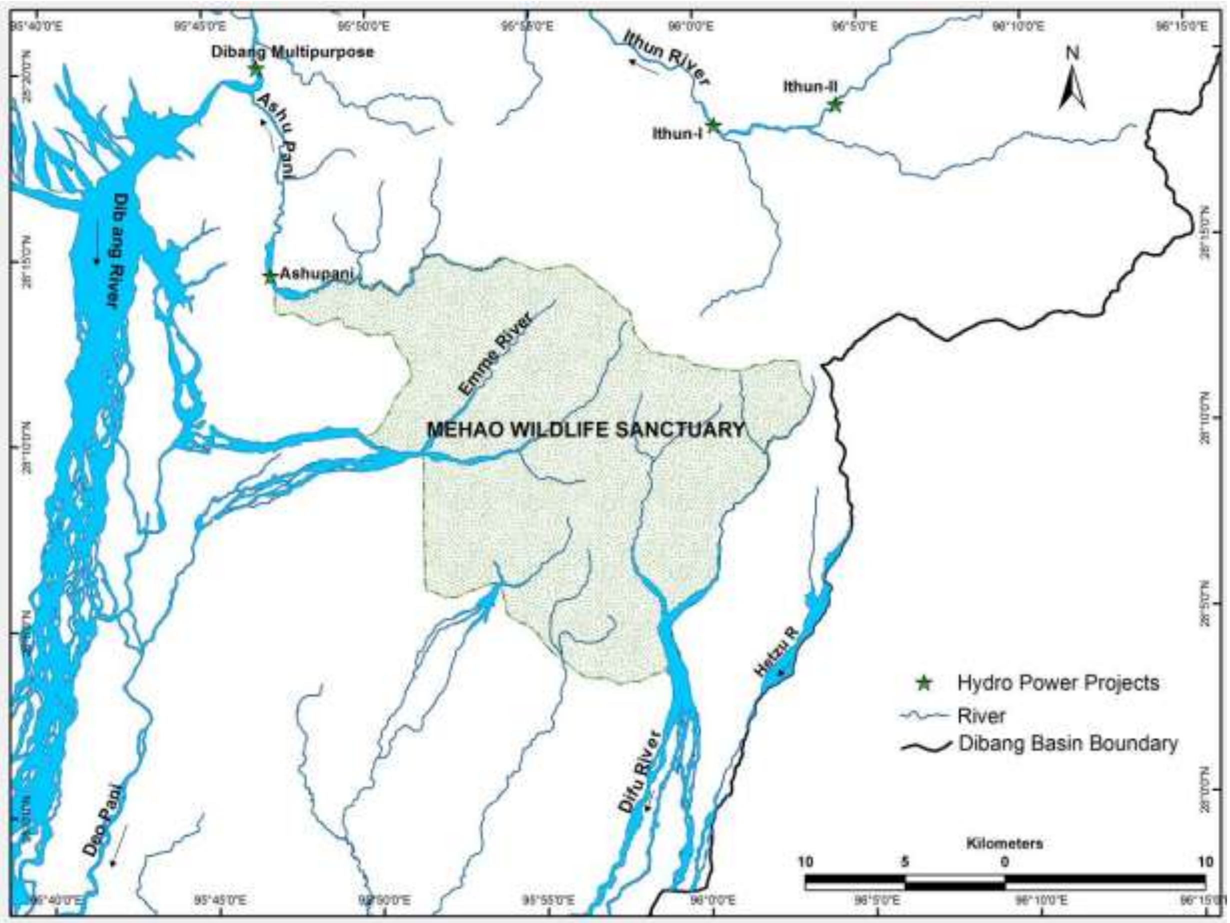


Figure 6.3: Map of Mehao Wildlife Sanctuary and location proposed Ashupani HE project

6.6.3 Dibang Dihang Biosphere Reserve

There is one Biosphere Reserve (BR) in the basin which is spread across Dibang and Siang basins. Biosphere Reserve (BR) is an international designation by UNESCO for representative parts of natural and cultural landscapes extending over large area of terrestrial or coastal/marine ecosystems or a combination thereof. These areas are internationally recognized within the framework of UNESCO's Man and Biosphere (MAB) programme, after receiving consent of the participating country. BR is not intended to replace existing protected areas but it widens the scope of conventional approach of protection and further strengthens the Protected Area Network. Existing legally protected areas (National Parks, Wildlife Sanctuary, Tiger Reserve and Reserve/Protected forests) may become part of the BR without any change in their legal status. On the other hand, inclusion of such areas in a BR will enhance their national value. It, however, does not mean that Biosphere Reserves are to be established only around the National Parks and Wildlife Sanctuaries.

The Dibang Dihang Biosphere Reserve (DDBR) is one of the important sites of wilderness in the Eastern Himalaya. It is located in the upper catchments of rivers Siang and Dibang (between the coordinates $28^0 27'$-$29^0 03'$N latitude and $94^0 29'$-$95^0 49'$E longitude inside the upper region of Abor Hills and Mishmi Hills tracts of Arunachal Pradesh (see **Figure 6.4**). In the west, it encompasses the north-eastern peripheral part of West Siang district extending to Mouling National Park then north-eastward and turning eastward through northern montane areas of the Upper Siang district, then through entire northern part of Dibang Valley district up to the eastern most part of the district on the east. It extends over an area of 5111.50 sq km; the Reserve is comprised of 1,016.7 sq km of Buffer area and 4,094.80 sq km of Core area. The DDBR area is characterized by rugged mountainous terrain with altitudinal range varying from 500m to about 6000 m. The forests of the area vary greatly from Sub-tropical to Alpine forests.

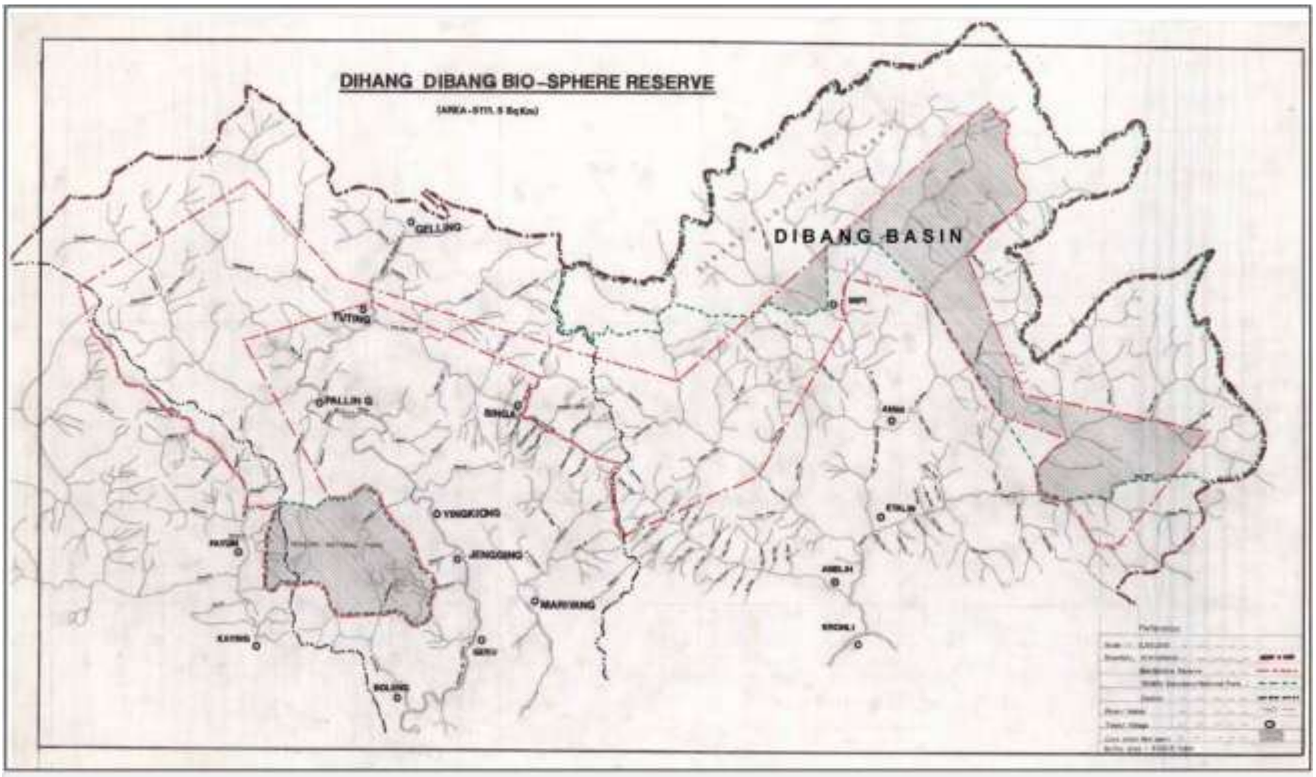


Figure 6.4: Map of Dihang Dibang Biosphere Reserve

CHAPTER-7
AQUATIC ECOLOGY

7.1 WATER QUALITY

The chemical and physical sampling and analyses provide a broad picture of the parameters that define the aquatic environment. Biological parameters detect water quality changes that other methods might miss or underestimate. Resident biotic components in their environments are indicators of environmental quality for assessing the impacts that chemical sampling is unlikely to detect due to any modification of river course or flow pattern. Plankton (phytoplankton and zooplankton), benthic macro-invertebrates, and fish are the most commonly used in assessing biological integrity of any river ecosystem. The benthic macroinvertebrates are most often studied for wadeable riffles in streams and rivers while algae are often used in lakes to examine eutrophication. Therefore the river water quality assessments are best analysed when these are based upon the biological together with physical and chemical assessments that provide a complete picture of the river water quality. In the description of physico-chemical and biological parameters the results have been discussed.

7.1.1 Physico-Chemical Water Quality

The detailed results of all the water quality parameters analysed for water samples from Dibang river and their tributaries at different sampling locations are discussed below.

It can be seen from the results of all the parameters analysed that water quality of Dibang and its tributaries is very good to execellent and is well within tolerance limits of inland surface water as per IS:2296 and falls under Class-A (**Table 7.1**) and within limits of prescribed Central Pollution Control Board (CPCB) standards for drinking water (**Table 7.2**). In addition the concentration of parameters like Iron is <0.01 whereas all the heavy metals i.e. As, Pb, Cd, Hg, Cu, Cr, Zn, and Mn are Not Detectable (ND) except few samples.

Therefore keeping above results in mind water quality objectives for Dibang basin focuses on a core indicator set that reflects their importance along a river stretch in a valley/basin. The key indicators like pH, electrical conductivity, total dissolved solids, total suspended solids, dissolved oxygen, nitrites, sulphates, chlorides and phosphates have been discussed in the present report. In addition other parameters like Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total coliforms have also been discussed.

7.1.1.1 Dibang River & its Tributaries:

The water temperature of Dibang river and its tributary streams varied from 14°C-24°C at all the sampling sites. The highest temperature was observed at Dri River- Near proposed Power House Site of Etalin HEP (Sampling site – W6) while the lowest temperature was recorded at Sampling site W8 located near Talo (Tangon) River- Edzon River Confluence. The pH of at most of the sampling sites was from almost neutral to slightly alkaline. It varied from 7.1- 7.68. Highest pH value was recorded at sampling site W9 at Anonpani Nala and lowest at sampling site (W2 & W6) (**refer Table 7.3**).

Dissolved oxygen values varied from 8.12-10.8 mg/l as highest value of DO was found at sampling site (W2) at Mathun river near Emini (**refer Table 7.3**).

Table 7.1: Tolerance Limits for Inland Surface Waters (as per IS:2296:1982)

S. No.	Parameter and Unit	Class-A	Class-B	Class-C	Class-D	Class-E
1	Colour (Hazen Units)	10	300	300	-	-
2	Odour	Unobjectionable	-	-	-	-
3	Taste	Tasteless	-	-	-	-

S. No.	Parameter and Unit	Class-A	Class-B	Class-C	Class-D	Class-E
4	pH (max) (min:6.5)	8.5	8.5	8.5	8.5	8.5
5	Conductivity (µS/cm))	-	-	-	1000	2250
6	DO (mg/L) (min)	6	5	4	4	-
7	BOD (3 days at 27^oC) (mg/L)	2	3	3	-	-
8	Total Coliforms (MPN/100 mL)	50	500	5000	-	-
9	TDS (mg/L)	500	-	1500	-	2100
10	Oil and Grease (mg/L)	-	-	0.1	0.1	-
11	Mineral Oil (mg/L)	0.01	-	-	-	-
12	Free Carbon Dioxide (mg/L CO_2)	-	-	-	6	-
13	Free Ammonia (mg/L as N)	-	-	-	1.2	-
14	Cyanide (mg/L as CN)	0.05	0.05	0.05	-	-
15	Phenol (mg/L C_6H_5OH)	0.002	0.005	0.005	-	-
16	Total Hardness (mg/L as $CaCO_3$)	300	-	-	-	-
17	Chloride (mg/L as Cl)	250	-	600	-	600
18	Sulphate (mg/L as SO_4)	400	-	400	-	1000
19	Nitrate (mg/L as NO_3)	20	-	50	-	-
20	Fluoride (mg/L as F)	1.5	1.5	1.5	-	-
21	Calcium (mg/L as Ca)	80	-	-	-	-
22	Magnesium (mg/L Mg)	24.4	-	-	-	-
23	Copper (mg/L as Cu)	1.5	-	1.5	-	-
24	Iron (mg/L as Fe)	0.3	-	50	-	-
25	Manganese (mg/L as Mn)	0.5	-	-	-	-
26	Zinc (mg/L as Zn)	15	-	15	-	-
27	Boron (mg/L as B)	-	-	-	-	2
28	Barium (mg/L as Ba)	1	-	-	-	-
29	Silver (mg/L as Ag)	0.05	-	-	-	-
30	Arsenic (mg/L as As)	0.05	0.2	0.2	-	-
31	Mercury (mg/L as Hg)	0.001	-	-	-	-
32	Lead (mg/L as Pb)	0.1	-	0.1	-	-
33	Cadmium (mg/L as Cd)	0.01	-	0.01	-	-
34	Chromium (VI) (mg/L as Cr)	0.05	0.05	0.05	-	-
35	Selenium (mg/L as Se)	0.01	-	0.05	-	-
36	Anionic Detergents (mg/L MBAS)	0.2	1	1	-	-

Class-A: *Drinking water source without conventional treatment but after disinfection*
Class-B: *Outdoor bathing*
Class-C: *Drinking water source with conventional treatment followed by disinfection*
Class-D: *Fish culture and wild life propagation*
Class-E: *Irrigation, industrial cooling and controlled waste disposal*

Table 7.2: Drinking Water Quality Standards (**as per IS:10500:2012**)

Parameters	Desirable Limit*	Permissible Limit**
Color (Hz)	5.0	25
Odour	Unobjectionable	-
Taste	Agreeable	-
Turbidity (ntu)	5	10
pH	5-8.5	No relaxation
Total coliforms (MPN/100 ml)	0	-
TDS (mg/l)	500	2000
Total hardness (mg/l) as $CaCO_3$	300	600
Total alkalinity (mg/l)	200	600
Chlorides (mg/l)	250	1000
Sulphates (mg/l)	200	400
Flourides (mg/l)	1.0	1.5
Nitrate (mg/l)	45	100

Parameters	Desirable Limit*	Permissible Limit**
Calcium (mg/l)	75	200
Magnesium (mg/l)	30	100
Manganese (mg/l)	0.05	0.5
Copper (mg/l)	0.05	1.5
Zn (mg/l)	5.0	15.0
Iron (mg/l)	0.30	1.0
Lead (mg/l)	0.05	No relaxation
Cadmium (mg/l)	0.01	No relaxation
Chromium (mg/l)	0.05	0.05
Phenolic compounds as phenol (mg/l)	0.001	0.001
Anionic detergents as MBAS (mg/l)	0.001	0.002
Arsenic as As (mg/l)	0.05	0.05
Selenium as Se (mg/l)	0.01	0.01
Mercury total as Hg (mg/l)	0.001	0.001
Cyanides (mg/l)	0.05	0.05
Mineral oil (mg/l)	0.01	0.3
Polynuclear aromatic hydrocarbons (PAH)	0.02μg/l	0.02μg/l

**1 The figures indicated under the column 'Acceptable' are the limits up to which water isgenerally acceptable to the consumers*

***2 Figures in excess of those mentioned under 'Acceptable render the water not acceptable, but still may be tolerated in the absence of alternative and better source but up to the limits indicated under column "Cause for Rejection" above which are supply will have to be rejected.*

Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity varied from 39.04-79.36 mg/l, 4.0-25.0 mg/l and 64.0-128.0 μS/cm, respectively at different sampling locations in Dibang and its tributaries. The highest values of TDS, TSS and EC varied from sampling site (W20) at Sissri river, sampling site (W2) near Emini at Mathun River and sampling site (W20) at Sissiri river (**refer Table 7.3**).

BOD and COD values at all sampling sites were very low. Total Coliforms could not be detected at any of the sampling sites.

Chloride concentration was found between 1.99 mg/l and 10.3 mg/l at various sampling locations. The highest chloride concentration was at sampling site (W20) at Sissri river (**refer Table 7.3**).

Alkalinity is a measure of the water ability to absorbed H+ without significant pH change. Maximum concentration of total alkalinity was 38 mg/l at sampling site (W18) at Ithun river near Hunli, and the minimum concentration was 22mg/l at sampling site (W14) at Dibang river near Dibang Multipurpose Dam Site (**refer Table 7.3**).

Total hardness concentration varies from 23.06 mg/l sampling site (W1) near Amulin at Mathun River to 43.24 mg/l at sampling site (W16) at Ahi river right bank tributary of Dibang river (**refer Table 7.3**).

Nitrate concentration in water were very low and it varied from <0.01mg/l to 1.41 mg/l. Phosphate concentration in water were very low at all sampling sites. Sulphate values was highest at sampling site (W10) near proposed Etalin Dam site at Talo (Tangon) River 10.6 mg/l and lowest values was at sampling site (W6) at Dri River- near Etalin Power House Site (**refer Table 7.3**).

Table 7.3: Physico-chemical characteristics of Dibang river and its tributaries

S.No.	Physical / Chemical Characteristics	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
1	Water Temperature (°C)	19.5	18	18.5	19.2	15	24	22.5	14	19.6	18.98	17.4	17.9	18.2	18.9	19.2	19.4	19.3	19.2	19.4	19.3
2	Dissolved Oxygen (mg/l)	10.2	10.8	10.5	10.2	10.3	10.1	10.2	10.1	10	9.11	9.88	9.25	9.51	8.12	8.14	8.2	8.6	8.9	8.7	8.6
3	Turbidity (NTU)	6	7	5	4	0	10	1	1	1	0	0	1	1	0	0	2	1	1	2	3
4	Total Suspended Solids (mg/l)	20	25	18	15	10	20	4	6	6	0	4	5	5	2	4	8	11	10	12	15
5	pH	7.2	7.1	7.15	7.3	7.2	7.1	7.59	7.62	7.68	7.21	7.34	7.36	7.45	7.52	7.61	7.48	7.5	7.61	7.2	7.15
6	Electrical Conductivity (µS/cm)	66	68	64	65.5	82	72	92	105	110	80	106	108	110	89	105	110	118	119	124	128
7	Total Dissolved Solids (mg/l)	40.26	41.48	39.04	39.95	50.02	43.92	56.12	65.1	68.2	49.6	65.72	66.96	68.2	55.18	65.1	68.2	73.16	73.78	76.88	79.36
8	Total alkalinity (mg/l of $CaCO_3$)	23.1	23.6	22.1	22.1	30	24.5	31	37	36	35.2	28	30	32	22	33	35	30	38	30	31
9	Sulphate (mg/l)	4.1	4.6	4.3	4.8	4.1	4	6.3	7.3	6.5	10.6	8.1	7.2	8	7	5.7	7.52	6.56	6.9	7.1	7.4
10	Chloride (mg/l)	2	1.99	1.75	2.4	2.01	3.99	2.98	3.8	3.1	4	5	5.8	6	7.5	7	7.21	9.34	8.69	8.56	10.3
11	Nitrates (NO_3) (mg/l)	1.23	1.41	1.32	1.38	0.69	1.32	0.58	0.62	0.56	<0.01	0.58	0.49	0.36	<0.01	<0.01	0.21	<0.01	0.15	<0.01	0.18
12	Phosphate (PO_4) (mg/l)	<0.004	<0.004	<0.005	<0.006	<0.004	<0.004	<0.004	<0.006	<0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
13	Total Hardness (mg/l)	23.06	24.22	23.31	23.79	28.085	28.48	37.88	39.2	36.81	30.53	33.14	33.44	36.56	28.05	41.96	43.24	35.87	39.76	31.136	26.13
14	Calcium ions (mg/ l)	6.6	6.9	6.7	6.4	8.2	2.7	8.1	8.3	8	6.8	8.5	7.8	7.9	6.3	7.6	6.9	9.1	5.9	6.78	5.86
15	Magnesium ions (mg/l)	1.6	1.7	1.6	1.9	1.85	5.3	4.3	4.5	4.1	3.3	2.9	3.4	4.1	3	5.6	6.34	3.2	6.1	3.46	2.8
16	Sodium (mg/l)	1.2	1.24	1.2	1.32	1.61	1.43	1.51	1.5	1.6	1.1	2.1	2.8	2.66	1.7	1.98	2.72	4.89	5.12	4.89	4.56
17	Potassium (mg/l)	0.5	0.54	0.5	0.76	0.45	0.56	0.6	0.6	0.5	0.7	1	0.95	0.54	0.76	0.91	1.02	0.9	0.98	2.45	0.95
18	Silicates (mg/l)	3.4	3.63	3.53	3.9	5.67	2.49	3.75	3.82	4.23	<0.01	2.1	2	1.9	<0.01	<0.01	2.1	1.78	1.75	2.1	2.6
19	Iron (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
20	Cadmium (Cd) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.01	ND	<0.01	ND
21	Arsenic (As) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
22	Mercury (Hg) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.001	ND	<0.001	ND
23	Copper (Cu) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.1	ND	<0.1	ND
24	Zinc (Zn) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.1	ND	<0.1	ND
25	Total Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.05	ND	<0.05	ND

S.No.	Physical / Chemical Characteristics	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
	(mg/l)																				
26	Manganese (Mn) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
27	Lead (Pb) (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.1	ND	<0.1	ND
28	Oil & Grease (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
29	Phenolic Compound (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
30	Residual Sodium Carbonate (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
31	Biological Oxygen Demand (mg/l)	0.11	0.2	0.2	0.1	0.2	0.2	0.1	0.28	0.18	0.23	0.22	0.76	0.95	0.86	1	0.24	1	0.67	1.1	1
32	Chemical Oxygen Demand (mg/l)	0.6	0.7	0.6	0.6	0.7	0.7	0.6	1.21	1	1.33	0.89	1.7	2	1.12	2.2	0.87	1.8	1.4	2	1.6
33	Total Coliform (MPN /100 ml)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

W1 - W20 - Sampling Sites

Water Quality Index (WQI):

Water quality index is a 100 point scale that summarizes results from a total of nine different measurements as dicussed in Chapter 3 on Methodology and its legends are given below.

Water Quality Index	
Range	**Quality**
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Water quality index (WQI) calculated for water samples collected from different locations is given in **Table 7.4**.

The water quality index of the study area reveals similar pattern at all sampling sites and lies in *Good* to *Excellent* water quality range as per the WQI.

Table 7.4: WQI of Dibang river & its tributaries

Sampling Sites	Water Quality Index	Category
W1	89.13	Good
W2	87.79	Good
W3	88.13	Good
W4	89.45	Good
W5	92.74	Excellent
W6	87.23	Good
W7	92.46	Excellent
W8	92.89	Excellent
W9	92.67	Excellent
W10	96.13	Excellent
W11	93.68	Excellent
W12	92.82	Excellent
W13	93.21	Excellent
W14	93.81	Excellent
W15	93.11	Excellent
W16	92.66	Excellent
W17	93.18	Excellent
W18	93.24	Excellent
W19	92.79	Excellent
W20	92.22	Excellent

W1 – W20 – Sampling Sites

7.1.2 Biological Water Quality

Rock surfaces, plant surfaces, leaf debris, logs, silt and sandy sediments and all other spaces in the stream provide habitat for different organisms. According to these habitats, organisms are divided into plankton, benthos, nektons and neuston. In order to evaluate the biological water quality various aquatic organisms viz. phytoplankton, phytobenthos, zooplankton and macro-invertebrates were sampled during the study in different seasons.

7.1.2.1 Phytoplankton

The word "plankton" is an umbrella term for organisms that live their lives adrift in the water and are unable to move independently. The term comes from an Ancient Greek word which means "floating," and these organisms do indeed float through bodies of water both fresh and salty around the world. They nourish larger animals, which are in turn eaten by even bigger animals, and so on up to organisms like humans at the top of the food chain. Plankton are also responsible for the Earth's atmosphere, thanks to the efforts of billions of photosynthesizing phytoplankton. The phytoplankton comprise of diatoms, dinoflagellates, cyanobacteria, and other groups of unicellular algae.

The damming of rivers for of hydropower invariably has profound impact on the planktonic communities as the planktonic organisms are forced to inhabit regulated stream/s with cascades of reservoirs. The species composition of two conditions as a result of damming of river i.e. lake conditions and free flowing river conditions are different. Hence, prior to dam construction it is necessary to know the species composition, density and diversity of phytoplankton.

In all total, 86 species of phytoplankton were identified in the samples collected from various sampling locations in the study area. The phytoplankton community comprised of 47 species of Bacillariophyceae, 24 species of Cyanophyceae, 8 species of Chlorophyceae and 4 species of Conjugatophyceae, 2 species of Ulvophyceae and one species of Euglenophyceae (**Table 7.5**). Most common species are *Achnanthes crenulata, Achnanthes exigua* var. *exigua, Achnanthidium biasolettianum* var. *biasolettiana, Cocconeis placentula* var. *lineata, Ceratoneis arcus* var. *recta, Encyonema silisiacum, Gomphonema olivaceum, Navicula cryptotenella, Navicula radiosaffalax, Surirella angusta, Gloeocapsa punctata, Anabaena aequalis, Rivularia angulosa, Cladophora* sp. and *Nitzschia linearis*.

7.1.2.2 Phytobenthos

Benthos is the community of organisms that live on or in the river bed also known as benthic zone. The main food sources for the benthos are algae and organic runoff from land. The depth of water, temperature and salinity, and type of local substrate all affect what benthos is present. Phytobenthos comprises the plants belonging to the benthos, mainly benthic diatoms.

In all total 70 species of Phytobenthos were identified from all the locations during surveys comprised of 5 classes with Bacillariophyceae as dominant class in the study area having 45 species, followed by Cyanophyceae with 15 species. Other classes recorded from the area are Chlorophyceae, Coleochaetophyceae and Conjugatophyceae. Highest number of species was recoded at sampling site (W1) near Amulin. Site-wise detailed list of all the phytobenthos species has been given at **Table 7.6**. The genus Cymbella was the most dominant genus represented by 6 species followed by Navicula with 5 species. *Achnanthes crenulata* are most common and abundant species as they were recorded from 19 sampling sites during all samplings. Other common species recorded from the all sampling sites area *Oscillatoria* sp., *Cymbella excisa* var. *angusta, Achnanthidium biasolettianum, Didymosphenia geminate, Scytonema* sp., *Gloeocapsa* sp., *Pediastrum* sp., *Navicula radiosaffalax, Navicula radiosaffalax, Planothidium lanceolata* var. *elliptica, Achnanthidium subhudsonis* and *Achnanthidium biasolettiana* var. *biasolettiana*.

Table 7.5: Phytoplankton species recorded from Dibang river and its tributaries

S. No.	Class/ Family	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
	Bacillariophyceae																					
1	Achnanthaceae	*Achnanthes crenulata*	+	+	+	-	+	-	+	-	+	+	-	+	+	-	+	-	+	-	+	+
2	Achnanthaceae	*Achnanthes exigua* var. *exigua*	-	-	-	+	-	+	+	+	-	+	+	+	+	+	-	+	+	+	+	-
3	Achnanthidiaceae	*Achnanthidium biasolettiana* var. *biasolettiana*	-	+	+	-	+	-	+	+	-	+	-	+	-	+	+	+	-	+	+	+
4	Achnanthidiaceae	*Achnanthidium biasolettianum*	+	+	+	+	-	-	-	+	+	+	+	-	+	-	+	-	+	-	+	+
5	Achnanthidiaceae	*Achnanthidium minutissima* var. *minutissima*	+	-	-	+	+	+	+	-	-	+	+	-	-	-	+	-	-	-	-	-
6	Achnanthidiaceae	*Achnanthidium subhudsonis*	+	+	+	+	+	-	-	+	-	+	-	+	-	+	-	+	-	-	-	-
7	Achnanthidiaceae	*Planothidium lanceolata* var. *elliptica*	+	+	+	-	-	-	-	+	+	-	-	-	-	+	+	-	-	-	+	-
8	Bacillariaceae	*Nitzschia linearis*	+	+	+	+		+	+	+	-	-	+	-	-	+	-	+	-	+	+	-
9	Catenulaceae	*Amphora pediculus*	+	+	+	-	+	-	-	+	+	+	-	+	+	+	-	-	-	-	-	-
10	Cocconeidaceae	*Cocconeis placentula* var. *euglypta*	-	+	+	-	-	+	+	-	+	-	+	+	-	+	-	-	+	-	-	-
11	Cocconeidaceae	*Cocconeis placentula* var. *lineata*	+	+	-	-	+	+	+	+	-	-	+	+	+	+	+	+	-	-	-	+
12	Cocconeidaceae	*Cocconeis placentula* var. *placentula*	+	+	+	+	-	-	-	+	-	-	+	-	+	+	+	-	+	-	-	-
13	Cymbellaceae	*Cymbella excisa* var. *angusta*	-	-	-	+	+	-	+	-	+	+	+	+	-	-	-	+	+	-	+	-
14	Cymbellaceae	*Cymbella excisa* var. *procera*	-	+	+	-	+	+	+	-	-	+	-	-	+	+	-	+	-	-	-	-
15	Cymbellaceae	*Cymbella leavis*	+	+	+	-	-	+	+	+	+	-	-	-	+	-	+	-	+	-	-	+
16	Cymbellaceae	*Cymbella parva*	-	-	+	+	+	+	-	-	-	-	+	+	-	-	-	-	+	+	-	-
17	Cymbellaceae	*Cymbella tumida*	+	+	-	+	-	+	+	+	-	-	+	-	+	+	-	-	-	+	-	+
18	Cymbellaceae	*Cymbella turgidula*	+	+	-	-	+	+	+	+	-	-	-	-	-	+	-	+	-	+	-	+
19	Cymbellaceae	*Cymbopleura anglica*	-	-	-	+	-	+	-	-	+	-	+	-	-	+	+	+	-	+	-	-
20	Cymbellaceae	*Cymbopleura* sp.	-	-	+	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	+
21	Cymbellaceae	*Didymosphenia geminata*	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
22	Fragilariaceae	*Ceratoneis arcus*	-	-	-	-	+	+	+	-	-	-	+	+	-	-	-	+	+	+	-	-
23	Fragilariaceae	*Ceratoneis arcus* var. *amphioxus*	+	+	-	+	+	+	+	-	-	+	+	+	-	-	-	-	-	-	-	-
24	Fragilariaceae	*Ceratoneis arcus* var. *recta*	+	-	+	+	+	-	+	-	-	+	+	+	+	-	-	+	-	+	-	+
25	Fragilariaceae	*Fragilaria capucina*	+	-	+	+	-	-	-	-	+	+	-	-	-	-	-	+	-		+	+
26	Fragilariaceae	*Fragilaria rumpens*	-	+	+	-	+	+	+	-	+	+	-	+	+	-	-	-	+	+	-	+
27	Fragilariaceae	*Synedra* sp.	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	+
28	Fragilariaceae	*Synedra ulna* var. *amphirhynchus*	-	-	-	+	+	+	-	+	-	-	+	+	-	-	+	+	-	-	-	+
29	Fragilariaceae	*Synedra ulna* var. *mediocontracta*	+	+	+	-	+	-	+	-	+	+	-	-	-	+	-	-	+	+	-	-

S. No.	Class/ Family	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
30	Gomphonemataceae	*Encyonema minutum*	+	+	+	-	+	-	+	-	+	+	-	+	-	+	-	-	-	-	-	-
31	Gomphonemataceae	*Encyonema silisiacum*	+	-	+	+	+	+	-	-	+	+	+	-	+	+	-	-	+	-	-	+
32	Gomphonemataceae	*Encyonema* sp.	+	+	+	+	-	-	+	+	-	+	+	-	+	-	+	-	-	+	-	-
33	Gomphonemataceae	*Gomphonema clevei*	-	-	-	+	+	+	-	+	+	+	+	-	+	+	+	+	-	-	-	-
34	Gomphonemataceae	*Gomphonema olivaceum*	-	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	-
35	Gomphonemataceae	*Reimeria sinuata*	-	+	-	-	+	-	-	-	+	-	-	+	-	+	+	-	+	-	+	-
36	Naviculaceae	*Navicula caterva*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-
37	Naviculaceae	*Navicula cryptotenella*	+	+	+	+	-	+	+	+	+	+	+	+	-	+	+	-	-	+	+	+
38	Naviculaceae	*Navicula gracilis*	+	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-
39	Naviculaceae	*Navicula radiosa*	-	-	+	+	-	+	+	+	-	+	+	-	-	-	+	-	+	-	-	-
40	Naviculaceae	*Navicula radiosaffalax*	+	-	+	+	+	+	+	-	+	-	+	+	+	+	-	+	-	-	+	+
41	Naviculaceae	*Navicula* sp.	-	-	-	-	-	-	-	+	-	+	-	-	+	-	-	+	-	-	+	-
42	Rhoicospheniaceae	*Rhoicosphenia abbreviata*	+	-	+	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	+
43	Rhopalodiaceae	*Epithemia sorex*	-	+	-	-	-	+	+	+	-	-	+	+	-	-	-	+	-	-	-	-
44	Surirellaceae	*Surirella angusta*	-	-	+	-	+	+		+	+	+	+	-	+	+	-	+	-	+	+	-
45	Surirellaceae	*Surirella linearis*	+	-	-	+	-	+	+	-	+	-	-	-	-	+	-	-	-	-	+	-
46	Tabellariaceae	*Diatoma mesodon*	+	+	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
47	Tabellariaceae	*Tabellaria flocculosa*	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	Chlorophyceae																					
48	Characiosiphoraceae	*Characiosiphora vivularis*	-	-	-	+	-	+	-	-	-	-	+	-	+	+	+	-	+	-	+	-
49	Chlamydomonadaceae	*Chlamydomonas* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	+	-
50	Hydrodictyaceae	*Pediastrum* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-
51	Oedogoniaceae	*Oedogonium abbreviatum*	-	+	+	+	-	-	+	-	+	-	-	+	-	-	+	-	-	+	-	-
52	Oedogoniaceae	*Oedogonium* sp.	-	+	+	-	+	+		+	-	+	-	-	-	-	+	+	+	-	+	+
53	Selenastraceae	*Ankistrodesmus* sp.	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-	-
54	Sphaerocystidaceae	*Sphaerocystis* sp.	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	-	-	+
55	Volvocaceae	*Volvox* sp.	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-
	Conjugatophyceae																					
56	Closteriaceae	*Closterium* sp.	-	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-
57	Desmidiaceae	*Cosmarium* sp.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	-	-	+
58	Zygnemataceae	*Spirogyra* sp.	+	-	-	-	-	-	-	+	+	+	-	-	+	-	+	+	+	-	+	-
59	Zygnemataceae	*Zygnema* sp.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-
	Cyanophyceae		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

S. No.	Class/ Family	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
60	Leptolyngbyaceae	*Leptolyngbya ambiguum*	-	+	+	+	-	-	+	-	+	-	-	-	-	-	+	-	-	+	-	-
61	Leptolyngbyaceae	*Leptolyngbya aspera*	+	+	-	-	+	-	-	-	+	+	-	+	+	-	+	-	-	+	-	+
62	Merismopediaceae	*Aphanocapsa albida*	+	+	-	-	-	-	+	+	-	+	+	+		-	+	+	+	-	-	-
63	Merismopediaceae	*Aphanocapsa* sp.	+	+	-	+	-	-	-	+	+	-	+	+	+	-	-	-	-	-	+	-
64	Microcystaceae	*Gloeocapsa punctata*	+	+	+	+	+	+	-	-	+	-	-	+	+	-	-	+	-	-	+	-
65	Microcystaceae	*Gloeocapsa rupestis*	-	-	-	+	-	-	-	+	-	-	-	+	+	-	+	-	+	-	+	-
66	Microcystaceae	*Gloeocapsa* sp.	-	-	-	-	-	-	-	+	-	+	-	-	-	-	+	-	-	+	-	-
67	Microcystaceae	*Microcystis* sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-
68	Nostocaceae	*Anabaena aequalis*	-	+	-	-	+	+	+	-	+	-	-	+	+	+	-	-	+	-	+	+
69	Nostocaceae	*Anabaena anomala*	+	+	+	-	+	-	-	-	+	-	-	+	-	+	+	-	-	+	-	-
70	Nostocaceae	*Anabaena* sp.	-	-	-	+	+	+	+	-	-	+	+	-	-	+	-	-	+	-	-	+
71	Nostocaceae	*Nostoc* sp.	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	Oscillatoriaceae	*Lyngbya ambiguum*	+	+	+	-	-	-	-	-	+	-	-	+	-	+	-	-	-	-	-	-
73	Oscillatoriaceae	*Lyngbya* sp.	-	-	-	+	-	-	+	+	-	-	+	-	+	+	-	+	+	-	+	-
74	Oscillatoriaceae	*Oscillatoria acuiformis*	+	-	-	-	-	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-
75	Oscillatoriaceae	*Oscillatoria curviceps*	+	+	-	+	-	+	-	-	-	-	-	-	-	+	-	+	-	+	-	+
76	Oscillatoriaceae	*Oscillatoria* sp.	+	-	-	+	+	+	-	-	+	-	+	-	+	-	-	-	-	-	-	-
77	Rivulariaceae	*Rivularia angulosa*	+	+	+	-	-	-	+	+	+	-	+	+	+	+	-	+	+	-	-	-
78	Rivulariaceae	*Rivularia* sp.	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+
79	Scytonemataceae	*Scytonema alatum*	-	+	+	+	+	+	-	-	-	+	-	-	-	+	-	-	-	+	-	+
80	Scytonemataceae	*Scytonema* sp.	+	-	+	+	-	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-
81	Stigonemataceae	*Stigonema aerugineum*	-	-	-	-	-	+	-	+	+	-	-	+	+	-	-	-	+	-	+	-
82	Stigonemataceae	*Stigonema* sp.	-	+	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
83	Tolypothrichaceae	*Tolypothrix amoena*	-	-	-	+	+	-	+	-	-	-	-	-	-	-	-	+	-	+	-	+
	Euglenophyceae																					
84	Phacaceae	*Phacus* sp.	-	-		-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-
	Ulvophyceae																					
85	Cladophoraceae	*Cladophora* sp.	+	-	-	+	+	-	-	+	-	-	+	-	+	+	+	-	-	+	-	+
86	Ulotrichaceae	*Ulothrix* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-
	Total number of species		**42**	**40**	**38**	**40**	**36**	**37**	**38**	**35**	**35**	**32**	**35**	**34**	**33**	**34**	**32**	**33**	**32**	**28**	**26**	**28**

W1 – W20 – Sampling Sites; '+' - Present; '-' - Absent

Table 7.6: Species of Phytobenthos recorded from Dibang river and its tributaries

S. No.	Class/ Family	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
	Bacillariophyceae																					
1	Achnanthaceae	*Achnanthes crenulata*	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
2	Achnanthaceae	*Achnanthes exigua* var. *exigua*	+	+	+	-	-	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-
3	Achnanthidiaceae	*Achnanthidium biasolettiana* var. *biasolettiana*	-	-	+	+	+	+	+	-	+	-	-	+	+	+	+	+	+	+	+	-
4	Achnanthidiaceae	*Achnanthidium biasolettianum*	+	+	-	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-
5	Achnanthidiaceae	*Achnanthidium minutissima* var. *minutissima*	+	+	-	-	-	+	+	+	+	+	+	+	-	-	-	+	-	-	-	-
6	Achnanthidiaceae	*Achnanthidium subhudsonis*	-	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	-	-	-	+
7	Achnanthidiaceae	*Planothidium lanceolata* var. *elliptica*	+	+	-	+	-	-	+	-	+	+	+	+	+	+	+	-	-	+	+	+
8	Bacillariaceae	*Nitzschia linearis*	+	-	-	-	+	-	-	-	-	-	+	+	+	+	+	-	-	-	-	+
9	Catenulaceae	*Amphora pediculus*	-	+	+	-	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-
10	Cocconeidaceae	*Cocconeis placentula* var. *euglypta*	+	+	+	+	+	+	-	+	+	+	+	-	-	+	+	-	-	+	-	-
11	Cocconeidaceae	*Cocconeis placentula* var. *lineata*	+	+	-	-	+	-	+	+	+	+	+	-	-	-	-	-	-	+	+	+
12	Cocconeidaceae	*Cocconeis placentula* var. *placentula*	+	+	+	+	+	-	+	-	-	-	-	+	+	+	-	-	-	+	+	+
13	Cymbellaceae	*Cymbella excisa* var. *angusta*	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	+	+	-	+
14	Cymbellaceae	*Cymbella excisa* var. *procera*	+	+	-	+	+	-	+	-	+	-	+	+	+	-	-	+	+	+	-	-
15	Cymbellaceae	*Cymbella leavis*	+	+	+	-	+	+	-	+	+	-	+	+	-	-	-	-	+	+	-	-
16	Cymbellaceae	*Cymbella parva*	-	+	+	-	-	-	+	+	+	-	+	+	+	+	+	+	-	-	-	-
17	Cymbellaceae	*Cymbella tumida*	+	-	-	+	+	+	+	-	-	-	-	-	+	-	-	-	+	+	+	+
18	Cymbellaceae	*Cymbella turgidula*	+	+	+	+	+	-	-	-	-	-	-	-	+	-	-	-	+	+	+	+
19	Cymbellaceae	*Cymbopleura* sp.	-	+	-	+	+	+	-	+	-	+	+	-	+	+	+	+	-	-	-	-
20	Cymbellaceae	*Didymosphenia geminata*	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	-	-	-	+	+
21	Fragilariaceae	*Ceratoneis arcus*	+	-	-	-	-	+	-	+	+	-	+	+	+	-	-	-	+	-	+	+
22	Fragilariaceae	*Ceratoneis arcus* var. *amphioxus*	+	-	+	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	+
23	Fragilariaceae	*Ceratoneis arcus* var. *recta*	+	-	-	+	+	-	+	-	+	-	-	-	-	+	+	+	-	-	+	+
24	Fragilariaceae	*Fragilaria capucina*	-	-	+	-	-	-	-	-	+	+	-	-	-	+	+	+	-	-	-	-
25	Fragilariaceae	*Fragilaria rumpens*	-	+	-	+	-	+	+	+	+	+	+	+	-	-	-	-	+	-	-	+
26	Fragilariaceae	*Synedra ulna* var. *amphirhynchus*	+	-	+	-	+	+	-	+	-	+	+	-	-	-	-	-	+	+	+	+
27	Fragilariaceae	*Synedra ulna* var. *mediocontracta*	+	+	-	+	+	+	-	-	-	+	+	-	-	+	+	+	+	+	+	+
28	Gomphonemataceae	*Encyonema minutum*	+	+	+	+	-	+	+	+	-	+	-	-	-	+	+	-	-	-	-	+

S. No.	Class/ Family	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
29	Gomphonemataceae	*Encyonema silisiacum*	+	+	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-
30	Gomphonemataceae	*Gomphonema clevei*	-	-	+	+	+	-	+	-	+	+	+	+	+	-	-	-	-	-	-	-
31	Gomphonemataceae	*Gomphonema minutum*	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	+	+	+	+	-
32	Gomphonemataceae	*Gomphonema olivaceum*	+	+	+	-	-	-	-	+	-	-	-	-	-	+	+	+	-	-	+	-
33	Gomphonemataceae	*Reimeria sinuata*	+	+	-	+	+	-	+	-	-	-	-	-	-	-	-	+	+	+	-	-
34	Naviculaceae	*Navicula caterva*	-	-	+	+	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-
35	Naviculaceae	*Navicula cryptotenella*	-	-	+	-	-	+	+	+	-	-	-	+	+	+	-	-	-	-	+	-
36	Naviculaceae	*Navicula radiosa*	+	+	-	+	+	-	-	-	-	-	-	+	+	+	-	-	-	-	-	+
37	Naviculaceae	*Navicula radiosaffalax*	-	-	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	-	+
38	Naviculaceae	*Navicula* sp.	+	+	+	+	-	-	+	-	+	+	-	-	+	+	+	+	+	-	-	+
39	Rhoicospheniaceae	*Rhoicosphenia abbreviata*	+	+	-	+	+	+	-	+	+	+	-	-	-	-	-	-	+	+	+	+
40	Rhopalodiaceae	*Epithemia sorex*	+	-	+	+	+	+	-	+	-	-	-	-	-	+	+	-	+	+	-	+
41	Surirellaceae	*Surirella angusta*	+	+	-	-	-	-	+	-	+	+	-	-	-	+	+	+	-	-	-	+
42	Surirellaceae	*Surirella linearis*	+	+	+	-	-	-	-	+	+	+	-	-	-	+	+	+	+	-	+	-
43	Tabellariaceae	*Diatoma mesodon*	-	-	-	-	-	+	+	+	-	-	-	+	-	-	-	+	+	+	+	-
44	Tabellariaceae	*Tabellaria flocculosa*	+	+	+	+	-	-	+	+	-	-	-	+	-	-	-	+	+	+	-	-
45	**Chlorophyceae**																					
	Chaetophoraceae	*Chaetophora attenuata*	+	-	-	-	-	-	+	-	-	-	-	+	+	+	+	+	+	+	+	+
46	Chaetophoraceae	*Chaetophora* sp.	+	+	+	+	-	+	-	+	-	-	-	+	-	-	-	-	-	-	-	+
47	Characiosiphoraceae	*Characiosiphora vivularis*	-	-	-	+	-	+	+	+	-	+	+	+	-	-	-	+	+	+	-	-
48	Chlamydomonadaceae	*Cladophora acrosperma*	+	+	-	-	+	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-
49	Chlamydomonadaceae	*Cladophora* sp.	+	+	+	+	+	+	-	+	+	+	+	+	-	-	-	-	-	+	+	-
50	Hydrodictyaceae	*Pediastrum* sp.	+	-	+	-	+	+	+	+	+	+	+	-	+	+	+	-	-	+	+	-
51	Oedogoniaceae	*Oedogonium abbreviatum*	-	+	+	+	+	+	+	-	+	-	-	-	-	-	-	-	-	+	+	-
52	Oedogoniaceae	*Oedogonium* sp.	-	-	-	-	+	+	+	+	-	+	+	+	+	+	+	-	-	-	-	-
53	**Coleochaetophyceae**																					
	Coleochaetaceae	*Coleochaete* sp.	+	+	+	+	+	+	-	+	-	+	+	+	-	-	-	+	+	-	-	-
54	**Conjugatophyceae**																					
	Zygnemataceae	*Spirogyra* sp.	-	-	-	+	+	+	+	-	-	+	+	+	-	-	-	-	+	+	+	-
55	Zygnemataceae	*Zygnema* sp.	-	+	+	+	-	-	+	-	-	+	+	+	+	+	+	+	-	+	-	-
56	**Cyanophyceae**																					
	Merismopediaceae	*Aphanocapsa albida*	-	+	-	+	-	-	+	-	+	-	-	-	+	-	+	-	-	-	+	-
57	Merismopediaceae	*Aphanocapsa* sp.	+	-	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	-	-	-

S. No.	Class/ Family	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
58	Microcystaceae	*Gloeocapsa punctata*	-	+	-	+	-	+	+	+	+	-	+	+	-	+	+	+	-	-	-	-
59	Microcystaceae	*Gloeocapsa rupestis*	-	-	+	+	-	-	+	-	+	-	-	-	+	+	+	+	+	-	+	-
60	Microcystaceae	*Gloeocapsa* sp.	+	+	-	+	+	+	-	+	+	+	-	-	+	+	-	-	+	+	+	+
61	Nostocaceae	*Anabaena anomala*	+	+	+	-	-	+	+	+	+	-	+	-	+	+	+	+	-	-	-	-
62	Oscillatoriaceae	*Lyngbya ambiguum*	-	-	-	+	+	-	-	-	+	+	+	-	-	+	+	-	-	+	+	-
63	Oscillatoriaceae	*Lyngbya* sp.	+	+	+	-	-	-	+	-	-	-	+	+	-	+	+	-	-	-	-	+
64	Oscillatoriaceae	*Oscillatoria curviceps*	-	+	-	-	-	-	-	-	-	-	-	+	-	+	-	-	+	+	+	+
65	Oscillatoriaceae	*Oscillatoria* sp.	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	-	+	+
66	Rivulariaceae	*Rivularia angulosa*	-	-	-	-	+	-	-	+	+	+	+	+	+	+	+	+	-	-	-	-
67	Scytonemataceae	*Scytonema* sp.	+	-	+	+	+	-	+	-	+	+	+	+	+	+	+	+	-	-	-	+
68	Stigonemataceae	*Stigonema aerugineum*	-	+	+	-	+	-	-	+	+	+	+	+	+	+	-	-	+	+	+	-
69	Stigonemataceae	*Stigonema* sp.	+	-	+	+	-	+	+	-	-	-	+	-	+	+	-	-	-	-	-	-
70	Tolypothrichaceae	*Tolypothrix amoena*	+	+	-	+	+	-	-	-	+	+	+	-	-	-	+	+	+	+	+	-
	TOTAL		**44**	**43**	**40**	**44**	**41**	**39**	**38**	**39**	**40**	**36**	**39**	**38**	**35**	**42**	**37**	**33**	**32**	**33**	**32**	**30**

W1 – W20 – Sampling Sites; '+'-Present; '-'-Absent

Table 7.7: Species of Zooplankton recorded in Dibang river and its tributaries

S.No.	Name of species	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
Protozoon																					
1	*Actinophrys* sp.	+	+	-	+	-	+	+	+	+	-	-	+	+	+	-	-	+	+	-	+
2	*Arcella* sp.	-	-	+	+	+	+	-	-	+	+	-	-	+	-	+	+	-	+	+	-
Rotifers																					
3	*Brachious* sp	-	-	-	-	-	-	+	+	-	-	-	+	-	-	+	-	-	+	-	-
4	*Keratella* sp.	+	+	+	-	-	+	-	+	+	-	+	+	+	+	+	-	+	+	-	+
5	*Philodena* sp.	-	-	-	+	-	-	+	-	-	-	-	-	+	-	-	+	-	-	+	+
6	*Trichocera* sp.	+	+	-	+	+	-	-	+	+	+	+	-	-	+	+	+	-	+	+	+
7	*Asplanchana* sp.	-	-	+	+	-	-	-	-	+	-	+	-	+	+	-	-	+	-	-	+
Cladoceran																					
8	*Bosmina* sp.	+	-	-	-	-	-	-	-	+	-		-	+	-	-	-	+	-	-	+
9	*Daphnia* sp.	+	+	-	+	+	+	+	-	+	+	+	+	-	+	-	+	+	-	+	+
Copepods																					
10	*Cyclops* sp.	-	-	+	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	+	-
	Total no. of Species	5	4	4	6	4	4	4	4	7	3	4	4	7	5	4	5	5	5	5	7

W1 – W20 – Sampling Sites; '+'-Present; '-'-Absent

7.1.2.3 Zooplankton

Zooplanktons were represented by protozoa, rotifer and crustacean (copepods and cladoceran) **(refer Table 7.7)**. Among protozoans Actinophrys and Arcella genera were observed at most of the sites in Dibang Basin, The Rotifers are represented by species of *Keratella, Brachionus, Epiphanes, Philodina,* and *Asplanchna*. Among Crustaceans *Daphnia* and *Bosmina* species of order Cladocera were found, whereas Copepods were represented by *Cyclopes* sp. (water fleas) only.

7.1.2.4 Macro-invertebrates

Macro-invertebrates are widely used to determine biological conditions and acts as an in-line monitoring system for pollution. They are important part of food chain especially for fish. During the study, macro–invertebrate fauna comprised of 25 species falling under 5 orders belonging to 24 families. Ephemeropterawas the dominant order representing six families and 11 genera followed by order Diptera with 4 families and 5 genra (**Table 7.8**). *Psephenus herricki* was the most abundant species and was recorded from 12 sampling sites during the surveys followed by *Hydropsyche* sp., *Heptagenia* sp., *Acroneuria* sp., *Caenis* sp. and *Centroptilum* sp. (**Table 7.8**).

7.1.2.5 Biological Water Quality Assessment

The Macro-invertebrates are one of the indicators of water quality of freshwater streams. The water quality assessment of Dibang river and its tributories were assessed by calculating BMWP and ASPT values which are an indicative of river water qualiy. The methodology to calculate these indicies has been given in Chaper 3-Methodology of the report.

For ease of interpretation, the BMWP cumulative total scores are banded to distinguish broad categories of water quality as shown in table below.

Water Quality Banding of BMWP Scores

Description	Score Band
Exceptional	>150
Very Good	101 - 150
Good	51 – 100
Moderate	26 – 50
Poor	<25

BMWP score calculated varied from 44 to 81 when the river flow is very high. Therefore water quality of Dibang river and its tributaries is good to excellent throughout the basin.

The average sensitivity of the families of the organisms present is known as the Average Score per Taxon (ASPT). The ASPT index gives an indication of the evenness of community diversity. ASPT is calculated by dividing the BMWP score for each site by the total number of scoring families found there, so it is independent of sample size. Likewise BMWP scores, a higher ASPT indicate better water quality. The ASPT score varied from 6.0 to 8.1 (see **Table 7.9**).

Table 7.8: Percent composition of Macro-invertebrates recorded from Dibang river and its tributaries at different sampling sites

ORDER/Family/Genus	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
ORDER: EPHEMEROPTERA																				
Ameletidae																				
Ameletus sp.	6.7						8.45			9.3		7.32		5.6		7.4	8.1		10.3	
Baetidae																				
Centroptilum sp.	12.32		15.23		11.23		12.32		12.45		10.5			11.45	10.4	11.87		9.8	10.2	
Baetis niger	21.52	20.56	24.34	26.48		12.56					21.45									
Baetis muticus							9.2						7.9							
Baetidae																				
Caenis sp.				20.5			24.5	11.33	22.87	21.56		12.67		15.6		12.57	18.4	21.2		25.4
Ephemerellidae																				
Ephemerella ignita													6.4					4.2		
Ephemerella excrucians					22.56					19.3		19.54	18.56	21.3	22.5	24.3			16.3	20.5
Ephemerella sp.		23.12	22.65			5.88	17.58				12.5								13.6	
Heptageniidae																				
Rithrogena sp.		3.01	4																	
Heptagenia sp.		6.12		7.9			7.39	4.3	4.8		6.3	4.2	7.4		8.4	4.5			3.98	4.3
Ecdynurus sp.				6.3													5.3			
Epeorus sp.	22.54					18.54				22.6	19.34		22.67	26.7	25.8	17.5		19.4		11.2
Cinygmula sp.	12.65	14.45			27.75	18.82	14.28	27.54	20.47								26.3		19.6	
Paraleptophlebia sp.1		7.69									5.3									
Paraleptophlebia sp.2		9.45		25.98				10.21		12.34		14.2					14.2			11.45
ORDER: PLECOPTERA																				
Perlidae																				
Acroneuria sp.	6.54		19.56		26.45	15.23			8.54	9.56				6.4	6.43	7.2		9.3		5.89
ORDER: COLEOPTERA																				
Psephenidae																				
Psephenus herricki	6.14			4.08	8.89	13.66	6.28	26.23	14.56	5.34		6.98		7.6	7.17			6.42		7.5
ORDER: TRICHOPTERA																				
Hydropsychidae																				
Hydropsyche sp.	2.76	6.32	4.81	3.87		12.5		4.42	11.34		14.2		6.7			5.3		6.98	8.9	
Leptoceridae																				
Leptocerus sp.												8.54	6.3		7.1		8.9		8.4	5.9
Brachycentridae																				

ORDER/Family/Genus	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20
Brachycentrus sp.												12.21	11.87				8.2	15.2		
ORDER: DIPTERA																				
Chironomidae																				
Chironomus sp.	5.85	4.5	5.2			2.81		5.21			3.43	2.83	4.2	3.1			6.4			
Ablabesmyia sp.								3.87							4.3			4.1		2.4
Tipulidae																				
Antocha saxicola		4.78	4.21	5.12				6.89	4.97		6.98	4.31		2.25		7.1			5.22	
Simuliidae																				
Simulium pictipes	2.98				2.89							2.7	3.8		3.7		4.2			5.46
Athericidae																				
Atherix variegata												4.5	4.2		4.2	2.26		3.4	3.5	

W1 – W20 – Sampling Sites

Table 7.9: Biological Water Quality at different locations in Dibang river and its tributaries

Sampling Sites	BMWP	ASPT	LQI	Index Category
W1	71	7.1	5	A
W2	73	7.3	5.5	A+
W3	47	5.9	5	A
W4	65	8.1	5	A
W5	38	6.3	5	A
W6	56	7.0	5	A
W7	63	7.9	5	A
W8	59	6.6	5	A
W9	59	7.4	5	A
W10	59	8.4	5	A
W11	60	6.7	5	A
W12	83	6.9	5.5	A+
W13	73	6.6	5.5	A+
W14	60	6.7	5	A
W15	62	6.2	5.5	A+
W16	70	7.0	5.5	A+
W17	77	8.6	5.5	A+
W18	63	6.3	5.5	A+
W19	64	6.4	5.5	A+
W20	76	7.6	5.5	A+

W1 – W20 – Sampling Sites

The Lincoln Quality Index (LQI) is biotic indices established to determine pollution effects in river particularly from organic pollutants based on aquatic macro-invertebrate populations and is expressed as Excellent, Good, Moderate, Poor and Very poor water quality as shown in the table below.

Quality Rating	Index	Interpretation
6 or better	A++	Excellent Quality
5.5	A+	Excellent Quality
5	A	Excellent Quality
4.5	B	Good Quality
4	C	Good Quality
3.5	D	Moderate Quality
3	E	Moderate Quality
2.5	F	Poor Quality
2	G	Poor Quality
1.5	H	Very Poor Quality
1	I	Very Poor Quality

As per the LQI the water quality of Dibang river and its tributaries are under Classes A+, and A only i.e. the Dibang river and its tributories have rich diversity of habitats. It is indicative of excellent quality of Dibang river and its tributaries.

7.2 FISH AND FISHERIES

The fish resources in the freshwaters of the state i.e. most of its rivers and their major tributaries have yet not been fully explored owing to unapproachable mountainous steep terrain with dense forest cover and relative low scale of fishery activities. In order to understand the fishery resources of Dibang basin information was collected from State Fishery Department, Itanagar which was supplemented with published literature like reports and research articles (Jhingran, 1961; Talwar & Jhingran, 1991; Nath & Dey, 2000; Sen, 1999, 2006; Bagra *et al*. 2009; Bagra & Das, 2010; Lakra *et al*. 2010; Jha *et al*. 2014; Laksar *et al*. 2010, Mahanta et al. 2012, Sarma *et al*. 2012).

Nath & Dey, 2000 had reported 45 species of fishes from Dibang river system. However more information and data was collected from ZSI and other secondary sources like published reports, EIA report of Dibang Multipurpose Project including interaction with locals during field survey to prepare a checklist of fishes reportedly found in Dibang. A list of fish species thus prepared from secondary sources as well as field survey along with their conservation status according to National Bureau of Fish Genetic Resources (NBFGR), CAMP report (Molur & Walker, 1998) and IUCN Red list is given at **Table 7.10.**

During the field survey experimental fishing was done. The fishing gears like cast and gill net were used with the help of local fishermen's at various sites in the basin. Interviews were also conducted with locals regarding the probable presence of fishes in the Dibang river and its tributaries. Due to fast flow of river during the survey no fish could be landed.

Table 7.10: List of Fish Species reported from the Dibang Basin

S. No.	ORDER/ Family	Name of species	Conservation Status			Distribution Range* (m)
			NBFGR	CAMP Report	IUCN Red List Ver 3.1	
ANGUILLIFORMES						
1	**Anguillidae**	*Anguilla bengalensis* subsp. *bengalensis*		EN	NT	Up to 200
BELONIFORMES						
2	**Belonidae**	*Xenentodon cancila*		LRnt/N	LC	Up to 200
CLUPEIFORMES						
3	**Clupeidae**	*Gudusia chapra*		LRlc	LC	Up to 300
4	**Engraulidae**	*Setipinna phasa*		LRlc	LC	Up to 500
CYPRINIFORMES						
5	**Balitoridae**	*Aborichthys elongatus*		EN	LC	Up to 2000
6	**Balitoridae**	*Aborichthys kempi* (=*Nemacheilus kempi*)		VU	NT	500-1000
7	**Balitoridae**	*Acanthocobitis botia*		LRlc	LC	400-600
8	**Cobitidae**	*Lepidocephalichthys arunachalensis* (=*Nemacheilus arunachalensis*)		EN/N	EN	500-1000
9	**Cobitidae**	*Botia dario* (=*Botia geto*)	VU	LRnt/N	LC	Up to 1500
10	**Cobitidae**	*Botia rostrata* (=*Botia almorhae*)		EN	VU	Up to 1500
11	**Cobitidae**	*Lepidocephalichthys annandalei* (=*Lepidocephalus annandalei*)		LRnt	LC	200-500
12	**Cobitidae**	*Lepidocephalichthys guntea* (=*Lepidocephalus guntea*)		LRlc	LC	Up to 300
13	**Cyprinidae**	*Amblypharyngodon mola*		LRlc/N	LC	Up to 1500
14	**Cyprinidae**	*Aspidoparia jaya*		VU/N	LC	Up to 250
15	**Cyprinidae**	*Aspidoparia morar*		LRnt/N	LC	Up to 500
16	**Cyprinidae**	*Bangana dero* (=*Labeo dero*)		VU/N	LC	100 to 1500
17	**Cyprinidae**	*Barilius barna*		LRnt/N	LC	Up to 2000
18	**Cyprinidae**	*Barilius bendelisis*		LRnt/N	LC	Up to 2000
19	**Cyprinidae**	*Barilius bola* (=*Raiamas bola*)		VU	LC	Up to 500
20	**Cyprinidae**	*Barilius tileo*		LRnt/N	LC	2000
21	**Cyprinidae**	*Cabdio morar* (=*Aspidoparia morar*)		LRnt/N	LC	Up to 500
22	**Cyprinidae**	*Chagunius chagunio*	EN	LRlc	LC	Up to 1500
23	**Cyprinidae**	*Crossocheilus latius*	VU	DD	LC	1500
24	**Cyprinidae**	*Cyprinion semiplotum* (=*Semiplotus semiplotus*)	VU	VU/N	VU	Up to 500
25	**Cyprinidae**	*Cypriuns carpio*		VU	VU	Up to 400
26	**Cyprinidae**	*Danio dangila*		LRlc	LC	100-300
27	**Cyprinidae**	*Danio rerio* (=*Brachydanio rerio*)		LRnt/N	LC	Up to 300
28	**Cyprinidae**	*Devario aequipinnatus*		LRnt/N	LC	1000
29	**Cyprinidae**	*Esomus dandricus*		LRlc/N	LC	100-300
30	**Cyprinidae**	*Garra annandalei*		LRlc	LC	500
31	**Cyprinidae**	*Garra gotyla gotyla*	VU	VU/N	LC	Up to 2000

S. No.	ORDER/ Family	Name of species	Conservation Status			Distribution Range* (m)
			NBFGR	CAMP Report	IUCN Red List Ver 3.1	
32	**Cyprinidae**	*Garra mcClellandi*		LRlc	LC	500-600
33	**Cyprinidae**	*Labeo pangusia*	VU	LRnt/N	NT	Up to 500
34	**Cyprinidae**	*Megarasbora elanga*		LRlc	LC	300-700
35	**Cyprinidae**	*Neolissochilus hexagonolepis* (=*Acrossocheilus hexagonolepis*)		LRnt/N	NT	300-1000
36	**Cyprinidae**	*Oreichthys cosuatis*		LRlc	LC	100-300
37	**Cyprinidae**	*Puntius chola*	VU	VU/N	LC	100-700
38	**Cyprinidae**	*Puntius conchonius*		VU/N	LC	Up to 1500
39	**Cyprinidae**	*Puntius sarana sarana*	VU	VU/N	NA	100
40	**Cyprinidae**	*Puntius sophore*		LRnt/N	LC	Up to 700
41	**Cyprinidae**	*Puntius ticto*		LRnt/N	LC	Up to 500
42	**Cyprinidae**	*Rasbora daniconius* (=*Parluciosoma daniconius*)		LRnt/N	LC	100-700
43	**Cyprinidae**	*Schizothorax esocinus*		LRnt/N	NA	Up to 2000
44	**Cyprinidae**	*Schizothorax progastus*		LRnt/N	LC	Up to 2500
45	**Cyprinidae**	*Schizothorax richardsonii*	VU	VU	VU	Up to 2500
46	**Cyprinidae**	*Tor putitora*	EN	EN/N	EN	Up to 1000
47	**Cyprinidae**	*Tor tor*	EN	EN/N	NT	Up to 1000
48	**Nemacheilidae**	*Nemacheilus rupecola*		LRnt	NA	1000-1500
49	**Psilorhynchidae**	*Psilorhynchus balitora*		LRlc	LC	Up to 500
OSTEOGLOSSIFORMES						
51	**Notopteridae**	*Notopterus notopterus*		LRnt	LC	Up to 200
PERCIFORMES						
52	**Ambassidae**	*Chanda nama*		LRlc	LC	100-300
53	**Ambassidae**	*Parambassis ranga* (=*Chanda ranga*)		LRlc	LC	100-300
54	**Ambassidae**	*Pseudambassis baculis* (=*Chanda baculis*)		LRlc	LC	200-600
55	**Badidae**	*Badis assamensis*			DD	100-300
56	**Badidae**	*Badis badis*		LRlc	LC	100-300
57	**Channidae**	*Channa orientalis*		VU/N	NA	Up to 500
58	**Channidae**	*Channa punctataus*		LRnt/N	LC	Up to 500
59	**Osphronemidae**	*Colisa fasciata*		LRnt/N	NA	Up to 600
SALMONIFORMES						
	Salmonidae	*Salmo trutta fario*		-	NA	-
SILURIFORMES						
60	**Amblycipitidae**	*Amblyceps mangois*	EN	LRnt/N	LC	1000
61	**Chacidae**	*Chaca chaca*	EN		LC	100-200
62	**Clariidae**	*Clarias batrachus*		VU	LC	100-150
63	**Erethistidae**	*Hara hara*			LC	100-250
64	**Heteropneustidae**	*Heteropneustes fossilis*	VU	VU/N	LC	100-650
65	**Olyridae**	*Olyra longicaudata*	VU	LRlc	LC	Up to 1000
66	**Siluridae**	*Ompok pabda*	VU	EN/N	NT	100-250
67	**Siluridae**	*Wallago attu*		LRnt/N	NT	100-250
68	**Sisoridae**	*Bagarius bagarius*	VU	VU	NT	Up to 500
69	**Sisoridae**	*Exostoma labiatum*		LRlc	LC	300-700
70	**Sisoridae**	*Glyptothorax horai*		LRnt/N	LC	Up to 1000
71	**Sisoridae**	*Glyptothorax pectinopterus*		LRnt/N	LC	2000
SYNBRANCHIFORMES						
72	**Mastacembelidae**	*Macrognathus pancalus* (=*Mastacembelus pancalus*)		LRnt	LC	Up to 300
73	**Mastacembelidae**	*Mastacembelus armatus*		LRlc	LC	500
74	**Synbranchidae**	*Monopterus cuchia*		LRnt/N	LC	Up to 500

NBFGR = National Bureau of Fish Genetic Resources; LRlc = Low Risk Least Concern; LRnt = Low Risk Near Threatened; VU= Vulnerable; EN = Endangered; DD = Data Deficient; - No data; N = Nationally; NA = Not Assessed

- *Based upon C.A.M.P. 1998.*

According to it Dibang basin harbours 74 species of fishes belonging to 8 Orders and 26 families. Cyprinidae is largest family with 36 species accounting for nearly 50% of total fish fauna while Cobitidae and Sisoridae are the next largest families with 5 and 4 species each and families like Balitoridae and Ambassidae are represented by 3 species each.

Following C.A.M.P. (1998) guidelines all the 76 fish species were assessed for their conservation status (**see Table 7.10**). Seven species are under Endangered category according to CAMP report (1998) of which 3 are under globally Endangered category viz. *Anguilla bengalensis* subsp. *bengalensis*, *Botia rostrata* (=*Botia almorhae*), *Aborichthys elongatus* while 4 species viz. *Tor tor, Tor putitora, Lepidocephalichthys arunachalensis* (=*Nemacheilus arunachalensis*) and *Ompok pabda* are categorized as nationally 'Endangered' species. Five species are placed under global 'Vulnerable' category (*Barilius bola* (=*Raiamas bola*), *Schizothorax richardsonii*, *Aborichthys kempi* (=*Nemacheilus kempi*), *Clarias batrachus* and *Bagarius bagarius* while 8 species are under 'Vulnerable' category nationally (*Aspidoparia jaya, Bangana dero* (=*Labeo dero*), *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Garra gotyla gotyla, Puntius chola, Puntius sarana sarana, Channa orientalis* and *Heteropneustes fossilis*). *Schizothorax richardsonii* (Snow trout) has been placed under 'Vulnerable' category an important species of cold waters where it is the predominant species of trouts. However key species of warmer waters are Mahseers (*Tor tor* and *Tor putotora*). The category of 'Near Threatened' only one species *Aborichthys kempi* is listed.

According of list of threatened freshwater fish species prepared by National Bureau of Fish Genetic Resources (NBFGR, 2010), 5 species have been categorized as Endangered while 12 species are placed in Vulnerable category (**refer Table 7.10**).

According to IUCN criterion *Tor putitora* while 4 species are under Vulnerable category (**see Table 7.10**). These are *Cyprinus carpio, Schizothorax richardsonii, Botia rostrata* and *Cyprinion semiplotum* (=*Semiplotus semiplotus*).

Golden mahseer has been declared as Arunachal Pradesh State fish (Anon, 2011).

CHAPTER-8
ENVIRONMENTAL FLOWS

8.1 INTRODUCTION

The environmental flow is an important aspect in the development of hydropower projects. Release of environmental flow is to be ensured immediately downstream of the diversion structure at all times to sustain the ecology and environment of project area. Protecting and maintaining river flow regimes and hence the ecosystems they support by providing adequate environmental flows have become a critical aspect of hydropower development. Ecological systems supported by the rivers are too complicated to be summarized by a single minimum flow requirement but require comprehensive environmental flow regimes to be defined. "Environmental flow regime" means a schedule of flow quantities that reflects seasonal fluctuations and should be adequate to support a sound ecological environment to maintain productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies.

The aquatic biota in Himalayan glacier-fed rivers has adapted to annual flow pulses, which vary from a gradual increase in discharge in summer, through floods in the monsoon period, and reduce to low flows in winter. During the dry season, the waters become clear, allowing algae (primarily diatoms) to obtain necessary light and carbon dioxide for photosynthesis. Effective quantification of flow includes the ecologically important range of flow magnitudes (low flows, high flow pulses, and floods), as well as the timing, duration, frequency, and rate of change of these flow conditions. Globally, these flows are most commonly referred to as “environmental flows”.

The most critical reach for assessing release of environmental flow is immediately downstream of diversion structure till first significant tributary meets river.

8.2 CURRENT NORMS BEING FOLLOWED FOR ENVIRONMENTAL FLOW

There are no set norms for minimum releases to be maintained at all times on account of ecology and environment and to address issues concerning riparian rights, drinking water, health, aquatic life, wildlife, fisheries, silt and even to honour the sensitive religious issues like cremation and other religious rites, etc. on the river banks.

Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of Ministry of Environment, Forests and Climate Change (MoEF&CC) recommends minimum environmental flow during lean season as 20% of the average discharge in four leanest months in 90% dependable year of the water availability series used to design the project. Lately, they have also started discussing the requirement of varied environmental flow during monsoon and other months as discharge available in the river and flow requirement cannot be the same as that of lean season. In absence of any site specific study or unless a site specific study specifies otherwise, EAC has been recommending ecological releases for monsoon months should be maintained as 30% of flows in monsoon months of 90% dependable year and for non-lean and non-monsoon months, environmental flow provision should be kept between 20-30%.

Scope of present study requires suggesting approach to be adopted for determining environmental flows and to determine environmental releases for various planned projects and river reaches in the Dibang basin.

8.3 DESCRIPTION OF VARIOUS METHODOLOGIES FOR E-FLOW

There are four relatively discrete types of environmental flow methodologies: (1) hydrological, (2) hydraulic rating, (3) habitat simulation and (4) holistic methodologies; among other techniques occasionally applied during Environmental flow Assessment. The four types are briefly described below.

8.3.1 Hydrological Methodologies

These represent the simplest set of techniques where, at a desktop level, hydrological data, as naturalized, historical monthly or average daily flow records are analysed to derive standard flow indices, which then become the recommended environmental flows.

Hydrological Index Methods provide a relatively rapid, non-resource intensive, but low-resolution estimate of environmental flows. The methods are most appropriate at the planning level of water resources development, or in low controversy situations where they may be used as preliminary estimates. Hydrological Index methods may be used as tools within habitat simulation, holistic or combination environmental flow methodologies. They have been applied in developed and developing countries. Commonly, the EFR is represented as a proportion of flow (often termed the 'minimum flow') intended to maintain river health, fisheries or other highlighted ecological features at some acceptable level, usually on an annual, seasonal or monthly basis. As a result of the rapid and non-resource intensive provision of low resolution flow estimates, hydrological methodologies are generally used mainly at the planning stage of water resource developments, or in situations where preliminary flow targets and exploratory water allocation trade-offs are required.

Environmental flow is usually given as a percentage of average annual flow or as a percentile from the flow duration curve, on an annual, seasonal or monthly basis.

The most frequently used methods under this category are:

(i) Tennant Method

Donald Tennant developed this method in Montana, USA through several field observations and measurements. The Tennant study used 58 cross sections from 11 streams in Montana, Nebraska and Wyoming (Mann, 2006). The technique utilizes only the Mean Annual Flow (MAF) for the stream. It then states that certain flows relate to the qualitative fish habitat rating, which is used to define the flow needed to protect fish habitat, expressed in tabular form. Tennant concluded that 10% of MAF is the minimum for short-term fish survival, 30% of MAF is considered to be able to sustain fair survival conditions and 60% of MAF is excellent to outstanding habitat (Tennant, 1975).

	Flow to be released during	
Description of Flow	**April to September**	**October to March**
Flushing flow (from 48 – 96 hours)	200% MAF (Mean Annual Flow)	Not Applicable
Optimum range of flow	60-100% MAF	60-100% MAF
Outstanding habitat	60% MAF	40% MAF
Excellent habitat	50% MAF	30% MAF
Good habitat	40% MAF	20% MAF
Fair or degrading habitat	30% MAF	10% MAF
Poor or minimum habitat	10% MAF	10% MAF
Severe degradation	<10% MAF	<10% MAF

This means that if the quantity of water that the basin managers can provide for EFR is ≤ 20% of MAF (10% during April to September and 10% during October to March) then the environmental quality of the habitat in that reach will face "Severe Degradation". If a "Good" habitat is desired, then at least 60% of the MAF must be allocated for EFR, 40% during April-September and 20% during October to March.

Tessman modified the Tennant method and it resulted in an approach called as Modified Tennant Method or Tessman Method. Tessman adopted Tennant seasonal flow recommendation to calibrate the percentage of Mean Annual flow (MAF) to local hydrologic and biological conditions including monthly variability in terms of Minimum Monthly Flow (MMF).

Under these changes, the following rules were formulated.

- If MMF < 40% of MAF, then monthly minimum equals the MMF
- If MMF > 40% MAF, then monthly minimum equals 40% MAF
- If 40% MMF > 40% MAF, then monthly minimum equals 40% MAF
- The flushing flow criterion is still a requirement to be met on an annual basis.

(ii) Index Method

This method defined the value of the Minimum In-stream Flow (MIF) that must be maintained downstream of water diversion in order to maintain vital conditions of ecosystem functionality and quality (Maran, 2007). Based on Q355 (the flow not exceeded more than 355 days per year) this means that, on average, the natural flow is less than Q355 value only for 10 days in a year (Maran, 2007).

MIF = Ka*Kb*Kc* Q355 where:

- Ka is corrective coefficient for different environmental sensitive of the interested river stretch [0.7 to 1.0]
- Kb = implementation factor [0.25 to 1.0]
- Kc is corrective coefficient to account for different level of protection due to the naturalistic value of the interested area [1.0 to 1.5].

The concept of "environmental sensitive" is linked with Flow Duration Curve (FDC). When the slope of the FDC is flat, for example when Q90 ≥ 30% AAF, the flow in the river is very stable thought the year, and the ecosystem is getting used to have a constant rate of flow in the river most of the time. This type of ecosystem is more sensitive to any change in river flow regime and the value of Ka will be taken as 1 (one). On other hand, when the FDC slope is steep, say Q90 < 10% AAF, the river flow is very unstable and present high extreme values (floods and droughts). Under this condition, ecosystem is getting used to water scarcity during some periods of the year, therefore this ecosystem is less sensitive to changes in flow regime, because the river naturally present a wide variability in flow regime. In this case, the value of Ka can be taken as 0.7.

The implementation factor refers to upgrade a degraded river condition, in which the quantity of water in the river is very low, due to abstractions made for different purposes (domestic, industrial, agriculture, etc.). The recovery of natural conditions of the river flow must be done gradually, because another uses of water will be affected. In this case, the value of Kb could be 0.25. In the case of no significant abstractions, the value of Kb will be 1.

The Kc factor increases the value of MIF, for protection of special conditions in the river ecosystem like naturalistic and tourism values, fisheries development and medicinal or religious issues.

(iii) Desktop Analysis

Desktop analysis can be sub-divided into (i) those based purely on hydrological data, and (ii) those that employ both hydrological and ecological data.

<u>**Desktop methods based on hydrological data**</u>

(a) Flow Duration Curve Based Method

A flow duration curve (FDC) is a plot of flow vs. percentage time equalled or exceeded. FDC can be prepared using the entire time series data of flow or the flow data pertaining to a specific period (such as a month) in different years. Further, it can be developed for a particular site or combining data for different sites on per unit catchment area basis in a hydro meteorologically homogeneous region.

(b) Environmental Management Class (EMC) based FDC Approach

Smakhtin and Anputhas (2006) reviewed various hydrology based environmental flow assessment methodologies and their applicability in Indian context. Based on the study, they suggested a flow duration curve based approach which links environmental flow requirement with environmental management classes.

This EFA method is built around a period-of-record FDC and includes several subsequent steps. The first step is the calculation of a representative FDC for each site where the environmental water requirement (EWR) is to be calculated. In this study, the sites where EF is calculated coincide with the major flow diversion. The sites with observed flow data are further referred to as 'source' sites. The sites where reference FDC and time series are needed for the EF estimation are referred to as 'destination' sites. All FDCs are represented by a table of flows corresponding to the 17 fixed percentage points. For each destination site, a FDC table was calculated using a source FDC table from either the nearest or the only available observation flow station upstream. To account for land-use impacts, flow withdrawal, etc., and for the differences between the size of a source and a destination basin, the source FDC is scaled up by the ratio of 'natural' long term mean annual run-off (MAR) at the outlet and the actual MAR calculated from the source record.

(c) Defining Environmental Management Classes

EF aim to maintain an ecosystem in, or upgrade it to, some prescribed or negotiated condition/ status also referred to as "desired future state", "environmental management class"/ "ecological management category", "level of environmental protection", etc. (e.g., Acreman and Dunbar 2004; DWAF 1997). This report uses the term 'environmental management class' (EMC). The higher the EMC, the more water will need to be allocated for ecosystem maintenance or conservation and more flow variability will need to be preserved. Ideally, these classes should be based on empirical relationships between flow and ecological status/conditions associated with clearly identifiable thresholds. However, so far there is insufficient evidence for such thresholds (e.g., Beecher, 1990; Puckridge *et al*. 1998). These categories are therefore a management concept, which has been developed and used in the world because of a need to make decisions in the conditions of limited lucid knowledge. Placing a river into a certain EMC is normally accomplished by expert judgment using a scoring system. Alternatively, the EMCs may be used as default 'scenarios' of environmental protection and corresponding EWR and EF - as 'scenarios' of environmental water demand. Six EMCs are used generally and six corresponding default levels of EWR may be defined. The set of EMCs starts with the *unmodified and largely natural conditions* (rivers in classes A and B), where no or limited modification is present or should be allowed from the management perspective. In *moderately modified* river ecosystems (class C rivers), the modifications are such that they generally have not (or will not – from the management perspective) affected the ecosystem integrity. *Largely modified* ecosystems (class D rivers) correspond to considerable modification from the natural state where the sensitive biota is reduced in numbers and extent. *Seriously and critically modified* ecosystems (classes E and F) are normally in poor conditions where most of the ecosystem's functions and services are lost. Rivers which fall into classes C to F would normally be present in densely populated areas with multiple man-induced impacts. Poor ecosystem conditions (classes E or F) are sometimes not considered acceptable from the management perspective and the management intention is always to "move" such rivers up to the least acceptable class D through river rehabilitation measures (DWAF 1997). This restriction is not however applied here, primarily because the meaning of every EMC is somewhat arbitrary and needs to be filled with more ecological substance in the future. Some studies use transitional EMCs (e.g., A/B, B/C, etc.) to allow for more flexibility in EWR determinations. It can be noted, however, that ecosystems in class F are likely to be those which have been modified beyond rehabilitation to anything approaching a natural condition. It is possible to estimate EWR corresponding to all or any of the above EMCs and then consider which one is best suited/feasible for the river in question, given existing and future basin developments. On the other hand, it is possible to use expert judgment and available ecological information in order to place a river into the most probable/achievable EMC. The EMCs are described in **Table 8.1** as scenarios of aquatic ecosystem condition.

Table 8.1: Environment Management Classes

EMC	Ecological description	Management perspective
A: Natural	Pristine condition or minor modification of in-stream and riparian habitat	Protected rivers and basins. Reserves and national parks. No new water projects (dams, diversions, etc.) allowed
B: Slightly modified	Largely intact biodiversity and habitats despite water resources development and/or basin modifications	Water supply schemes or irrigation development present and/or allowed
C: Moderately	The habitats and dynamics of the modified biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present	Multiple disturbances associated with the need for socio-economic development, e.g., dams, diversions, habitat modification and reduced water quality
D: Largely modified	Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail	Significant and clearly visible disturbances associated with basin and water resources development, including dams, diversions, transfers, habitat modification and water quality degradation
E: Seriously modified	Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	High human population density and extensive water resources exploitation
F: Critically modified	Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible	This status is not acceptable from the management perspective. Management interventions are necessary to restore flow pattern, river habitats, etc. (if still possible/feasible) – to 'move' a river to a higher management category

8.3.2 Hydraulic Rating Methodologies

Hydraulic rating methodologies use changes in simple hydraulic variables, such as wetted perimeter or maximum depth, usually measured across single, flow-limited river cross-sections (commonly riffles), as a surrogate for habitat factors known or assumed to be limiting to target biota. Environmental flows are determined from a plot of the hydraulic variable(s) against discharge, commonly by identifying curve breakpoints where significant percentage reductions in habitat quality occur with decreases in discharge. It is assumed that ensuring some threshold value of the selected hydraulic parameter at a particular level of altered flow will maintain aquatic biota and thus, ecosystem integrity. These relatively low-resolution hydraulic techniques have been superseded by more advanced habitat modeling tools, or assimilated into holistic methodologies (Tharme, 1996; Jowett, 1997; Arthington and Zalucki, 1998; Tharme, 2003). However, select approaches continue to be applied and evaluated, notably the Wetted Perimeter Method (e.g. Gippel and Stewardson, 1998).

8.3.3 Habitat Simulation or Micro-Habitat Modeling Methodologies

Habitat simulation methodologies also make use of hydraulic habitat-discharge relationships, but provide more detailed, modelled analyses of both the quantity and suitability of the physical river habitat for the target biota. Thus, environmental flow recommendations are based on the integration of hydrological, hydraulic and biological response data. Flow-related changes in physical microhabitat are modelled in various hydraulic programs, typically using data on depth, velocity, substratum composition and cover; and more recently, complex hydraulic indices (e.g. benthic shear stress), collected at multiple cross-sections within each representative river reach. Simulated information on available habitat is linked with seasonal information on the range of habitat conditions used by target fish or invertebrate species (or life-history stages, assemblages and/or activities), commonly using habitat suitability index curves (e.g. Groshens and Orth, 1994). The resultant outputs, in the form of habitat-discharge relationships for specific biota, or extended as habitat time and exceedance series, are used to derive optimum environmental flows. The habitat simulation-modeling package PHABSIM (Bovee, 1982, 1998; Milhous, 1998, 1982; Milhous *et al.,* 1989; Stalnaker *et al.,* 1994), housed within the In-stream Flow Incremental Methodology (IFIM), is the pre-eminent modeling platform of this type.

8.3.4 Holistic Methodologies

Over the past decade, river ecologists have increasingly made the case for a broader approach to the definition of environmental flows to sustain and conserve river ecosystems, rather than focusing on just a few target fish species (Arthington and Pusey, 1993; King and Tharme, 1994; Sparks, 1992, 1995; Richter *et al*., 1996; Poff *et al*., 1997). From the conceptual foundations of a holistic ecosystem approach, a wide range of holistic methodologies has been developed and applied, initially in Australia and South Africa and later in the United Kingdom. This type of approach reasons that if certain features of the natural hydrological regime can be identified and adequately incorporated into a modified flow regime, then, all other things being equal, the extant biota and functional integrity of the ecosystem should be maintained (Arthington *et al*., 1992; King and Tharme 1994). Importantly, holistic methodologies aim to address the water requirements of the entire "riverine ecosystem" rather than the needs of only a few taxa (usually fish or invertebrates). These methodologies share a common objective - to maintain or restore the flow related biophysical components and ecological processes of in-stream and groundwater systems, floodplains and downstream receiving waters (e.g. terminal lakes and wetlands, estuaries and near-shore marine ecosystems). Ecosystem components that are commonly considered in holistic assessments include geomorphology, hydraulic habitat, water quality, riparian and aquatic vegetation, macro-invertebrates, fish and other vertebrates with some dependency upon the river/riparian ecosystem (i.e. amphibians, reptiles, birds, mammals). Each of these components can be evaluated using a range of field and desktop techniques and their flow requirements are then incorporated into EFA recommendations, using various systematic approaches.

Holistic approaches have been described as either 'bottom-up' methods, which are designed to 'construct' a modified flow regime by adding flow components to a baseline of zero flows; or 'top-down' methods i.e. by assessing how much a river's flow regime can be modified before the aquatic ecosystem begins to noticeably change or degrade.

8.3.4.1 The Building Block Methodology (BBM)

The BBM is introduced in King & Tharme (1994) and King (1996), and is comprehensively described in Tharme & King (1998), and King & Louw (1998). The methodology is under on going development, and has been applied routinely in South Africa, with some application in Australia and UK. The methodology is based on the concept that some flows within the complete hydrological regime of a river are more important than others for maintenance of the riverine ecosystem, and that these flows can be identified, and described in terms of their magnitude, duration, timing, and frequency. In combination, these flows constitute the EFR as a river-specific modified flow regime, linked to a predetermined future state. A number of specialists in a workshop situation use hydrological base flow and flood data, including various hydrological indices, cross-section based hydraulic data, and information on the flow-related needs of ecosystem components, to identify specific flow elements for the EFR.

8.3.4.2 The Downstream Response to Imposed Flow Transformations Methodology

The DRIFT Methodology was developed in southern Africa for use in the Palmiet IFR study (Brown *et al.*, 2000) and Lesotho Highlands Water Project (Brown & King, 1999, 2000). It is an interactive, top-down holistic approach based on the same conceptual tenets and multidisciplinary, workshop-based interaction as the BBM and Holistic Approach. However, it focuses on the identification of a series of river water levels associated with a particular set of biophysical functions and of specific hydrological and hydraulic character. Specialists in each discipline describe the consequences of reducing discharges through these identified flow bands and their thresholds, in terms of deterioration in biotic and abiotic condition. The identification of the 'minimum degradation' reduction level and its consequences typically provides the starting point for the process. Once a wide range of flow reductions has been assessed, there is considerable scope for the comparative evaluation of a vast number of EFR scenarios, each reflecting the presence or absence of different flow bands with attendant consequences.

Holistic methodologies exhibit several advantages over other types of environmental flow methodology, most importantly in that they can potentially be used to address all components of the riverine ecosystem and have strong links with the natural hydrological regime. Also, they incorporate biological, geomorphological and hydrological data, and consider all aspects of the flow regime, such as the magnitude and timing of both base flow and flood events. However, holistic methodologies rely to a considerable extent on professional judgment, so care must be taken to apply them in a rigorous, well-structured manner, in order to ensure sufficiently reproducible results. The methodologies are firmly based on South African and Australian experiences of variable climate and hydrology, heterogeneous geomorphology, and of limited available information on biological flow dependencies of riverine biota (Growns & Kotlash, 1994; Tharme, 1996). As with most other current environmental flow methodologies, there are few applications of holistic methodologies other than in their place of origin.

For the purpose of environmental flow assessment in Dibang basin, hydraulic modeling and habitat simulation methodologies is considered to be best suited as discussed in the following section.

8.4 ADOPTED METHODOLOGY TO ESTABLISH ENVIRONMENTAL FLOW

8.4.1 Basics of Environmental Flow Assessment Methods

Environmental flows (EF) are an ecologically acceptable flow regime designed to maintain a river in an agreed or predetermined state. Therefore, EF are a compromise between hydro development, on one hand, and river maintenance in a healthy or at least reasonable condition, on the other. Difficulties in the actual estimation of EF values arise primarily due to the inherent lack of both the understanding of and quantitative data on relationships between river flows and multiple components of river ecology. The major criteria for determining EF should include the maintenance of both spatial and temporal patterns of river flow, i.e., the flow variability, which affect the structural and functional diversity of rivers, and which in turn influence the species diversity of the river. All components of the hydrological regime have certain ecological significance. High flows of different frequency are important for channel maintenance, bird breeding, wetland flooding and maintenance of riparian vegetation. Moderate flows are critical for cycling of organic matter from river banks and for fish migration, while low flows of different magnitudes are important for algae control, water quality maintenance and the use of the river by local people. Therefore, many elements of flow variability have to be maintained in a modified-EF-regime.

The focus on maintenance of flow variability has several important implications. First, it moves away from a 'minimum flow attitude' to aquatic environment. Second, it effectively considers that aquatic environment is also 'held accountable' and valued similarly to other sectors – to allow informed trade-offs to be made in water deprived conditions. Because wetland and river ecosystems are naturally subjected to droughts or low flow periods and can recover from those, then building this variability into the picture of EFA may be seen as environmental water demand management. This brings us back to the issue of 'compromise' and implies that EF is a very pragmatic concept: it does not accept a bare minimum, but it is for a trade. Bunn and Arthington (2002) have formulated four basic principles that emphasize the role of flow regime in structuring aquatic life and show the link between flow and ecosystem changes:

- Flow is a major determinant of physical habitat in rivers, which in turn is the major determinant of biotic composition. Therefore, river flow modifications eventually lead to changes in the composition and diversity of aquatic communities.

- Aquatic species have evolved life history strategies primarily in response to the natural flow regimes. Therefore, flow regime alterations can lead to loss of biodiversity of native species.

- Maintenance of natural patterns of longitudinal and lateral connectivity in river systems determines the ability of many aquatic species to move between the main river and its tributaries. Loss of longitudinal and lateral connectivity can lead to local extinction of species.

In this report, hydraulic rating methodologies and habitat simulations or micro-habitat modeling methodologies have been used. The primary reason for using this method is objectivity of the methodology, availability of data including surveyed river cross-sections and limited timeframe available for the study.

Main reasons for not using Hydrological Index Methods is that though these provide a relatively rapid, non-resource intensive, but give low resolution estimate of environmental flows. The methods are only appropriate at the planning level where they may be used as preliminary estimates. These methods may be used as tools within habitat simulation, holistic or combination environmental flow methodologies. Commonly, the EFR is represented as a proportion of flow (often termed the 'minimum flow') intended to maintain river health, fisheries or other highlighted ecological features at some acceptable level, usually on an annual, seasonal or monthly basis.

Building Block Method (BBM) could not be used because of following reasons:

- The BBM is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition. Building Block Method can use detailed data from different sectors and have the provision of consultation among the experts and stakeholders. However, application of BBM for large number of sites requires a lot of time and resources.

- The BBM has advanced the field of environmental flow assessment and being a holistic methodology it addresses the health (structure and functioning) of all components of the riverine ecosystem, rather than focusing on selected group or species. But in context of Dibang basin study, the major stakeholder is only riverine ecology and fish. Hence adopting such rigorous exercise is neither needed nor practical within a limited time frame and resources.

Environmental flow regime has been worked out keeping annual occurrence of following main seasons in this region. These are:

(a) Season I: This season is considered as low or lean or dry flow season which covers the months from December to March. However, in case of Sissiri HEP, November to February covers low or lean or dry flow season.
(b) Season II: It is considered as high flow season influenced by monsoon. It covers the months from June to September. However, in case of Sissiri HEP, May to August covers high flow season influenced by monsoon.
(c) Season III: This season is considered as average flow period, covers the months of April, May and October, November. However, in case of Sissiri HEP, this period covers the months of March, April and September, October.

8.5 HYDRO-DYNAMIC MODELING

To assess environmental flow requirements, a flow simulation study has been carried out using one dimensional mathematical model **MIKE 11** developed by Danish Hydraulic Institute of Denmark.

8.5.1 MIKE 11 Model

MIKE 11 is an integrated system of software, designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The core of the MIKE 11 system consists of the HD (hydrodynamic) module, which is capable of simulating unsteady flows in a network of open channels. The results of a HD simulation consist of time series of water levels, discharges, flow velocities, water widths etc. MIKE 11 hydrodynamic module is an implicit, finite difference model for unsteady flow computation. The model can describe sub-critical as well as supercritical flow conditions through a numerical description, which is altered according to the local flow conditions in time and space. The MIKE 11 system contains three one-dimensional hydraulic components for: i) Steady flow surface profile computations; ii) quasi-unsteady flow simulation and iii) unsteady flow simulation. The steady/unsteady flow components are capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. The system can handle a full network of channels, a dendritic system, or a single river reach. The basic computational procedure is based on the solution of one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied.

The graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and many other hydraulic variables. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer, or passed through the Windows clipboard to other software, such as word processor or spread sheet. Reports can be customized as to the amount and type of information desired..

The following approach has been used for various data inputs:

8.5.2 Hydropower Projects considered for Modeling

There are 18 hydro projects being planned in the Dibang river basin on different tributaries and their details and status is discussed in Chapter 2. Two projects are less than 25 MW i.e. they do not fall under the purview of EIA notification; therefore they are not covered for the modeling exercise.

None of the projects have started construction; only some of the projects are at various stages of survey and investigation and remaining projects have yet to start the survey and investigation work as well and therefore data availability of such projects is very limited. Out of 16 projects, which are of installed capacity greater than or equal to 25 MW; 4 projects viz. Agoline, Etabue, Elango and Malinye have not yet been allotted to anyone. Reliable discharge data and river cross sections are not available for these projects, therefore, they have been excluded from modeling exercise. For one more projects, Ashupani HEP (30 MW), discharge data/river cross sections are not available, therefore it could not be included in the modeling exercise. Hence 11 projects have been chosen for simulation modeling based on data availability and to ensure that major tributaries and main Dibang river are covered in this modeling exercise. These are listed in **Table 8.2**. As Etalin project has diversion structure on Dri River as well as Talo (Tangon) River, for the purpose of Environmental flow assessment these two have been studied separately.

Table 8.2: HEPs covered for Hydrodynamic Modeling

S. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Intermediate River Length* (km)
1	Dibang Multipurpose	2880	Dibang	Dibang	1.2
2	Etalin (Dri Limb)	3097	Dri	Dri	16.50
3	Etalin (Talo/Tangon Limb)		Talo (Tangon)	Talo (Tangon)	18.00
4	Attunli	680	Talo (Tangon)	Talo (Tangon)	10.68
5	Mihumdon	400	Dri	Dri	9.39
6	Emini	500	Mathun	Dri	6.43
7	Amulin	420	Mathun	Dri	8.62
8	Emra I	275	Emra	Dibang	6.12
9	Emra II	390	Emra	Dibang	1.30 **
10	Ithun I	84	Ithun	Dibang	6.35
11	Ithun II	48	Ithun	Dibang	4.47
12	Sissiri	100	Sissiri	Dibang	0.5

* Intermediate River length is the distance along the river between diversion site and tail water discharge point i.e. the river reach, which will be deprived of flow due to diversion of water to HRT. Adequate environmental flow will ensure that river in this reach should have sufficient water throughout the year.

** Intermediate river length is distance along the river from diversion site up to reservoir tail of downstream project.

Input data used for present modeling study has been described below:

8.5.3 Discharge Data

Efforts have been made to procure discharge data for various projects from Central Water Commission (CWC). Out of 11 projects listed above, CWC has approved water availability series for only three projects (Etalin, Attunli and Dibang Multipurpose Projects); this data was provided to us and same is used for simulation modeling. For remaining 8 project locations, series have been taken from PFRs.

From the long term flow series, 90% dependable year for different projects have been derived as the year with over 90% dependability and shall be used in the modeling exercise as input flow data. Discharge data for all these projects for 90% dependable year has been shown in **Tables 5.8 to 5.10** in Chapter 5, “Hydro-meteorology”.

Out of the full year flow series (90% Dependability), three average values have been calculated viz.

- Average of four leanest months
- Average of four monsoon months
- Average of remaining four months

Flow simulations have been carried out for 10%, 15%, 20%, 25%, 30%, 40%, 50% and 100% releases of the average discharge for each of above three scenarios for the identified 11 projects. Various key parameters for establishing habitat requirement have been calculated which include water depth, flow velocity and top width of waterway.

Average discharge for four leanest months, monsoon months and other months have been calculated for 90% dependable year and is shown in **Tables 8.3 to 8.5**.

Table 8.3: 90% DY Average Discharge Data for Dibang, Etalin and Attunli Projects

	Dibang Multipurpose Project	Etalin HEP		Attunli HEP
	Dibang river	Dri Limb	Talo (Tangon) Limb	Talo river
	CA: 11276 Km^2	CA: 3685 Km^2	CA: 2358 Km^2	CA: 2573 Km^2
90% DY	**2001-02**	**2001-02**	**2001-02**	**2001-02**
	cumec	cumec	cumec	cumec
Monsoon (June-September)				
Average	**1457.78**	410.78	261.66	235.95
10 % of average	145.78	41.08	26.17	23.60
15 % of average	218.67	61.62	39.25	35.39
20 % of average	291.56	82.16	52.33	47.19
25 % of average	364.45	102.69	65.41	58.99
30 % of average	437.33	123.23	78.50	70.79
40 % of average	583.11	164.31	104.66	94.38
50 % of average	728.89	205.39	130.83	117.98
Lean (December-March)				
Average	**543.74**	153.20	97.60	88.01
10 % of average	54.37	15.32	9.76	8.80
15 % of average	81.56	22.98	14.64	13.20
20 % of average	108.75	30.64	19.52	17.60
25 % of average	135.94	38.30	24.40	22.00
30 % of average	163.12	45.96	29.28	26.40
40 % of average	217.5	61.28	39.04	35.20
50 % of average	271.87	76.60	48.80	44.00
Non-monsoon, non-lean (October, November, April, May)				
Average	**815.67**	229.83	146.4	132.02
10 % of average	81.57	22.98	14.64	13.20
15 % of average	122.35	34.47	21.96	19.80
20 % of average	163.13	45.97	29.28	26.40
25 % of average	203.92	57.46	36.60	33.00
30 % of average	244.70	68.95	43.92	39.61
40 % of average	326.27	91.93	58.56	52.81
50 % of average	407.84	114.91	73.20	66.01

Table 8.4: 90% DY Average Discharge Data for, Mihumdon, Emini, Amulin and Emra I projects

	Mihumdon HEP	Emini HEP	Amulin HEP	Emra I
	Dri river	Mathun river	Mathun river	Emra river
	CA: 968 Km^2	CA: 2600 Km^2	CA: 2175 Km^2	CA: 1472 Km^2
90% DY	**1994-95**	**1994-95**	**1994-95**	**2001-02**
	cumec	cumec	cumec	cumec
Monsoon (June-September)				
Average	102.31	274.80	229.88	195.80
10 % of average	10.23	27.48	22.99	19.58
15 % of average	15.35	41.22	34.48	29.37
20 % of average	20.46	54.96	45.98	39.16
25 % of average	25.58	68.70	57.47	48.95

	Mihumdon HEP	Emini HEP	Amulin HEP	Emra I
30 % of average	30.69	82.44	68.96	58.74
40 % of average	40.92	109.92	91.95	78.32
50 % of average	51.16	137.40	114.94	97.90
Lean (December-March)				
Average	42.32	113.66	95.08	74.13
10 % of average	4.23	11.37	9.51	7.41
15 % of average	6.35	17.05	14.26	11.12
20 % of average	8.46	22.73	19.02	14.83
25 % of average	10.58	28.41	23.77	18.53
30 % of average	12.69	34.10	28.52	22.24
40 % of average	16.93	45.46	38.03	29.65
50 % of average	21.16	56.83	47.54	37.06
Non-monsoon, non-lean (October, November, April, May)				
Average	79.55	213.66	178.74	112.82
10 % of average	7.95	21.37	17.87	11.28
15 % of average	11.93	32.05	26.81	16.92
20 % of average	15.91	42.73	35.75	22.56
25 % of average	19.89	53.42	44.68	28.20
30 % of average	23.86	64.10	53.62	33.85
40 % of average	31.82	85.47	71.50	45.13
50 % of average	39.77	106.83	89.37	56.41

Table 8.5: 90% DY Average Discharge Data for Emra II, Ithun I, Ithun II and Sissiri projects

	Emra II	Ithun I	Ithun II	Sissiri
	Emra river	Ithun river	Ithun river	Sissiri river
	CA: 1557 Km^2	CA: 841 Km^2	CA: 708 Km^2	CA: 610 Km^2
90% DY	**2001-02**	**2001-02**	**2001-02**	**1992-93**
	cumec	cumec	cumec	cumec
Monsoon (June-September)				May-Aug
Average	201.31	94.08	72.01	48.55
10 % of average	20.13	9.41	7.20	4.85
15 % of average	30.20	14.11	10.80	7.28
20 % of average	40.26	18.82	14.40	9.71
25 % of average	50.33	23.52	18.00	12.14
30 % of average	60.39	28.22	21.60	14.56
40 % of average	80.52	37.63	28.80	19.42
50 % of average	100.65	47.04	36.00	24.27
Lean (December-March)				Nov-Feb
Average	76.21	35.11	26.86	19.33
10 % of average	7.62	3.51	2.69	1.93
15 % of average	11.43	5.27	4.03	2.90
20 % of average	15.24	7.02	5.37	3.87
25 % of average	19.05	8.78	6.71	4.83
30 % of average	22.86	10.53	8.06	5.80
40 % of average	30.48	14.04	10.74	7.73
50 % of average	38.10	17.55	13.43	9.67
Non-monsoon, non-lean (October, November, April, May)				Sept, Oct, Mar, Apr
Average	112.82	52.63	40.30	31.65
10 % of average	11.28	5.26	4.03	3.17
15 % of average	16.92	7.90	6.05	4.75
20 % of average	22.56	10.53	8.06	6.33
25 % of average	28.20	13.16	10.08	7.91
30 % of average	33.85	15.79	12.09	9.50
40 % of average	45.13	21.05	16.12	12.66
50 % of average	56.41	26.32	20.15	15.83

8.5.4 River cross sections

Environmental flow assessment is carried out for the stretch of river, which starts downstream of diversion structure and up to the tailrace channel outfall point; generally termed as intermediate stretch between dam and powerhouse. For each project this stretch is calculated and given in **Table 8.2**. Out of this stretch initial 1-2 Km or the length up to which first major tributary meets the river is considered critical as for the rest of the stretch tributary will add to the environmental flow released from the diversion structure. Therefore, modeling exercise to work out the environmental flow to meet the habitat requirement for the initial critical stretch hold good for the rest of the river. Keeping this in view, 8-10 cross sections of the river were taken immediately downstream of the diversion structure for each project and used in the modeling exercise. These sections have been represented in MIKE 11 model set up. Typical model set up showing locations of river cross-sections and actual surveyed river cross sections have been shown in **Figures 8.1 and 8.2.**

Except for Dibang Multipurpose project, Etalin and Attunli HEPs most of the projects in Dibang basin have not made any progress and no data on river profile is available. Therefore digital data available in public domain i.e. The Shuttle Radar Topography Mission (SRTM) elevation data on a near-global scale to generate Digital Elevation Model. SRTM data is the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew on-board the Space Shuttle Endeavour. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA), NASA, the Italian Space Agency (ASI) and the German Aerospace Center (DLR). As there are three resolution outputs available, 1 kilometer, 90 meter and a 30 meter resolution. For the present study 30 meter resolution data was used. The cross-sections were generated from DEM in GIS environment using GIS software. In order to check the accuracy of the cross-sections thus generated, random ground checks were performed in the field for different rivers wherever the field conditions permitted. In case of any error the cross-sections were reconciled based upon inputs of ground checks. This methodology has been consistently adopted by central agencies like Central Water Commission also.

8.5.5 Manning's roughness coefficient

Manning's roughness coefficient for different type of channels as suggested in HEC-RAS manual is given in **Table 8.6**. For the present study the river reaches correspond to mountain stream with steep bank and bed consisting of cobbles and large boulders. For such type of river the value of Manning's n varies from 0.040 to 0.070. For a lower value of Manning's n the depth of water will be less in comparison to a higher value of Manning's n for the same discharge. Hence to have a conservative estimate of water depth the Manning's n has been adopted as 0.045 for the study reach in all projects except Dibang Multipurpose Project where the Manning's n has been adopted as 0.04 for the study reach.

Table 8.6: Manning's roughness coefficient

	Type of Channel and Description	Minimum	Normal	Maximum
	Natural Streams			
1	**Main Channels**			
	a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
	b. Same as above, but more stones and weeds	0.030	0.035	0.040
	c. Clean, winding, some pools and shoals	0.033	0.040	0.045
	d. Same as above, but some weeds and stones	0.035	0.045	0.050
	e. Same as above, lowwe stages, more ineffective slopes and sections	0.040	0.048	0.055
	f. Same as "d" but more stones	0.045	0.050	0.060
	g. Sluggish reaches, weedy. deep pools	0.050	0.070	0.080
	h. Very weedy reaches. deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2	**Flood Plains**			

	Type of Channel and Description	Minimum	Normal	Maximum
	a. Pasture no brush			
	1. Short grass	0.025	0.030	0.035
	2. High grass	0.030	0.035	0.050
	b. Cultivated areas			
	1. No crop	0.020	0.030	0.040
	2. Mature row crops	0.025	0.035	0.045
	3. Mature field crops	0.030	0.040	0.050
	c. Brush			
	1. Scattered brush, heavy weeds	0.035	0.050	0.070
	2. Light brush and trees, in winter	0.035	0.050	0.060
	3. Light brush and trees, in summer	0.040	0.060	0.080
	4. Medium to dense brush, in winter	0.045	0.070	0.110
	5. Medium to dense brush, in summer	0.070	0.100	0.160
	d. Trees			
	1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
	2. Same as above, but heavy sprouts	0.050	0.060	0.080
	3. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
	4. Same as above, but with flow into branches	0.100	0.120	0.160
	5. Dense willows, summer, straight	0.110	0.150	0.200
3	**Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged**			
	a. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
	b. Bottom: cobbles with large boulders	0.040	0.050	0.070

8.5.6 MIKE 11 Model set up

The MIKE 11 model set up for flow simulation study consist of a river reach, upstream boundary and a downstream boundary. The reach of rivers from diversion site of a hydroelectric project up to its confluence with first stream has been represented in model by number of surveyed cross sections or derived using SRTM data as discussed already. The releases from the respective diversion sites are the upstream boundary of the model set up applied at upper most cross section. The normal depth has been used as the downstream boundary for the model set up. In order to have independent results of water depth the downstream boundary has been applied at the cross section of respective rivers at few hundred meters downstream of the study reach. A typical MIKE 11 model set up is given in **Figures 8.1 & 8.2**. The model set up for all other projects have been carried out in the same manner.

8.5.7 Model outputs

Model output for each HEP is for three different scenario viz. monsoon average, lean season average and other four months average discharge values. For each scenario, output is in the form of water depth, flow velocity and flow top width for each river cross-section considered in the critical reach i.e. from diversion structure to where first tributary meets the river. The model output for all the projects for all the scenarios has been given as **Annexure-VI, Volume-II**. To discuss the results of the simulation modeling and assess the environmental flow requirement for each project separately, average values calculated for depth, velocity and flow top width for each scenario have been worked out and are given in **Tables 8.7** & **8.18**.

Table 8.7: Model Output for Different Release Scenarios for Dibang Multipurpose Project

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (54.370 cumec)	108.525	1.347	42.142
	15% release (81.560 cumec)	133.275	1.543	45.780
	20% release (108.750 cumec)	155.025	1.705	49.001
	25% release (135.940 cumec)	172.775	1.841	51.792
	30% release (163.120 cumec)	188.675	1.963	54.339
	40% release (217.500 cumec)	214.425	2.139	59.095
	50% release (271.870 cumec)	237.700	2.291	63.482
	100% release (543.740 cumec)	330.500	2.865	76.394
Monsoon (June-Sept)	10% release (145.780 cumec)	179.150	1.890	52.801
	15% release (218.670 cumec)	215.375	2.144	59.256
	20% release (291.560 cumec)	246.150	2.344	65.059
	25% release (364.450 cumec)	273.500	2.518	69.298
	30% release (437.330 cumec)	298.400	2.673	72.386
	40% release (583.110 cumec)	341.400	2.928	77.735
	50% release (728.890 cumec)	377.800	3.145	82.175
	100% release (1457.780 cumec)	519.425	3.857	101.872
Intermediate (April, May & Oct, Nov)	10% release (81.570 cumec)	133.825	1.547	45.844
	15% release (122.350 cumec)	164.675	1.778	50.489
	20% release (163.130 cumec)	188.975	1.965	54.380
	25% release (203.920 cumec)	208.575	2.099	57.984
	30% release (244.700 cumec)	226.600	2.219	61.369
	40% release (326.270 cumec)	259.600	2.429	67.562
	50% release (407.840 cumec)	288.350	2.612	71.142
	100% release (815.670 cumec)	397.900	3.264	84.636

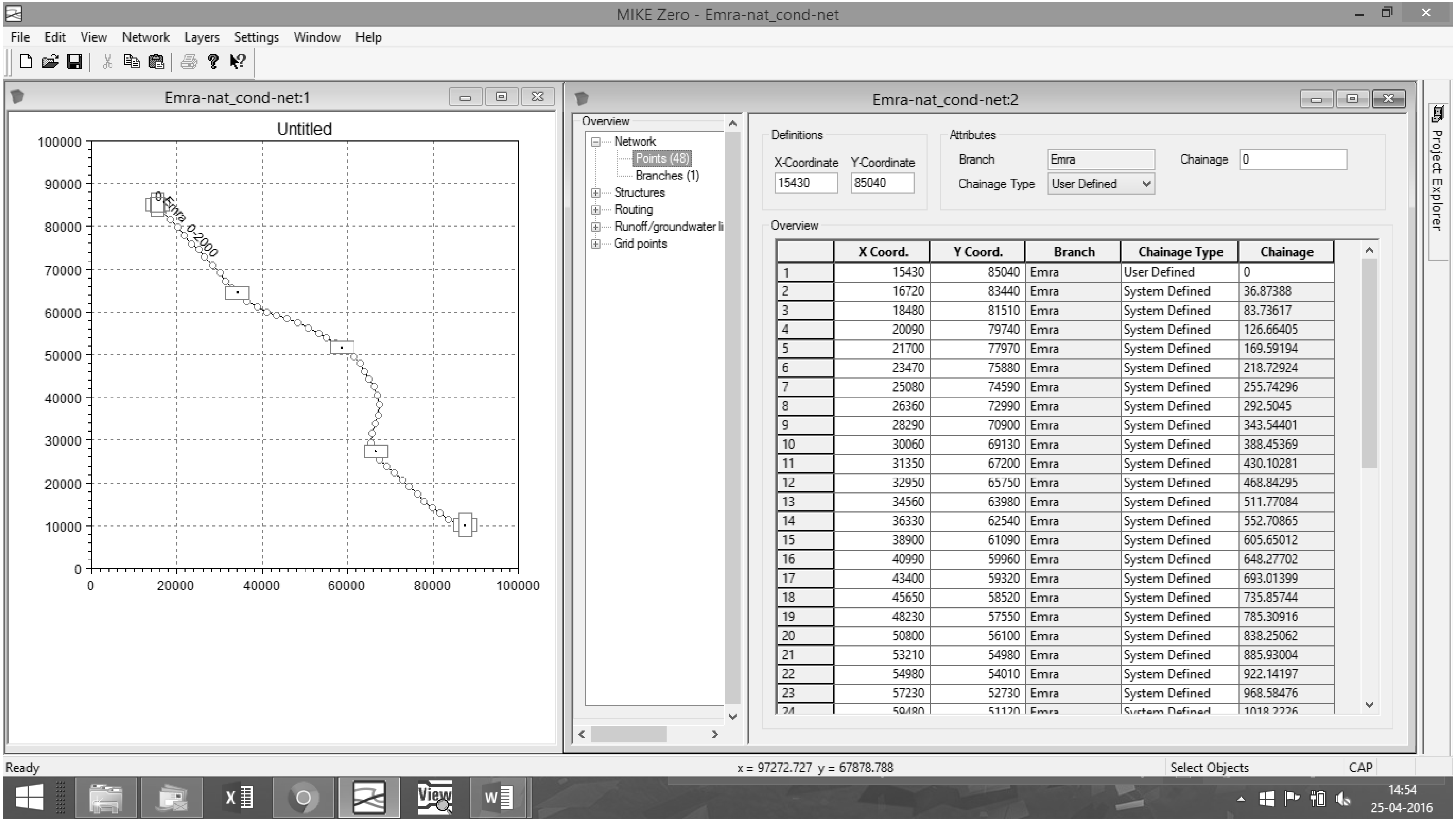


Figure 8.1: Location of various surveyed river cross sections in Dibang river basin (A typical MIKE 11 model set-up)

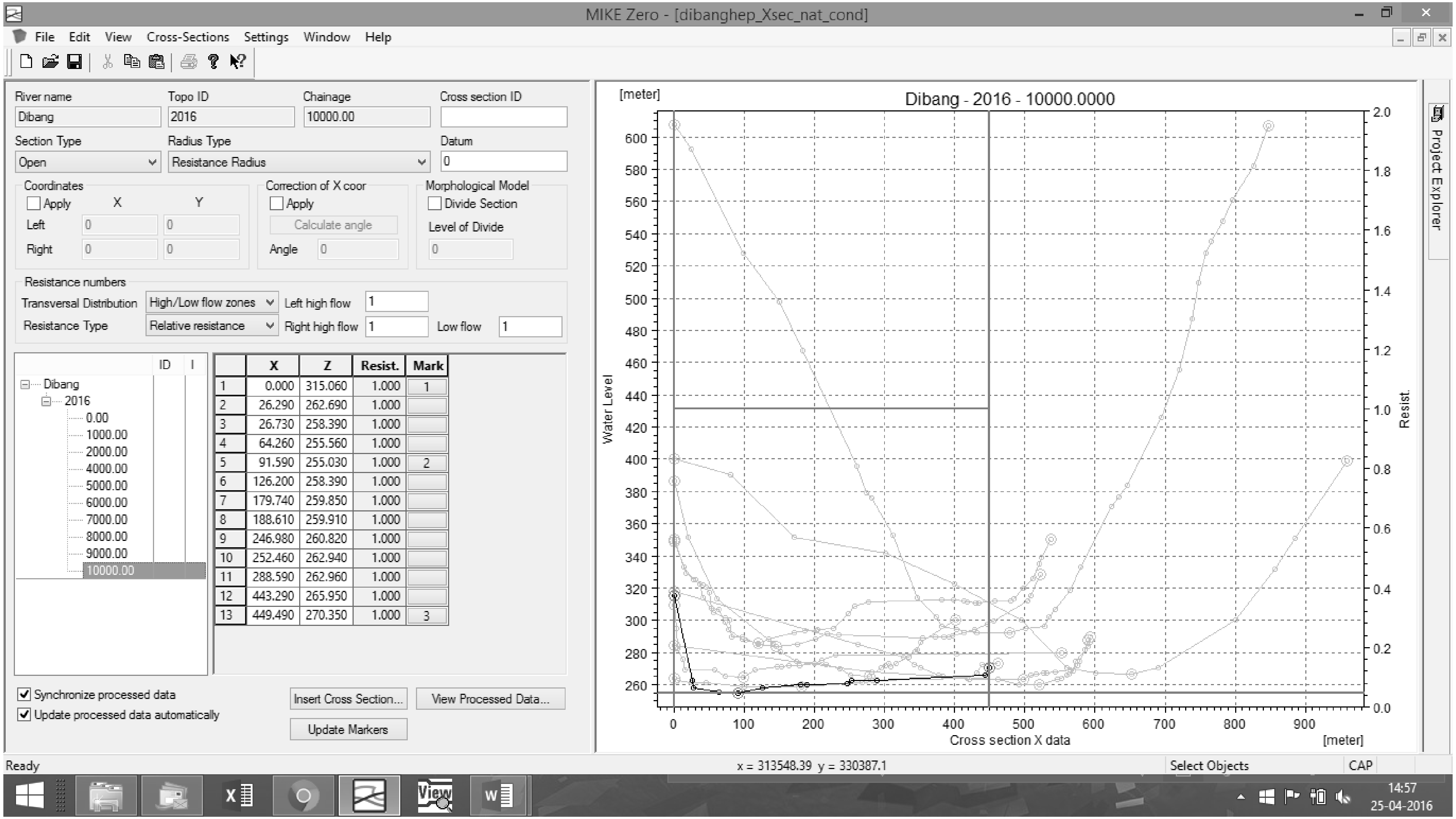


Figure 8.2: A typical view of surveyed river cross section considered for hydro-dynamic modeling (A typical MIKE 11 model set-up)

Table 8.8: Model Output for Different Release Scenarios for Etalin (Dri limb) HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (15.320 cumec)	80.273	1.895	13.935
	15% release (22.980 cumec)	95.000	2.116	15.240
	20% release (30.640 cumec)	108.182	2.298	16.395
	25% release (38.300 cumec)	119.727	2.452	17.377
	30% release (45.960 cumec)	130.636	2.588	18.294
	40% release (61.280 cumec)	149.636	2.837	19.907
	50% release (76.600 cumec)	149.636	2.837	19.907
	100% release (153.200 cumec)	235.636	3.820	27.261
Monsoon (June-Sept)	10% release (41.080 cumec)	128.182	2.555	18.063
	15% release (61.620 cumec)	153.545	2.889	20.223
	20% release (82.160 cumec)	176.000	3.163	22.135
	25% release (123.230 cumec)	196.455	3.394	23.848
	30% release (164.310 cumec)	214.636	3.592	25.385
	40% release (178.740 cumec)	245.455	3.921	28.145
	50% release (205.390 cumec)	271.182	4.165	30.621
	100% release (410.780 cumec)	363.182	4.973	38.723
Intermediate (April, May & Oct, Nov)	10% release (22.980 cumec)	96.545	2.140	15.384
	15% release (34.470 cumec)	115.364	2.395	17.004
	20% release (45.970 cumec)	131.727	2.605	18.394
	25% release (57.460 cumec)	146.182	2.795	19.608
	30% release (68.950 cumec)	159.636	2.963	20.739
	40% release (91.930 cumec)	184.182	3.254	22.807
	50% release (114.910 cumec)	205.818	3.496	24.651
	100% release (229.830 cumec)	283.364	4.278	31.849

Table 8.9: Model Output for Different Release Scenarios Etalin (Talo limb) HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (9.760 cumec)	64.217	1.978	17.929
	15% release (14.640 cumec)	73.304	2.148	18.571
	20% release (19.520 cumec)	80.739	2.284	19.057
	25% release (24.400 cumec)	87.826	2.407	19.497
	30% release (29.280 cumec)	94.565	2.518	19.915
	40% release (39.040 cumec)	106.565	2.717	20.693
	50% release (48.800 cumec)	117.696	2.891	21.372
	100% release (97.600 cumec)	161.783	3.554	23.842
Monsoon (June-Sept)	10% release (26.170 cumec)	108.217	2.741	20.576
	15% release (39.250 cumec)	122.696	2.971	21.523
	20% release (52.330 cumec)	135.565	3.167	22.300
	25% release (65.410 cumec)	147.304	3.344	22.982
	30% release (78.500 cumec)	158.261	3.502	23.584
	40% release (104.660 cumec)	178.043	3.777	24.637
	50% release (130.830 cumec)	195.870	4.017	25.611
	100% release (261.660 cumec)	267.261	4.900	29.373
Intermediate (April, May & Oct, Nov)	10% release (14.640 cumec)	79.696	2.267	18.912
	15% release (21.960 cumec)	90.304	2.450	19.580
	20% release (29.280 cumec)	99.957	2.608	20.196
	25% release (36.600 cumec)	108.826	2.751	20.769
	30% release (43.920 cumec)	116.957	2.882	21.290
	40% release (58.560 cumec)	131.870	3.113	22.178
	50% release (73.200 cumec)	145.217	3.314	22.931
	100% release (146.400 cumec)	199.261	4.062	25.840

Table 8.10: Model Output for Different Release Scenarios for Attunli HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (8.800 cumec)	59.607	1.644	7.037
	15% release (13.200 cumec)	70.039	1.834	8.173
	20% release (17.600 cumec)	79.396	1.996	9.191
	25% release (22.000 cumec)	87.896	2.137	10.117
	30% release (26.400 cumec)	95.546	2.261	10.979
	40% release (35.200 cumec)	108.164	2.458	12.582
	50% release (44.000 cumec)	119.057	2.622	13.922
	100% release (88.010 cumec)	163.385	3.264	17.611
Monsoon (June-Sept)	10% release (23.600 cumec)	104.360	2.390	13.490
	15% release (35.390 cumec)	119.275	2.617	14.086
	20% release (47.190 cumec)	132.296	2.809	15.680
	25% release (58.990 cumec)	144.057	2.977	17.076
	30% release (70.790 cumec)	154.207	3.118	18.183
	40% release (94.380 cumec)	172.546	3.366	20.179
	50% release (117.980 cumec)	188.704	3.577	21.936
	100% release (235.950 cumec)	256.104	4.418	26.874
Intermediate (April, May & Oct, Nov)	10% release (13.200 cumec)	75.857	1.931	8.852
	15% release (19.800 cumec)	88.771	2.148	10.249
	20% release (26.400 cumec)	99.614	2.323	11.550
	25% release (33.000 cumec)	108.746	2.464	12.702
	30% release (39.610 cumec)	117.000	2.589	13.709
	40% release (52.810 cumec)	131.707	2.805	15.520
	50% release (66.010 cumec)	144.85	2.992	17.105
	100% release (132.020 cumec)	196.748	3.700	20.443

Table 8.11: Model Output for Different Release Scenarios for Mihumdon HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (4.230 cumec)	26.638	0.979	10.033
	15% release (6.350 cumec)	33.188	1.124	12.548
	20% release (8.460 cumec)	39.500	1.244	14.738
	25% release (10.580 cumec)	43.813	1.346	16.521
	30% release (12.690 cumec)	48.038	1.436	17.901
	40% release (16.930 cumec)	55.863	1.594	20.432
	50% release (21.160 cumec)	62.913	1.730	22.722
	100% release (42.320 cumec)	91.950	2.243	32.224
Monsoon (June-Sept)	10% release (10.230 cumec)	43.050	1.331	16.283
	15% release (15.350 cumec)	53.063	1.538	19.521
	20% release (20.460 cumec)	61.763	1.708	22.356
	25% release (25.580 cumec)	69.663	1.856	24.929
	30% release (30.690 cumec)	76.913	1.988	27.301
	40% release (40.920 cumec)	90.238	2.215	31.661
	50% release (51.160 cumec)	102.313	2.411	35.618
	100% release (102.310 cumec)	142.275	3.023	45.214
Intermediate (April, May & Oct, Nov)	10% release (7.950 cumec)	37.550	1.216	14.230
	15% release (11.930 cumec)	46.563	1.405	17.415
	20% release (15.910 cumec)	54.425	1.558	19.848
	25% release (19.890 cumec)	60.850	1.691	22.055
	30% release (23.860 cumec)	67.088	1.809	24.090
	40% release (31.820 cumec)	78.462	2.015	27.803
	50% release (39.770 cumec)	88.813	2.191	31.194
	100% release (79.550 cumec)	127.900	2.805	42.040

Table 8.12: Model Output for Different Release Scenarios for Emini HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (11.730 cumec)	57.231	1.331	6.705
	15% release (17.050 cumec)	71.923	1.564	7.894
	20% release (22.730 cumec)	84.638	1.755	8.923
	25% release (28.410 cumec)	96.000	1.919	9.845
	30% release (34.100 cumec)	106.415	2.066	10.691
	40% release (45.460 cumec)	124.823	2.320	12.144
	50% release (56.830 cumec)	140.623	2.537	13.288
	100% release (113.660 cumec)	204.738	3.355	17.921
Monsoon (June-Sept)	10% release (27.480 cumec)	94.208	1.893	9.700
	15% release (41.220 cumec)	118.415	2.231	11.668
	20% release (54.960 cumec)	138.123	2.503	13.107
	25% release (68.700 cumec)	155.715	2.738	14.380
	30% release (82.440 cumec)	171.862	2.947	15.546
	40% release (109.920 cumec)	201.031	3.310	17.653
	50% release (137.400 cumec)	227.223	3.623	19.545
	100% release (274.800 cumec)	325.546	4.712	25.429
Intermediate (April, May & Oct, Nov)	10% release (21.370 cumec)	81.738	1.712	8.688
	15% release (32.050 cumec)	102.746	2.015	10.394
	20% release (42.730 cumec)	120.792	2.263	11.852
	25% release (53.420 cumec)	136.054	2.475	12.956
	30% release (64.100 cumec)	150.023	2.663	13.967
	40% release (85.470 cumec)	175.269	2.990	15.792
	50% release (106.830 cumec)	197.908	3.272	17.428
	100% release (213.660 cumec)	286.262	4.294	23.134

Table 8.13: Model Output for Different Release Scenarios for Amulin HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (9.510 cumec)	53.236	1.006	12.456
	15% release (14.260 cumec)	66.321	1.143	14.468
	20% release (19.020 cumec)	76.993	1.253	15.919
	25% release (23.770 cumec)	86.629	1.348	17.218
	30% release (28.520 cumec)	95.236	1.428	18.258
	40% release (38.030 cumec)	110.850	1.568	20.148
	50% release (47.540 cumec)	125.114	1.689	21.878
	100% release (95.080 cumec)	181.950	2.100	27.676
Monsoon (June-Sept)	10% release (22.990 cumec)	85.107	1.333	17.021
	15% release (34.480 cumec)	105.200	1.519	19.465
	20% release (45.980 cumec)	122.857	1.671	21.603
	25% release (57.470 cumec)	138.521	1.795	23.328
	30% release (68.960 cumec)	153.021	1.905	24.886
	40% release (91.950 cumec)	178.657	2.079	27.362
	50% release (114.940 cumec)	200.614	2.242	29.310
	100% release (229.880 cumec)	285.386	2.888	36.148
Intermediate (April, May & Oct, Nov)	10% release (17.870 cumec)	74.507	1.228	15.583
	15% release (26.810 cumec)	92.250	1.400	17.895
	20% release (35.750 cumec)	107.243	1.537	19.712
	25% release (44.680 cumec)	120.943	1.655	21.372
	30% release (53.620 cumec)	133.450	1.756	22.782
	40% release (71.500 cumec)	156.079	1.927	25.210
	50% release (89.370 cumec)	175.907	2.061	27.101
	100% release (178.740 cumec)	250.479	2.633	33.357

Table 8.14: Model Output for Different Release Scenarios Emra-I HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (7.410 cumec)	38.025	1.370	23.787
	15% release (11.120 cumec)	44.688	1.552	25.206
	20% release (14.830 cumec)	50.438	1.703	26.436
	25% release (18.530 cumec)	55.587	1.833	27.544
	30% release (22.240 cumec)	60.338	1.950	28.563
	40% release (29.650 cumec)	60.338	1.950	28.563
	50% release (37.060 cumec)	76.050	2.318	31.886
	100% release (74.130 cumec)	103.312	2.900	37.401
Monsoon (June-Sept)	10% release (19.580 cumec)	56.988	1.868	27.840
	15% release (29.370 cumec)	68.525	2.145	30.329
	20% release (39.160 cumec)	77.925	2.361	32.281
	25% release (48.950 cumec)	86.088	2.541	33.972
	30% release (58.740 cumec)	93.163	2.692	35.378
	40% release (78.320 cumec)	105.900	2.951	37.919
	50% release (97.900 cumec)	117.038	3.173	40.058
	100% release (195.800 cumec)	159.288	3.973	46.263
Intermediate (April, May & Oct, Nov)	10% release (10.970 cumec)	44.950	1.559	25.262
	15% release (16.460 cumec)	53.425	1.779	27.074
	20% release (21.950 cumec)	60.725	1.959	28.647
	25% release (27.430 cumec)	67.250	2.115	30.063
	30% release (32.920 cumec)	73.050	2.250	31.263
	40% release (43.890 cumec)	83.113	2.477	33.357
	50% release (54.870 cumec)	91.513	2.657	35.052
	100% release (109.730 cumec)	124.713	3.324	41.365

Table 8.15: Model Output for Different Release Scenarios Emra-II HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (7.620 cumec)	40.483	1.930	11.254
	15% release (11.430 cumec)	49.000	2.180	13.250
	20% release (15.240 cumec)	55.550	2.367	14.796
	25% release (19.050 cumec)	61.533	2.531	16.203
	30% release (22.860 cumec)	66.550	2.670	17.394
	40% release (30.480 cumec)	74.133	2.870	19.172
	50% release (38.100 cumec)	80.683	3.032	20.694
	100% release (76.210 cumec)	107.667	3.666	26.934
Monsoon (June-Sept)	10% release (20.130 cumec)	63.117	2.575	16.582
	15% release (30.200 cumec)	73.883	2.864	19.114
	20% release (40.260 cumec)	82.450	3.076	21.106
	25% release (50.330 cumec)	90.300	3.263	22.931
	30% release (60.390 cumec)	97.533	3.430	24.721
	40% release (80.520 cumec)	110.233	3.725	27.474
	50% release (100.650 cumec)	120.967	3.967	29.621
	100% release (201.310 cumec)	162.367	4.858	37.559
Intermediate (April, May & Oct, Nov)	10% release (11.280 cumec)	48.750	2.172	13.186
	15% release (16.920 cumec)	58.250	2.442	15.432
	20% release (22.560 cumec)	66.200	2.660	17.314
	25% release (28.200 cumec)	72.083	2.818	18.692
	30% release (33.850 cumec)	77.100	2.944	19.859
	40% release (45.130 cumec)	86.333	3.169	22.006
	50% release (56.410 cumec)	94.767	3.368	23.969
	100% release (112.820 cumec)	127.000	4.101	30.785

Table 8.16: Model Output for Different Release Scenarios for Ithun-I HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (3.510 cumec)	36.875	0.809	8.771
	15% release (5.270 cumec)	46.237	0.944	10.466
	20% release (7.020 cumec)	53.300	1.044	11.600
	25% release (8.780 cumec)	59.337	1.129	12.309
	30% release (10.530 cumec)	64.675	1.203	12.800
	40% release (14.040 cumec)	74.350	1.334	13.692
	50% release (17.550 cumec)	83.075	1.448	14.496
	100% release (35.110 cumec)	113.875	1.848	17.324
Monsoon (June-Sept)	10% release (9.410 cumec)	61.300	1.157	12.490
	15% release (14.110 cumec)	74.525	1.337	13.709
	20% release (18.820 cumec)	85.688	1.483	14.734
	25% release (23.520 cumec)	94.688	1.602	15.560
	30% release (28.220 cumec)	102.925	1.709	16.321
	40% release (37.630 cumec)	117.088	1.889	17.612
	50% release (47.040 cumec)	128.450	2.032	18.631
	100% release (94.080 cumec)	175.887	2.575	22.874
Intermediate (April, May & Oct, Nov)	10% release (5.260 cumec)	45.937	0.939	10.418
	15% release (7.900 cumec)	56.500	1.089	12.048
	20% release (10.530 cumec)	64.675	1.203	12.800
	25% release (13.160 cumec)	72.025	1.303	13.478
	30% release (15.790 cumec)	78.800	1.393	14.102
	40% release (21.050 cumec)	90.038	1.541	15.136
	50% release (26.320 cumec)	99.662	1.667	16.020
	100% release (52.630 cumec)	134.787	2.110	19.200

Table 8.17: Model Output for Different Release Scenarios for Ithun-II HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Dec-March)	10% release (2.690 cumec)	29.533	0.654	3.259
	15% release (4.030 cumec)	36.900	0.765	4.124
	20% release (5.370 cumec)	43.283	0.857	4.874
	25% release (6.710 cumec)	48.967	0.936	5.549
	30% release (8.060 cumec)	54.200	1.007	6.173
	40% release (10.740 cumec)	63.567	1.130	7.292
	50% release (13.430 cumec)	72.017	1.237	8.298
	100% release (26.860 cumec)	104.633	1.631	11.809
Monsoon (June-Sept)	10% release (7.200 cumec)	50.900	0.963	5.782
	15% release (10.800 cumec)	63.767	1.133	7.316
	20% release (14.400 cumec)	74.867	1.272	8.639
	25% release (18.000 cumec)	84.750	1.393	9.818
	30% release (21.600 cumec)	93.767	1.502	10.893
	40% release (28.800 cumec)	108.283	1.674	12.085
	50% release (36.000 cumec)	121.033	1.823	13.043
	100% release (72.010 cumec)	173.400	2.396	16.954
Intermediate (April, May & Oct, Nov)	10% release (4.030 cumec)	36.900	0.765	4.124
	15% release (6.050 cumec)	46.217	0.898	5.225
	20% release (8.060 cumec)	54.200	1.007	6.173
	25% release (10.080 cumec)	61.383	1.102	7.029
	30% release (12.090 cumec)	67.917	1.185	7.810
	40% release (16.120 cumec)	79.717	1.331	9.218
	50% release (20.150 cumec)	90.233	1.460	10.470
	100% release (40.300 cumec)	128.117	1.905	13.577

Table 8.18: Model Output for Different Release Scenarios for Sissiri HEP

Season	Release Scenario	Water depth (cm)	Flow Velocity (m/s)	Flow Width (m)
Lean (Nov-Feb)	10% release (1.93 cumec)	19.133	0.641	20.769
	15% release (2.90 cumec)	23.800	0.736	26.857
	20% release (3.87 cumec)	27.600	0.805	35.578
	25% release (4.83 cumec)	30.867	0.864	40.570
	30% release (5.80 cumec)	33.733	0.918	42.521
	40% release (7.73 cumec)	38.833	1.014	46.113
	50% release (9.67 cumec)	42.967	1.084	48.556
	100% release (19.33 cumec)	58.367	1.332	56.693
Monsoon (May-Aug)	10% release (4.85 cumec)	31.833	0.882	41.221
	15% release (7.28 cumec)	38.833	1.013	46.096
	20% release (9.71 cumec)	44.133	1.103	49.159
	25% release (12.14 cumec)	48.633	1.177	51.500
	30% release (14.56 cumec)	52.733	1.242	53.665
	40% release (19.42 cumec)	60.067	1.359	57.632
	50% release (24.27 cumec)	66.633	1.462	61.188
	100% release (48.55 cumec)	90.000	1.827	77.589
Intermediate (Mar, April & Sept, Oct)	10% release (3.17 cumec)	24.933	0.757	29.387
	15% release (4.75 cumec)	30.667	0.860	40.430
	20% release (6.33 cumec)	35.267	0.948	43.605
	25% release (7.91 cumec)	39.367	1.023	46.481
	30% release (9.50 cumec)	42.733	1.080	48.427
	40% release (12.66 cumec)	48.367	1.172	51.350
	50% release (15.83 cumec)	53.367	1.253	54.013
	100% release (31.65 cumec)	73.600	1.572	64.924

8.6 ENVIRONMENTAL FLOW ASSESSMENT

Environmental flows are flows that are to be released into a river system with the specific purpose of managing the modified river regime as close as possible to the natural state.

In Himalayan Rivers, annual discharges vary by orders of magnitude from year to year. Species that persist in such rivers generally survive, though not necessarily breed, during years when there is much less water than average. The presence of sequences of wet and dry years supports the suggestion that the biota can survive repeated years when the total annual discharge is less than the average, however, it may not remain unchanged in permanent drought conditions.

Studies in South African rivers (Weeks *et al.*, 1996) showed that major community shifts occur among the fish fauna during droughts, and also during normal low flow seasons. However, provided conditions do not drastically differ from those that have occurred in the past, recovery reflects in the short to medium term. Some studies have shown evidence that a lower than normal flow regime, which still incorporates all the major features of the natural regime, would not permanently change the biota of the river. It is therefore suggested that, other things such as catchment condition being equal, a carefully designed modified flow regime which maintains the ecologically important components of the natural flow regime should be able to maintain a river's natural biota.

Therefore, for assessment of environmental flow focus should be on the characteristic features of the natural flow regime of the river. The most important of these are degree of perenniality; magnitude of base flows in the dry and wet season; magnitude, timing and duration of floods in the wet season; and small pulses of higher flow, that occur between dry and wet months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired future condition of the river, and thus should not be eradicated during development of the river's water resources.

Fish assemblages often include a range of species and reflect the integrated effects of environmental changes. Their presence is used to infer the presence of other aquatic organisms, since the adult fish occupy the top of the food chain in most aquatic systems. They also pass through most trophic levels above the primary producer stage during their development from larvae to adults. Fish can thus be regarded as reflecting the integrated environmental health of a river (Karr *et al.,* 1986). Fish species in river can guide to prepare specification of the flows necessary to meet their needs, and be useful in the monitoring and management of those flows. It is often surmised that if management of flows for fish maintenance is successful, then flow requirements for aquatic invertebrates will also be satisfied. This is because of the larger scale of fish habitat.

Therefore, the approach adopted for environmental flow assessment is based on the meeting the needs of dominant fish species with larger habitat requirement. Baseline data on fish fauna in Dibang basin is discussed in **Chapter – 7, Section 7.2.6**, where entire Dibang basin can be divided in two predominant fish zones viz. Mahseer Zone and Trout Zone. Mahseer being a large fish requires more flow in all the seasons and this aspect has been kept in mind while recommending environmental flow for projects in Mahseer zone.

Mahseer zone covers the main Dibang river below confluence of Dri and Talo (Tangon) rivers Projects fall in Mahseer zone are Dibang, Ashupani, Ithun – I, Ithun – II, Ithipani, Elango, Emra – I & Emra – II HEPs. Rest of the basin where remaining HEPs are located falls in trout zone. Therefore, environmental flow assessment should be based on meeting its habitat requirement in lean, monsoon and pre/post monsoon period.

A minimum depth requirement of 40 cm and 50 cm is considered for trout and mahseer zones respectively to assess the environmental flow requirement in lean season. Higher depth is considered for intermediate period and monsoon period to ensure mimicking of natural discharge pattern. For intermediate period in Mahseer zone, a depth range of 60-75 cm is considered and for monsoon season a depth range of 85-100 cm is considered. Similarly, for intermediate period in trout zone, a depth range of 55-65 cm is considered and for monsoon season in trout zone, a depth range of 70-80 cm is considered as minimum requirement.

As the depth is calculated at the deepest point and cannot be the only criteria for the habitat requirement; a second level assessment is done to check the reduction in river top width. If the reduction in top width is more than 50%, then next higher percentage is recommended to ensure that reduction in top width is not reduced more than half the original width under natural discharge condition in different seasons/period.

Keeping in view the EAC/MoEF&CC's requirement of minimum release in lean season as 20% of average discharge in four leanest months in 90% dependable year of discharge series, the same has been considered as the minimum for lean season. Even if the modeling results show that the lesser value can meet the habitat requirement in any period/season, 20% of the average discharge in four leanest months has been kept as the minimum value.

For projects such as Dibang Valley and Sissiri HEPs which have dam toe powerhouses and intermediate river stretch is very small, continuous running of at least one turbine has been found a better way to ensure that river does not run dry and environmental flow requirements are adequately met with.

Based on the above criteria, environmental flow requirements have been established for each project separately and final recommendations are discussed below.

8.6.1 Project Specific Recommendation for Environmental flow

Dibang Multipurpose Project

As can be seen from modeling output for Dibang Multipurpose Project (**Table 8.7**), 10% of release in lean, monsoon and intermediate period is giving a depth of 108.52 cm, 179.15 cm and 133.82 cm respectively and these are adequately meeting the habitat requirement. Reduction in river top width is also checked and is less than 50% in all the seasons for 10% release scenario. Further, keeping in view, MoEF&CC/EAC requirement, 20% of average discharge in four leanest months in 90% dependable year is considered as the minimum release. This works out to be a release of 108.75 cumec in lean, 145.78 cumec in monsoon and 108.75 cumec in intermediate period.

Dibang Multipurpose Project has already been granted environment clearance (EC) as well as forest clearance (FC). MoEF&CC has recommended that minimum environmental flow of 20 cumec shall be maintained throughout the year through an un-gated opening. Moreover, at least one turbine out of 12 turbines shall be operated 24 hours in full/part load throughout the year, which shall provide the sufficient discharge downstream of TRT outlet with adequate depth and velocity of water for sustenance of aquatic life in the downstream.

Design discharge to run one turbine at full load is 119.5 cumec, this along with 20 cumec of un-gated release works out to be 139.5 cumec; which is more than what is worked out based on habitat simulation modeling for lean and intermediate period. During monsoon, more than one turbine will be running all the time and hence adequate discharge will be available in the river.

Therefore, EC condition should prevail and same is kept as environmental flow recommendation for Dibang Multipurpose Project.

Etalin HEP

It can be seen from modeling output for Etalin HEP –Dri Limb (**Table 8.8**), 10% of release in lean, monsoon and intermediate period is resulting in a depth of 80.27 cm, 128.20 cm and 96.5 cm, respectively and these are adequately meeting the aquatic habitat requirement. River width reduction is more than 50% in monsoon, therefore slightly higher value (12.5%) needs to be recommended for monsoon. Further, keeping in view, MoEF&CC/EAC requirement, 20% of average discharge in four leanest months in 90% dependable year is considered as the minimum release. This works out to be a release of 30.64 cumec in lean, 50 cumec in monsoon and 30.64 cumec in intermediate period.

Similarly modeling output for Etalin HEP –Talo (Tangon) Limb (**Table 8.9**) show, 10% of release in lean, monsoon and intermediate period is giving a depth of 64.21 cm, 108.21 cm and 79.69 cm, respectively and these are adequately meeting the habitat requirement in terms of depth as well as width. Further, keeping in view, MoEF&CC/EAC requirement, 20% of average discharge in four leanest months in 90% dependable year is considered as the minimum release. This works out to be a release of 19.52 cumec in lean, 26.17 cumec in monsoon and 19.52 cumec in intermediate period.

Etalin HEP has already been considered for appraisal, however, EAC's final recommendation on environment clearance is pending till completion of Dibang Basin study. Environmental flow study for Etalin HEP has been carried out by CIFRI, Barrackpore and season-wise recommendations have been made for Dri and Talo limbs separately. The matter was discussed in 82nd EAC meeting held during February 2015, where it is recommended ***"Project proponent must follow the recommendations of CIFRI on minimum environmental flow & also obtain approval of CEA for any increase in IC from the two dam toe powerhouses"***. Minutes of 82nd EAC meeting also mentioned in detail CIFRI's recommendations to be adopted by Etalin HEP for environmental flow:

For Dri Limb

a) Release of 30 cumec (19.6%) from the powerhouse during the lean season (December to March).
b) During the monsoon season (June-September) the flow regime exhibits high flows up to 1400 cumec with several daily spikes which ensure not only base flow but also high pulses occurring in the monsoon. In monsoon (June to September), even 41.08 cumec (10%) will meet the habitat requirement in terms of depth. This gives an average depth of 1.3 m. However, to provide adequate river width during monsoon, a higher flow of 50 cumec (12.2%) is recommended.
c) During the non-monsoon – non-lean period (April-May & October-November – Intermediate period), a discharge of 35 cumec (15.2%) is recommended to be released.

For Talo Limb

a) Release of flow at 20 cumec (20.5%) from the powerhouse during the lean season (December-March)
b) During the monsoon season (June-September), the flow regime exhibits high flows up to 800 cumec with several daily spikes which ensure not only base flow but also high flood pulses in monsoon, 38 cumec discharge would meet the habitat requirement in terms of depth and velocity. This gives an average depth of 1.08 m as against the minimum requirement of 1 m. As such, a discharge of 38 cumec (14.5%) is recommended.
c) During non-monsoon–non-lean period (April-May and October-November), discharge of 27 cumec (18.4%) is recommended to be released.

CIFRI's recommendations for Etalin HEP are almost similar for Dri limb to those of worked by simulation modeling in the present study; however, they are higher for Talo limb. It is also noted that there is discrepancy in the recommendation made by CIFRI for Talo limb in terms of water depth recommended in monsoon as 1.08 m and corresponding flow value as 38 cumec; which should be 26.17 cumec.

Keeping this in view, we recommend the environmental flow release for Etalin HEP as has been assessed based on the modeling study, i.e.

	Dri (cumec)	Talo (cumec)
Lean Season	30.64	19.52
Monsoon Season	50.00	26.17
Intermediate Period	30.64	19.52

Attunli HEP

It can be seen from modeling output for Attunli HEP (**Table 8.10**) that 10% of release in lean, monsoon and intermediate period will provide adequate depth i.e. 59.60 cm, 104.36 cm and 75.85 cm, respectively. However, keeping in view, MoEF&CC/EAC requirement of 20% of average discharge in four leanest months in 90% dependable year as the minimum release and also reduction in width should not be more than 50% of the natural river depth in respective season/period; 20%, 10% and 15% release is recommended for lean, monsoon and intermediate period i.e. a discharge of 17.60 cumec in lean, 23.60 cumec in monsoon and 19.80 cumec in intermediate period.

Mihumdon HEP

Modeling output for Mihumdon HEP is given in **Table 8.11**. Keeping in view the minimum depth requirement, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 20%, 25% and 20% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 8.46 cumec in lean, 25.58 cumec in monsoon and 15.91 cumec in intermediate period.

Amulin HEP

Modeling output for Amulin HEP is given in **Table 8.12**. Keeping in view the minimum depth requirement, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 20%, 15% and 15% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 19.02 cumec in lean, 34.48 cumec in monsoon and 26.81 cumec in intermediate period.

Emini HEP

Modeling output for Emini HEP is given in **Table 8.13**. Keeping in view the minimum depth requirement, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 20%, 20% and 20% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 22.73 cumec in lean, 54.96 cumec in monsoon and 42.73 cumec in intermediate period.

Emra I HEP

Modeling output for Emra I HEP is given in **Table 8.14**. Keeping in view the minimum depth requirement for Mahseer Zone, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 20%, 25% and 20% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 14.83 cumec in lean, 48.95 cumec in monsoon and 21.95 cumec in intermediate period.

Emra II HEP

Modeling output for Emra II HEP is given in **Table 8.15**. Keeping in view the minimum depth requirement for Mahseer Zone, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 20%, 25% and 20% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 15.24 cumec in lean, 50.33 cumec in monsoon and 22.56 cumec in intermediate period.

Ithun I HEP

Modeling output for Ithun I HEP is given in **Table 8.16**. Keeping in view the minimum depth requirement for Mahseer Zone, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 20%, 20% and 20% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 7.02 cumec in lean, 18.82 cumec in monsoon and 10.53 cumec in intermediate period.

Ithun II HEP

Modeling output for Ithun II HEP is given in **Table 8.17**. Keeping in view the minimum depth requirement for Mahseer Zone, reduction in river width requirement and ensuring that a minimum of 20% of average discharge in lean season is released; a 25%, 25% and 25% release is recommended for lean, monsoon and intermediate period/season. These works out to be a minimum release of 6.7 cumec in lean, 18.80 cumec in monsoon and 10.08 cumec in intermediate period.

Sissiri HEP

Modeling output for Sissiri HEP is given in **Table 8.18**. The project is envisaged with dam toe powerhouse and affected intermediate stretch will be about 500 m. Modeling results show that almost 75% of the lean season discharge may need to be released to meet the habitat requirement of 50 cm depth. Similarly in monsoon, 100% of release will give only 90 cm of the depth. Therefore, Sissiri HEP environmental flow cannot be recommended based on the modeling study using the present discharge series.

Therefore, CWC approved discharge series and power potential study as approved by CEA were reviewed before making environmental flow recommendation for Sissiri HEP. Average monsoon discharge in 90% dependable year is only 48.54 cumec whereas project is designed to draw 102 cumec at full load and therefore, it is achieving only 25% PLF in 90% dependable year. Further project is designed for peaking power generation – for 5.4 hours in lean season; 5.4 hours to 11 hours in intermediate months and 7.9 to 24 hours (only for one 10 daily) in monsoon season. Environmental flow provision is 1.5 cumec throughout the year, which is 8% of lean season average, 5% of intermediate average and 3% of monsoon months' average based on 90% DY discharge.

It is recommended that environmental flow release should be 20% of average discharge of four leanest months (3.87 cumec) in 90% dependable year and it should be released at all the time through un-gated opening and one turbine should be operational at full/partial load throughout the year.

Modelling Output and Recommendations

Except for four projects, final recommendations made are based on the modelling output only. Comparison of modelling output and final recommendations along with justification of recommendation with respect to four projects are given below.

<table>
<tr><th rowspan="3">Project</th><th rowspan="3">Capacity (MW)</th><th colspan="6">EFR (as % of average values of corresponding season/period in 90% DY)</th><th rowspan="2">Remarks</th></tr>
<tr><th colspan="3">EFR (as per Modeling Study Output)</th><th colspan="3">EFR (Recommended)</th></tr>
<tr><th>Lean</th><th>Monsoon</th><th>Inter-mediate</th><th>Lean</th><th>Monsoon</th><th>Inter-mediate</th><th></th></tr>
<tr><td>Dibang Multipurpose</td><td>2880</td><td>10</td><td>10</td><td>10</td><td colspan="3">20 cumec throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year</td><td>EAC recommendation during EC is retained</td></tr>
<tr><td>Etalin (Dri Limb)</td><td>3097</td><td>10</td><td>12.2</td><td>10</td><td>20</td><td>12.2</td><td>13.3</td><td>Intermediate Season discharge is enhanced to ensure minimum 20% of lean season is maintained at all the times</td></tr>
<tr><td>Etalin (Talo Limb)</td><td>3097</td><td>10</td><td>10</td><td>10</td><td>20</td><td>10</td><td>13.3</td><td>Minimum 20% is recommended in lean season in line with EAC/MoEF&CC requirement</td></tr>
<tr><td>Sissiri</td><td>100</td><td>75</td><td>100</td><td>100</td><td colspan="3">20% of average discharge of four leanest months (3.87 cumec) in 90% DY throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year</td><td>Recommendation has been made in line with recommendation for Dibang</td></tr>
</table>

8.6.2 Summary of Environmental flow Release Recommendations

Based on the above analysis and discussion, environmental flow release recommendations have been summarised at **Table 8.19**.

There are four projects, which are yet to be allotted viz. Malinye, Agoline, Etabue and Elango and due to non-availability of data environmental flow simulation modeling could not be carried. In addition, for Ithipani HEP also, simulation modeling could not be carried out due to non-availability of data. For these five projects viz., Malinye, Agoline, Etabue, Elango and Ithipani; environmental flow release recommendations have been kept as the standard requirement set in the TOR issued to all the hydropower projects i.e. 20% in lean season, 30% in monsoon season and 25% in intermediate period. Once the project development process will start and required site specific data is available, simulation modeling exercise can be carried out and more specific recommendations can be made.

Table 8.19: Summary of Environmental flow Release Recommendations

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Intermediate River Length* (km)	EFR (as % of average values of corresponding season/period in 90% DY)			EFR (Minimum Absolute Values in cumec)		
						Lean	Monsoon	Intermediate	Lean	Monsoon	Intermediate
1	Dibang Multipurpose	2880	Dibang	Dibang	1.20	20 cumec throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year					
2	Etalin (Dri Limb)	3097	Dri	Dri	16.50	20.00	12.20	13.30	30.64	50.00	30.64
3	Etalin (Talo Limb)		Talo	Talo	18.00	20.00	10.00	13.30	19.52	26.17	19.52
4	Attunli	680	Talo	Talo	10.68	20.00	10.00	15.00	17.60	23.60	19.80
5	Malinye#	335	Talo	Talo	-	20.00	30.00	25.00	-	-	-
6	Agoline#	375	Dri	Dri	9.38	20.00	30.00	25.00	-	-	-
7	Etabue#	165	Ange Pani	Dri	3.10 **	20.00	30.00	25.00	-	-	-
8	Mihumdon	400	Dri	Dri	9.39	20.00	25.00	20.00	8.46	25.58	15.91
9	Emini	500	Mathun	Dri	6.43	20.00	20.00	20.00	22.73	54.96	42.73
10	Amulin	420	Mathun	Dri	8.62	20.00	15.00	15.00	19.02	34.48	26.81
11	Emra I	275	Emra	Dibang	6.12	20.00	25.00	20.00	14.83	48.95	21.95
12	Emra II	390	Emra	Dibang	1.30 ***	20.00	25.00	20.00	15.24	50.33	22.56
13	Elango#	150	Ahi	Dibang	-	20.00	30.00	25.00	-	-	-
14	Ithun I	84	Ithun	Dibang	6.35	20.00	20.00	20.00	7.02	18.82	10.53
15	Ithun II	48	Ithun	Dibang	4.47	25.00	25.00	25.00	6.70	18.00	10.08
16	Ashupani#	30	Ashu Pani	Dibang	11.10 **	20.00	30.00	25.00	-	-	-
17	Sissiri	100	Sissiri	Dibang	0.50	20% of average discharge of four leanest months (3.87 cumec) in 90% DY throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year					

* Intermediate River length is the distance along the river between diversion site and tail water discharge point i.e. the river reach, which will be deprived of flow due to diversion of water to HRT. Adequate environmental flow will ensure that river in this reach should have sufficient water throughout the year.

** Intermediate river length is distance along the river from diversion site up to tributary's confluence with main river.

*** Intermediate river length is distance along the river from diversion site up to reservoir tail of downstream project.

Simulation Modeling could not be carried out due to non-availability of data, EFR is recommended based on Standard TOR of MoEF&CC for Hydropower projects.

CHAPTER-9
DOWNSTREAM IMPACTS DUE TO HYDRO DEVELOPMENT

9.1 INTRODUCTION

There are 18 HE projects proposed in Dibang basin. Most of the projects are in different stages of planning and development. During the monsoon period there will be significant discharge in Brahmaputra river. The peaking discharges of these hydroelectric projects which are quite less in comparison to Brahmaputra discharge will hardly have any impact on Brahmaputra. Some impact in form of flow regulation can be expected during the lean season peaking from these projects. Most of the projects are likely to be operated at MDDL during monsoon period and at FRL during the lean season. Further during the lean season the peaking discharge release of the projects in upper reaches of Dibang basin will be utilized by the project at lower reaches of the basin and net peaking discharge from the lower most project of the basin in general will be the governing one for any impact study.

In Dibang basin, Dibang Multipurpose Project is the lowermost storage project on main river. The peaking discharge of Dibang Multipurpose Project is about 1441 cumec for lean season peaking of 6.5 hours. Accordingly the downstream impact study has been carried out for the condition taking releases from power plant considering 6.5 hours peaking distributed in morning and evening and discharge varying from 111 cumec to 1441 cumec including environmental releases from dam.

9.2 APPROACH ADOPTED

For the downstream impact study the typical half hourly Lean season releases during 24 hour from Dibang Multipurpose Project has been estimated and the same is given in **Table 9.1**.

Table 9.1: Lean season release and peaking discharge

Time (hr)	Lean season releases from Dibang Multipurpose Project (cumec)	Time (hr)	Lean season releases from Dibang Multipurpose Project (cumec)
0	111	12	111
0.5	111	12.5	111
1	111	13	111
1.5	111	13.5	111
2	111	14	111
2.5	111	14.5	111
3	111	15	111
3.5	111	15.5	111
4	111	16	1441
4.5	1441	16.5	1441
5	1441	17	1441
5.5	1441	17.5	1441
6	1441	18	1441
6.5	1441	18.5	1441
7	1441	19	1441
7.5	111	19.5	111
8	111	20	111
8.5	111	20.5	111
9	111	21	111
9.5	111	21.5	111
10	111	22	111
10.5	111	22.5	111
11	111	23	111
11.5	111	23.5	111

For the above estimated release, the study has been carried out for the above scenario and for natural condition of river (without considering Dibang Multipurpose Project).

9.3 MIKE11 MODEL

MIKE11 is an integrated system of software, designed for interactive use in a multi-tasking environment. The core of the MIKE 11 system consists of the HD (hydrodynamic) module, which is capable of simulating steady, quasi-unsteady and unsteady flows in a network of open channels. The results of a HD simulation consist of time series of water level and discharge. MIKE 11 hydrodynamic module is an implicit, finite difference model for unsteady flow computations. The model can describe sub-critical as well as supercritical flow conditions through a numerical description, which is altered according to the local flow conditions in time and space. Advanced computational modules are included for description of flow over hydraulic structures, including possibilities to describe structure operation. The formulations can be applied for looped networks and quasi two-dimensional flow simulation on flood plains. The computational scheme is applicable for vertically homogeneous flow conditions extending from steep river flows to tidal influenced tributaries.

The following three approaches simulate the flow in branches as well as looped systems.

i) **Kinematic wave approach**: The flow is calculated from the assumption of balance between the friction and gravity forces. The simplification implies that the Kinematic wave approach can not simulate backwater effects.
ii) **Diffusive wave approach**: In addition to the friction and gravity forces, the hydrostatic gradient is included in this description. This allows the user to take downstream boundaries into account, and thus, simulate backwater effects.
iii) **Dynamic wave approach**: Using the full momentum equation, including acceleration forces, the user is able to simulate fast transients, tidal flows, etc., in the system.

Depending on the type of problem, the appropriate description can be chosen. The dynamic and diffusive wave descriptions differ from kinematic wave description by being capable of calculating backwater effects. For the present case, dynamic wave approach has been adopted to have a better simulation of attenuation and translation pattern of flood wave.

The basic theory for dynamic routing in one dimensional analysis consists of two partial differential equations of open channel flow originally derived by Barre De Saint Venant in 1871. The equations are:

i. **Conservation of mass (continuity) equation**

$(\partial Q/\partial X) + \partial(A + A_0) / \partial t - q = 0$

ii. **Conservation of momentum equation**

$(\partial Q/\partial t) + \{ \partial(Q^2/A)/\partial X \} + g A ((\partial h/\partial X) + S_f + S_c) = 0$

where Q = discharge;
A = active flow area;
A_0 = inactive storage area;
h = water surface elevation;
q= lateral outflow;
x = distance along waterway;
t = time;
S_f = friction slope;
S_c = expansion contraction slope and
g = gravitational acceleration.

The boundary conditions in MIKE 11 are distinguished between external and internal boundary conditions. Internal boundary conditions are (i) links at nodal points, (ii) structures and (iii) internal inflows etc. External boundary conditions may consist of (i) constant values for **h** or **Q**,

(ii) time varying values for **h** or **Q**, and (iii) relation between **h** and **Q**.
Generally, model boundaries should be chosen at points, where either water level or discharge measurements are available so that the model is used for predictive purposes. It is important that the selected boundary locations lie outside the range of influences of any anticipated changes in the hydraulic system.

9.4 MIKE11 MODEL SET UP FOR IMPACT STUDY

For present study, Dibang river from Dibang Multipurpose Project up to Pandu for a reach length of about 512 km has been represented in MIKE11 model through surveyed cross sections which are at various different intervals. The Manning's roughness coefficient for the study river reach from Dibang Multipurpose Project and up to the Dibang - Lohit confluence has been adopted as 0.035. From this point onward and up to Guwahati the Manning's roughness coefficient has been adopted as 0.030 considering the alluvial bed of river. For the case impact study with Dibang Multipurpose Project peaking, the upstream boundary of model set up which is the discharge series as per **Table 9.2** repeated for 60 continuous days, has been applied at Dibang Multipurpose Project location. The normal depth has been assumed as downstream boundary and the same applied at the lower most cross section of the MIKE11 model set up located about 512 km downstream of Dibang Multipurpose Project i.e. at river cross section near Guwahati. Dibang River cross-sections from Dibang HE Project dam site up to its confluence with Lohit river were provided NHPC and beyond this point after becoming Brahmaputra river up to Guwahati, cross-sections were provided by CWC. Average Lean season flow of Dibang river for the months November to April is about 477 cumec at Dibang Multipurpose Project site where the catchment area of is about 11276 sq km. The same at Pandu G&D site (Guwahati) with catchment area of about 417100 sq km is about 5377 cumec. The flow of Dibang/Brahmaputra river between Dibang Multipurpose Project and Pandu G&D site (Guwahati) has been distributed for natural condition of river and for the post Dibang Multipurpose Project scenario using the catchment area proportioning. The distributed flow impinged as lateral inflow at different locations of MIKE11 model set up is given below in **Table 9.2**.

Table 9.2: Distributed average Lean season flow of river Dibang/Brahmaputra

Location	Catchment area (sq km)	Distributed flow for natural condition of river (cumec)	Distributed flow for post Dibang Multipurpose Project scenario (cumec)
1	2	3	4
Dibang Multipurpose Project location	11276	477	Peaking release and Environmental flow
At chainage 45 km (Near Assam border above Dibang-Lohit confluence)	13933	590	113
At Dibru- Saikhowa National Park (78 km d/s of Dibang Multipurpose Project; below confluence of Dibang River and Lohit River	41445	1180	590
At Dibru- Saikhowa National Park (108 km d/s of Dibang Multipurpose Project; below confluence of Siang, Dibang and Lohit)	293164	2600	2123
Dibrugarh	301730	2641	2164
Jorhat	314825	2951	2474
Tezpur	379088	4475	3998
Pandu (Guwahati)	417100	5377	4900

In the above distribution for post Dibang Multipurpose Project scenario only flow of 4900 cumec which is (5377-477) cumec has been assumed to be available in the river reach between Dibang Multipurpose Project and Pandu (Guwahati) apart from the peaking release and environmental flow release from Dibang Multipurpose Project. Accordingly the flow of 4900 cumec only has been distributed for impingement at different locations of Brahmaputra river between Dibang Multipurpose Project and Pandu (Guwahati) during the hydrodynamic simulations in post Dibang Multipurpose Project scenario.

With the above model set up and lateral inflow as per flow distribution of **Table 9.2**, the necessary hydro dynamic simulation has been carried out to get the net discharge and water level series at different locations of Study reach. The MIKE11 model set up for impact study is given in **Figure 9.1**.

Dibang - Brahmaputra 0-512000 denotes the Dibang/Brahmaputra river reach from Dibang Multipurpose Project up to Guwahati. The first cross section of this river reach is at chainage 0 m and last cross section is at chainage 512000 m.

The chainage of some of the important locations from Dibang Multipurpose Project as per MIKE11 model set up where discharge pattern and water level has been estimated are as follows:

- At chainage 45 km near Assam border above Dibang - Lohit confluence
- At chainage 61 km just before Dibang - Lohit confluence
- Dibru Saikhowa National Park – 78 km & 108 km
- Dibrugarh – 130 km
- Bokaghat (near Kaziranga National Park) –297 km
- Tezpur – 383.5 km
- Guwahati – 490.5 km

9.5 FLOW SIMULATION RESULTS IN NATURAL CONDITION OF RIVER

In order to assess the change in water level at different locations of river reach due to peaking release from Dibang hydroelectric project in Dibang basin it is essential to estimate the water level at these locations for the average lean season discharge corresponding to natural condition of river. In the natural condition of river, the water levels at different locations of the study reach for the discharge as per column 3 of **Table 9.2**, as obtained from MIKE11 simulation are given in **Table 9.3**.

Table 9.3: Water level at salient locations in natural condition of Dibang river for average Lean season discharge

Place	Chainage from Dibang Multipurpose Project (km)	Average non-monsoon discharge (cumec)	Bed level of river (m)	Simulated water level (m)
At chainage 45 km (Near Assam border above Dibang-Lohit confluence)	45	477	135.25	136.506
At chainage 61 km (Just above Dibang-Lohit confluence)	61	590	111.41	119.160
At Dibru- Saikhowa National Park (78 km d/s of Dibang Multipurpose Project; just below confluence of Dibang River and Lohit River	78	1180	111.36	119.094
At Dibru- Saikhowa National Park (108 km d/s of Dibang Multipurpose Project; below confluence of Siang, Dibang and Lohit)	108	2600	103.543	107.242
Dibrugarh	130	2641	92.375	96.002
Bokaghat-Kaziranga	297	2951	86.570	93.190
Tezpur	383.5	4475	67.212	73.518
Guwahati	490.5	5377	30.96	41.529

9.6 FLOW SIMULATION RESULTS FOR PEAKING RELEASE FROM DIBANG MULTIPURPOSE PROJECT

The peaking discharge of Dibang Multipurpose Project is about 1441 cumec for lean season peaking of 6.5 hours. Accordingly, the simulation study has been carried out for the condition taking releases from power plant considering 6.5 hours peaking distributed in morning and evening and discharge varying from 111 cumec to 1441 cumec including environmental releases from dam.

Apart from that the distributed flow has also been impinged at different locations of study reach as per column 4 of **Table 9.2**. The stabilized flow pattern and water level at salient locations as obtained are described in subsequent paragraphs.

9.6.1 Flow simulation results at 45 downstream of Dibang Multipurpose Project (before Lohit confluence; near Assam border) for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Project and resulting stabilized discharge/water level series in Dibang river at about 45 km downstream (before its confluence with Lohit River and near Assam border) as obtained from MIKE11 simulation is shown in **Figure 9.2**.The dates given on X-axis of the plots are the arbitrary dates used for hydro dynamic simulation.

For 24 hour duration, release from Dibang Multipurpose Project and resulting discharge/water level series at 45 km downstream of Dibang Multipurpose Project near Assam border before Dibang river's confluence with Lohit river is given in **Table 9.4**.

From **Table 9.4**, it can be seen that the simulated discharge series at chainage 45 km varies from 170.73 cumec to 1338.39 cumec, while fluctuation in daily water level series is from EL 136.131 m to 136.993 m. The average Lean season discharge and corresponding water level at chainage 45 km in natural condition of river as obtained by MIKE11 simulation is about 477 cumec and 136.506 m, respectively.

Table 9.4: Release from Dibang Multipurpose Project and resulting discharge/water level series at chainage 45 km near Assam border before confluence of Dibang and Lohit Rivers

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series at chainage 45 km	Stabilized water level series at chainage 45 km with river bed level at EL 135.25 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
0	111.00	170.73	136.131	136.506
0.5	111.00	174.39	136.136	
1	111.00	217.67	136.192	
1.5	111.00	419.30	136.415	
2	111.00	798.27	136.706	
2.5	111.00	1095.91	136.870	
3	111.00	1234.56	136.941	
3.5	111.00	1221.64	136.937	
4	111.00	1098.45	136.875	
4.5	1441.00	937.59	136.785	
5	1441.00	772.15	136.681	
5.5	1441.00	630.83	136.582	
6	1441.00	512.84	136.488	
6.5	1441.00	424.63	136.410	
7	1441.00	354.18	136.343	
7.5	111.00	303.27	136.289	

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series at chainage 45 km	Stabilized water level series at chainage 45 km with river bed level at EL 135.25 m	Water level corresponding to Average lean season flow
8	111.00	261.93	136.243	
8.5	111.00	233.66	136.210	
9	111.00	214.09	136.185	
9.5	111.00	200.98	136.169	
10	111.00	190.56	136.157	
10.5	111.00	182.18	136.146	
11	111.00	176.37	136.138	
11.5	111.00	172.96	136.134	
12	111.00	175.70	136.138	
12.5	111.00	218.51	136.193	
13	111.00	419.87	136.415	
13.5	111.00	800.12	136.707	
14	111.00	1111.64	136.877	
14.5	111.00	1289.21	136.967	
15	111.00	1338.39	136.993	
15.5	111.00	1270.74	136.964	
16	1441.00	1119.84	136.887	
16.5	1441.00	947.02	136.790	
17	1441.00	775.89	136.683	
17.5	1441.00	632.60	136.584	
18	1441.00	513.63	136.489	
18.5	1441.00	424.98	136.410	
19	1441.00	354.34	136.344	
19.5	111.00	303.34	136.289	
20	111.00	261.96	136.243	
20.5	111.00	233.66	136.210	
21	111.00	214.09	136.185	
21.5	111.00	200.98	136.169	
22	111.00	190.56	136.157	
22.5	111.00	182.18	136.146	
23	111.00	176.35	136.138	
23.5	111.00	172.63	136.133	

9.6.2 Flow simulation results at 61 downstream of Dibang Multipurpose Project (just before Dibang-Lohit confluence) for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Project and resulting stabilized discharge/water level series in Dibang river at about 61 km downstream (just before its confluence with Lohit River) as obtained from MIKE11 simulation is shown in **Figure 9.3.**The dates given on X-axis of the plots are the arbitrary dates used for hydro dynamic simulation.

For 24 hour duration, release from Dibang Multipurpose Project and resulting discharge/water level series at 61 km downstream of Dibang Multipurpose Project just before Dibang river's confluence with Lohit river is given in **Table 9.5**.

From **Table 9.5**, it can be seen that the simulated discharge series at chainage 61 km varies from 265.52 cumec to 1169.18 cumec, while fluctuation in daily water level series is from EL 119.088 m to 119.168 m. The average Lean season discharge and corresponding water level at chainage 61 km in natural condition of river as obtained by MIKE11 simulation is about 590 cumec and 119.160 m, respectively.

Table 9.5: Release from Dibang Multipurpose Project and resulting discharge/water level series at chainage 61 km just before confluence of Dibang and Lohit Rivers

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series at chainage 61 km	Stabilized water level series at chainage 61 km with river bed level at EL 111.41 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
0	111.00	265.52	119.093	119.160
0.5	111.00	266.75	119.095	
1	111.00	294.94	119.101	
1.5	111.00	397.94	119.110	
2	111.00	596.87	119.120	
2.5	111.00	825.23	119.131	
3	111.00	994.90	119.139	
3.5	111.00	1063.65	119.146	
4	111.00	1045.15	119.150	
4.5	1441.00	973.49	119.153	
5	1441.00	880.50	119.153	
5.5	1441.00	787.47	119.152	
6	1441.00	698.17	119.150	
6.5	1441.00	615.55	119.146	
7	1441.00	544.04	119.142	
7.5	111.00	483.41	119.136	
8	111.00	432.42	119.130	
8.5	111.00	390.96	119.124	
9	111.00	357.85	119.117	
9.5	111.00	331.27	119.111	
10	111.00	310.01	119.104	
10.5	111.00	293.43	119.097	
11	111.00	280.81	119.091	
11.5	111.00	272.06	119.088	
12	111.00	271.22	119.090	
12.5	111.00	297.68	119.097	
13	111.00	400.46	119.107	
13.5	111.00	605.13	119.120	
14	111.00	850.84	119.133	
14.5	111.00	1052.62	119.145	
15	111.00	1158.79	119.154	
15.5	111.00	1169.18	119.161	
16	1441.00	1108.17	119.165	
16.5	1441.00	1007.97	119.168	
17	1441.00	899.43	119.168	
17.5	1441.00	797.45	119.167	
18	1441.00	703.56	119.164	
18.5	1441.00	618.38	119.160	
19	1441.00	545.37	119.156	
19.5	111.00	483.97	119.150	
20	111.00	432.57	119.144	
20.5	111.00	390.96	119.138	
21	111.00	357.71	119.131	
21.5	111.00	331.21	119.124	
22	111.00	310.07	119.117	
22.5	111.00	293.62	119.109	
23	111.00	281.04	119.102	
23.5	111.00	271.65	119.096	

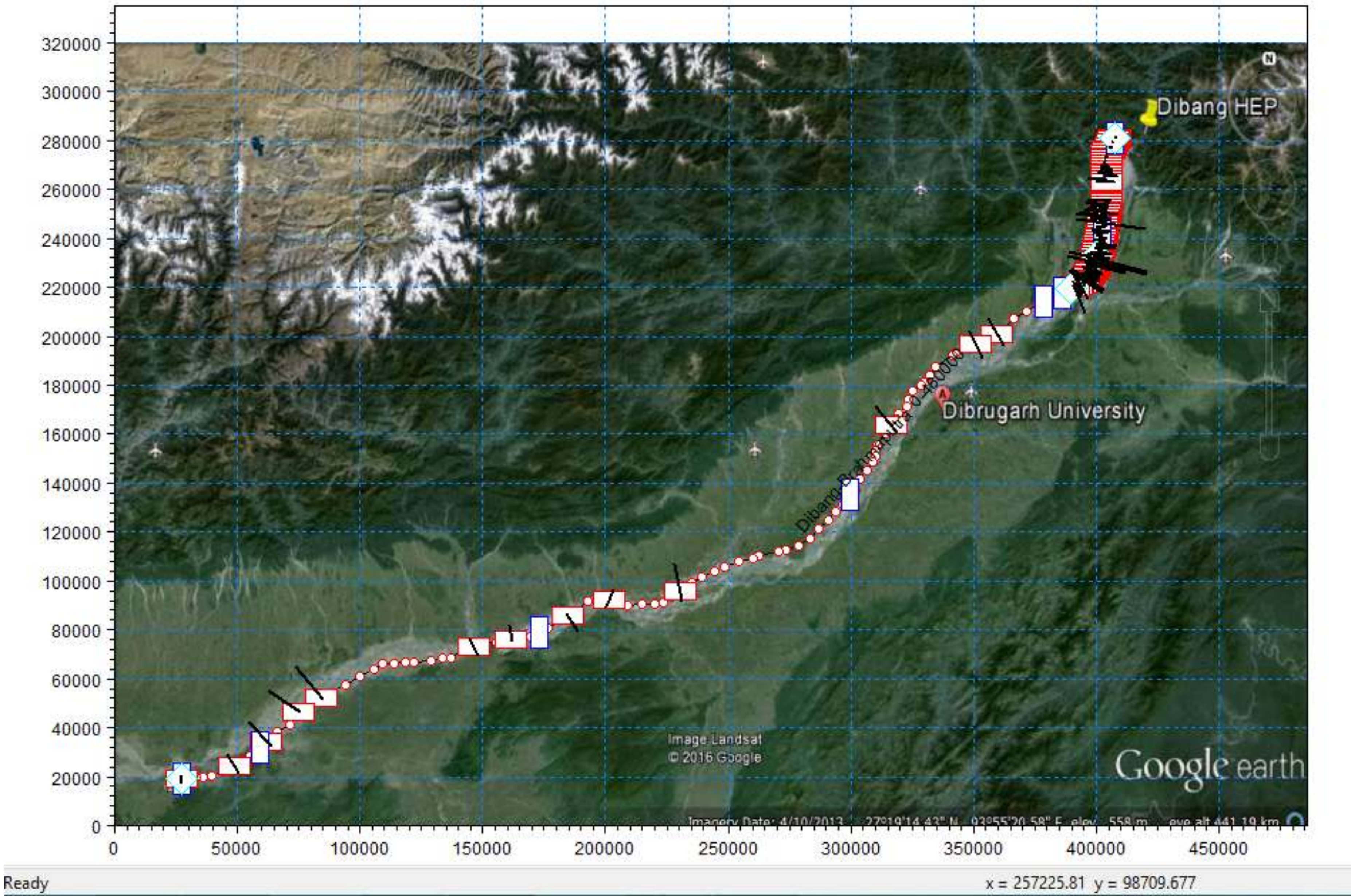


Figure 9.1: MIKE11 model set up for the Study

9.6.3 Flow simulation results at Dibru - Saikhowa National Park for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Project and resulting stabilized discharge/water level series in Dibang river near Dibru – Saikhowa National Park at chainage 78 km and 108 km downstream of Dibang Multipurpose Project as obtained from MIKE11 simulation is shown in **Figure 9.4 (A&B).**The dates given on X-axis of the plots are the arbitrary dates used for hydro dynamic simulation.

For 24 hour duration, release from Dibang Multipurpose Project along with the stabilized discharge series at Dibru – Saikhowa National Park at chainage 78 km and 108 km downstream of Dibang Multipurpose Project is given in **Table 9.6**. The corresponding stabilized water level pattern is given in **Table 9.7**.

From **Figure 9.4a,** it can be seen that variation in discharge in Dibang river during 24 hour at Dibru – Saikhowa National Park (78 km downstream of Dibang Multipurpose Project) is from 1114.10 cumec to about 1251.75 cumec. The consequent fluctuation in water level is from EL 119.028 m to 119.113 m. Water level in natural condition of river is 119.094 m

While From **Figure 9.4b** it can be seen that variation in discharge in Dibang river during 24 hour at Dibru – Saikhowa National Park (108 km downstream of Dibang Multipurpose Project) is from 2619.90 cumec to about 2651.18 cumec. The consequent fluctuation in water level is from EL 107.233 m to 107.246 m. Water level in natural condition of river is 107.242 m

Table 9.6: Release from Dibang Multipurpose Project along with stablised flow pattern at Dibru – Saikhowa National Park

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series of Dibang river at Dibru – Saikhowa National Park (starting segment; 78 km)	Stabilized discharge series of Dibang river at Dibru – Saikhowa National Park (End segment, 108 km)
[hr]	[cumec]	[cumec]	[cumec]
0	111.00	1116.59	2619.90
0.5	111.00	1124.87	2620.36
1	111.00	1149.19	2621.95
1.5	111.00	1183.86	2624.55
2	111.00	1212.91	2627.90
2.5	111.00	1228.98	2631.75
3	111.00	1234.18	2635.78
3.5	111.00	1231.75	2639.71
4	111.00	1224.73	2643.29
4.5	1441.00	1215.85	2646.34
5	1441.00	1206.00	2648.71
5.5	1441.00	1195.08	2650.31
6	1441.00	1184.22	2651.14
6.5	1441.00	1174.40	2651.18
7	1441.00	1165.17	2650.50
7.5	111.00	1156.54	2649.15
8	111.00	1148.90	2647.22
8.5	111.00	1141.96	2644.80
9	111.00	1135.48	2641.96
9.5	111.00	1129.58	2638.81
10	111.00	1124.20	2635.45
10.5	111.00	1119.26	2632.04
11	111.00	1115.18	2628.84
11.5	111.00	1114.10	2626.13
12	111.00	1122.29	2624.19
12.5	111.00	1147.16	2623.19
13	111.00	1183.95	2623.22
13.5	111.00	1217.41	2624.24

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series of Dibang river at Dibru - Saikhowa National Park (starting segment; 78 km)	Stabilized discharge series of Dibang river at Dibru - Saikhowa National Park (End segment, 108 km)
14	111.00	1239.60	2626.09
14.5	111.00	1250.54	2628.56
15	111.00	1251.75	2631.39
15.5	111.00	1245.84	2634.30
16	1441.00	1236.35	2637.07
16.5	1441.00	1225.88	2639.48
17	1441.00	1214.94	2641.38
17.5	1441.00	1203.33	2642.65
18	1441.00	1192.02	2643.26
18.5	1441.00	1181.86	2643.18
19	1441.00	1172.44	2642.44
19.5	111.00	1163.70	2641.07
20	111.00	1155.97	2639.16
20.5	111.00	1148.97	2636.78
21	111.00	1142.46	2634.00
21.5	111.00	1136.52	2630.95
22	111.00	1131.07	2627.81
22.5	111.00	1126.00	2624.82
23	111.00	1121.35	2622.32
23.5	111.00	1117.51	2620.60

Table 9.7: Water level pattern of Dibang river at different locations along Dibru – Saikhowa National Park

Time	Stabilized water level pattern at ch 78 km of Dibang river near Dibru - Saikhowa National Park with river bed level at EL 111.360 m (Water level corresponding to Average lean season flow: 119.094 m)	Stabilized water level pattern at ch 108 km of Dibang river near Dibru - Saikhowa National Park with river bed level at EL 103.543 m (Water level corresponding to Average lean season flow: 107.242 m)
[hr]	[m]	[m]
0	119.028	107.233
0.5	119.034	107.234
1	119.046	107.234
1.5	119.061	107.235
2	119.076	107.236
2.5	119.088	107.238
3	119.098	107.239
3.5	119.106	107.241
4	119.110	107.242
4.5	119.112	107.244
5	119.113	107.245
5.5	119.111	107.245
6	119.108	107.246
6.5	119.104	107.246
7	119.100	107.246
7.5	119.094	107.245
8	119.088	107.245
8.5	119.081	107.244
9	119.074	107.242
9.5	119.067	107.241
10	119.060	107.240
10.5	119.053	107.239
11	119.046	107.238
11.5	119.039	107.236
12	119.034	107.235
12.5	119.033	107.235

Time	Stabilized water level pattern at ch 78 km of Dibang river near Dibru - Saikhowa National Park with river bed level at EL 111.360 m (Water level corresponding to Average lean season flow: 119.094 m)	Stabilized water level pattern at ch 108 km of Dibang river near Dibru - Saikhowa National Park with river bed level at EL 103.543 m (Water level corresponding to Average lean season flow: 107.242 m)
13	119.039	107.235
13.5	119.050	107.235
14	119.062	107.236
14.5	119.074	107.236
15	119.084	107.238
15.5	119.091	107.239
16	119.095	107.240
16.5	119.098	107.241
17	119.098	107.242
17.5	119.097	107.242
18	119.094	107.243
18.5	119.090	107.243
19	119.086	107.243
19.5	119.080	107.242
20	119.074	107.241
20.5	119.068	107.241
21	119.061	107.240
21.5	119.054	107.238
22	119.047	107.237
22.5	119.040	107.236
23	119.033	107.235
23.5	119.028	107.234

9.6.4 Flow simulation results at Brahmaputra river near Dibrugarh and for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Project and resulting discharge/ water level series in Brahmaputra near Dibrugarh as obtained from MIKE11 simulation is shown in **Figure 9.5**. The dates given on X-axis of the plot are the dates used for hydro dynamic simulation set up and the same are indicative only.

It may be noted that in MIKE11 the water level series are computed at h-point which is the location of river cross section while the discharge series are computed between two river cross sections. Hence, the discharge and water level computations obtained for Brahmaputra River near Dibrugarh and also at other salient locations will be at two different chainages. For 24 hour duration, release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Dibrugarh is given in **Table 9.8**.

From **Table 9.8**, it can be seen that the simulated discharge series near Dibrugarh varies from 2628.56 cumec to 2642.73 cumec, while fluctuation in daily water level series is from EL 95.996 m to 96.001 m. The average Lean season discharge and corresponding water level at Dibrugarh is natural condition of river as obtained by MIKE11 simulation is about 2641 cumec and 96.002 m, respectively.

Table 9.8: Release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Dibrugarh

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 92.375 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
0	111.00	2638.67	95.998	96.002

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 92.375 m	Water level corresponding to Average lean season flow
0.5	111.00	2640.01	95.999	
1	111.00	2641.14	95.999	
1.5	111.00	2641.99	96.000	
2	111.00	2642.53	96.000	
2.5	111.00	2642.73	96.000	
3	111.00	2642.59	96.001	
3.5	111.00	2642.11	96.001	
4	111.00	2641.31	96.001	
4.5	1441.00	2640.24	96.001	
5	1441.00	2638.98	96.000	
5.5	1441.00	2637.61	96.000	
6	1441.00	2636.22	96.000	
6.5	1441.00	2634.91	95.999	
7	1441.00	2633.75	95.999	
7.5	111.00	2632.83	95.998	
8	111.00	2632.18	95.998	
8.5	111.00	2631.84	95.998	
9	111.00	2631.80	95.998	
9.5	111.00	2632.04	95.998	
10	111.00	2632.52	95.998	
10.5	111.00	2633.17	95.998	
11	111.00	2633.94	95.998	
11.5	111.00	2634.76	95.998	
12	111.00	2635.54	95.998	
12.5	111.00	2636.23	95.998	
13	111.00	2636.77	95.999	
13.5	111.00	2637.10	95.999	
14	111.00	2637.18	95.999	
14.5	111.00	2637.00	95.999	
15	111.00	2636.53	95.999	
15.5	111.00	2635.80	95.999	
16	1441.00	2634.85	95.999	
16.5	1441.00	2633.73	95.998	
17	1441.00	2632.53	95.998	
17.5	1441.00	2631.34	95.998	
18	1441.00	2630.27	95.997	
18.5	1441.00	2629.40	95.997	
19	1441.00	2628.81	95.997	
19.5	111.00	2628.56	95.997	
20	111.00	2628.67	95.996	
20.5	111.00	2629.15	95.996	
21	111.00	2629.98	95.996	
21.5	111.00	2631.10	95.997	
22	111.00	2632.46	95.997	
22.5	111.00	2633.98	95.997	
23	111.00	2635.58	95.998	
23.5	111.00	2637.17	95.998	

9.6.5 Flow simulation results at Brahmaputra river near Bokaghat (Kaziranga National Park) for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Project and resulting discharge /water level series in Brahmaputra river near Bokaghat (Kaziranga National Park) as obtained from MIKE11 simulation is shown in **Figure 9.6**.

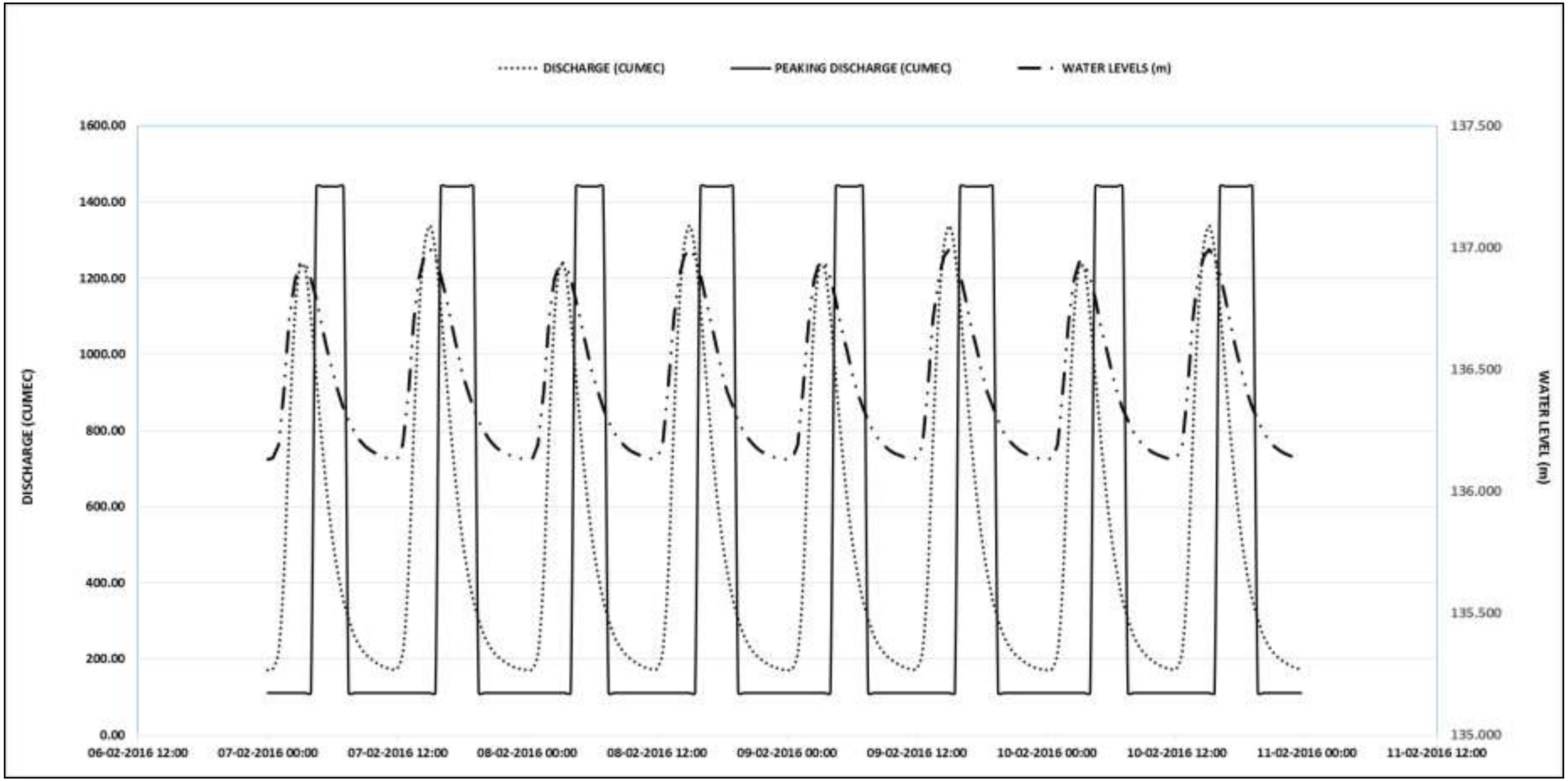


Figure 9.2: Plot of release from Dibang Multipurpose Project and resulting discharge/water level series at Chainage 45 km (before its confluence with Lohit river and near Assam border)

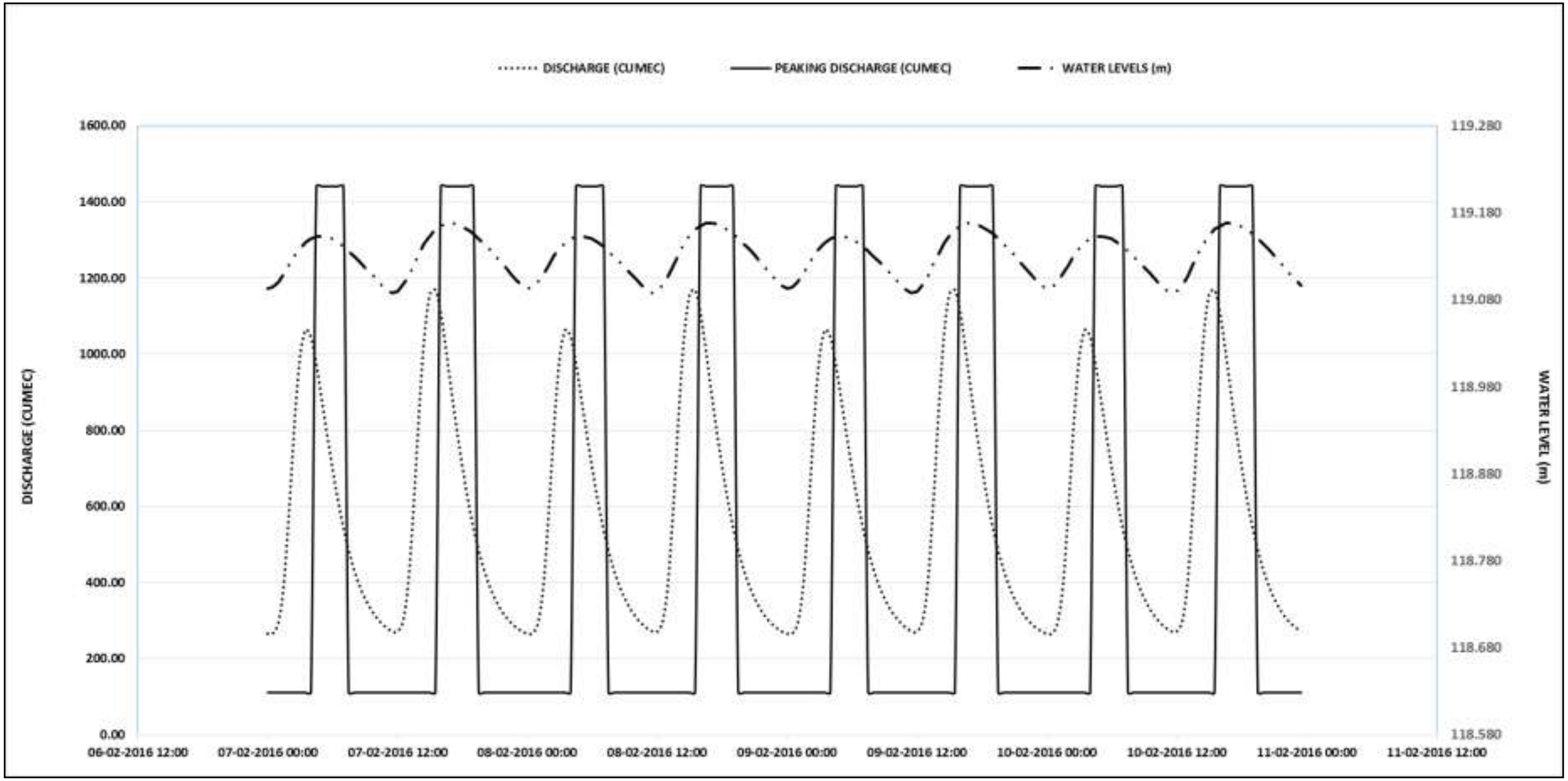


Figure 9.3: Plot of release from Dibang Multipurpose Project and resulting discharge/water level series at Chainage 61 km (just before its confluence with Lohit river)

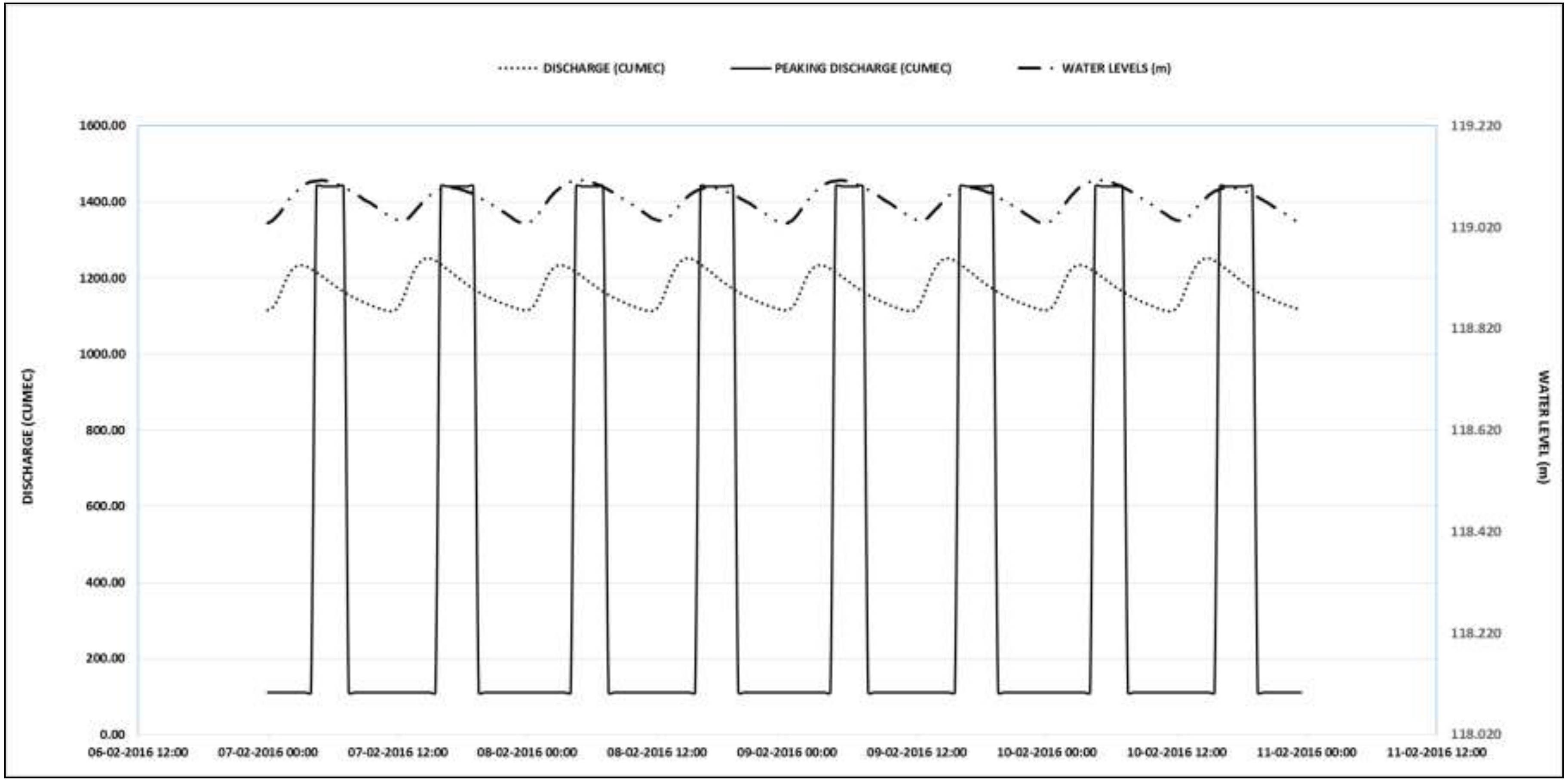


Figure 9.4 (a): Plot of release from Dibang Multipurpose Project and resulting discharge/water level series at Dibru – Saikhowa National Park

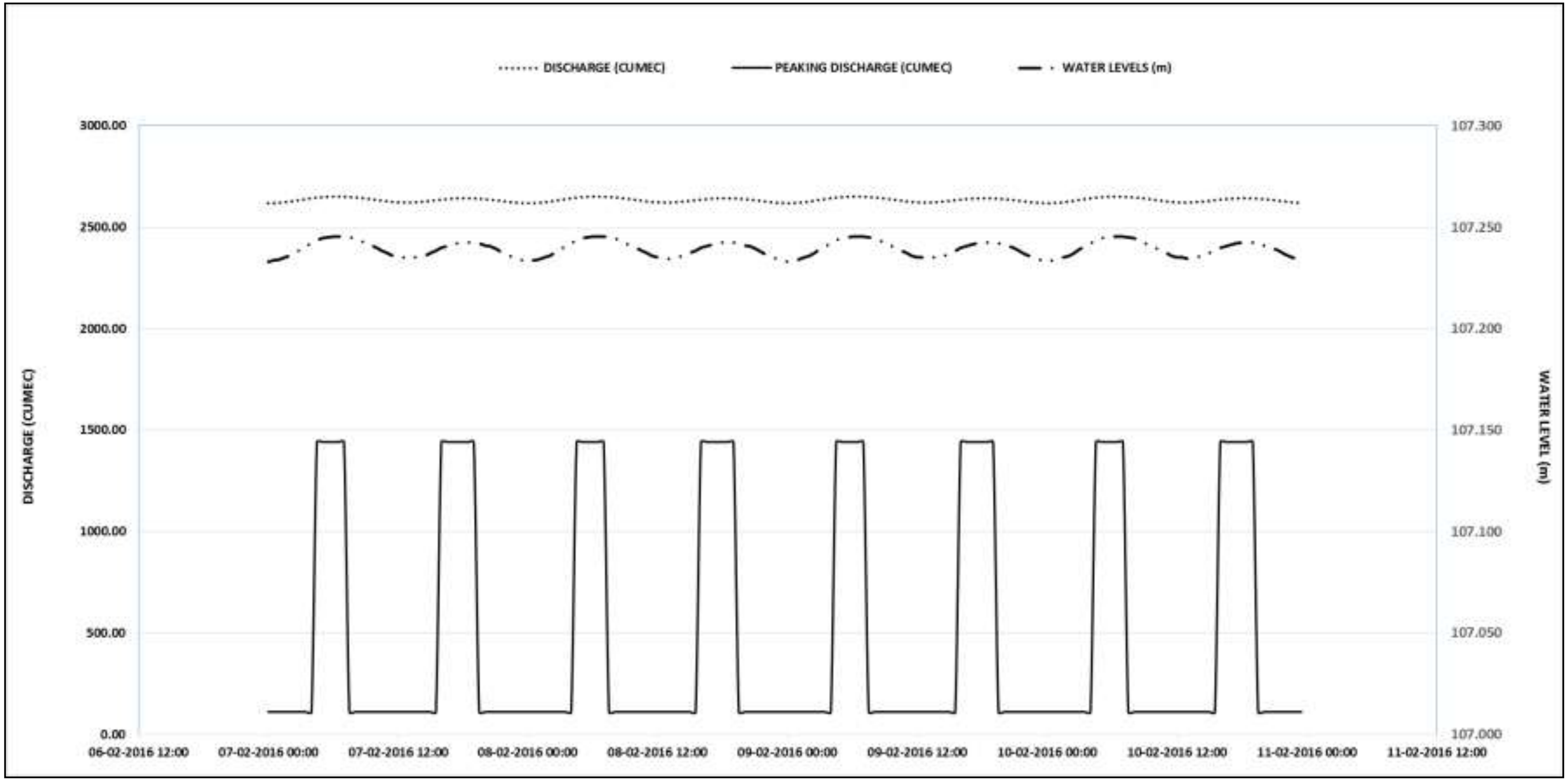


Figure 9.4 (b): Plot of release from Dibang Multipurpose Project and resulting discharge/water level series at Dibru – Saikhowa National Park

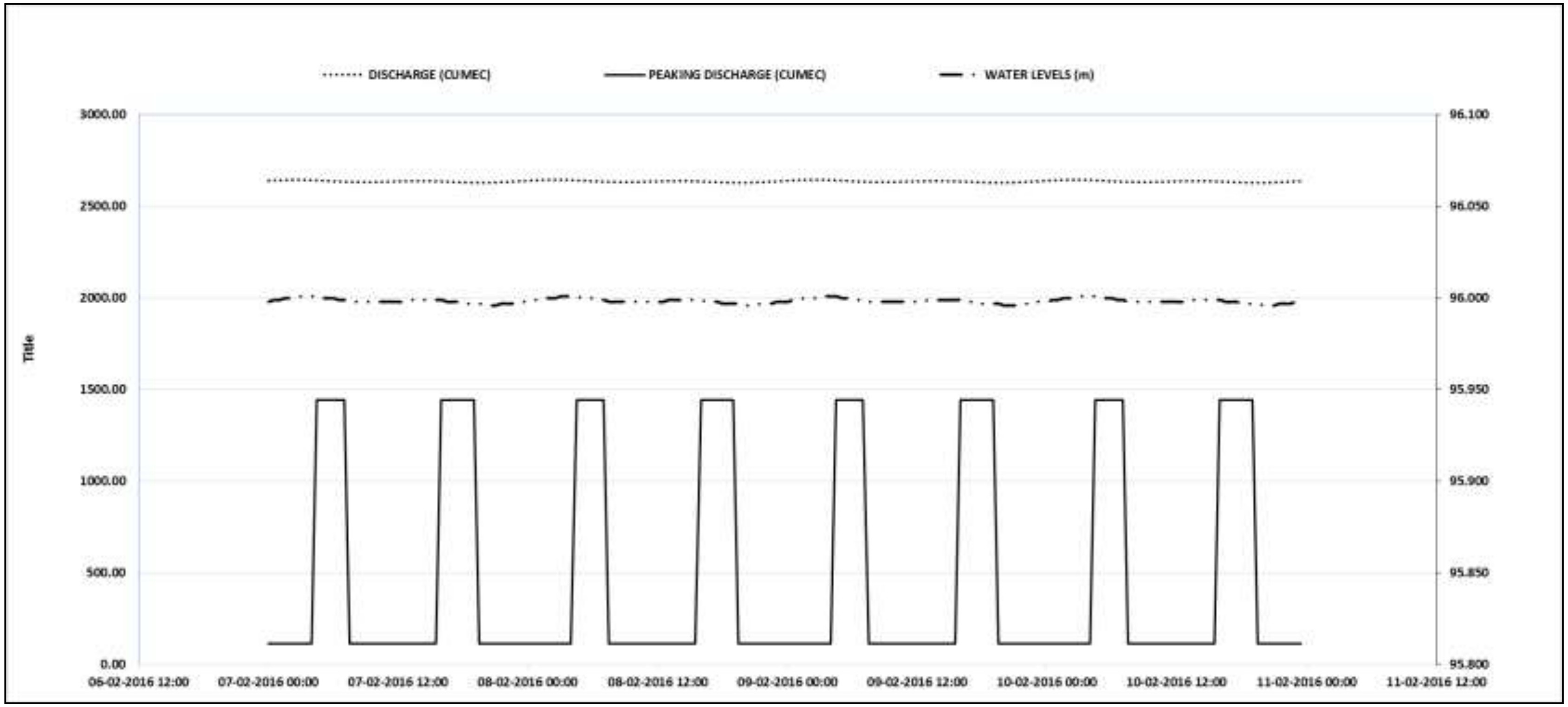


Figure 9.5: Plot of release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Dibrugarh

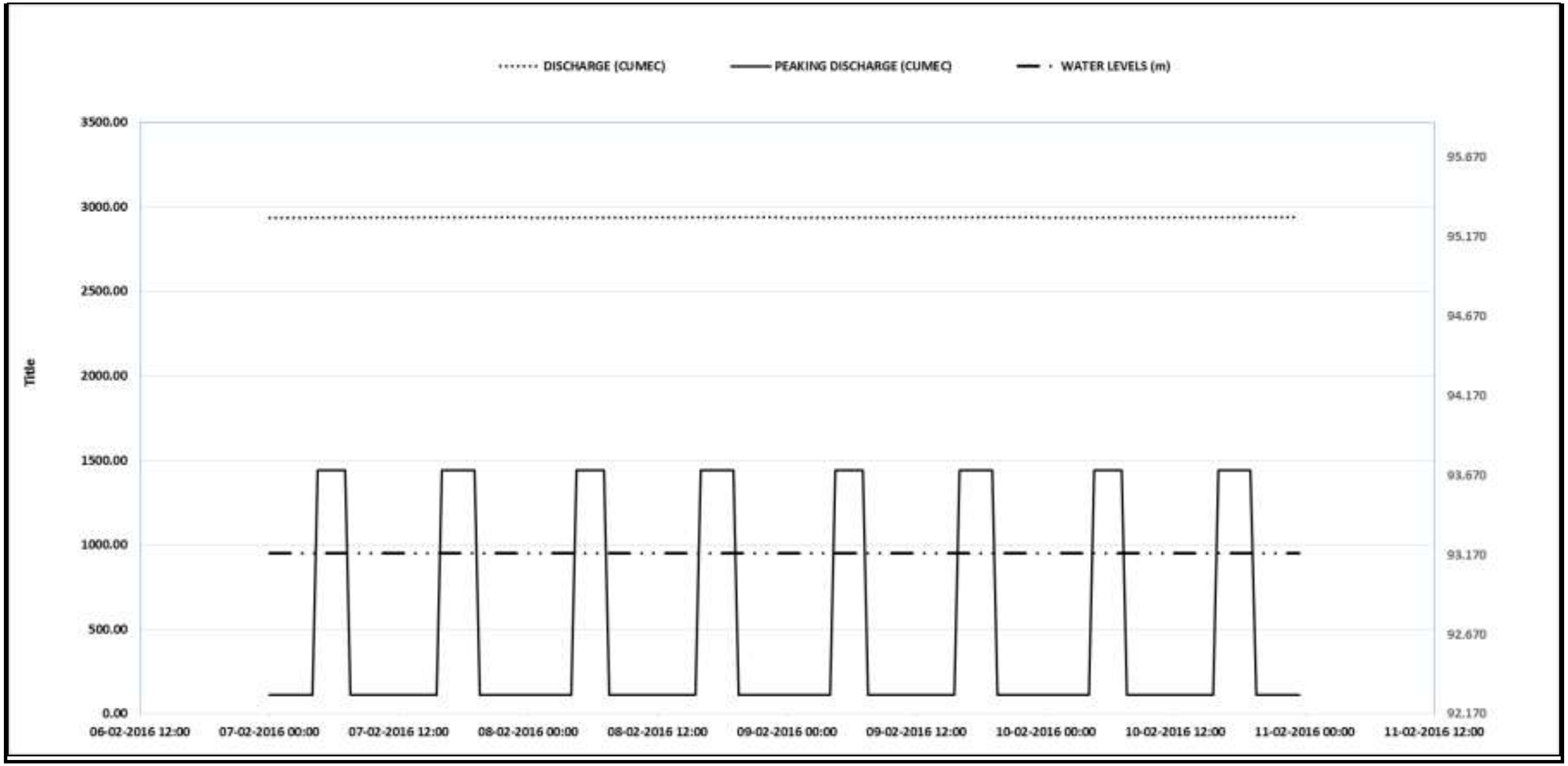


Figure 9.6: Plot of release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga National Park)

For 24 hour duration, release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga National Park) is given in **Table 9.9**.

From **Table 9.9**, it can be seen that the simulated discharge series near Bokaghat varies from 2935.39 cumec to 2936.80 cumec, while fluctuation in daily water level series is from EL 93.178 m to 93.179 m. This may be noted that the average Lean season discharge and corresponding water level at Bokaghat in natural condition of river is about 2951 cumec and 93.191 m respectively.

Table 9.9: Release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Bokaghat

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 86.57 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
0	111.00	2935.39	93.178	93.191
0.5	111.00	2935.43	93.178	
1	111.00	2935.46	93.178	
1.5	111.00	2935.49	93.178	
2	111.00	2935.52	93.178	
2.5	111.00	2935.56	93.178	
3	111.00	2935.59	93.178	
3.5	111.00	2935.62	93.178	
4	111.00	2935.65	93.178	
4.5	1441.00	2935.68	93.178	
5	1441.00	2935.72	93.178	
5.5	1441.00	2935.75	93.178	
6	1441.00	2935.78	93.178	
6.5	1441.00	2935.81	93.178	
7	1441.00	2935.84	93.178	
7.5	111.00	2935.87	93.178	
8	111.00	2935.90	93.178	
8.5	111.00	2935.93	93.178	
9	111.00	2935.96	93.178	
9.5	111.00	2936.00	93.179	
10	111.00	2936.03	93.179	
10.5	111.00	2936.06	93.179	
11	111.00	2936.09	93.179	
11.5	111.00	2936.11	93.179	
12	111.00	2936.14	93.179	
12.5	111.00	2936.17	93.179	
13	111.00	2936.20	93.179	
13.5	111.00	2936.23	93.179	
14	111.00	2936.26	93.179	
14.5	111.00	2936.29	93.179	
15	111.00	2936.32	93.179	
15.5	111.00	2936.35	93.179	
16	1441.00	2936.38	93.179	
16.5	1441.00	2936.40	93.179	
17	1441.00	2936.43	93.179	
17.5	1441.00	2936.46	93.179	
18	1441.00	2936.49	93.179	
18.5	1441.00	2936.52	93.179	
19	1441.00	2936.55	93.179	
19.5	111.00	2936.57	93.179	
20	111.00	2936.60	93.179	
20.5	111.00	2936.63	93.179	
21	111.00	2936.66	93.179	
21.5	111.00	2936.69	93.179	

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 86.57 m	Water level corresponding to Average lean season flow
22	111.00	2936.72	93.179	
22.5	111.00	2936.74	93.179	
23	111.00	2936.77	93.179	
23.5	111.00	2936.80	93.179	

9.6.6 Flow simulation results at Brahmaputra river near Tezpur for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Project and resulting discharge /water level series in Brahmaputra river near Tezpur as obtained from MIKE11 simulation is shown in **Figure 9.7**.

For 24 hour duration, release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Tezpur is given in **Table 9.10**.

From **Table 9.10**, it can be seen that the simulated discharge series near Tezpur varies from 4458.50 cumec to 4460.03 cumec, while fluctuation in daily water level series is from EL 73.508 m to 73.509 m. The average Lean season discharge and corresponding water level at Tezpur in natural condition of river as obtained by MIKE11 simulation is about 4475 cumec and 73.518 m respectively.

Table 9.10: Release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Tezpur

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 67.212 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
0	111.00	4458.50	73.508	73.518
0.5	111.00	4458.53	73.508	
1	111.00	4458.56	73.508	
1.5	111.00	4458.60	73.508	
2	111.00	4458.63	73.508	
2.5	111.00	4458.67	73.508	
3	111.00	4458.70	73.508	
3.5	111.00	4458.74	73.508	
4	111.00	4458.77	73.508	
4.5	1441.00	4458.81	73.508	
5	1441.00	4458.84	73.508	
5.5	1441.00	4458.87	73.508	
6	1441.00	4458.91	73.508	
6.5	1441.00	4458.94	73.508	
7	1441.00	4458.98	73.508	
7.5	111.00	4459.01	73.509	
8	111.00	4459.04	73.509	
8.5	111.00	4459.08	73.509	
9	111.00	4459.11	73.509	
9.5	111.00	4459.14	73.509	
10	111.00	4459.18	73.509	
10.5	111.00	4459.21	73.509	
11	111.00	4459.24	73.509	
11.5	111.00	4459.27	73.509	
12	111.00	4459.31	73.509	
12.5	111.00	4459.34	73.509	
13	111.00	4459.37	73.509	
13.5	111.00	4459.41	73.509	

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 67.212 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
14	111.00	4459.44	73.509	
14.5	111.00	4459.47	73.509	
15	111.00	4459.50	73.509	
15.5	111.00	4459.53	73.509	
16	1441.00	4459.57	73.509	
16.5	1441.00	4459.60	73.509	
17	1441.00	4459.63	73.509	
17.5	1441.00	4459.66	73.509	
18	1441.00	4459.69	73.509	
18.5	1441.00	4459.73	73.509	
19	1441.00	4459.76	73.509	
19.5	111.00	4459.79	73.509	
20	111.00	4459.82	73.509	
20.5	111.00	4459.85	73.509	
21	111.00	4459.88	73.509	
21.5	111.00	4459.91	73.509	
22	111.00	4459.94	73.509	
22.5	111.00	4459.97	73.509	
23	111.00	4460.00	73.509	
23.5	111.00	4460.03	73.509	

9.6.7 Flow simulation results at Brahmaputra river near Guwahati for peaking release from Dibang Multipurpose Project

The plot of release from Dibang Multipurpose Projects and resulting discharge /water level series in Brahmaputra river near Guwahati as obtained from MIKE11 simulation is shown in **Figure 9.8**.

For 24 hour duration, release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Guwahati is given in **Table 9.11**.

From **Table 9.11**, it can be seen that the simulated discharge series near Guwahati varies from 5358.31 cumec to 5360.16 cumec, while fluctuation in daily water level series is from EL 41.799 m to 41.801 m. The average Lean season discharge and corresponding water level in Brahmaputra near Guwahati in natural condition of river as obtained by MIKE11 simulation is about 5377 cumec and 41.529 m, respectively.

Table 9.11: Release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Guwahati

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 30.96 m	Water level corresponding to Average lean season flow
[hr]	[cumec]	[cumec]	[m]	[m]
0	111.00	5358.31	41.799	41.529
0.5	111.00	5358.35	41.800	
1	111.00	5358.40	41.800	
1.5	111.00	5358.44	41.800	
2	111.00	5358.48	41.800	
2.5	111.00	5358.52	41.800	
3	111.00	5358.57	41.800	
3.5	111.00	5358.61	41.800	
4	111.00	5358.65	41.800	

Time	Lean season release from Dibang Multipurpose Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 30.96 m	Water level corresponding to Average lean season flow
4.5	1441.00	5358.69	41.800	
5	1441.00	5358.73	41.800	
5.5	1441.00	5358.77	41.800	
6	1441.00	5358.81	41.800	
6.5	1441.00	5358.85	41.800	
7	1441.00	5358.89	41.800	
7.5	111.00	5358.93	41.800	
8	111.00	5358.98	41.800	
8.5	111.00	5359.02	41.800	
9	111.00	5359.06	41.800	
9.5	111.00	5359.10	41.800	
10	111.00	5359.14	41.800	
10.5	111.00	5359.18	41.800	
11	111.00	5359.22	41.800	
11.5	111.00	5359.25	41.800	
12	111.00	5359.29	41.800	
12.5	111.00	5359.33	41.800	
13	111.00	5359.37	41.800	
13.5	111.00	5359.41	41.800	
14	111.00	5359.45	41.800	
14.5	111.00	5359.49	41.800	
15	111.00	5359.53	41.800	
15.5	111.00	5359.57	41.800	
16	1441.00	5359.60	41.800	
16.5	1441.00	5359.64	41.800	
17	1441.00	5359.68	41.800	
17.5	1441.00	5359.72	41.800	
18	1441.00	5359.76	41.800	
18.5	1441.00	5359.79	41.800	
19	1441.00	5359.83	41.800	
19.5	111.00	5359.87	41.800	
20	111.00	5359.91	41.800	
20.5	111.00	5359.94	41.800	
21	111.00	5359.98	41.800	
21.5	111.00	5360.02	41.800	
22	111.00	5360.05	41.800	
22.5	111.00	5360.09	41.800	
23	111.00	5360.13	41.800	
23.5	111.00	5360.16	41.801	

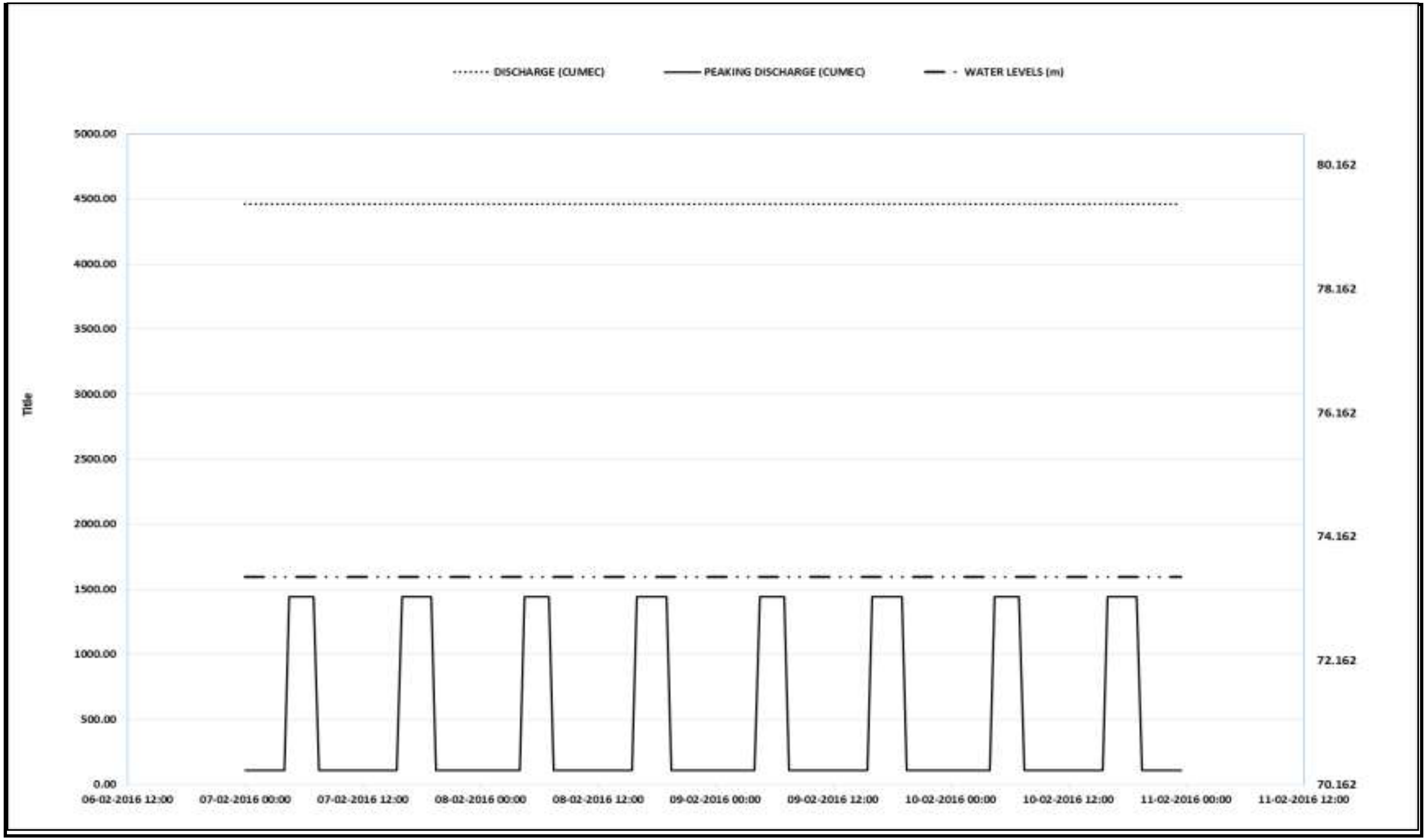


Figure 9.7: Plot of release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Tezpur

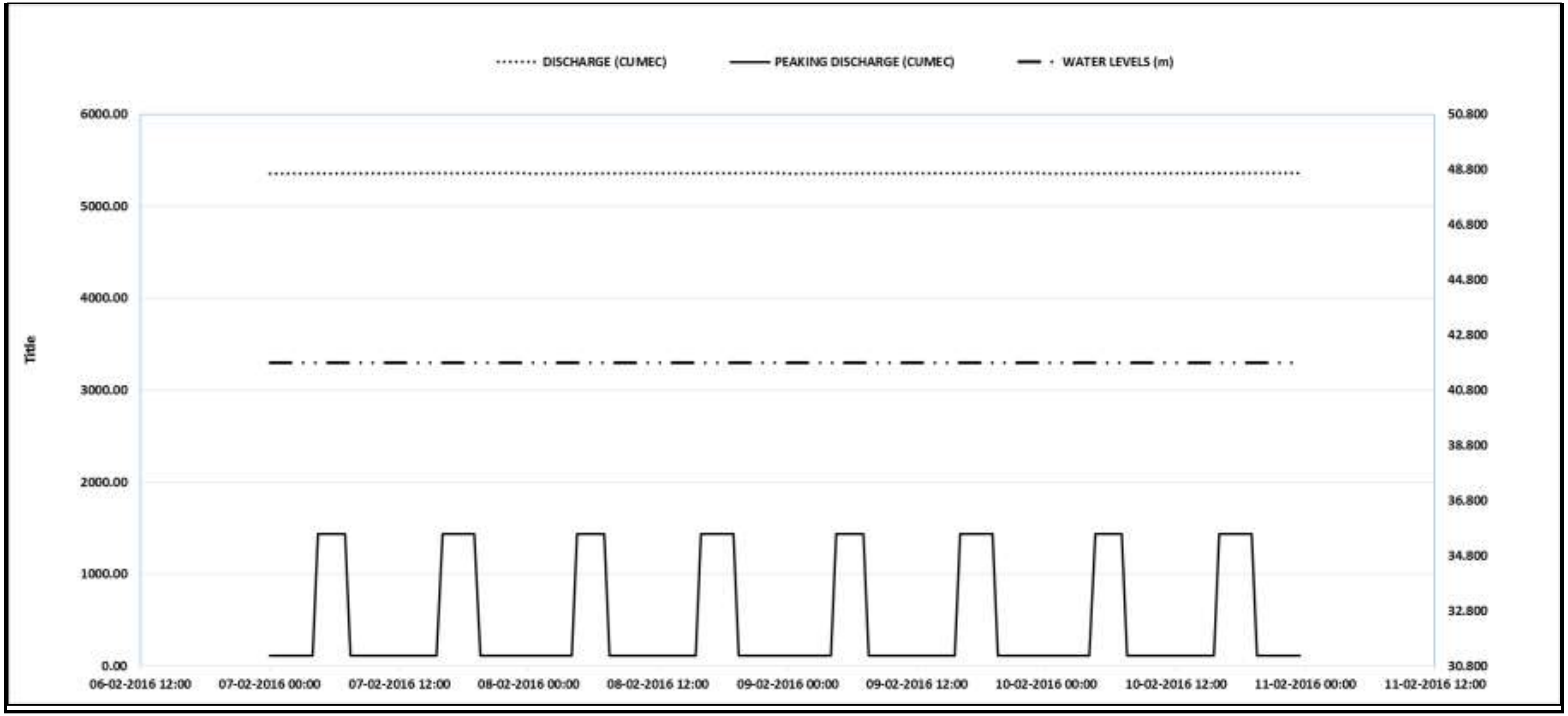


Figure 9.8: Plot of release from Dibang Multipurpose Project and resulting discharge/water level series in Brahmaputra near Guwahati

9.7 COMPARISON OF DISCHARGE AND WATER LEVEL PATTERN OF DIFFERENT SIMULATIONS

A comparison of discharge and water level pattern at salient locations for different simulations is given in **Table 9.12**.

Table 9.4: Comparison of discharge and water level pattern at salient location for different simulations

At chainage 45 km d/s of Dibang Multipurpose Project near Assam border before Dibang – Lohit confluence (River bed EL 135.25 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**477**
Water level in natural condition of river (m)	**136.506**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**170.73 – 1338.39**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**136.131 – 136.993**
At chainage 61 km d/s of Dibang Multipurpose Project just before Dibang – Lohit confluence (River bed EL 111.41 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**590**
Water level in natural condition of river (m)	**119.160**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**265.52 – 1169.18**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**119.088 - 119.168**
Dibru – Saikhowa National Park upper segment located about 78 km d/s of Dibang Multipurpose Project (River bed EL 111.36 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**1180**
Water level in natural condition of river (m)	**119.094**
Discharge pattern due to peaking release from Dibang Multipurpose Project	**1114.10 – 1251.18**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**119.028 - 119.113**
Dibru – Saikhowa National Park upper segment located about 108 km d/s of Dibang Multipurpose Project (River bed EL 103.74 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**2600**
Water level in natural condition of river (m)	**107.242**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**2619.90 – 2651.18**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**107.233 – 107.246**
Dibrugarh located about 130 km d/s of Dibang Multipurpose Project (River bed EL 92.375 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**2641**
Water level in natural condition of river (m)	**96.002**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**2628.56 - 2642.73**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**95.996 - 96.001**
Bokaghat (Kaziranga) located about 297 km d/s of Dibang Multipurpose Project (River bed EL 86.57 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**2951**
Water level in natural condition of river (m)	**93.190**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**2935.39 - 2936.80**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**93.178 - 93.179**
Tezpur located about 383.5 km d/s of Dibang Multipurpose Project (River bed EL 67.212 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**4475**
Water level in natural condition of river (m)	**73.518**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**4458.50 - 4460.03**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**73.508 - 73.509**
Guwahati located about 490.5 km d/s of Dibang Multipurpose Project (River bed EL 30.96 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	**5377**
Water level in natural condition of river (m)	**41.529**
Discharge pattern due to peaking release from Dibang Multipurpose Project (cumec)	**5358.31 – 5360.16**
Water level pattern due to peaking release from Dibang Multipurpose Project (m)	**41.799 - 41.801**

A plot of river cross sections at identified locations along with water level corresponding to different simulations is given at the end of this Chapter.

9.8 CONCLUSIONS

Due to non-availability of data for model calibration the water level estimated at different locations may vary by few centimeters in absolute term. Hence, the results obtained should be considered in terms of fluctuations in water level pattern and relative rise or fall with respect to natural condition only. Error if any in absolute water level estimate at different locations will get nullified when relative rise or fall in water level is considered.

With the above limitations, from the impact study of different simulated conditions, It has been concluded that in general the impact of peaking of hydroelectric projects of Dibang basin on Brahmaputra river is almost NIL in terms of discharge and water level fluctuations from Bokaghat up to Guwahati. This is due to very wide reach and large discharge carrying capacity of Brahmaputra river. In this reach of the Brahmaputra river the discharge and water level pattern will be approximately close to the natural condition discharge and water level pattern.

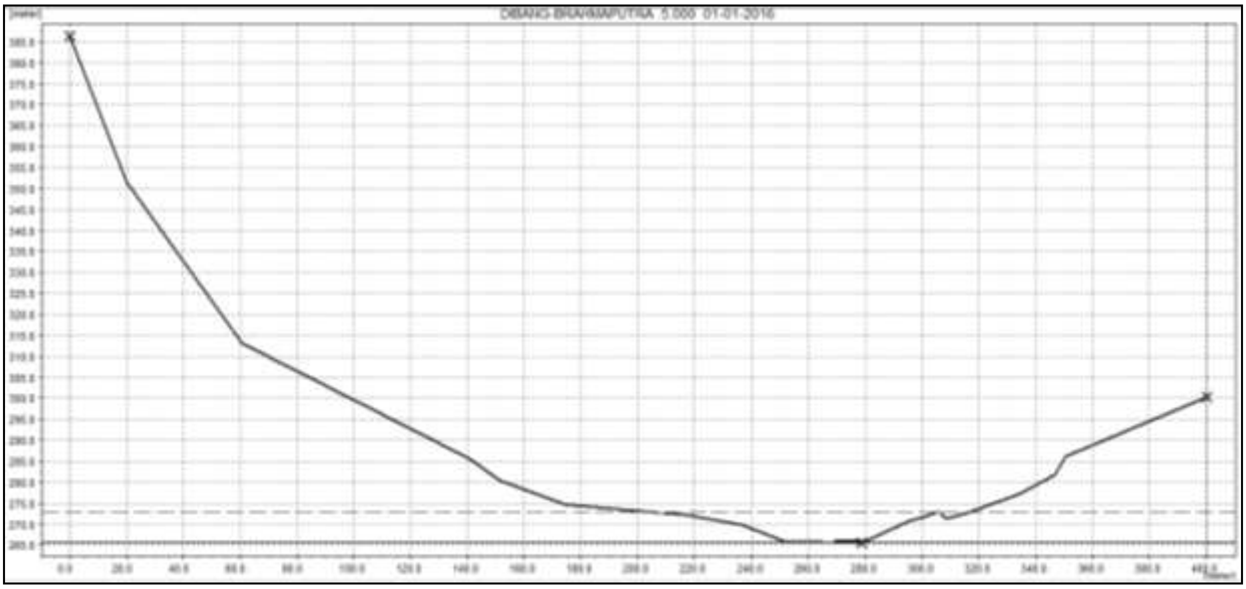
The Lean season peaking discharge releases in Dibang basin ultimately will result a stabilized discharge/water level series from Bokaghat onward resulting a discharge of about 2900 cumec at Bokaghat with water level about at EL 93.178 m, and a discharge of about 5300 cumec at Guwahati with water level about at EL 41.80 m. All these patterns are approximately same to the natural condition discharge and water level pattern.

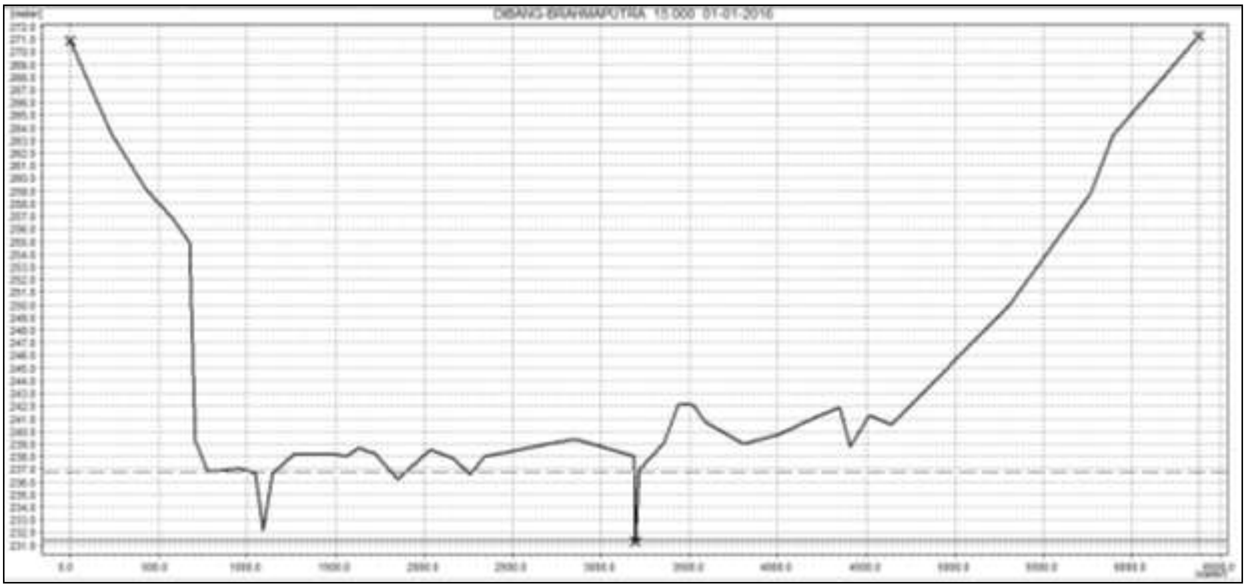
Further, from Dibang Multipurpose Project location and up to Dibrugarh there will be daily fluctuations in discharge and water level due to peaking. These fluctuations will be of the order of 170.73 – 1338.39 cumec with water level variation from El 136.131 – 136.993 m at 45 km d/s of Dibang Multipurpose Project near Assam border before Dibang – Lohit confluence, discharge variation 265.52 – 1169.18 cumec with water level variation from El 119.088 - 119.168 m at 61 km d/s of Dibang Multipurpose Project just before Dibang – Lohit confluence, at Dibru- Saikhowa National Park (78 & 108 km chainage) 1114.10 – 1251.75 cumec with water level variation from El 119.028 - 119.113 m and 2619.90 – 2651.18 cumec with water level variation of 107.233 – 107.246 m respectively. Corresponding figures near Dibrugarh are 2628.56 – 2642.73 cumec with water level variation from EL 95.996 -96.001 m.

A study was undertaken in 2011 by WAPCOS on behalf of Ministry of Environment, Forest & Climate Change to assess impact of peaking power generation by Siang Lower HEP, Demwe Lower HEP and Dibang Multipurpose HEP on Dibru-Saikhowa National Park. Study modeled scenarios when only Dibang Multipurpose HEP is constructed and peaking for 3 hours and Siang and Lohit rivers are in their natural regimes and when all three projects are constructed and are peaking for 3 hours. Water levels in first scenario were calculated varying from 0.26 m to 0.62 m at various locations of Dibru-Saikhowa National Park. Corresponding water level variation in other scenario was estimated between 1.11 m to 2.34 m. Since the study considered peaking hours as 3 only, water level variation appears bit more than the actual scenario where peaking hours are 6.5 distributed in morning and evening.

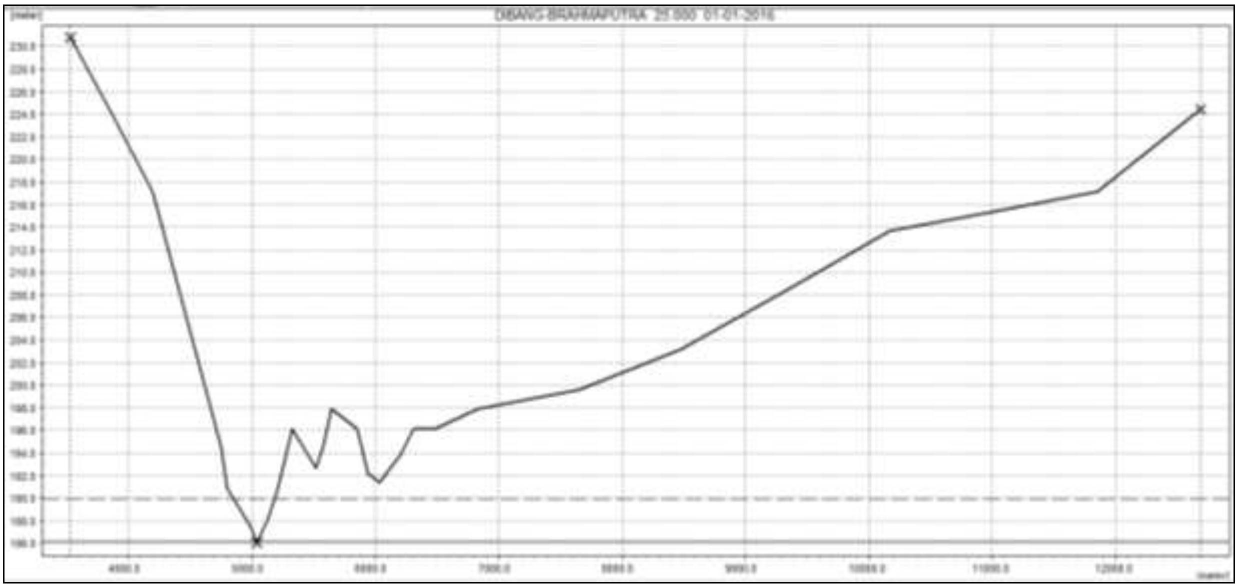
Plot of Cross Sections of Dibang/Brahmaputra river at Identified Locations

(Note: The dates shown on the plots are not the absolute dates but are arbitrary dates used in model simulation)

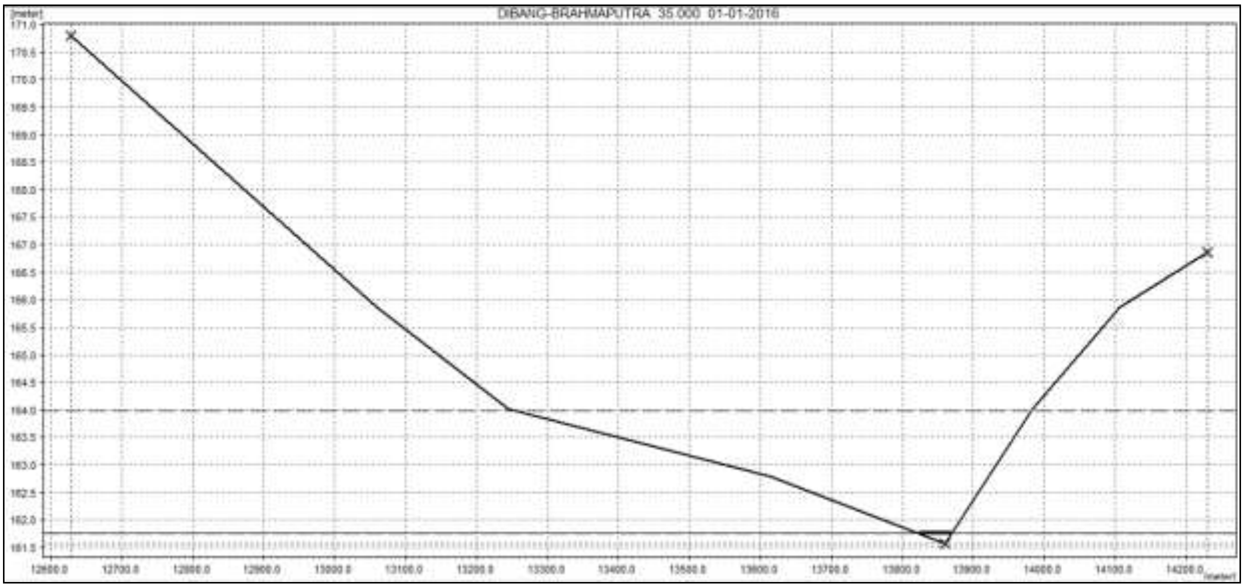



DIBANG-BRAHMAPUTRA 15.000 01-01-2016


DIBANG-BRAHMAPUTRA 18.000 01-01-2016

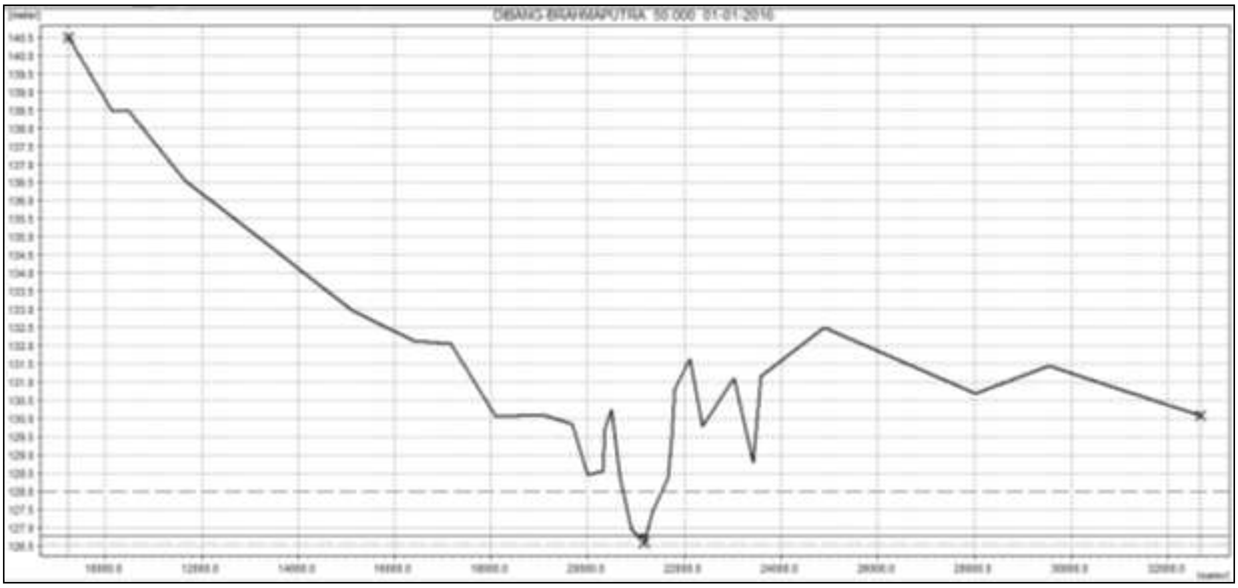

DIBANG-BRAHMAPUTRA 25.000 01-01-2016

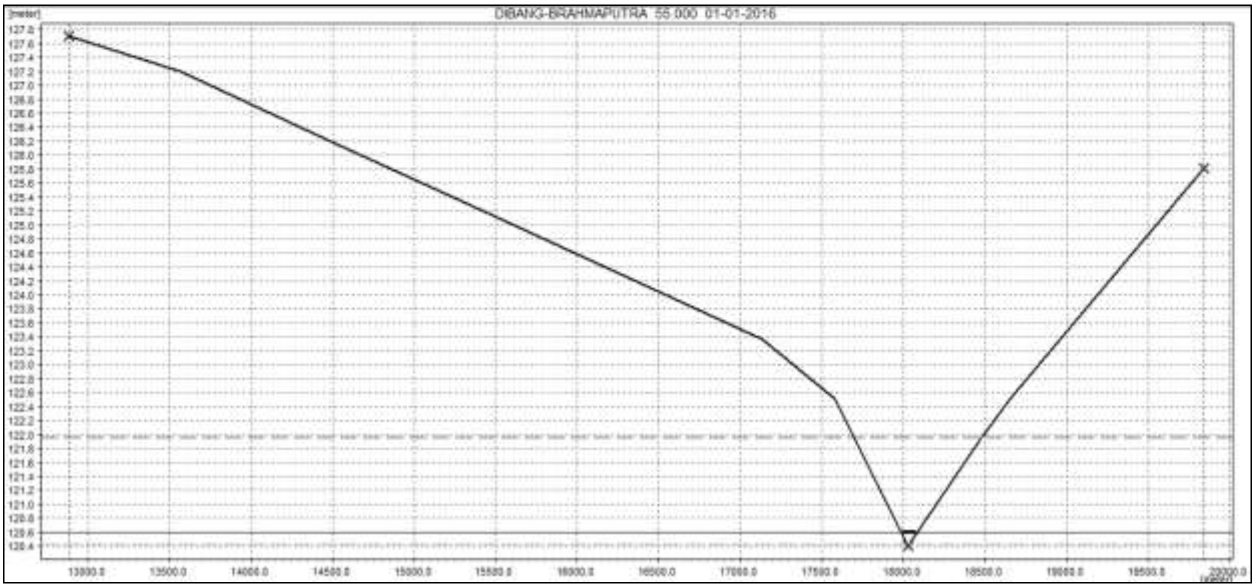

DIBANG-BRAHMAPUTRA 30.000 01-01-2016


DIBANG-BRAHMAPUTRA 35.000 01-01-2016

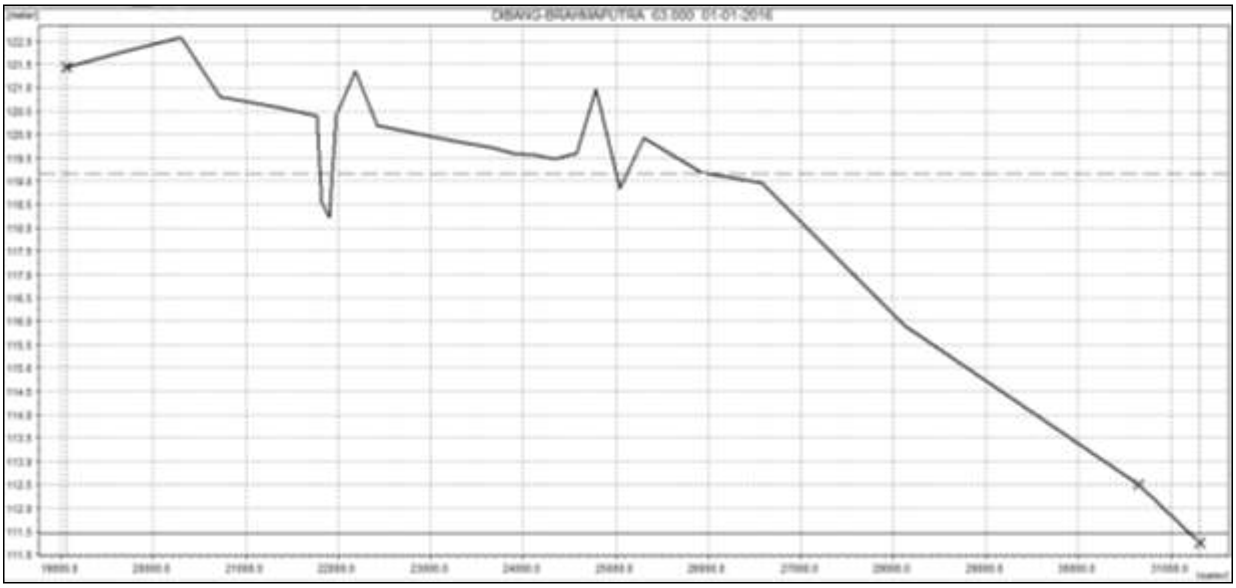

DIBANG-BRAHMAPUTRA 40.000 01-01-2016

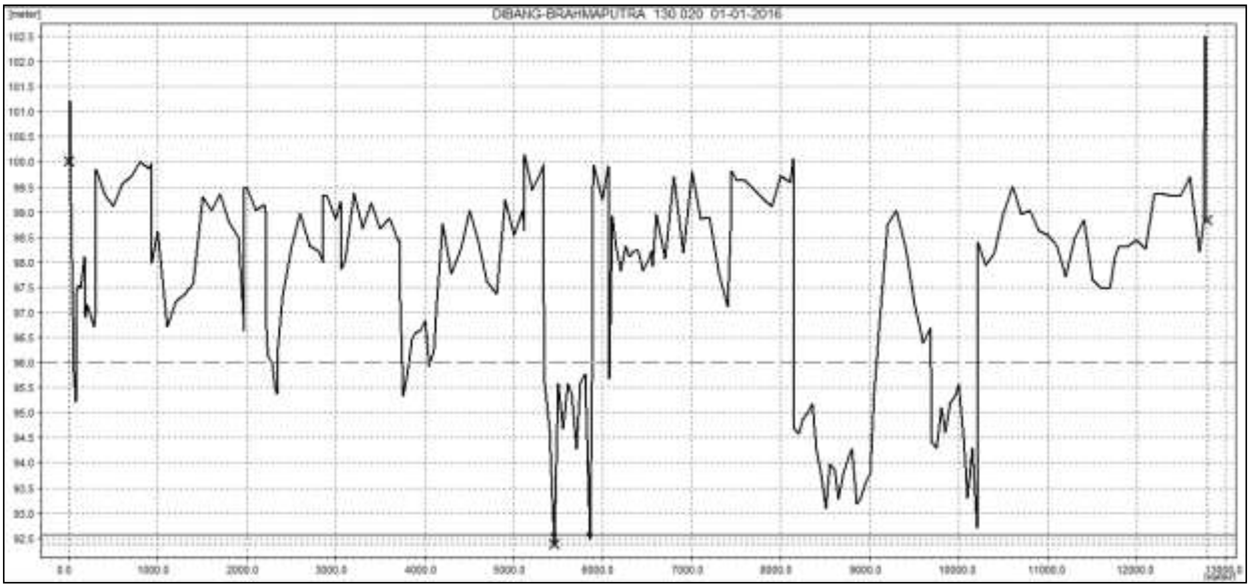

DIBANG-BRAHMAPUTRA 45.000 01-01-2016
[meter]


DIBANG-BRAHMAPUTRA 50.000 01-01-2016
[meter]

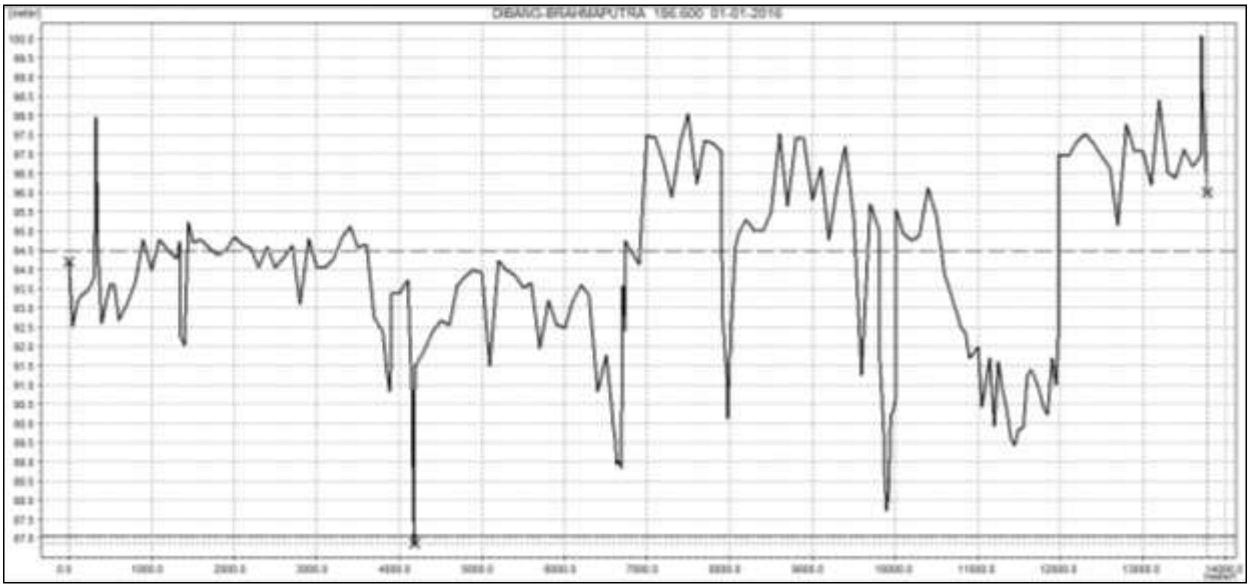

DIBANG-BRAHMAPUTRA 55.000 01-01-2016
[meter]

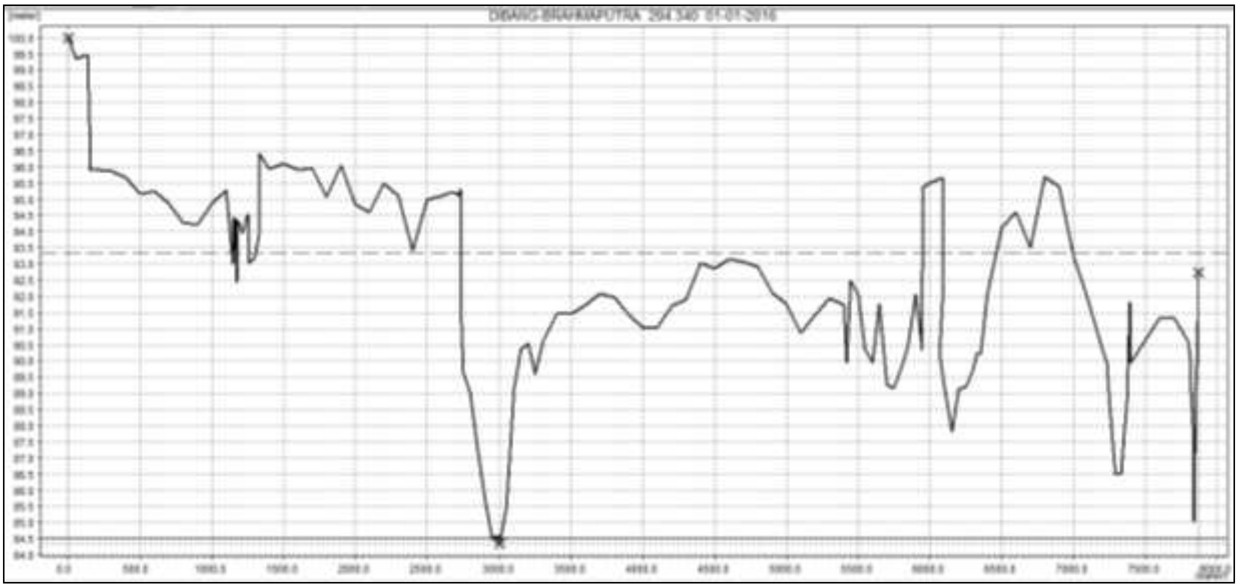

DIBANG-BRAHMAPUTRA 60.000 01-01-2016
[meter]

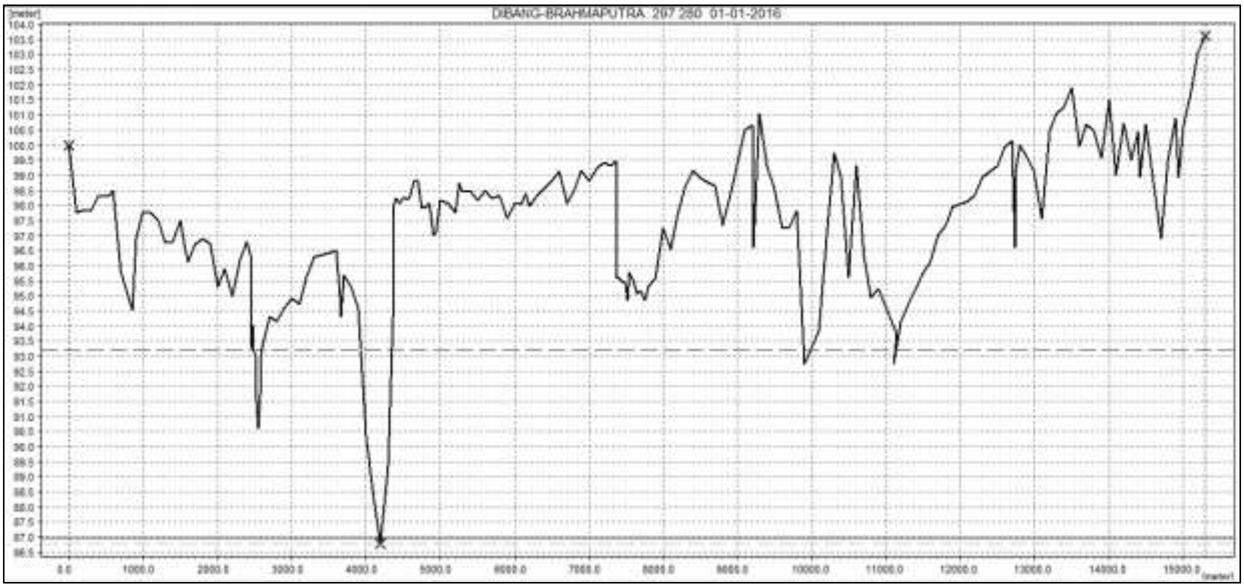

DIBANG-BRAHMAPUTRA 63.000 01-01-2016


DIBANG-BRAHMAPUTRA 130.020 01-01-2016
[meter]

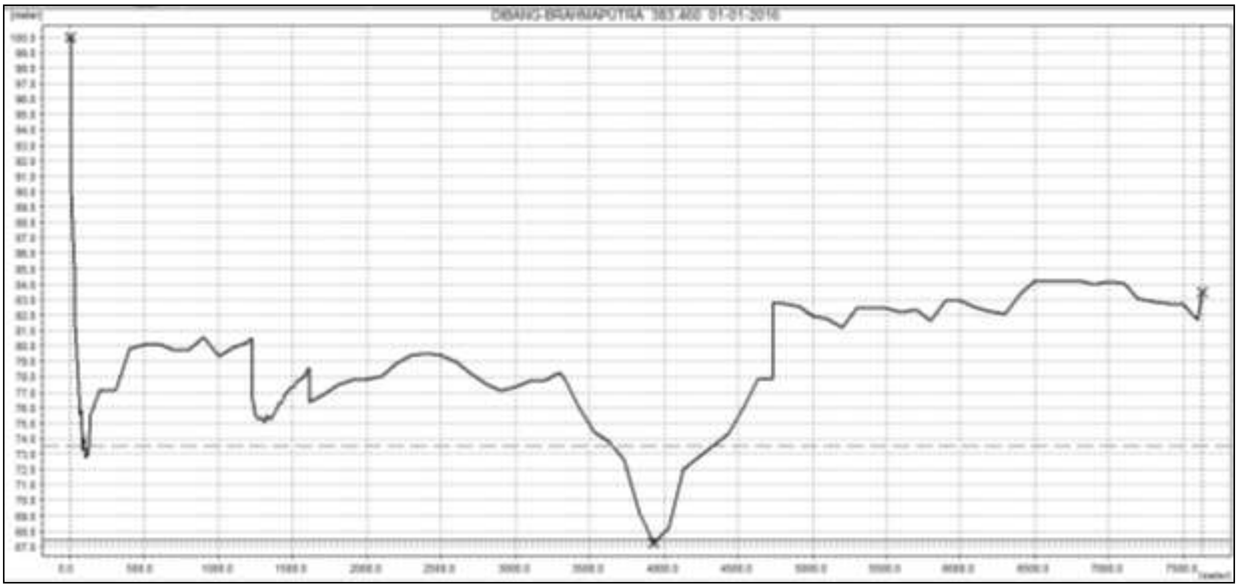

DIBANG-BRAHMAPUTRA 139.150 01-01-2016

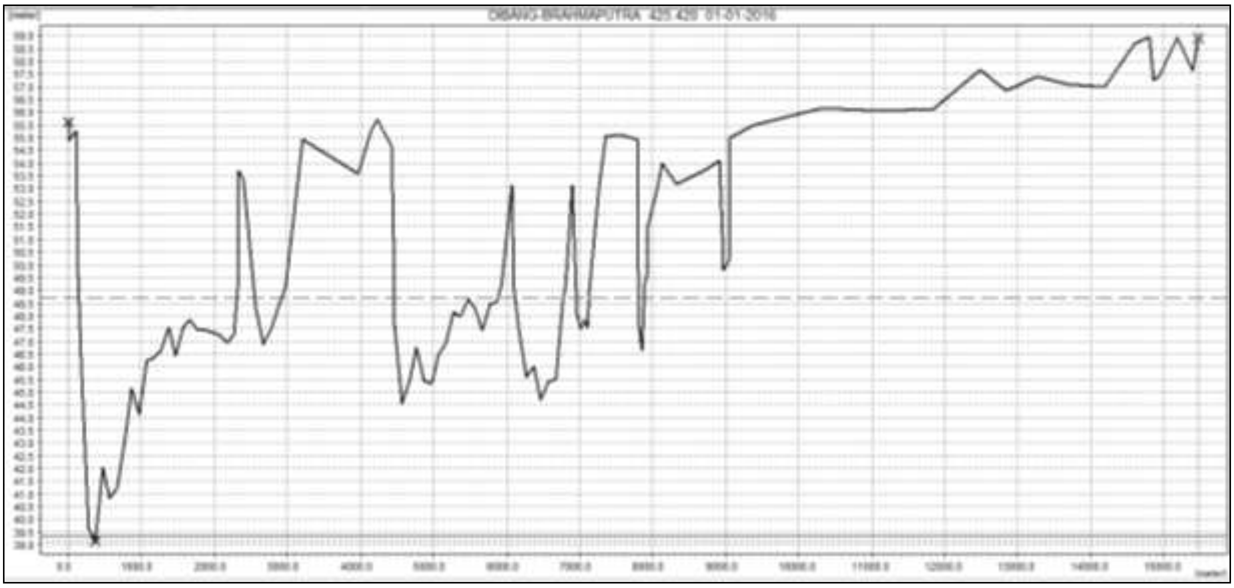

DIBANG-BRAHMAPUTRA 156.600 01-01-2016

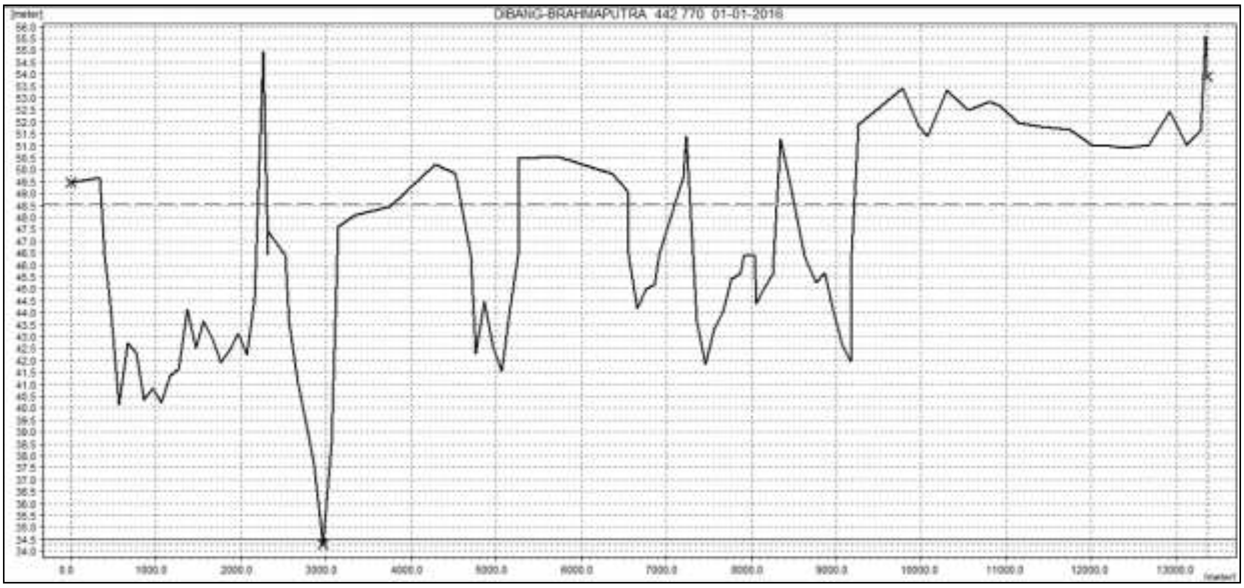

DIBANG-BRAHMAPUTRA 294.340 01-01-2016

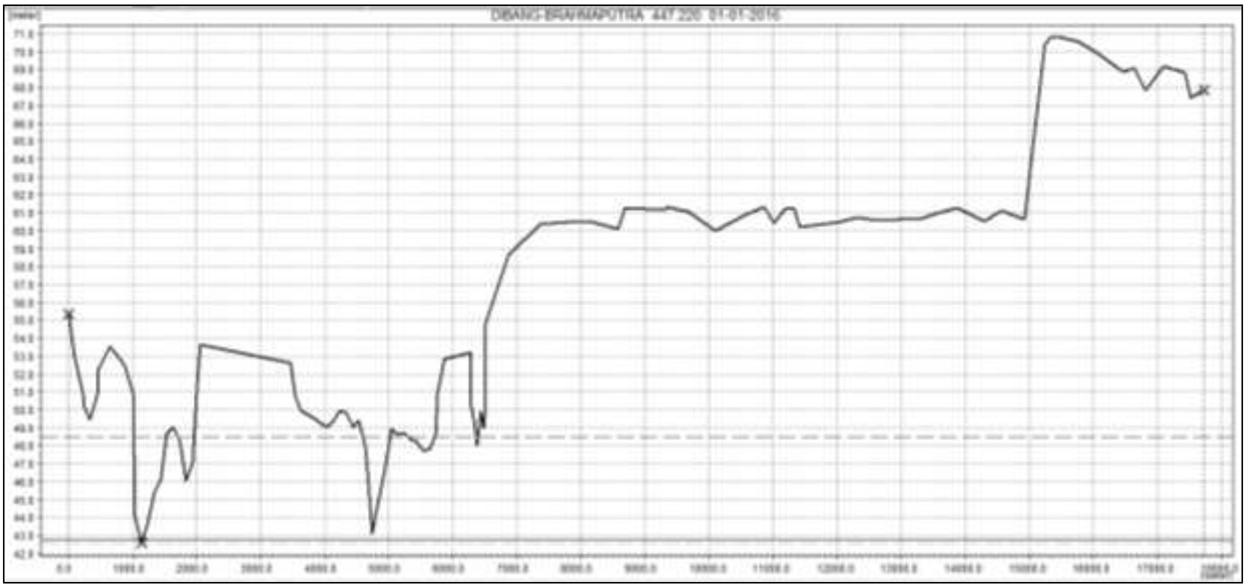

DIBANG-BRAHMAPUTRA 297.280 01-01-2016
[meter]

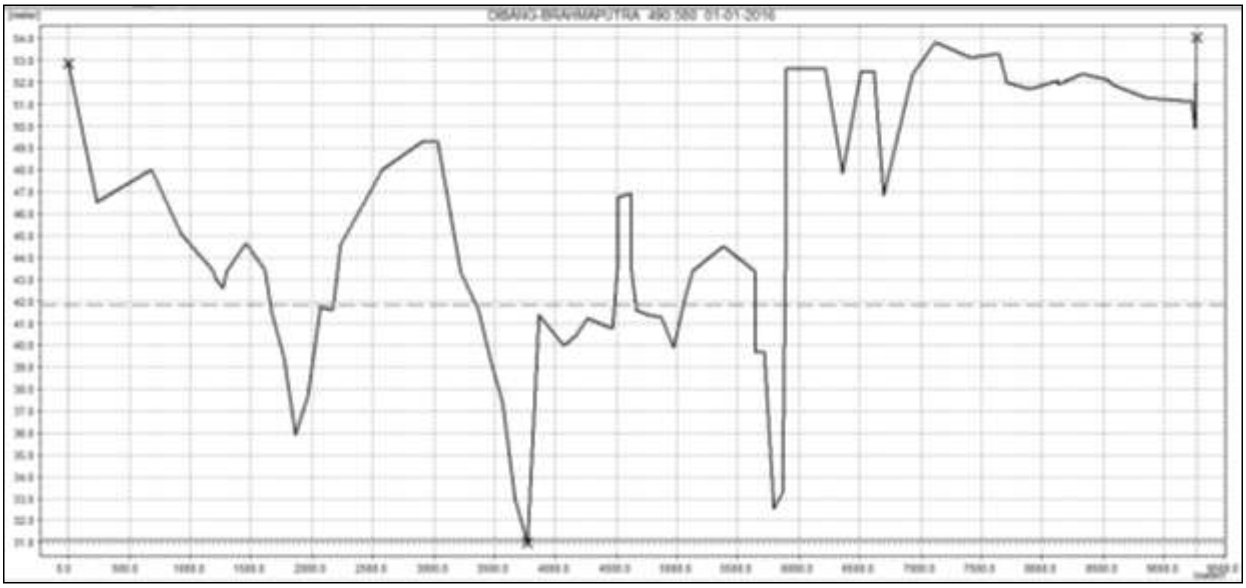

DIBANG-BRAHMAPUTRA 344.190 01-01-2016






DIBANG-BRAHMAPUTRA 442.770 01-01-2016


DIBANG-BRAHMAPUTRA 447.220 01-01-2016


DIBANG-BRAHMAPUTRA 490.580 01-01-2016

CHAPTER-10
CUMULATIVE IMPACT ASSESSMENT

10.1 INTRODUCTION

Cumulative Impact Assessment (CIA) is the analysis of all affects /impacts on an area from one or more activities as they tend to accumulate over time and space. CIA and Carrying Capacity Studies are focused on assessing long term changes in the environmental quality, not only as result of a single action or development, but as the combined effect of many actions over a period of time. Project/site specific Environmental Impact Assessment has its own limitations when it comes to evaluating and assessing the potential cumulative impacts on environmental resources. Each individual development, when assessed for its potential impacts, may produce impacts that are ecologically and socially acceptable, however, when the effects of the numerous individual developments are combined, impacts may become larger, additive, or even new and are therefore significant. The CIA study assesses additive impacts of a group of planned activities and provides optimum support for various natural processes while allowing sustainable development; therefore it is important to go for CIA, as a holistic development approach to be followed by project specific EIAs.

The objective of cumulative environmental impact assessment study of Dibang basin is to assess stress/ load due to hydropower development in the basin and envisage a broad framework of environmental action plan to mitigate the adverse impacts. Assessment of projects specific environmental impacts is part of the individual projects' EIA studies, where impacts are assessed by establishing site-specific environmental settings through baseline data collection and project development plan. In CIA study of Dibang basin, where 18 hydropower projects are planned, focus of impact assessment is towards the broader issues or cumulative impacts of overall development.

10.2 IMPACTS ON TERRESTRIAL ECOLOGY

The formation of reservoir by construction of diversion structure results in permanent flooding of riverine and terrestrial habitats, and depending upon the topography and habitats of the river valley upstream from the site of the diversion structure, the impacts can vary greatly in extent and severity. Due to impoundment, all terrestrial animals disappear from the submerged areas and vicinity and animal populations decrease in directly affected area and vicinity within a few years in proportion to the habitat area that is lost (Dynesius and Nilsson, 1994). Particularly hard hit are the species dependent upon riverine forests, and other riparian ecosystems, and those adapted to the fast-flowing conditions of the main river course. From a biodiversity conservation standpoint, the terrestrial natural habitats lost to flooding are usually much more valuable than the aquatic habitats created by the reservoir (McAllister *et al.*, 1999).

Dams can also have significant and complex impacts on downstream riparian plant communities. An important downstream manifestation of river impoundment is the loss of pulse-stimulated responses at the water-land interface of the riverine system. High discharges can retard the establishment of true terrestrial species, but many riparian plants have evolved with, and have become adapted to the natural flood regimes. Species adapted to pulse-stimulated habitats are often adversely affected by flow regulation and invasion of these habitats by terrestrial weeds is frequently observed (Malanson, 1993).

Typically riparian forest tree species are dependent on river flows and shallow aquifers. When diversion structures are constructed the variability in water discharge over the year is reduced; duration of high flows are decreased and low flows may be increased. Reduction of flood peaks reduces the frequency, extent and duration of floodplain inundation. Reduction of channel-forming flows reduces channel migration. Truncated sediment transport (i.e. sedimentation within the reservoir) results in complex changes in degradation and aggregation below the diversion structure. These changes and others directly and indirectly influence a myriad of dynamic factors that affect the diversity and abundance of invertebrates, fish, birds and mammals downstream of diversion structures (Berkamp *et al.* 2000). Moreover, human disturbances during construction and operational phases of hydro projects would keep away several shy wild animals from the vicinity.

One of the major impacts of hydropower development on terrestrial biodiversity is the landscape degradation and fragmentation as a result of diversion of forestland for project and conversion of natural resource into commodity, which is an irreversible process.

In order to assess the cumulative impacts it essential to set up criteria for sensitivity analysis of a particular resource or ecosystem vis-à-vis construction of proposed hydropower projects and related activities or resource use. The Impact Assessment is made in form of degradation, exploitation of natural resources in changed and altered scenario that can be visualized in habitat destruction or disruption of essential ecological functions in due course of time. For the assessment of impacts on terrestrial and aquatic biodiversity, a conceptual methodology followed broadly in the present study is described below:

RET (Rare, Endangered and Threatened) Species, as per IUCN and Criteria of BSI, ZSI and CAMP and WPA Schedules	**Number of RET species present in the basin**
Endemic Species	Number of endemic species present in the Study Area of each project as well as major tributary catchments reflecting the irreplaceability, and national importance that the species command
Habitat Diversity	Number of habitat types available. This is a surrogate for habitat heterogeneity and biodiversity richness
Species Richness	Number of different species present in a given area
Biological Richness Index	Based upon available data on IIRS portal (http://bis.iirs.gov.in/) for entire basin as well as Direct Impact Zones of respective projects Indicator of Biodiversity Richness of an area
Fragmentation & Disturbance Indicies	Based upon available data on IIRS portal (http://bis.iirs.gov.in/) for entire basin as well as Direct Impact Zones of respective projects Indicator of biotic interference and fragmentation of habitats
Breeding/Congregation	Presence/ absence of breeding sites and congregation opportunities for the target taxonomic group in Study Area
Migratory Pathways/Corridor	Presence/ absence of migratory pathways/corridor for aquatic biodiversity in the impact zones of projects

It is well known that the spatial configuration of ecosystems at a landscape scale plays a major part in determining how they function and the composition of their plant and animal populations. Fragmentation is the subdivision of a habitat or ecosystem by human activities like clearing forest for roads, colonies, and other structures required during project construction.
The main impacts of changes in the size and connectivity of land (particularly forest) ecosystems include:

- changes in patch size (impacts through species/area relationships)
- edge effects (biophysical impacts, sometimes increasing access for other uses)
- isolation effects (distance from core area increases vulnerability of predation and disease impacts and decreases ability of species to recolonize)

Less fragmented ecosystems are better for biodiversity, although many ecosystems are probably mosaics in an undisturbed state and eco-tones often increase species diversity. To avoid unnecessary fragmentation of ecosystems and habitats is a key aspect of national and regional land use plans and other relevant instruments such as environmental impact assessment at the project and the strategic levels and cumulative impact assessment.

10.2.1 Direct Forest Cover Loss

More than 65% of the Dibang basin is under forest cover (80.30% for entire state). Of this 12.33% is under Very Dense Forest cover, 37.06% under Dense Forest cover while 19.13% is under Open Forest cover category (**refer Figure 10.1**). Non-forest constitutes only 18% which is mainly comprised of *jhummed* area and wide river bed in the lower reaches of Arunachal Pradesh and also in part of basin in Assam comprised of floodplains of Dibang river and snow covered areas at higher elevations.

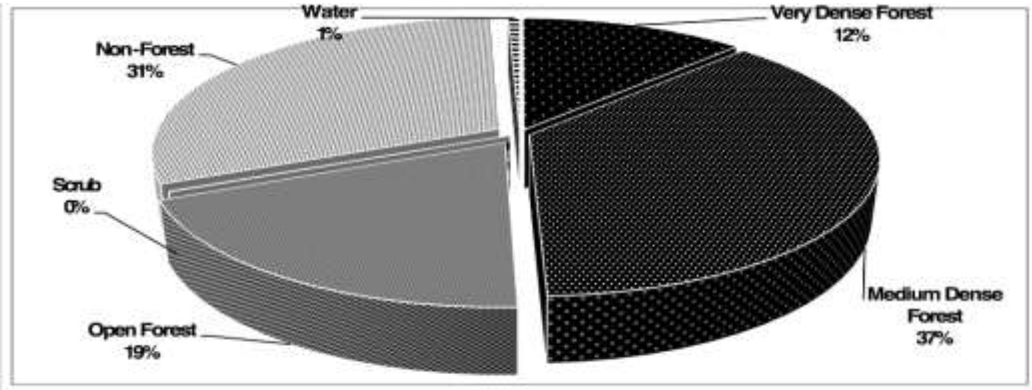


Figure 10.1: Area under different forest cover classes in Dibang basin

Temperate Coniferous forest is the dominant forest in the basin (8.27%), followed by agricultural land mainly in plains of Assam (5.87%), Moist deciduous forest (5.59%), Abandoned *jhummed* land (3.54%) mainly in catchments of Mathun river and catchment area of Dri river upstream of confluence of Dri and Mathun rivers (**Figure 10.2**).

Nearly 64% of the basin area is under Very High and High Biological Richness Index even as about 30% of its area is under abandoned *jhum*, agriculture, riverbed, water, riverine grasslands, snow/glaciers, etc. (**refer Figure 10.3**). Biological rich areas are those habitats where landscape ecological conditions are favourable for natural speciation and evolutionary processes and area is in equilibrium where species can occur, grow, and evolve in natural conditions. Each species requires a special ecological niche (minimum/optimum area for its survival, growth and evolution). Therefore contiguous landscapes would require conservation measures.

Landscape fragmentation an indicator of patchiness of forest cover and is computed as the number of patches of forest and non-forest types per unit area. Landscape Fragmentation Index map of Dibang basin reveals that fragmentation of landscape is low at present i.e. less than 10% area in under High Fragmentation Index (**refer Figure 10.4**).

There are 18 planned hydropower projects in Dibang basin and together they are likely to divert about 14000 ha of forest area, which amounts to 1.4 ha/MW of installed capacity (**Refer Table 10.1**). All these projects are distributed all over the basin which would lead to fragmentation of contiguous patches of forests in the basin due to diversion of forest land for different projects. Out of 18 proposed projects about 11500 ha of forest is likely to be lost due to 6 projects only.

10.2.2 Forest Cover Loss due to Nibbling effect/ loss

A new land use would be created due to clearing of forest areas for reservoirs, muck dumping, construction works, quarrying, etc. and building of roads into otherwise remote forest areas and would lead to direct loss of forest land and habitat. This landscape change and its fragmentation would become apparent only over a long period of time. During the construction period, the projects would lead to gradual disturbance and loss of forestland and habitat due to increased access to otherwise remote forest areas. The impact cannot be quantified at this stage, however, these activities would lead to landscape change and its fragmentation which would become apparent only over a long period of time. This is a nibbling impact, which goes unnoticed during construction whereas its impacts are felt in long term especially due to cumulative impact from several projects. The loss of forest does not occur directly only due to diversion of forest land for non-forest use but also due to fragmentation of contiguous forest landscapes into patches of forests interrupted by forest land converted into other land uses like roads, colonies, muck dumping, quarrying, and other project construction activities. Therefore in a scenario when several projects are taken up for construction together, the project related activities too would also lead to forest cover degradation due to bunching of projects.

10.2.3 Impact of Spatial and Temporal Crowding

In a scenario where several projects undergo construction simultaneously substantial activities happening might happen simultaneously within a small area, which is otherwise pristine and has never faced any major disturbance. This type of spatial crowding would result in overlapping of different impacts e.g. land use change, change from lotic to lentic environment of river, fragmentation of wildlife habitat, reduction in flow in river, change in riverine habitat, etc. Temporal crowding might also occur if impacts generated by different projects taken up for construction over different periods of time but overlapping of construction period would add to the impact already generated before the resource (river, forest area, etc.) has had time to recover. The cumulative impact of several projects bunched together for construction would also result in forest losses due to nibbling effect.

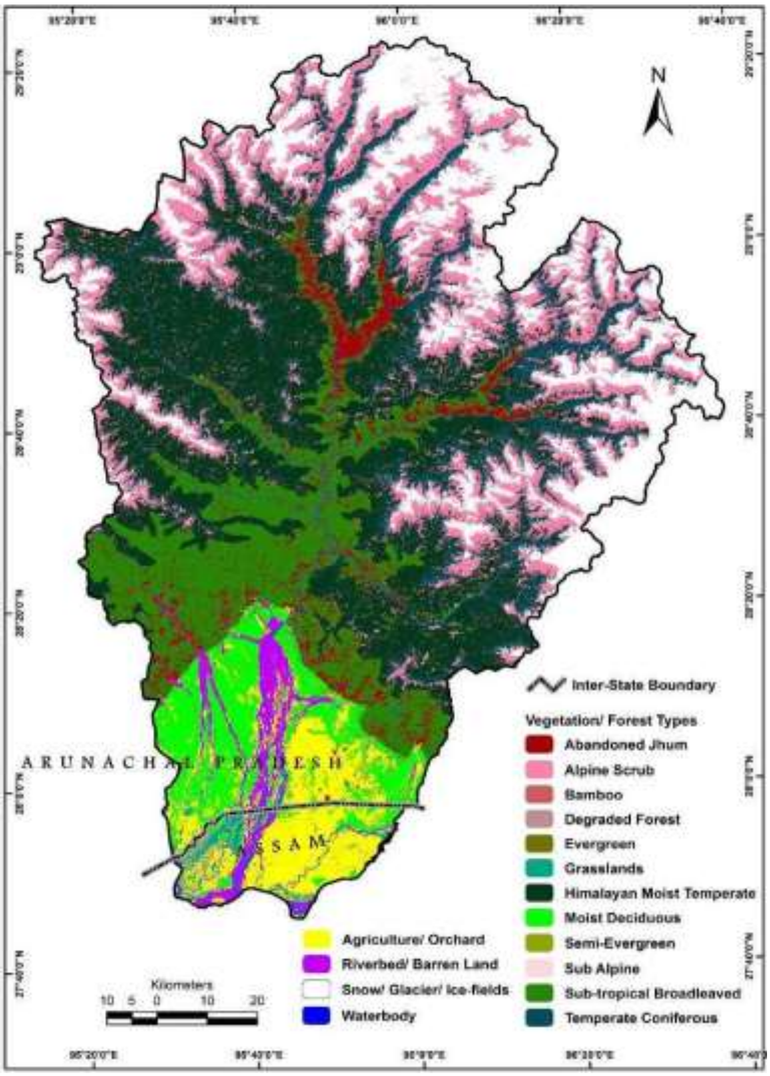


Figure 10.2: Vegetation/Forest types map of Dibang basin

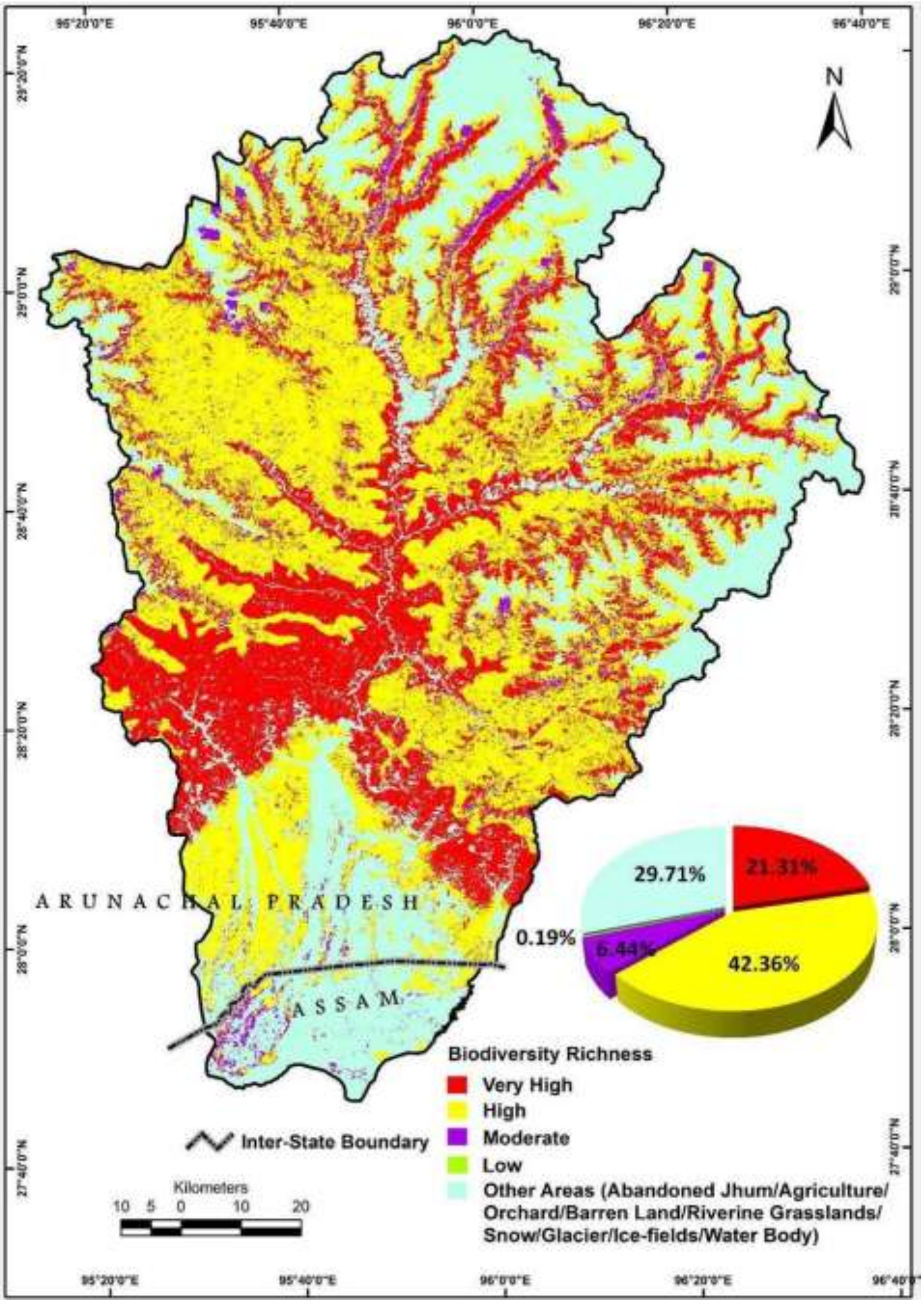


Figure 10.3: Biological Richness Index map of Dibang Basin

10.2.4 Impacts on Wildlife

The Dibang basin is a part of the Eastern Himalaya- Province 2D according to biogeographic classification of Rodgers *et al.* (2002). Faunal elements of Arunachal Pradesh, easternmost part of Himalaya and as well as Dibang basin i.e. mammals, birds, reptiles and fish species are similar to the North-eastern states of India. Mammalian fauna of the basin comprises of about 78 species excluding families of bats, rats and shrews. Twenty seven species of mammals have been included in Schedule-I according to WPA 1972, another 26 species in Schedule-II and rest of the species are either under Schedule- III, IV or V. According to IUCN Red List 12 species under Endangered category like *Manis pentadactyla, Cuon alpinus* and *Caprolagus hispidus*. In addition there are 14 more species which are under Vulnerable category viz. *Capricornis sumatraensis, Budorcas taxicolor, Helarctos malayanus, Ursus thibetanus, Melursus ursinus* and *Trachypithecus pileatus* while 7 species are listed as Near Threatened category. One hundred and thirteen (113) species of mammals reported from the basin are under Least Concern (LC) category of IUCN Red List.

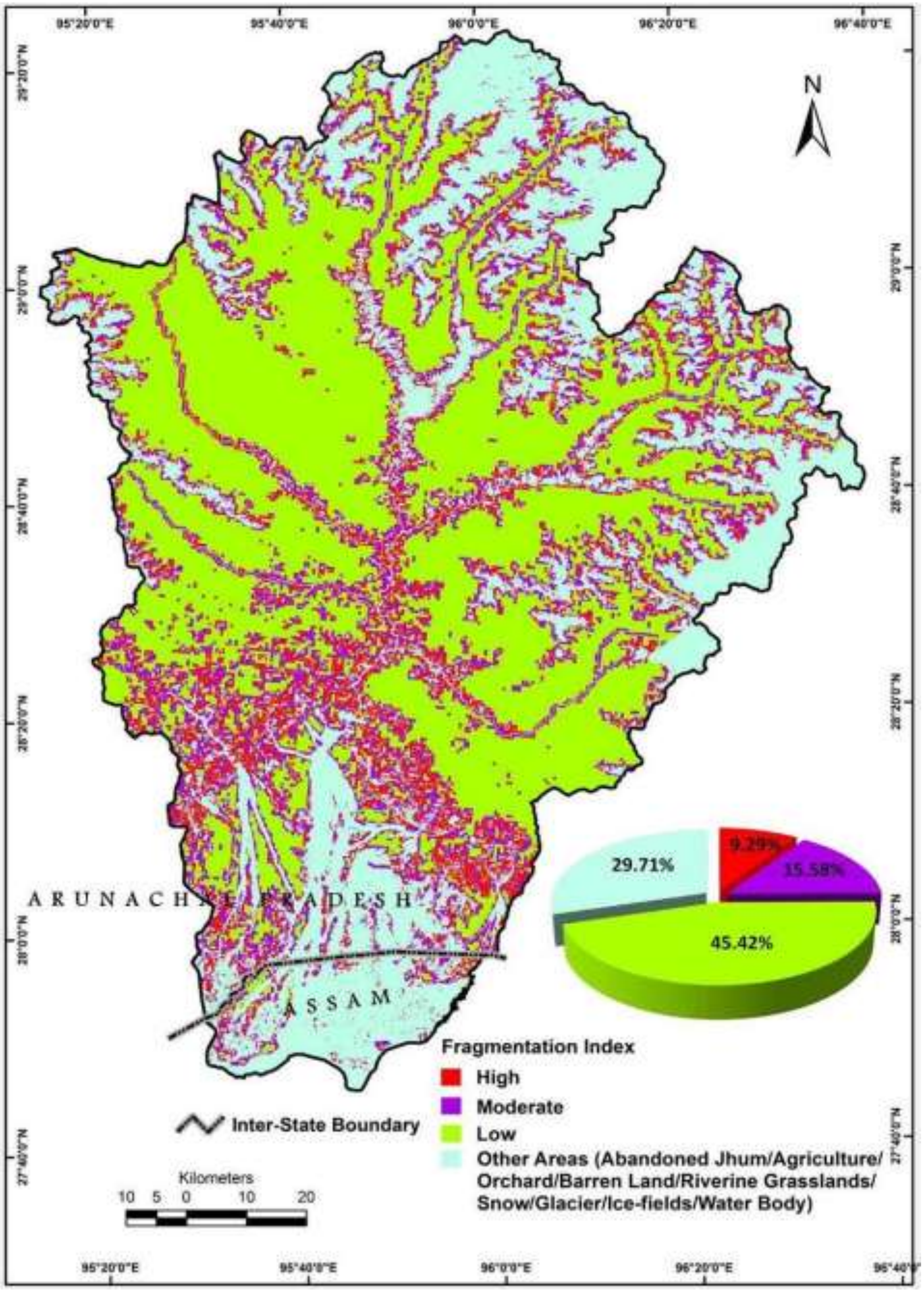


Figure 10.4: Fragmentation Index map of Dibang Basin

In Dibang basin **679 species** of birds belonging to **90 families** have been reported. Muscicapidae with 63 species is the largest family in the basin followed by Sylviidae and Accipitridae with 32 species and Timaliidae with 30 species of birds.

Owing to rich avi-faunal diversity 3 International Birding Areas (IBA) have been identified in Dibang basin by Birdlife International.

The Dibang basin is home to 2 Protected Areas (Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary) and also there is a Dibang Dihang Biosphere Reserve extending across Dibang and Siang basins.

Only one project i.e. part of Malinye HEP falls within Dibang Wildlife Sanctuary (refer **Figure 6.2** in chapter 6). However 4 projects fall within 10 Km radius of the sanctuary viz. Mihumdon, Etabue, Amulin and Attunli HEPs. **No project falls within Eco Sensitive Zone of Mehao Wildlife Sanctuary according to recently issued draft notification by MoEF&CC.** The tail end of proposed reservoir of Ashupani HEP apparently encroaches into the Mehao WLS boundary based upon the contour map derived from Survey of India (1:50000 toposheets) and salient features and layout provided by the project developer which however requires ground verification by the state forest department and the project developer.

10.2.5 Impact on RET & Endemic Species

The highest number of RET plant species (7 species) are found in study area of Emra-I HEP followed by 6 species in study area of Emra-II and Mihumdon HEPs, out of 30 found in the entire Dibang basin. Similarly, number of endemic plant species is highest in Emra-II study area (6) followed by 5 each in study areas of Emra-I and Dibang Multipurpose project.

The number of mammalian species under RET (IUCN Red list) is maximum in study area of Dibang Multipurpose Project i.e. 19 species out of 31 found in entire basin and 14-15 RET species in study areas of Emra-II, Attunli, Mihumdon, Amulin, Emini and Emra-I HEPs. Similarly number of bird species under RET (IUCN Redlist) is maximum in study area of Ashupani, Emra-I & Emra-II HEPs i.e. 12, 11 and 10 species, respectively. Dibang Multipurpose Project study area harbours largest number of fish species i.e. 60 species out of total 74 reported from the entire basin.

The direct forest loss due to diversion of forest land and degradation of forest cover in the Direct Impact Zones of projects mentioned above will adversely affect the RET species populations. The impacts of RET species occur due to loss of their habitat and their populations sizes decrease due to gradual degradation and shrinkage of their habitats which ultimately results in disappearance of their populations and which become known only over a longer period of time. Such species rich areas need to be preserved in addition to the existing protected areas in the basin.

The number of RET bird species is highest in Dibang Multipurpose project study area along with highest number of fish species reported.

It has been noted that large number of endemic plant species have been reported from Emra river catchment where Emra-I & Emra-II have been planned.

10.3 IMPACTS ON AQUATIC ECOLOGY

Freshwater ecosystems including rivers, lakes and wetlands are extremely rich in species, but unfortunately, are also amongst the most altered and threatened ecosystems in the world. The natural flow regime and the longitudinal and lateral connectivity of rivers, which are essential to sustain the biophysical and ecological processes necessary for life in freshwaters, are disrupted when dams and their reservoirs fragment the rivers. This fragmentation and the consequent loss of ecosystem processes do not only affect ecosystems and species, but humans as well. For example, the loss of floodplain inundation patterns affects both native ecosystems and human communities dependent on floodplain fisheries and flood recession agriculture. In freshwater habitats the main impacts of fragmentation from dam-building are:

- changes in water flow/oxygenation rates/temperature regimes, and
- effects of physical barriers obstructing migratory movements of species.

The impacts on aquatic ecology happen in following ways:

- Reduced flows in downstream stretches
- Altered flow regime in different seasons viz. lean, monsoon, pre- and post-monsoon

Discontinuity of river flow i.e. conversion of free flowing river into alternating small stretches of free flowing lotic ecosystem to lentic ecosystems of reservoirs and deprived stretches of river (run-of-the-river with long head race tunnels).

- Submergence
  - Alteration of river system from lotic to lentic environment
  - Loss of forest land
  - Alteration of landscape/aesthetics of area
- Alteration of river flow pattern downstream resulting due to variation in energy generation requirements in different periods.
  - Alteration of local ecosystem/ increased moisture conditions
  - Disruption of migration behaviour of fishes and other migratory animals
  - Health risks/Increased incidence/ proneness to unknown diseases
  - Downstream flooding due to sudden peaking

10.3.1 Loss of Riparian Habitats

The areas of special vegetation that grow along the sides of rivers are called the river's **riparian zone**. Riparian zones are critical to the health of rivers. Often the greatest contributor of plant food to streams is the **riparian zone** - the margins along the stream that are filled with vegetation. These plants, like all plants, drop their leaves, which fall into or are washed into the stream. This is **allochthonous** matter (from outside the stream), as opposed to **autochthonous** matter (from inside the stream, like algae and diatoms). These leaves can't make oxygen, since they are dead, but they provide food to the creatures in the stream. Not only the leaves themselves can be eaten, but also whatever bacteria or fungus is covering the leaves, rotting them. It is this bacteria and fungus that is what crayfish are really after when they eat decaying plant matter. Riparian plants also have bugs on them, which drop into the stream and provide food to stream-dwellers.

The riparian habitats are adversely affected by the altered flow regime i.e. the reduced flows in the river below the dam disturbs the natural ecological function of flood pulses vis-à-vis riparian vegetation. Periodic flood pulses inundating the riparian vegetation facilitate the exchanges of biota, sediments, organic matter and inorganic nutrients between the riparian vegetation and riverine ecology. It often leads to near disappearance or alteration of riparian vegetation due to non-wetting of vegetation, which acts as lateral connectivity of the river with the terrestrial landscape.
The riparian habitats of Dri, Mathun and Talo rivers will be severely affected due to proposed projects resulting in long stretches of changed river flow regime i.e. the long stretches of these rivers will have reduced flows wherein the water would be diverted into head race tunnels and natural riparian vegetation will be deprived of wetting and resultant reduced nutrient flow into the river.

10.3.2 Impact on Free Riverine Stretch

As discussed above of the 18 planned projects in Dibang basin, 4 are planned on main Dibang river, 3 on Talo and 2 on Mathun river. Four projects on Dri/Dibang river will affect **92.22 km** of river wherein the river will be flowing either through tunnels or will be converted into reservoir leading to significant alteration of free flowing fresh water ecosystem of Dibang river. To understand the contribution of individual project to cumulative impacts of diminishing river reach, river length affected by per MW of generation capacity was calculated project wise and is given in **Table 10.1**.

As can be seen from the **Table 10.1**, more than 45% of Dri/Dibang river stretch will be affected by 4 projects. Similarly more than one third of Talo river will be affected by 3 proposed projects. However 48% of Mathun river will be affected due to 2 projects. Only 38% of Ithun river is likely to be affected by 2 projects.

Six projects are planned on tributaries of Dri/Talo/Dibang rivers, one each of Ange Pani, Anonpani, Ahi river, Ithipani, Ashupani and Sissiri river.

Table 10.1: River Reach likely to be affected

S. No.	Name of Project	Capacity (MW)	River	River Length Likely to be Affected (km)			Free Stretch (km)
				Reservoir Length (km)	Intermediate Stretch (km)	Total (km)	
1	Mihumdon	400	Dri	5.20	9.39	14.59	Uppermost project
2	Agoline	375	Dri	4.79	9.38	14.17	5.50
3	Etalin (Dri limb)	3097	Dri	4.30	16.50	20.80	0.97
	Total					**49.56**	
	TOTAL DRI RIVER LENGTH (Up to confluence with Talo River)					**113.30**	
On Dibang River							
1	Dibang Multi-Purpose	2880	Dibang	41.46	1.20	42.66	4.50
	TOTAL DIBANG RIVER LENGTH (from Confluence of Dri and Talo up to Arunachal-Assam Border)					**90.50**	
1	Malinye	335	Talo				Uppermost project
2	Attunli	680	Talo	2.60	10.68	13.28	0.00
3	Etalin (Talo limb)	3097	Talo	2.44	18.00	20.44	1.02
	Total					**32.86**	
	TOTAL TALO RIVER LENGTH (Up to confluence with Dri)					**65.72**	
1	Amulin	420	Mathun	3.23	8.62	11.85	Uppermost project
2	Emini	500	Mathun	6.69	6.43	13.12	1.88
	Total					**24.97**	
	TOTAL MATHUN RIVER LENGTH (Up to confluence with Dri)					**80.00**	
1	Emra-I	275	Emra	4.34	6.12	10.46	Uppermost project
2	Emra-II	390	Emra	4.78	1.30	5.78	1.80
3	Dibang Multi-Purpose	2880	Emra	1.70	0.00	1.70	1.00
	Total					**18.24**	
	TOTAL EMRA RIVER LENGTH (Up to confluence with Dibang)					**93**	
1	Ithun-II	84	Ithun	1.09	4.47	5.56	Uppermost project
2	Ithun-I	48	Ithun	1.16	6.35	7.51	1.90
3	Dibang Multi-Purpose	2880	Ithun	18.10		18.10	2.25
	Total					**31.17**	
	TOTAL ITHUN RIVER LENGTH (Up to confluence with Dibang)					**77.00**	
Single project on tributaries of Dri, Talo and Sissiri rivers							
1	Etabue	165	Ange Pani	1.2	3.1	-	-
2	Anonpani	22	Anonpani	-	2.4	-	-
3	Ithipani	22	Ithipani	-	2.52	-	-
4	Elango	150	Ahi river	-	-	-	-
5	Ashupani	30	Ashupani	1.0	11.1	-	-
6	Sissiri	100	Sissiri	8.1	0.5	-	-

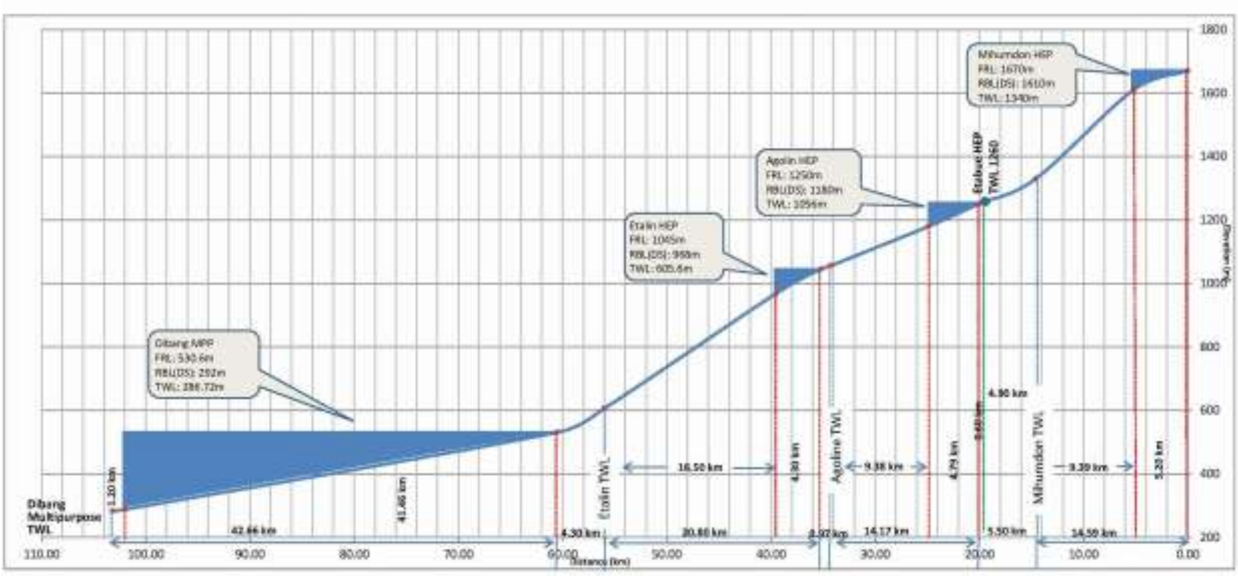


Figure 10.5: L-section of Dibang river along Dri river stretch

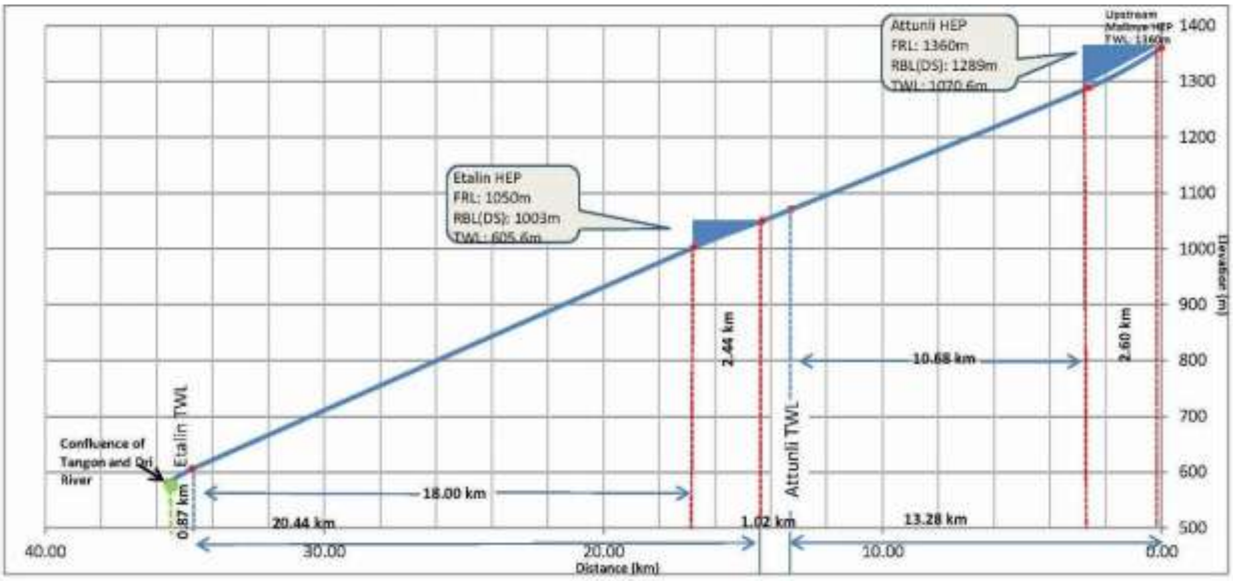


Figure 10.6: L-section of Talo river

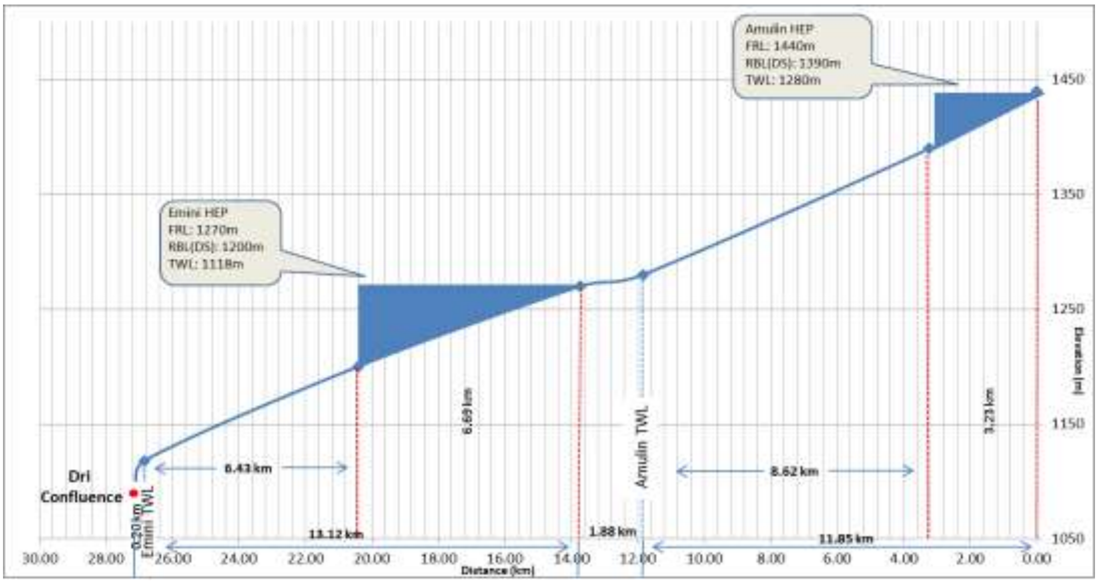


Figure 10.7: L-section of Mathun river up to its confluence with Dri river

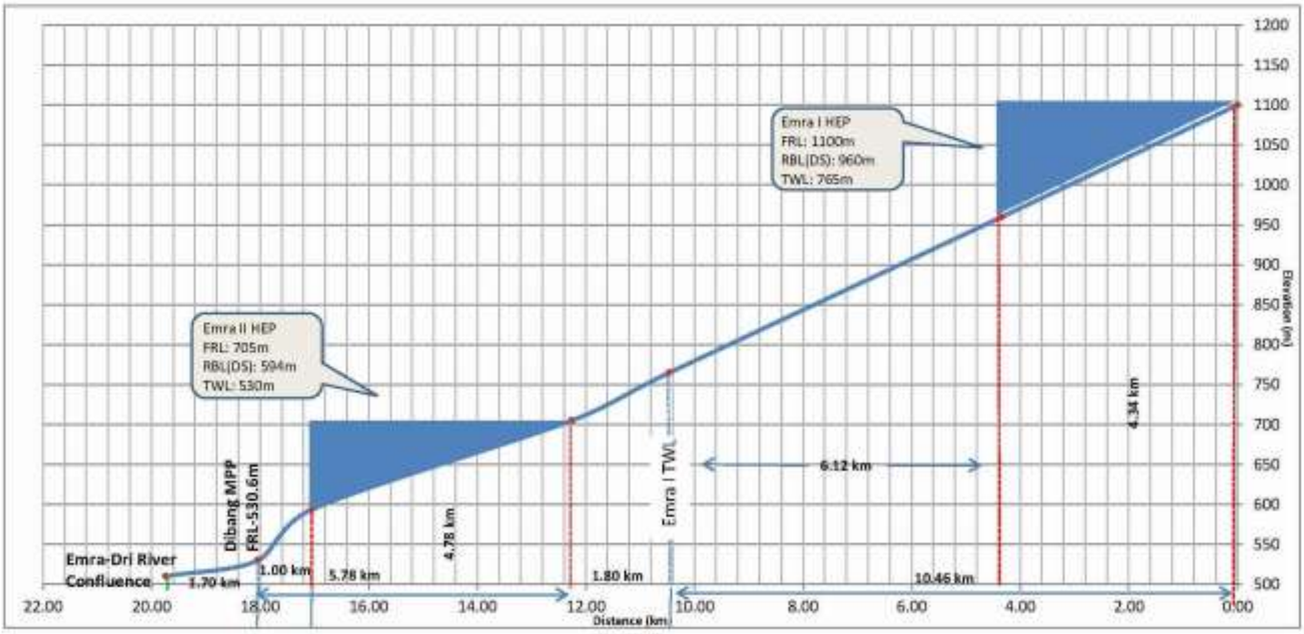


Figure 10.8: L-section of Emra river

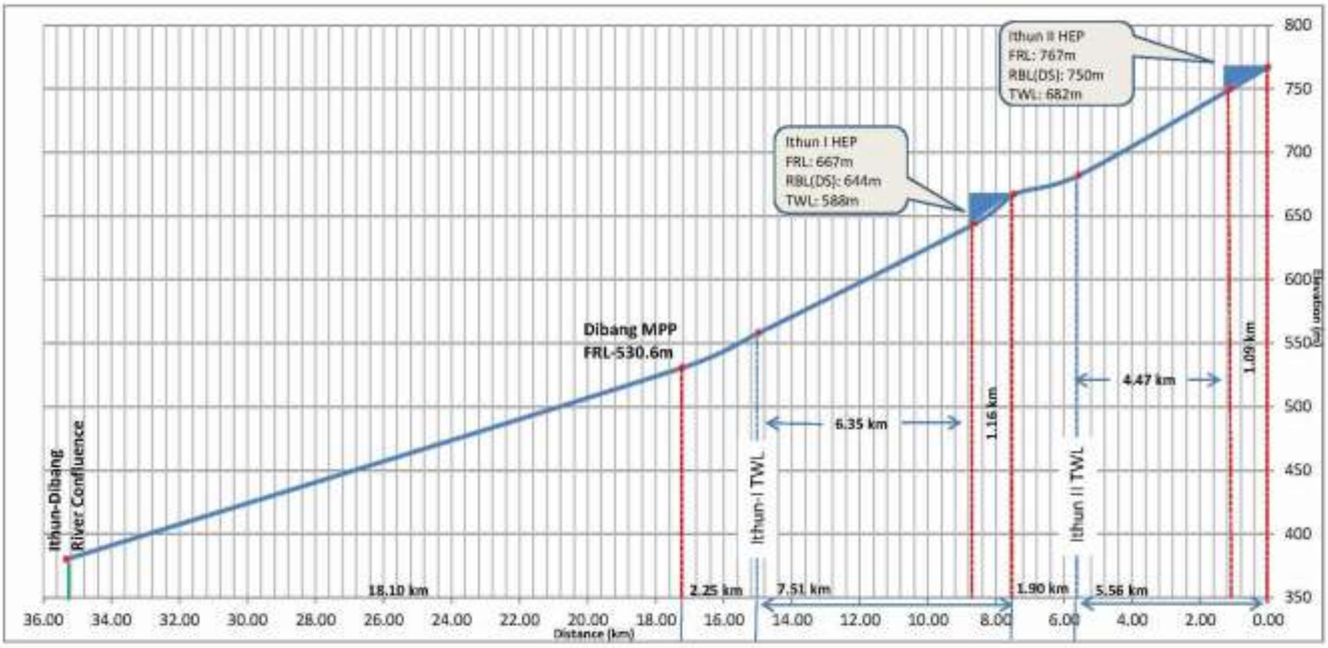


Figure 10.9: L-section of Ithun river

10.3.3 Impacts due to Damming of River

A large reservoir area implies the substantial loss of natural habitat and wildlife and/or the displacement of many people. Very large reservoirs are typically in the lowlands (often with tropical disease and aquatic weed problems) and usually impound larger rivers (with more fish and other aquatic species at risk).

Typical Impacts of large reservoirs are:

a) flooding large areas of natural habitats and consequent loss of biodiversity;
b) a large river with high aquatic biodiversity damaged;
c) few or no downstream river/tributaries;
d) water quality problems due to the decay of submerged forests;
e) their location in the sub-tropics is conducive to the spread of vector-borne diseases; and
f) serious problems with floating aquatic weeds.

10.3.4 Direct Impacts of Reservoir based projects

- Barriers (high) severely restricts aquatic life migration
- Bottom layers are devoid of oxygen
- Changes river bottom profile

Direct impact of large reservoirs is the conversion of fast flowing river into stagnant reservoirs. Its direct impact is on oxygen concentration in the water. In the large reservoirs oxygen depletion results from eutrophication in which plant nutrients enter a river and phytoplankton blooms are encouraged. While phytoplankton, through photosynthesis raise DO saturation during daylight hours, the dense population of a bloom reduces DO saturation during the night by respiration. When phytoplankton cells die, they sink towards the bottom and are decomposed by bacteria, a process that further reduces DO in the water column. If oxygen depletion progresses to hypoxia, fish kills can occur and invertebrates like worms and clams on the bottom may be killed as well. Below 5 mg/L, most fish, especially the more desirable species such as trout, do not survive. Actually, trouts need at least 8 mg/L during their embryonic and larval stages and the first 30 days after hatching.

The consequence of river impoundment is the transformation of lotic environment to lentic habitats. Independent of free passage problems, species which spawn in relatively fast flowing reaches can be eliminated. From a study of the threatened fish of Oklahoma, Hubbs and Pigg (1976) suggested that 55% of the man-induced species depletions had been caused by the loss of free-flowing river habitat resulting from flooding by reservoirs, and a further 19% of the depletion was caused by the construction of dams, acting as barriers to fish migration.

Projects such as Dibang Multipurpose Project and Sissiri HEP on Dibang river and Sissiri river, respectively are dam toe projects with large reservoirs. In addition other run of the river large projects such as Etalin, Attunli, Emini and Amulin will also submerge substantial forest area. The creation of large reservoirs behind the proposed dams of Dibang Multipurpose Project and Sissiri HEP would change free flowing character of Dibang and Sissiri rivers i.e. from lotic to lentic - running water becomes still. This results in silt deposition and the formation stratified bodies like reservoirs would change the temperature and oxygen conditions making it unsuitable for existing riverine species. The projects would obstruct the migration of mahseer and there is no other stream in which fish like mahseer can effectively migrate into for breeding and spawning, which is part of natural life cycle of mahseer. The modified flow of the river adversely affects the fish populations by obstructing the migration as well as changed riverine profile.

10.3.5 Impact on Fish Populations

In Dibang river basin mahseer and trouts are the two key fish species. Mahseer is found up to the confluence of Dri and Talo rivers i.e. up to elevation of about 750-800m in Dibang river and in tributaries like Ithun, Ahi river and Emra rivers where they are reported for breeding and spawning in monsoon. It could not be found in streams in upstream areas i.e. in Dri and Talo rivers. In these streams trouts are dominant fish species especially snow trout (*Schizothorax richardsonii*).

i) Mahseer Group fishes

The migratory phenomenon of the fish species is directly related to its life cycle as fish moves from one habitat (stationary ground) to other (breeding ground) to spawn. The breeding migration in fish may be of a few meters to many hundreds of kilometers. In the Himalayan rivers Mahseer (*Tor putitora* and *T. tor*), important potamodromous fish species, ascend longest distance for breeding purpose, which move from main stream to the tributaries. Other species like *Neolissochilus hexagonolepis*, *Labeo pangusia* (all potamodromous fish) and *Anguilla* *bengalensis* (catadromous) and snow trout species traverse relatively short distances. Mahseer and *Neolissochilus hexagonolepis* start their migration during the onset of monsoon and perform tri-phased migration. All 'schizothoracines' show migration variably. They descend in monsoon towards warmer places and spawn in the main streams or tributaries. *Labeo pangusia* migrates into the nearby tributaries for breeding.

The golden mahseer, *Tor putitora* is the most popular mahseer and the most popular game fish in India. These fish like fast flowing, rocky waters, and are seen frequently around the Himalayan foothills. Dibang Multipurpose project on Dibang river with large reservoir will stall the migration of mahseer and in addition the projects on tributaries also would affect the breeding grounds and shelters of mahseer during monsoon.

ii) Trout Group fishes

Trout thrive in cooler water than most other fish in temperatures that range from about 2–20^{0}C. However, their optimum feeding range is about 10–18^{0}C. Cold mountain streams with good snow melt provide those temperatures and are an ideal environment for trout.

Trouts are cold-blooded by nature so their food needs vary with the temperature of the water as well as their body temperature. When the water is very cold, trout are almost dormant and require very little food to survive. As the water warms, they need more food and will become more aggressive in their feeding habits. In shallow mountain streams, the temperature can change rather abruptly as the temperature in the air changes along with snow melt, rainfall and direct sunlight on the water. Larger rivers provide a more stable water temperature due to the sheer volume of water.

The water where trout lives can be either a few centimeters or 1-2 m deep depending on if there is water close by that is deep enough (about 40-50cm) or if there is an overhanging bank or downed log to protect them from overhead threats such as hawks and eagles. When the snow melts there are usually good cold-water flow and just enough food to sustain the trout. As the air temperature warms and the water warms a few degrees with a good flow, trout then become very aggressive eaters. This is the time when the insects start hatching and provide the trout with one of their favourite diets. Spring rains increase the water flow and enabling more number of insects to hatch, which ensures that more food is available to them.

As the water flow slows down after November-December and the water level drops causing some areas to dry up completely and due to slowing of current the water temperature gets warmer and the water begins to form pools. The riffles become less prevalent and there is less oxygen content in the water. With the continuation of this process, the fish generally start to become sluggish, but they are still in their feeding cycle. If there is one available, the fish may move to an area with better oxygen content (closer to a riffle or waterfall) and /or move to a cooler water source such as a small colder stream in a shaded location. With the cooling of weather the trout becomes aggressive again. They begin feeding and loading up on the abundant insects gaining weight for the winter. When winter arrives, the water cools and the trout's metabolism slows so they don't require as much food to keep them nourished. They then move to the deeper holes even though they can still be enticed into taking an occasional offering.

Trout spends most of their lives in a small area of the stream and undertakes little movement unless there is a shortage of food, changes in the water temperature changes and /or the oxygen content gets too low. Since they live in such a small area of the stream, they are acutely aware of their surroundings. They know where the current is ideal for feeding or resting and will move to those positions as needed.

Schizotharax richardsonii (Snow trout), the predominant trout species is a column feeder and are known to move relatively shorter distance as compared to mahseer. *Schizothorax richardsonii* generally performs migration within same river. In order to cope with the low temperature in peak winter season it starts to move downwards. It finds a tributary to spawn from May to September.

10.3.6 Impact on Fish Migration

The species *Schizothorax richardsonii* and *Neolissochilus hexagonolepis* migrate from lower elevations to higher elevations in summer months and return to lower elevation in winter months. These species were observed at various sampling locations. Construction of proposed dams would hamper the upward and downward migratory movement of these fish species in summer and winter seasons. Likewise, migration of fish species from tributaries to Dibang river would be affected on account of creation of reservoir due to construction of proposed hydroelectric projects. Thus, the projects will lead to adverse impact on migration of these fish species. The fish migration would be restricted in the following stretches:

- Upstream of dam site of Dibang Multipurpose Project and Sissiri HEPs
- Upstream and Downstream of dam sites of Etalin and Attunli hydroelectric projects

Majority of the fish species found in the Dibang river and its tributaries prefer fast flowing, rocky bottom waters. Mahseer is the main fish species of Dibang river and the main breeding zone for mahseer is river Dibang and its tributaries like Ithun, Ahi and Emra rivers which offer suitable habitats for its spawning and growth. Golden mahseer (*Tor putitora*) is an important endangered migratory fish, which migrates longitudinally upstream during April-May in Dibang river and then undertakes lateral migration in the tributaries of Dibang river for breeding, feeding and as refuge location. Thereafter it migrates downstream via main channel during post-monsoon period (September-October) to feed, thrive and grow in the main Dibang where the temperature and oxygenation conditions in winters are conducive for its growth along with availability of substratum in Dibang river. Chocolate mahseer (*Neolissochilus hexagonolepis*) is another important migratory mahseer fish species found in Dibang river and its tributaries.

Construction of hydropower projects in stretch of Dibang river where mahseer is dominant species, will severely affect its habitat. The projects like Dibang Multipurpose Project on Dibang river would permanently block the movement of migratory mahseer species up and down in Dibang river, causing extirpation (loss of populations from a part of the species range) as these projects are planned in that part of river where mahseer is the key species. These projects would also result in change in turbidity/sediment levels to which species/ecosystems are adapted. The trapping of silt in reservoirs would deprive the downstream Dibang river ecosystem of maintenance materials and nutrients that help in maintaining productivity of Dibang river ecosystem.

Emra river is one of the rivers where fish species like mahseer (*Tor putitora*) migrates for spawning and breeding. *Labeo pangusia* is another fish, which prefers waters of tributaries for spawning. In addition snow trout *(Schizothorax* spp.*)* is important fish of the colder waters upstream. The species like *Labeo pangusia* and *Anguilla bengalensis* ascend comparatively for short distance. Among catfishes *Aorichthys seenghala* also migrates for breeding and spawning purposes.

The projects like Etalin and Attunli on Dri and Talo rivers, Amulin and Emini HEPs on Mathun river and Emra-I & Emra-II HEPs on Emra river would affect the habitat of these fishes. Owing to diversion of water for power generation there will be reduced flow of water downstream of these projects up to the tailrace discharge of water from powerhouse. The reduced flows in these stretches would affect the movement of trout leading to reduction in their population.

10.3.7 Major impact on Fishes

i) Loss of Habitat

The suppression of flood regime downstream from an impoundment by means of flow regulation can deprive many fish species of spawning grounds and valuable food supply (Petts, 1988). This can lead to changes in species composition with loss of obligate floodplain spawners. Dam construction for industrial uses within the Rio Mogi Guassu Brazil has resulted in the progressive loss of flood plain wetlands (Godoy, 1975). The cumulative effect of diminished peak discharges, stabilized water levels, reduced current velocities and water temperature eliminated spawning grounds below the dams on the Qiantang and Han rivers: six migratory fish and five species favouring torrential habitats declined severely (Zhong and Power, 1996). The reaction of the fish communities of the Chari, Niger and Senegal rivers to flood failures provoked by natural climatic variations illustrates the highly detrimental effect of suppressing the flood (Welcomme, 1985). The construction of proposed dams on Dibang river would result in loss of habitat of native fish species inhabiting the Dibang river and its tributaries.

ii) Impact on Fish Migration

One of the major effects of the construction of a dam on fish populations is the decline of anadromous and potamodromous fish species. The dams prevent migration between feeding and breeding zones. The effect can become severe, leading to the extinction of species, where no spawning grounds are present in the river or its tributary downstream of the dam.

The concept of obstruction to migration is often associated with the height of the dam. However, even low weirs can constitute a major obstruction to upstream migration. Whether an obstacle can be passed or not depends on the hydraulic conditions over and at the foot of the obstacle (velocity, depth of the water, aeration, turbulence, etc.) in relation to the swimming and leaping capacities of the species concerned. The swimming and leaping capacities depend on the species, the size of the individuals, their physiological condition and water quality factors such as water temperature and dissolved oxygen. Certain catadromous species (species of *Anguilla*) have a special ability to clear obstacles during their upstream migration: in addition to speed of swimming, the young eels are able to climb through brush, or over grassy slopes, provided they are kept thoroughly wet; some species (i.e. gobies) possess a sucker and enlarged fins with which they can cling to the substrate and climb around the edge of waterfalls and rapids (Mitchell, 1995).

For a migratory species, an obstruction may be total, i.e. permanently insurmountable for all individuals. It may be partial, i.e. passable for certain individuals wherever the diversion structures are not very high. It may be temporary, i.e. passable at certain times of the year (under certain hydrological or temperature conditions). During low flow conditions diversion dams may be insurmountable because the depth of water on the face is too shallow to permit fish to swim. They may however become passable at a higher discharge rate, as water depth increases and the fall at the structure generally decreases. The negative impact on fish caused by temporary obstacles, which delay them during migration and which may cause them to stay in unsuitable zones in the lower part of the river, or cause injury as a result of repeated, fruitless attempts to pass, should not be underestimated.

iii) Modification of Discharge

The modification of downstream river flow characteristics (regime) by an impoundment can have a variety of negative effects upon fish species: loss of cues/ stimuli for migration, loss of migration routes and spawning grounds, decreased survival of eggs and juveniles, diminished food production.

Regulation of stream flow during the migratory period can alter the seasonal and daily dynamics of migration. Regulation of a river can lead to a sharp decrease in a migratory population, or even to its complete elimination. Any reduction in river discharge during the period of migratory activity can diminish the attractive potential of the river, hence the numbers of spawners entering the river is reduced. Because of this, regulation of a river can greatly influence the degree of migration to the non-regulated part of the river below the dam site. This aspect will affect the migration behaviour of migratory fishes in Dibang river.

Modification of discharge will take place in all the projects and cumulatively this impact will become serious as projects are planned in cascade in all the rivers and tributaries leading to discharge modification in almost the entire basin. This impact cannot be eliminated, however can be mitigated to certain extent by ensuring adequate environmental flow in the intermediate stretch so that continuity with tributaries can be maintained; ensuring free flowing river stretches for the river to recover and maintain continuity with the tributaries in the free flowing river stretches, wherever tributaries are ensuring continuity of habitat with the free flowing stretch and intermediate stretch, development should be restricted on such tributaries.

iv) Water Temperature and Water Quality Changes

Dams can modify thermal and chemical characteristics of river water: the quality of dam-releases is determined by the limnology of the impoundment, with surface-release reservoirs acting as nutrient traps and heat exporters and deep-release reservoirs exporting nutrient and cold-waters (Petts, 1988). This can affect fish species and populations downstream.

Water temperature changes have often been identified as a cause of reduction in native species, particularly as a result of spawning success (Petts, 1988). Cold-water release from high dams of the Colorado river has resulted in a decline in native fish abundance (Holden and Stalnaker, 1975). The fact that *Salmo* spp. had replaced some twenty native species has been attributed to the change from warm-water to cold-water.

Water-chemistry changes can also be significant for fish. Release of anoxic water from the hypolimnion can cause fish mortality below dams (Bradka and Rehackova, 1964).

During high water periods, water which spills over the crest of the dam can become over-saturated with atmospheric gases (oxygen and nitrogen) to a level which can be lethal for fish. Mortality can result from prolonged exposure to such lethal concentrations downstream of the spillways. Substantial mortalities of both adult and juvenile salmonids caused by high spillway flows which produced high supersaturation (120-145%) have been observed below the John Day dam on the Columbia river (Raymond, 1979). The Yacyreta dam on the Parana river generates supersaturated levels of total dissolved gases that can affect the health condition of fish: in 1994, massive fish mortality was observed in a 100 km reach below the dam (Bechara *et al.*, 1996).

Therefore not only the migration behaviour is likely to change due the proposed projects but changes in water temperature and quality also will have impact on fish populations and high fish mortality.

v) Increased Exposure to Predation

Normal predation behaviour may become modified with the installation of a dam, and although few data exist to date, it appears that migrating species suffer increased predation in the vicinity of an installation, whether by other fish or birds. This may be due to the unnatural concentration of fish above the dam in the forebay, or to fish becoming trapped in turbulence or recirculating eddies below spillways, or to shocked, stressed and disoriented fish being more vulnerable to predators after turbine passage. In some rivers or hydroelectric schemes, predation may affect a substantial proportion of the fish population. On the Columbia river, predator exposure associated to turbine passage was the major causes of salmon mortality. Tests at the Kaplan turbines indicated a mean loss of 7% and studies showed that the indirect mortality on juvenile coho salmon could reach 30% when indirect mortality from predation was included (Ebel *et al*. 1979).

The proposed projects in Dibang basin will lead to increased exposure of fishes to predation which will affect their mortality and populations.

10.3.8 Impacts on Tributaries

Ecosystems of small streams or tributaries of Dibang, Dri and Talo rivers if exploited for hydropower generation would severely affect their role as natural resource replenishment character as these streams are the main contributors of biological production of the main rivers. These small streams act as hatcheries for biological production at the first and second trophic levels.

The tributaries are a source of nutrients and energy by way of contributing dissolved organic matter from falling litter, overland flow and subsurface movement into the main channel. Their importance has been very well document by Wipfli *et al.* (2007). Therefore any modification of tributary streams of large rivers like Dibang, Dri and Talo would impair their capability to rejuvenate the main river channel by reduced resource flow. Their contribution assumes more significance especially in the stretch downstream of projects which have been affected by reduced flows by diversion of water for power generation. Therefore role of tributaries to reduce the impact of projects on main river should be taken into account before planning any project on tributaries.

Projects on tributaries like Ithun river, Ahi river, Anonpani, Ashupani and Ange Pani would impair the capabilities of these tributaries to resource flow into the main channel Dibang river.

10.4 CUMULATIVE IMPACT ASSESSMENT

The approach followed in the present study is a combination of both the matrix as well as overlay method. Such approach helps in identifying or "flagging", cumulative effects of bunch of proposed projects planned in cascade. This method does not lends itself to measurement or prediction, but it does allow for identification of potential cumulative effects. This technique is derived from both the matrix and overlay methods and required a series of matrices for either different levels of effects or for the cumulative effects of several activities. Once individual matrices are completed, the composite that results from overlaying them highlights areas for particular attention.

Since Dibang basin especially in Arunachal Pradesh is under forest cover of 71.54% and is endowed with rich biodiversity the focus of CEIA is primarily in assessment of impacts of proposed hydropower development in context of ecological attributes of the area that are likely to be affected by the proposed projects. In order to make such assessment biodiversity values were evaluated at landscape level which in turn was based upon vegetation /forest types mapping of entire basin. In addition to assessment of impact of cascade of projects on a particular tributary an assessment of biodiversity values were assessed incorporating biodiversity related data in the respective immediate impact zones of the proposed projects separately as well as bunching them together. For adopting Biodiversity Assessment & Mapping Methodology (BAMM) Impact zones of proposed projects were delineated as 1 km buffer around the main project components like dam complex, reservoir, powerhouse complex, construction areas, colonies, etc. BAMM is frequently used by scientists around the world especially by Department of Environment & Natural Resource Management, Queensland, Australia.

For this baseline data is used to assess ecological concepts such as rarity, diversity, fragmentation, habitat condition, threats, etc. in a particular area/zone. This information is used in Geographic Information System (GIS) and based upon expert's knowledge/opinion results of quantitative data is refined into qualitative estimates. Expert's knowledge is used to identify wildlife corridors, specialised habitats e.g. areas with special biodiversity value like endemism. It also uses the data that is not uniformly available across the entire study area. Landscape properties were analysed using various quantitative indices which measure the heterogeneity of landscape within a specific distance (1 km buffer). Fragmentation increases the vulnerability of patches to external disturbance with consequences for the survival of these patches and of the supporting biodiversity (Nilsson & Grelsson, 1995).

The quantitative attributes like Impact area species richness – no. of plant species, RET species based upon IUCN Redlist and BSI Red Data Book, Endemic species, medicinal plants with conservation priorities identified by FRLHT, amongst faunal elements mammals and avi-fauna along with their conservation status like RET species, WPA Schedule-I species, spatial parameters like Forest Cover, Biological Richness Index, and Fragmentation Index. Though this methodology is primarily focused on terrestrial values however it also accounts for aquatic components like fishes and affected riverine stretch and reduced free flowing river stretches between cascade of upstream and downstream projects.

Therefore in Biodiversity Assessment data was compiled on various attributes and a summary list has been prepared for 14 allotted projects planned and allotted in Dibang Basin. Similar details however could not be compiled for projects which are yet to be allotted as no information is available about these projects except for PFR of Etabue HEP while no information is available for Elango, Malinye and Agoline HEPs.

A table was compiled listing information on project capacity, location with respect to river/tributary, total river reach affected by the project either in submergence or in the intermediate stretch where river is bypassed in tunnel and forest area likely to be acquired for the project. Information on forest area required for each project is not available for all the projects, as investigation work has not yet started in 10 projects though ToR has been obtained by 5 of them while 4 of them are yet to be allotted. For such projects, estimation is made based on the information available from PFRs prepared under 50000 MW PM's initiative on their size and type of project in order to get a comprehensive picture and make basin level assessment. The impacts have been studied for cascade of projects together on main river as well its tributaries. On Dri river, main source river 4 projects are planned viz. Mihumdon, Agoline, Etalin (Dri Limb) and Dibang Multipurpose HEP while one Etabue HEP is planned on Ange Pani one of its tributaries. On Mathun 2 projects i.e. Amulin and Emini HEPs before it confluences with Dri river upstream of Etalin (Dri Limb) HEP. Three projects ate planned on Talo river i.e. Malinye, Attunli and Etalin (Talo Limb) HEP upstream of its confluence with Dri to form Dibang river. One project Anonpani is planned on left bank tributary of Talo river downstream of Etalin HEP. On Emra river right bank tributary of Dibang 2 projects are planned i.e. Emra-I & Emra-II. On Ithun river two projects i.e. Ithun-I & Ithun-II HEPs are planned in cascade while one is planned on its tributary Ithipani.

An assessment of major tributary catchments of Dibang river for their biodiversity characterisation was made by mapping Biological Richness, Fragmentation and Disturbance indicies. Biological Richness index as it is a cumulative property of an ecological habitat and its surrounding environment while Fragmentation Index is a measure of patchiness of ecological habitat. These indicies were also derived for Direct Impact Zones of each of the 18 proposed projects also. In addition area under forest cover in Direct Impact Zones was also mapped.

Dri, Talo, Emra, Mathun and Ithun are the major tributary catchments of Dibang river where projects have been planned. Among them forest cover is highest in catchments of Emra and Ithun rivers i.e. 87% and 81%, respectively. Talo catchment has least area under forest cover (58.19%). Area under Very High and High Biological Richness Index also is highest in these two catchments. Landscape fragmentation is also low in these two catchment as less than 6% of their area is under High Fragmentation Index category. Landscape fragmentation is more in catchments of Talo and Mathun rivers. Overall fragmentation in entire Dibang basin is low except for river flowing in plains where it is characterised by wide riverbed consisting of sandy and grassland tracts.

Among all 15 projects in Dibang basin for which project details were available, area under Direct Impact Zone (DIZ) is highest in Dibang Multipurpose project i.e. about 199 sq km area will be affected directly due to project components (**see Table 10.2**) and more than 95% of it is under forest cover. However highest percentage of Very Dense and Moderately Dense Forest cover in DIZ area is in Attunli, Ithun-I, Anonpani and Ashupani HEPs where it is more than 70% (**see Table 10.2**). Only in DIZ areas of Amulin and Mihumdon HEPs it is less than 50% i.e. 47.61 and 36.57%, respectively.

About 75% of its area is under High Biological Richness index an indicator of high species richness, and biodiversity value. Fragmentation index is comparatively low i.e. it is around 36% of landscape in Direct Impact Zone is fragmented. The project will require diversion of 5794 ha of forest land. The diversion of large area of forest is would lead to fragmentation of contiguous patches of forests into patches of forest thereby increased fragmentation index. In comparison though only 8.26 sq km of area would be directly affected by Ithipani project highest percent of forest cover (98%) is likely to be affected due to this project whereas among large projects in the affected area (DIZ) more than 95% area in under forest cover in Ithun-I, Emra-I, Emra-II and Dibang Multipurpose projects (**see Table 10.2**). Total Forest cover also as already discussed in DIZ of Amulin and Mihumdon HEP is lowest among all projects.

Direct Impact Zones of projects on Ithun river are characterised by high percentage of their areas under Very High and High Biological Richness Index (varying from 81% to 85%) (**see Table 10.2**). DIZs of Emini, Amulin and Mihumdon HEPs this area varies from 36-40%. Emini and Amulin are planned on Mathun river while Mihumdon on Dri river. Landscape fragmentation interestingly is lowest in DIZs of these projects. Landscape fragmentation is highest in DIZ of Emra-II HEP where area under High Fragmentation Index is more than 45%. Similarly area under High Fragmentation Index in DIZs of Emra-I, Anonpani and Dibang MPP is more than 33% (**see Table 10.2**).

10.4.1 Impact on Biodiversity Values

The direct loss of nearly 14000 ha of Very Dense and Dense category forests in entire Dibang basin will adversely affect the biodiversity contained in these forests. In addition to direct loss of forest cover due to development of 18 projects, large tracts of forests would be indirectly affected by construction activities which will lead to degradation of forests in the vicinity of project sites and more forest areas will become accessible due to construction of roads resulting in disturbance of habitats of many RET plant species reported from these areas. It assumes importance in case of Dibang basin which is rich in floral diversity as Dibang basin falls in the Eastern Himalayan biogeographic zone and owes its high floral and faunal diversity to its strategic location being at the junction of three biogeographic realms viz. the Palaearctic, the Indo-Malayan and the Indo-Chinese. According to the biogeographic classification, the area resides in the Himalaya-East-Himalaya biogeographic region (Rodgers and Panwar, 1988).

In all 1548 higher plant species have been documented which include 1329 Angiosperms, 17 Gymnosperms and 202 Pteridophytes. Among the lower plants bryophytes are represented by 21 species and lichens are represented by 16 species. Amongst angiosperms orchids, bamboos, canes and rhododendrons are the important plant groups that are predominantly found in the basin.

Orchidaceae is represented by 199 species, rhododendrons by 16 species and bamboos and canes together are represented by 27 species.

Table 10.2: Forest Cover (%) in Direct Impact Zones of proposed Projects in Dibang Basin

Forest Cover	Etalin HEP	Attunli HEP	Emra-I HEP	Emini HEP	Amulin HEP	Mihumdon HEP	Emra-II HEP	Etabue HEP	Sissiri HEP	Ithun-I HEP	Ithun-II HEP	Ashupani HEP	Anonpani HEP	Ithipani HEP	Dibang MPP
Very Dense Forest	**29.77**	**32.62**	**20.82**	**17.58**	**20.15**	**9.41**	**16.24**	**20.75**	**15.80**	**29.05**	**29.10**	**22.68**	**31.29**	**17.76**	**22.34**
Moderately Dense Forest	**32.57**	**44.61**	**34.51**	**33.54**	**27.46**	**27.16**	**41.13**	**57.53**	**42.47**	**44.17**	**30.10**	**47.64**	**39.28**	**47.33**	**41.72**
Open Forest	**29.65**	**12.41**	**41.52**	**17.96**	**9.29**	**20.61**	**37.86**	**12.86**	**22.64**	**23.49**	**35.61**	**13.14**	**22.18**	**33.28**	**31.17**
Non Forest	6.84	10.36	2.39	29.67	40.93	40.18	2.80	8.40	12.33	3.29	5.19	16.54	7.11	1.64	3.37
Water	1.17	0.00	0.75	1.25	2.17	2.63	1.96	0.47	6.75	0.00	0.00	0.00	0.14	0.00	1.40
Direct Impact Area (Sq km)	**111.82**	**29.36**	**26.23**	**28.99**	**28.16**	**34.26**	**7.43**	**29.57**	**7.59**	**21.51**	**13.21**	**12.18**	**13.84**	**8.26**	**198.34**

Table 10.3: Percent Area under Biological Richness Index in Direct Impact Zones of proposed Projects in Dibang Basin

Biological Richness Index	Etalin HEP	Attunli HEP	Emra-I HEP	Emini HEP	Amulin HEP	Mihumdon HEP	Emra-II HEP	Etabue HEP	Sissiri HEP	Ithun-I HEP	Ithun-II HEP	Ashupani HEP	Anonpani HEP	Ithipani HEP	Dibang MPP
Very High	**66.81**	**31.31**	**74.59**	**40.19**	**28.60**	**28.66**	**70.68**	**16.14**	**57.23**	**9.46**	**25.24**	**30.25**	**71.89**	**63.93**	**68.26**
High	**7.82**	**41.21**	**1.58**	**0.44**	**8.24**	**11.61**	**0.00**	**63.48**	**0.00**	**71.61**	**58.91**	**32.33**	**2.46**	**21.25**	**7.66**
Moderate	0.60	0.57	0.77	0.23	0.42	1.18	0.28	4.47	1.67	8.45	4.95	0.06	0.13	0.91	0.94
Low	0.05	0.07	0.25	0.04	0.05	0.00	0.12	0.09	0.11	0.03	0.00	0.00	0.08	0.00	0.04
Other Areas	24.72	26.84	22.80	59.10	62.68	58.55	28.92	15.82	40.99	10.46	10.90	37.37	25.44	13.90	23.11
Direct Impact Area (Sq km)	**111.82**	**29.36**	**26.23**	**28.99**	**28.16**	**34.26**	**7.43**	**29.57**	**7.59**	**21.51**	**13.21**	**12.18**	**13.84**	**8.26**	**198.34**

Table 10.4: Percent Area under Fragmentation Index in Direct Impact Zones of proposed Projects in Dibang Basin

Fragmentation Index	Etalin HEP	Attunli HEP	Emra-I HEP	Emini HEP	Amulin HEP	Mihumdon HEP	Emra-II HEP	Etabue HEP	Sissiri HEP	Ithun-I HEP	Ithun-II HEP	Ashupani HEP	Anonpani HEP	Ithipani HEP	Dibang MPP
High	**28.27**	**22.95**	**5.40**	**15.11**	**15.07**	**8.68**	**5.79**	**5.16**	**22.86**	**18.41**	**15.70**	**20.50**	**35.23**	**17.97**	**33.85**
Moderate	27.01	11.22	22.84	17.61	17.76	18.98	21.50	13.53	26.41	27.76	20.21	24.00	22.71	23.44	24.61
Low	20.62	40.90	20.88	7.19	6.18	12.35	3.63	66.22	8.96	42.53	53.34	18.39	16.42	45.57	18.26
Other Areas	24.10	24.93	22.88	60.09	61.00	59.99	29.08	15.08	41.77	11.30	10.75	37.11	25.64	13.03	23.28
Direct Impact Area (Sq km)	**111.82**	**29.36**	**26.23**	**28.99**	**28.16**	**34.26**	**7.43**	**29.57**	**7.59**	**21.51**	**13.21**	**12.18**	**13.84**	**8.26**	**198.34**

Fifty three (53) plant species that are endemic to Arunachal Pradesh have been reported from Dibang basin (see **Table 6.13 in Chapter 6**). These belong to 28 families and 42 genera. These species predominantly attributed to six plant families (i.e. Orchidaceae – 6 species; Gesneriaceae – 5 species, Balsaminaceae - 4 species; and Ericaceae, Rubiaceae, Begoniaceae and Acanthaceae represented by 3 species each). Three of these species viz. *Acer oblongum, Livistona jenkinsiana* and *Paphiopedilum fairrieanum* are under Endangered category according to BSI Red Data Book while *Begonia scintillans* and *Sapria himalayana* are under Rare category. IUCN has placed *Coptis teeta* and *Paphiopedilum fairrieanum* under Endangered and Critically Endangered categories.

In order to make an overall assessment of biodiversity values in study area (10 km radius) of projects, data on different biodiversity components was compiled and the same is given at **Table 10.5**. This data then was used to make comparative assessment of different projects with respect to their biodiversity values/ importance.

From the data compiled it can be seen that Dibang Multipurpose Project being the largest in terms of affected area, harbours maximum number of plant species as well as mammals and bird species in its study area. The formation of large reservoir shall submerge vast area of forest which contains number of important plant species populations and would lead to conversion of lotic system of Dibang river into lentic system which shall completely stall the migration of mahseer fish species which is known for upstream and downstream migration in Dibang river and its tributaries like Ahi, Ithun and Emra rivers especially. The resultant reservoir shall also submerge riparian vegetation along Dibang river as well as Ahi river (12 km), Ithun river (18 km) and Emra (1.7 km) rivers as reservoir will extend into these tributaries also.

Etalin HEP is the largest project in terms of Installed Capacity, total affected area is however is much less (111 sq km) as compared to Dibang Multipurpose Project (199 sq km). In addition total area under submergence is also quite low i.e. 119.44 ha only (covering both Dri and Talo Limbs). Attunli, Amulin, Emini, Mihumdon and Emra-I HEPs are the other projects where submergence area varies from 26 ha to 34 ha while in rest of the projects it is less than 20 ha. The projects when assessed for their forest land requirement (including submergence area) vis-a-vis installed capacity Ashupani HEP ranked highest with forest land ratio per MW i.e. 7.53 followed by Sissiri and Emra-II HEPs with ratio of 4.03 and 3.57, respectively. Among large projects in Dibang Multipurpose Project it is 2.01 while in Etalin and Attunli HEPs it is less than 0.37 only.

After assessing the project wise impacts; for understanding of Cumulative Impacts of on sensitivity of Direct Impact Zones and Biodiversity values in Study area, a system of comparative assessment was developed. Relative scoring of proposed HEPs in Dibang basin was carried out for environmental sensitivity parameters like Very Dense and Moderately Dense forest cover, Forest land to be diverted (direct forest cover loss), area under Very High and High Biological Richness Index and High Fragmentation Index categories in Direct Impact Zones (**highlighted rows in Tables 10.2, 10.3 & 10.4**) of the projects. Highest value was taken as 100 and other HEP values were proportionately scored. The scores obtained by each project for all four above mentioned parameters were then clubbed and averaged out.

Similar exercise was also undertaken for Valued Ecosystem Components (VECs) in the Study Area both for terrestrial and aquatic ecosystems viz. Floristic Diversity (number of species, RET species, Medicinal plants and Endemic species), Faunal diversity (Mammals and Birds - number of species, RET species, Schedule-I species), and under aquatic ecosystem - Fish species. Scoring of all the projects were done based upon the average scores obtained for sensitivity as well as biodiversity richness values as follows and relative impact index generated.

Table 10.5: Environmental sensitivity parameters & Bio-diversity values of proposed Projects in Dibang Basin

	DMPP (2880 MW)	Etalin (3097 MW)	Attunli (680 MW)	Amulin (420 MW)	Emini (500 MW)	Mihumdon (400 MW)	Etabue (165 MW)	Emra-I (500 MW)	Emra-II (315 MW)	Ithun-I (84 MW)	Ithun-II (48 MW)	Ithipani (22 MW)	Sissiri (100 MW)	Ashupani (30 MW)	Anonpani (22 MW)	Dibang Basin
A. DIRECT IMPACT ZONE (1 KM RADIUS)																
Direct Impact Area (Sq km)	198.34	111.82	29.36	28.16	28.99	34.26	29.57	26.23	7.43	21.51	13.21	8.26	7.59	12.18	13.84	-
Forest Cover in Impact Area (%)	95.23	91.99	89.64	56.9	69.02	57.19	91.13	96.86	95.23	96.71	94.81	98.36	80.92	83.46	92.75	**-**
Forest land Requirement (ha)	4577.84	1160.73	250	1102	1251	1044	370	860	1125	76	58	58	402.74	226	29.76	-
Biological Richness Index - Very & High (%)	75.91	74.63	72.52	36.85	40.42	40.27	79.61	76.17	70.68	81.07	84.15	85.18	58.9	62.57	74.35	**63.67**
Fragmentation Index - High (%)	33.85	28.27	22.95	15.07	15.11	8.68	5.16	5.40	5.79	18.41	15.7	17.97	22.86	20.5	35.23	**9.29**
B. 10 KM RADIUS STUDY AREA – INFLUENCE ZONE																
Floristic Diversity																
No. of species	528	447	330	189	212	194	291	265	289	317	328	167	272	**187**	302	**1548**
No. of RET species	5	6	5	5	4	6	6	7	6	3	3	4	1	2	2	**30**
Medicinal FRLHT	5	4	4	6	5	5	5	7	6	2	2	3	1	2	2	**19**
Endemic to Arunachal Pradesh	5	4	2	4	4	4	5	5	6	3	2	2	1	4	2	**53**
Faunal Diversity																
Mammals																
No. of species	30	26	25	21	21	22	**29**	**12**	14	17	17	16	16	18	19	**78 (Excluding Bats, Rats and Shrews)**

	DMPP (2880 MW)	Etalin (3097 MW)	Attunli (680 MW)	Amulin (420 MW)	Emini (500 MW)	Mihumdon (400 MW)	Etabue (165 MW)	Emra-I (500 MW)	Emra-II (315 MW)	Ithun-I (84 MW)	Ithun-II (48 MW)	Ithipani (22 MW)	Sissiri (100 MW)	Ashupani (30 MW)	Anonpani (22 MW)	Dibang Basin
RET -IUCN	19	10	15	14	14	15	15	14	15	9	8	8	4	5	8	**31**
WPA Schedule-I Species	15	**5**	10	9	10	12	12	8	8	9	9	8	4	4	2	**26**
Avi-fauna																
No. of species	83	63	61	56	58	62	62	60	58	32	29	28	41	35	26	679
RET-IUCN Red List	5	1	4	6	6	7	4	11	10	9	8	8	9	12	0	30
WPA Schedule-I Species	6	1	3	2	3	4	4	6	5	4	3	4	1	3	1	22
Fishes																
No. of species	60	12	16	9	8	7	4	12	11	14	15	12	31	28	6	**74**
RET-IUCN	11	2	1	1	**1**	1	1	2	2	3	3	3	5	4	1	**4**
RET-CAMP	15	3	**3**	3	3	2	2	4	4	5	4	3	6	5	1	**13**
No. of Endemic species	3	1	1	1	**2**	2	1	2	2	2	2	1	1	1	0	**4**
NBFGR	9	3	2	3	3	2	2	4	5	3	4	2	2	5	1	18

The data on Land Requirements of some of the projects was not available and has been extrapolated is based upon the data available for project in immediate vicinity.

NBFGR = National Bureau of Fish Genetic Resources

All the 15 projects, for which project details were available (No data for three projects viz. Agoline, Elango and Malinye is available and have not been allotted yet), were assessed as discussed above based upon the data given in **Table 10.5**. Based upon these parameters comparative sensitivity, Biodiversity and overall score is tabulated below.

Table 10.6: Relative Impact Scoring

Project	Sensitivity Score	Biodiversity Score	Overall Score
Amulin	54	48	49
Anonpani	63	23	32
Ashupani	62	45	48
Attunli	66	48	52
DMPP	89	91	91
Emini	59	51	52
Emra-I	77	63	65
Emra-II	76	62	65
Etabue	74	54	58
Etalin	71	46	51
Ithipani	72	40	47
Ithun-I	70	47	52
Ithun-II	71	44	50
Mihumdon	56	54	54
Sissiri	54	35	41

As seen from the above table; apart from Dibang Multipurpose Project, projects such as Emra-I, Emra-II, Etabue, Ithipani, Ithun-I & Ithun-II have scored high on sensitivity parameters. Dibang Multipurpose Project scores the highest due to large Impact Area and Direct Forest Cover loss.

However when all the 15 projects were assessed with respect to Biodiversity Values (15 parameters) i.e. Floristic and Faunal diversity as well as fishes and in their respective Study Areas, Dibang Multipurpose Project still scores the highest. Other projects with relatively high scores on biodiversity values, which have also scored high on Sensitivity Values, are Emra-I, Emra-II and Etabue HEPs. Mihumdon was low on Sensitive score, however, scored high on Biodiversity Score.

Cumulative Impact Assessment scores were obtained combining sensitivity and biodiversity richness parameters. As can be seen from the above table, Dibang Multipurpose Project ranks the highest in terms of sensitivity as well as biodiversity values and therefore on the overall score as well. The extent of Direct Impact Zone of Dibang Multipurpose Project is highest among all projects as extends over an area of 198.34 sq km with reservoir spread of about 3564 ha. Its study area harbours 528 plant species, and 5 species endemic to entire Arunachal Pradesh are found here (DMPP EIA Report). More than 95% of Direct Impact Zone is under forests. Therefore activities in project area need to be taken up with a caution taking into consideration its biodiversity richness.

Apart from DMPP, other projects which have scored high overall or cumulative score are Emra I, Emra II, Etabue and Mihumdon. It may be noted here that Etabue, and Mihumdon are located close to Dibang Wildlife Sanctuary while part of Ashupani HEP is located within Mehao Wildlife Sanctuary. The increased biotic disturbance due to implementation of these projects is likely to exert pressure on wildlife of the sanctuary especially in view of reports of occurrence of good population of Tiger in the Dibang Wildlife Sanctuary. Therefore strict guidelines need to be followed while implementing these projects. Relative impact scoring has been kept in view while making recommendations for individual projects.

10.4.2 Impact due to Modification of Flow Regime

Whereas storage projects with large reservoir result into obstruction of migration paths of fishes, and conversion of large sections of river from lotic to lentic ecosystems, the run-of-river (ROR) affects the riverine ecosystem in a different way. In general impacts of ROR projects are:

- Dry stretches
- Barrier (even low) may affect migration of aquatic life

Main Dibang River has one large hydropower project planned on it. Three projects are planned on Ithipani, its left bank tributary and two projects are planned on Emra river and one project is planned on Ahi river its right bank tributaries.

Higher up before the confluence of Dri river with Talo river to Dibang river, three projects are planned on Talo river, 4 projects on Dri river and two projects on Mathun which in turn is tributary of Dri river.

Longitudinal profile of different of Dri, Talo, Mathun, Emra and Ithun rivers is given at **Figures 10.5-10.9**.

Total length of Dibang river likely to submerged by proposed Dibang Multipurpose project about 45 km i.e. lotic ecosystem will be converted into lentic ecosystem altering the entire Dibang river aquatic system which will adversely impact the aquatic biodiversity and seriously affecting fish populations and their migration behaviour.

In addition, the proposed dams on Dibang river will submerge large areas of forest land and would store water to enable peaking power generation. As a result the Dibang river will have relatively less water flow for few hours daily for generation of peaking power during lean season. This storage period will result in drying up of the river, downstream of the Dibang Lower dam site during winters. During this time the dry period will be followed by a wet or flow period with uniform flow corresponding to the number of units/turbines generating hydropower. Thus, the riverine ecology will be severely affected on account of modification in flow regime. This change will have significant impact on the riverine fisheries affecting physiological behaviour like migration and also affecting their growth cycle like maturation and spawning periods.

Projects on Tributaries:

Tributaries draining into intermediate stretch/free flowing stretch are aso being exploited for hydropower development, whereas they should be left undisturbed so that they can rejuvenate the main river channel as they are the main contributors of biological production of the main rivers.

Etabue, Elango, Ashupani and Anonpani projects have been planned on tributaries of Dibang, Dri and Talo rivers.

Assessment of contribution of intermediate catchment needs to be assessed during individual project EIA studies. Any major nallah/stream falling in intermediate catchment should be kept free of hydropower development.

10.5 DOWNSTREAM AREAS

The area downstream of Dibang Multipurpose project is comprised of wide gently sloping almost flat river bed of Dibang river up to Arunachal Pradesh –Assam border and also up to its confluence with Lohit river in Assam. Dibang river here is as wide as 8 km at places with sandy and grassy tracts. Most of the downstream area constitutes parts of Dibang Reserve Forest (RF), Kerim RF and the whole of Sirkee RF (Choudhury, 1996) (**refer Figure 10.10**). Tall wet savanna grassland occurs on the islets of the Dibang river, while the forest away from the river is mostly Tropical Wet Evergreen. The main forested areas are between Dambuk-Bomjir and Bijari.

Dibang river habitat in this stretch is quite suitable for the wildlife in the region but the population of mammalian fauna is quite low to moderate due to rampant hunting and poaching. The major issue in this stretch is encroachment and presence of large number of human settlements. Due to increased demand for flat land, there is tremendous pressure on the area. Poaching, grazing of cattle and buffalos, collection of thatching and felling of trees are other major issues. They kill the wild animals for meat, skin, trophy and traditionally use for medicine and rituals for curing different diseases.

Among the major mammals are the Asian Elephant (*Elephas maximus*), Asiatic Wild Buffalo (*Bubalus arnee*) and Hog Deer (*Axis porcinus*) (Choudhury 2003). The population of bird and insects is also quite good in the region. These animals are found in the riverbed of Sissiri, Dibang and Deopani rivers flowing through the plains. The habitat as already mentioned is characterized typically with tall grasses up to 5 m high (*Alpinia allughas*) and large areas are under agriculture which provides feeding and nesting grounds for the animals especially avi-fauna. Accordingly Birdlife International has delineated Dibang Reserve Forest and adjacent areas as IBA (see Chapter 6) with IBA criteria A1 and A2. This IBA is known for its rich assemblage of threatened birds including the Lesser Adjutant (*Leptoptilos javanicus*), Swamp Francolin (*Francolinus gularis*), Black-breasted Parrotbill (*Paradoxornis flavirostris*), Jerdon's Babbler (*Chrysomma altirostre*) and Marsh Babbler (*Pellorneum palustre*), White-winged Duck (*Cairina scutulata*) and the Bengal Florican (*Houbaropsis bengalensis*). Spot-billed Pelican (*Pelecanus philippensis*) was first time reported from Arunachal Pradesh from the northern edge of this IBA by Choudhury (2000). It also constitutes an important staging area for migratory birds and a new migration route of the Common Crane (*Grus gru*s) (Choudhury 1994).

The predominant fish species are mahseer (*Tor putitora* and *Neolissochilus hexagonolepis*), barils (*Barilius bendelisis* and *B. teleo*), and Glyptothorax (*Glyptothorax* spp.) especially in streams like Deopani river.

Small sized fishes of species of *Barilius, Danio, Neolissochilus, Garra, Puntius, Xenentodon, Mystus* and *Chanda* are also found in these areas. *Barilius* was most common in catch. However, *Danio* spp. are the most dominant fishes followed by *Barilius bendelisis, Barilius teleo*, *Neolissochilus hexagonolepis* and *Garra* sp. In this downstream section the quantity of water gets divided into different channels and riffles hence, large size fishes get isolated in deep pools.

Dattung river is formed by a branch of Dibang river and a channel of Sissiri river near the Bijari village. The current velocity and discharge of water is comparatively higher in this river. The species like *Puntius conchonius* and *Barilius bendelisis*, *Xenentodon cancila*, *Chanda ranga*, *Cyprinion semiplotus* and *Mystus* sp. were landed in the catch from Dattung river. *Chanda ranga* and *Mystus* sp. were also captured during the fishing.

Breeding/migration of fish

The fish fry of *Barilius* spp. were observed in a small pool habitats only (20-30 cm depth) at left bank of the Sissiri river (**refer Photographs**), suggesting that the fish breeds in post monsoon or early winter in the main river itself. The lean season (November to March) is most productive period of the river and in this period fishes come back to the deep pools of main river from the smaller channels and tributaries for feeding. They do not breed and migrate in lean period; instead this is their feeding period.

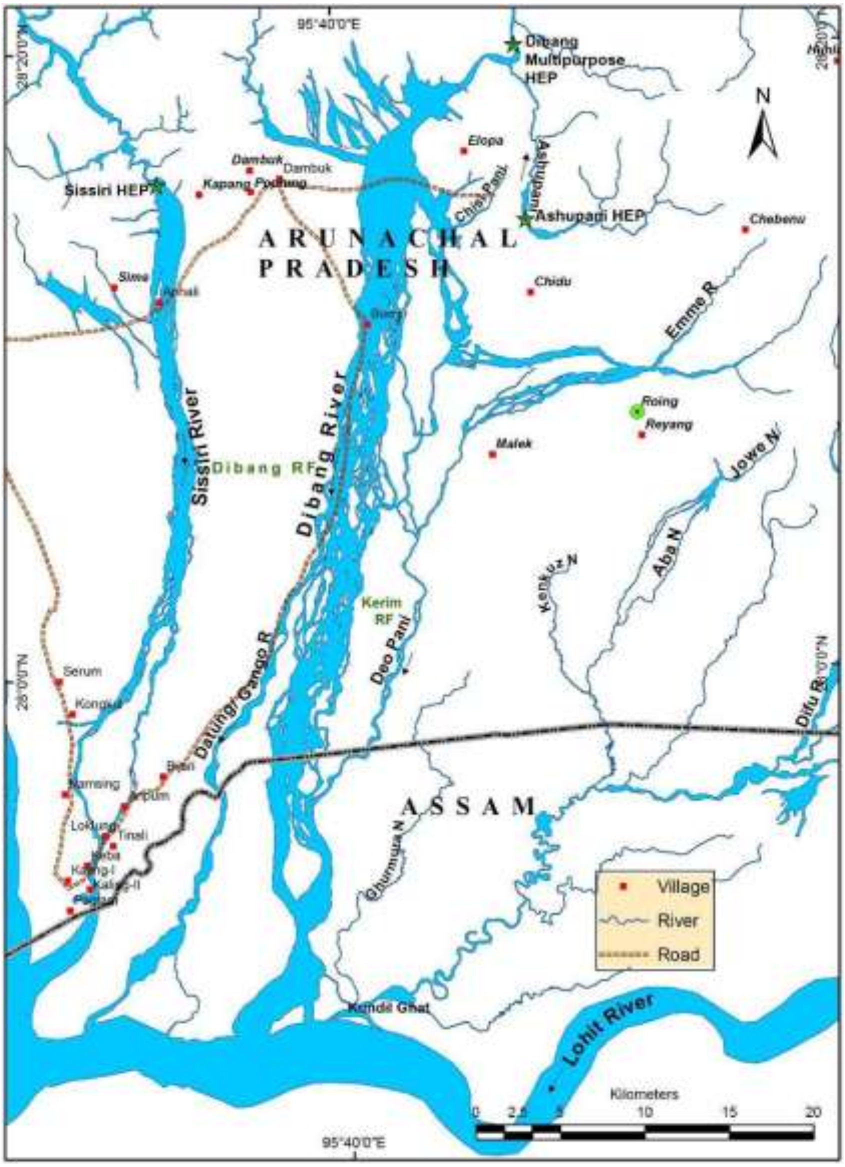


Figure 10.10: Downstream area of Dibang river showing Dibang and Karim RFs

The flow in the main channel is important for the distribution of fish fauna among the tributaries. The fish inhabiting different channels or tributaries often get flushed into the main channel during monsoon floods. They find refuge in the subsequent streams along the left or right bank and thus provide connectivity and facilitate exchange among the populations. **In the absence of reduced flow during lean season this function will be hampered.**

The villagers informed that various unscientific fishing methods like blasting, electric shock, small mesh size net and other local fishing traps are used for capturing the fishes from the river. These types of methods not only kill the large size fishes but also destroy the small fry/ fingerlings and feeding grounds which impacts the population of fish fauna of the river.

10.6 DOWNSTREAM IMPACTS

Maintenance of natural patterns of longitudinal and lateral connectivity in river-floodplain systems is essential to many aquatic species. Variability of aquatic species depends on their ability to move freely between the river and floodplain or between the main river and its tributaries. Loss of longitudinal and lateral connectivity due to drying up of river in floodplains can lead to decrease in populations of some fish species. Alternatively flooding caused due to excessive release of water during peaking operation can lead to washing away or inundation of breeding and nesting sites of birds and in addition might hamper the free movements locals engaged in agricultural activities during winters in the floodplains of Dibang river.

A study was carried out to quantify the downstream impacts due to peaking power generation by Dibang Multipurpose Project on Dibang River. Hydrodynamic routing was carried out using MIKE 11 model, where different combinations of operations were simulated and flow variation was studied in the extended downstream reach up to Guwahati. Impacts of modification of flow regime in downstream reach due to peaking operations are discussed in ensuing paragraphs.

The discharge control resulting from the damming of Dibang and Sissiri rivers will affect flow variability downstream. It would lead to increase in flood peaks but the magnitude and timing of flood peaks would change considerably. The effect of the project on individual flood flows depends on the way the dams will be operated. Altered floodplain inundation and hydrology downstream of these projects would reduce groundwater recharge in the riparian zone, resulting in lowering of the groundwater table, with consequent impacts on riparian vegetation.

Dibang Multipurpose Project has been planned as dam toe project with sufficient storage capacity to generate peaking power. Peaking power generation in most part of monsoon is generally of the order of 24 hours where plant runs at installed capacity round the clock releasing water downstream which is equivalent to its design discharge. As the projects operate as run-of-the-river projects, downstream releases are expected to be in tune with that of normal monsoon discharge in the river. Water available in addition to that of design discharge is released from the spillway and thereby variation in river flow is also reflected in the downstream discharge. In non-monsoon season i.e. during 4 months of lean period and other 4 months of pre-monsoon and post-monsoon season, discharge in river is not enough to do 24 hours peaking or run the plant at installed capacity, therefore, reservoir storage capacity is used to store water to run the plant during the time of peak demand. During the storage period only, minimum prescribed environment flow is released. This alternating dry and flooding is likely to affect the downstream areas, the flood plains which is home to rich avian diversity. However, provision of environment flow release will mitigate this impact to large extent.
Diurnal variation in river flows downstream of Dibang Multipurpose Project will be observed during lean season due to peaking power generation from 6-8 hours and releasing environment flow for rest of the day. The average winter (lean season) flow in the Dibang river in its natural state is approximately 477 cumec (90% DY year discharge data). Both the ecology of the downstream areas and people’s use of the riverine tracts in winter is adapted to this ‘lean’ but relatively uniform flow of water on any particular day. After the implementation of the Dibang Multipurpose Project; Dibang river flows, in winter in downstream reach up to its confluence with Lohit River, will fluctuate on a daily basis. Fluctuation will be due to base discharge of 114 cumin for 16-18 hours to peaking discharge of 1282 cumec for 6-8 hours. The corresponding fluctuation in water levels shall be of the order of 86 cm at 45 km downstream of Dibang dam, which is significantly reduced at 61 Km downstream location to just about 8 cm. Therefore there wouldn’t be any significant variation in water levels in the downstream reach. The details these results have been given in Chapter 9 of this report.

10.6.1 Impact on Terrestrial Biodiversity

The reduced water flow also affects the ecology and biodiversity of terrestrial fauna in downstream section. The species and materials may move laterally away from the river, extending the effect of river changes to a band of varying width, parallel to the river. As long as there is sufficient river flow below the dam, wildlife such as deer, antelope and elephants come to the water, especially in the dry and hot season for drinking. Many birds fly in to drink. These lateral movements can extend to several kilometers from the river. But the reduced flow or partially drying condition of river trigger the large animals and birds migrate to nearby aquatic body like Sibia river, Dattung river and Deopani river. But the small animals do not perform long migration hence they will be worst affected fauna due to the construction of dams.

Diurnal variation in winter in the downstream reach of Dibang will have adverse impact on Dibang river floodplain ecology, particularly for ground flora and fauna. Mammals, birds, reptiles and amphibians that live on the ground of the islets that form in the winter season) will be severely affected and some of them will either be drowned or obliterated. The eggs or young ones of the breeding animals will suffer badly. These islets do experience seasonal flooding due to change of river flow in monsoon during which most of the animals move away to drier areas. In the dry lean winter season there is hardly any flooding of river for several months and this is the time when most of these birds and animals come to inhabit these islets and often breed there. Sudden releases of water flow even for a few hours in the lean season will cause daily floods in large parts of these low-lying islets. The breeding behaviour of birds, reptiles and mammals is not adapted to such levels of daily flooding in the breeding season. The populations of highly threatened species like the Bengal Florican and Swamp Francolin found in small pockets of suitable habitat for the survival of these species in these areas will be lost.

The river is also carrying the mineral and nutrients for downstream floodplains during rainy season. The river and floodplain ecosystems are closely adapted to the annual cycle of flooding and drying. Many species depend on seasonal droughts or pulses of nutrients or water to give the signals to start reproduction, hatching, migration or other important lifecycle stages. The nutrients and minerals carried by river have also promoted the growth of grasses like *Alpinia allughas* in river floodplain. The productive grasses that depend on the seasonal floods provide the habitat for small animals like hare, rat and moles, snakes, and lizards. Some birds like flycatchers, warblers, robins and bush chats used these grasses for their nesting material as well as habitat.

The reduced water flow in downstream section will also affect the riparian vegetation especially the stretch from below the dam. The riparian vegetation provides food and shelter for riverside creatures and branches on which birds such as kingfishers can wait for their prey to swim by. Furthermore, leaves and twigs falling into the river are an important source of food for insects and other aquatic fauna. The plants and animals of the river bank and floodplain also suffer when the area no longer floods or when the river is in spate at the wrong time. The flow alterations on this scale have numerous ecological consequences. Rapid water level fluctuations speed up erosion downstream and can wash away the trees, shrubs and grasses along its banks.

Evergreen forests in and around Mehao WLS show medium elephant abundance, and has been reported to be highly disturbed with a high degree of encroachment (especially in the Koronu and Ippipaani areas) near the sanctuary. Elephants that use the Dibru-Deomali elephant corridor sometimes visit this area (Sundaram *et al.*, 2003).

Dibang river in plains of Assam comprised of Sadiya sub-division of Tinsukia district are highly degraded due to number of habitations in the area and recurrent flooding during monsoon and terrestrial biodiversity is very low and only scattered populations of Hoolock gibbon can be seen (Chetry *et al.* 2012) restricted only to Reserved Forests.

10.6.2 Impact on Fish fauna

The impact of dams on natural flood regimes can drastically reduce fish populations in both river channel and floodplain. Many floodplain fishes are stimulated by rising seasonal flood flows to move into the floodplain to breed in the warm organically rich water. As the flood subsides, fish move back to the river channel, and in many cases eventually to the small and deoxygenated pools of largely dry river beds. If a dam reduces flood peaks fish fail to move or breed, reducing the population size and the economic return to the fish catchers.

The low fluctuations would also affect the fish populations thriving in the transition zones in the foothills. For example, in the winter, some species breed in the shallow waters (*Barilius* species), while other species such as *Channa* spp. hibernate along the shorelines. Such massive flow fluctuations will destroy these natural processes for many such species.

The reduced flow also affects the spawning and breeding of fishes in downstream section. The pools and shallow banks having slow moving water, moderate temperature and good quantity of feeding materials for young fishes will dry and water will remain in the central portion only which ultimately hampers the breeding of fishes and ultimately reduce the fish stocks of downstream section.

The aquatic species such as invertebrates and fishes require minimal flows in which to navigate and feed. Such species may be affected by reduced flows including a reduction in the area of habitat utilised. This may lead to smaller populations, reduced growth rates and, where populations are already at risk, extirpation or extinction.

A certain level of downstream flow is needed to maintain a minimum volume and area of habitat, oxygen concentration and other 'desirable' in-stream conditions and avoid lethal temperatures. Normal seasonal flow patterns are a key to maintaining river biodiversity. Balancing reservoirs may help avoid pulse discharges, delay peak discharges and reduce them to an ecologically acceptable levels and guarantee a certain minimum discharge.

10.7 CONSTRUCTION PHASE IMPACTS

Construction phase impacts are generally dealt in detail during individual project EIA study with respect to local environment setting. For cumulative environment impact assessment, it is important to visualize the cumulative impacts of several projects under construction, simultaneously. Total 18 hydropower projects are considered as part of this cumulative EIA study of Dibang basin and none of the projects have started construction though EC & EC has been granted to Dibang Multipurpose Project. Two projects Etalin and Attunli are at advanced stages and remaining are still in preliminary stages without any investigation work on ground. It is expected that it may take another few years before a medium to large size project will start construction in the basin, followed by another and so on. Thereafter there will be a peak period when several projects will be under construction at the same time. This construction phase might last for 10-15 years before large part of construction work will be over in the basin and many of the projects will be under operation.

Though environmental impacts attributed to construction phase of hydropower projects are considered temporary in nature, lasting mainly during the construction phase and often do not extend much beyond the construction period, their impacts however need to be minimised during this phase. The construction phase of Hydroelectric Projects is fairly large; therefore these impacts are required to be managed by strict implementation of pollution control and environment management measures. As the limited project data is available at this stage, quantification of construction phase impacts in detail is not possible. This is also not part of the scope of the present study. Broad framework of major impacts is discussed with recommendations/guidelines wherever possible.

10.7.1 Human Interference

Entire Arunachal Pradesh is scarcely populated. Average population density of two districts of Dibang i.e. Lower Dibang Valley and Dibang Valley is 14 and 1 persons per sq km, respectively. Construction of hydropower projects is labour intensive work and would lead to influx of manpower. Type of manpower needed in terms of skill sets and number, locals can only meet a small part of the total requirement and rest will come from outside the state. Project construction being long-term activity and generally located in remote areas, establishment of labour camps near construction sites is only practical solution. Labour requirement for a project will depend upon size and type of project and construction management and planning schedule. For a typical 1000 MW project, migrant population will be of the order of 2500-3000 persons including labours and their families, during peak construction period. With a few projects under construction simultaneously on the same river in cascade, this number will be multiplied and far exceeds the local population in that area. Such a large influx of people in otherwise pristine tribal area, can lead to several impacts requiring careful management to minimize their impacts. Major impacts include:

- Labour camps, in the absence of waste management system, can have serious impact on water and land environment as disposal of sewage and solid waste, in otherwise pristine and hilly terrain will seriously pollute land and water environment. Therefore, it is important to ensure that Sewage Treatment and Solid Waste Management measures are designed and implemented for the entire duration of the project. Pollution Control Board needs to be strengthened to monitor implementation of such measures.

- Labour generally resort to tree cutting to source wood for cooking and space heating and also hunting and poaching of wildlife in remote areas can become a common practice, if not controlled strictly. Developers need to ensure that the provision of adequate fuel to labour for cooking and space heating is made binding in contract for all the contractors. Forest Department need to monitor and control such damages with penalties to offenders.

- Influx of large labour force will increase the load on local infrastructure such as schools, hospitals, etc. Therefore, developers should plan as part of project budget to improve local infrastructure with a view to provide adequate medical and other amenities to migrant labour force as well as to local population.

- Influx of large labour force can also lead to introduction of new diseases in the area. Developers have to ensure through contractors, that before introduction of labour, they should undergo health check-up and persons with communicable disease should not be given entry unless he/she is disease free. After initial screening regular health check-ups should be organized and record maintained till the completion of the project. Local medical officers need to be involved for certification.

10.7.2 Sourcing, Storing and Transportation of Construction Material

Out of main construction material viz. cement, steel, coarse aggregate and fine aggregate; aggregate requirement is met locally. In addition, to use the muck generated from excavation, some specific quarry sites are identified near the project site to quarry material for construction. Opening of the quarries cause visual impacts because they remove a significant part of the hills and with several projects coming under construction on the same river, large quarry sites or several quarry sites can spoil the local land scape altogether, unless the impact is adequately managed. Other impacts will be the noise generated during aggregate acquisition through explosive and crushing, which could affect wildlife in the area, dust produced during the crushing operation to get the aggregates to the appropriate size and transport of the aggregates, and transport of materials.

Storage of large quantities of construction material near construction sites and temporary storage of muck before disposal can spoil the local air quality with high levels of SPM and RPM. Strict implementation of Pollution Control and Environment Management measures can only mitigate such impacts. Regular monitoring, auditing and reporting to authorities should be made part of the EMP and Pollution Control Board should be strengthened to supervise all the construction activities to ensure that planned measures are implemented.

Transportation of construction material from outside the project area to the site will be a regular activity, once a project becomes operational. This should be considered as one of the major impact of hydropower project during construction phase. With several projects under construction at the same time, such impact will multiply with the number of projects. Road network is not designed to handle heavy traffic carrying raw material for construction; with substantial increase of heavy traffic impact will be severe and long term. A detailed separate study is needed at this stage where based on predicted traffic volume, infrastructure improvement plan can be prepared and implemented.

10.7.3 Operation of Construction Plant and Machinery

Operation of construction plants, machines and equipment will lead to pollution generation in various manifestations viz. air pollution, noise generation, wastewater generation, solid and hazardous waste generation, etc. These construction plants set up locally near the project sites are as good as industrial units generating pollution. Pollution generation should be controlled by use of pollution control equipment such as silencers/mufflers for DG sets, waste water treatment plants, etc. Pollution Control Board will play an important role in ensuring that pollution control measures are taken and all the required emission limits are adhered to at all the time.

10.7.4 Muck Disposal

The construction of hydropower involves generation large quantities of as a result of activities like tunneling, road construction, etc. In a hilly terrain like Himalaya the disposal of muck generated from excavation has been a matter of grave concern over the years. The biggest obstacle in the way of dumping of muck and its rehabilitation is the non-availability of sites for safe disposal as the hydropower project sites in Himalaya characterised by steep slopes and fragile geology. It has invariably been seen that from designated areas for muck disposal, the muck tends to fall into the river and contaminate its waters. These coupled with faulty disposal practices and improper management further deteriorates the landscape and augment the sediment load in the stream causing severe impact to the aquatic ecosystem as well as increased sediment deposition, siltation etc.

As part of the engineering study an estimation of the muck quantities likely to be generated is made. A part of it is considered for reuse in construction and balance for disposal after adding swell factor. Several samples of muck should be tested for correct estimation of reusable material and swell factor. Data, on quantum of muck generation, re-use and muck requiring disposal including area required for muck disposal, is available only for some of the projects in the basin. Based on this data, a broad estimation is made about the quantity of muck that would be required to be disposed of due to implementation of 18 projects in Dibang basin and this amounts to about **700 lakh cum.** Disposal area requirement would depend upon topography and terrain, however, a general estimation showed that about 800 ha of land would be needed for muck disposal.

CHAPTER-11
CONCLUSIONS & RECOMMENDATIONS

11.1 INTRODUCTION

During the Cumulative Impact Assessment (CIA) study various issues and concerns relevant to implementation of proposed 18 hydropower projects in Dibang basin were assessed. Baseline data superimposed with the project parameters of proposed HEPs have been used to analyse cumulative impacts of hydropower development in the basin. Recommendations have been made for sustainable and optimal ways for hydropower development in the basin keeping in view the environmental baseline characteristics of Dibang basin as well its major tributaries. The recommendations have been made for Dibang river as well as its tributaries, wherever the project development have been proposed. The recommendations are based upon the cumulative impacts evaluated on biodiversity values, riverine ecosystem, riparian habitats, lateral connectivity and environmental flow requirements vis-à-vis planned hydropower projects.

11.2 PROJECTS STATUS

Progress status of projects in Dibang basin is summarised below:

- Etalin, Attunli and Anonpani of Jindal Power and Dibang Multipurpose Project of NHPC; are the only four projects in the basin which are making progress.
    - Dibang Multipurpose Project has got the environment and forest clearance in place and is under the process of revising the DPR to accommodate the recommendations of EAC and conditions imposed by MoEF&CC during environment clearance.
    - Etalin DPR has got CEA concurrence, however, environment and forest clearance is pending for want of Dibang Basin study; EIA EMP reports have been discussed and concluded in EAC.
    - Attunli is making progress with DPR preparation and interlinked sections of EIA EMP reports.

- Ithun I, Ithun II and Ithipani of JVKIL consortium has started the work on DPR preparation and have obtained scoping clearances (for Ithun I and Ithun II only), however, for last couple of years all work on the projects is suspended. Scoping clearances have also lapsed for both the projects and have not been applied again for extension/re-issue.

- Emini, Amulin and Mihumdon of Reliance Power; have not made any significant progress; TOR obtained in 2010/11 have also expired and have not been revised /extended.

- Sissiri HEP has prepared a draft DPR of 222 MW and submitted to CEA for appraisal and approval. CEA has asked to furnish details/justification for proposed 222 MW installed capacity including examining the possibility of reducing the IC/dam height. The developer while submitting the justification have requested for consideration of 100 MW installed capacity, which CEA has found to be in order subject to certain conditions and approvals. (Refer CEA Letter dated July 01, 2011 enclosed as **Annexure VII**, **Volume II**). TOR obtained for 222 MW installed capacity, which was never revised for 100 MW. No further information was made available to us by developer, therefore status of preparation/updation of DPR for 100 MW installed capacity is not clear.

- Two projects have been planned on Emra river i.e. Emra-I (275 MW) & Emra-II (390 MW) HEPs as per the data submitted by the State Government of Arunachal Pradesh. Developer has submitted salient features for Emra I and Emra II for revised installed capacities of 600

MW and 315 MW for Emra I and Emra II HEPs. A communication dated May 09, 2016 from the Department of Hydropower Development (Monitoring), Government of Arunachal Pradesh has mentioned that, *"these projects can be developed in one or more schemes/stages of run-of-the-river and/or storage type to capture 275 MW (390 MW) or more of the installed capacity to optimally explore the entire hydropower potential available in the Emra Basin."* (copy of the letter is enclosed as **Annexure VIII**, **Volume II**). Emra I and Emra II of Athena Energy, could not make any progress since the allotment of the projects. Large part of Emra catchment is inaccessible, therefore no site investigation has been initiated so far. The lower project i.e. Emra II was denied by EAC at MoEF&CC in 2010, when developer informed that entire basin is allotted to them and they need permission to proceed with investigation. EAC recommended carrying out basin study and then apply for fresh TOR, however, no progress is made till date.

- Ashupani HEP has been allotted to Arti Power, however, no progress has been made till date. Only available document is PFR prepared by NHPC under the 50,000 MW initiative. Developer has not started any work till date. According to available layout of Ashupani HE project tail end of its reservoir encroaches into Mehao Wildlife Sanctuary.

- Agoline, Malinye, Etabue and Elango HEPs have not been allotted till to date. PFRs for Agoline, Elango and Elango HEPs have never been prepared. PFR is available only for Etabue HEP which was prepared under 50,000 MW initiative. Project location of Malinye HEP, as provided by State government, show that it falls within Dibang Wildlife Sanctuary.

11.3 PROJECTS PLANNED ON DIBANG/DRI RIVER AND TRIBUTARIES

Dibang is the main river in the basin formed by confluence of Dri and Talo rivers. Four projects have been planned on Dibang river including Dri stretch. Dibang Multipurpose Project is on Dibang river; Etalin, Agoline and Mihumdon are on Dri River. Etabue HEP is proposed on Ange Pani, which is tributary of Dri and Ashupani HEP is on Ashupani, which is tributary of Dibang river.

Area under Direct Impact Zone (DIZ) is highest in Dibang Multipurpose Project (2880 MW) i.e. about 199 sq km area will be affected directly due to project components. Affected area is much less in case of Etalin (Dri Limb) (3097 MW) i.e. only 111 sq km covering both the limbs and less than 34 sq km in case of Etabue (165 MW) and Mihumdon (400 MW) HEPs. Collectively these projects are likely to affect around 10000 ha of forest area. On an average about 65% of entire area is under Very High and High Biological Richness index. In Etabue, Dibang Multipurpose Project and Etalin HEPs together more than 75% area in Direct Impact Zone is under Very High and High Biological Richness index. Fragmentation index is comparatively low i.e. around 32% of landscape in Direct Impact Zone is fragmented. However in DIZ of Mihumdon and Ashupani HEPs fragmentation is much lower as only about 8% area is under High Fragmentation Index and in Etabue HEP it is as low as 5%.

Dibang Multipurpose and Etalin projects together will require nearly 5739 ha of forest land (Dibang Multipurpose Project 4578 ha & Etalin HEP 1161 ha). The diversion of large area of forest would lead to fragmentation of contiguous patches of forests into patches of forest thereby increased forested landscape fragmentation.

According to assessment based upon total affected area (Direct Impact Zone), Forest land requirement, Biological Richness Index and Fragmentation Index, Dibang Multipurpose Project gets the highest environmental sensitivity score; followed by Etabue, Mihumdon, Etalin and Ashupani in that order. Details were not available for Agoline except for its location, so no analysis could be carried out.

Mahseer reportedly migrates from Dibang river into its waters of tributaries like Ithun, Ahi and Emra rivers during monsoon for spawning and breeding. However after the implementation of Dibang Multipurpose project, mahseer no longer will be able to visit these tributary streams as upstream migration of mahseer is likely to be stopped completely due to high dam of Dibang Multipurpose Project. Therefore life cycle of mahseer will completely restricted to downstream of Dibang Multipurpose Project only. This will have severe impact on the populations of mahseer and other migratory fish species in Dibang river.

11.4 PROJECTS ON TALO RIVER

Four projects are planned in Talo river catchment i.e. Etalin (Talo Limb), Attunli, and Malinye HEPs on Talo river, while a small hydropower project Anonpani is on Anonpani which is a tributary of Talo river downstream of Etalin (Talo Limb) project diversion site.

More than 58% of Talo river catchment is under forests and 67% of area in Direct Impact Zones of planned projects is under Very High and High Biological Richness Index categories. As the area is sparsely populated and accordingly fragmentation in catchment is low to moderate.

Etalin HEP has already been discussed in the previous section as it spread in both Dri and Talo rivers. Attunli HEP is located within 10 km radius of Dibang Wildlife Sanctuary, however according to sensitivity and biodiversity richness values this project falls in moderate sensitivity category. Anonpani another small project on a tributary of Talo river falls in low impact category. Malinye HEPs is the uppermost project on Talo river and part of it falls within the sanctuary.

11.5 PROJECTS ON MATHUN RIVER

Two projects are planned in Mathun river catchment i.e. Amulin and Emini HEPs. They have been planned immediately upstream of confluence of Mathun with Dri river. Forest cover in Mathun river catchment is 64.30%. Area under Very High and High Biological Richness Index is quite low as compared to Talo and Dri catchments. Large continuous patches of slopes can be seen cleared of vegetation for *jhum* cultivation. Even then overall fragmentation of landscape is not high. Forest cover in Direct Impact Zone of two projects on Mathun river is 56.90 and 69.08%. Overall score on sensitivity assessment show that both projects are in medium category, however being situated close to Dibang Wildlife Sanctuary especially Amulin HEP which is only few kilometres from the sanctuary boundary, wildlife conservation measures need to be stressed upon during implementation these two projects.

11.6 PROJECTS ON EMRA RIVER

Emra river catchment as a whole is least disturbed of all tributary catchments of Dibang river with almost no habitation and there are no approach roads also at present. The forest cover is as high as 87.26% while area under Very High and High Biological Richness Index is nearly 81%, the highest amongst all catchments. Fragmentation of landscape too is quite low (less than 6% area is under High Fragmentation Index) as these is no habitation in the area.

Area under Very High and High Biological Richness index categories in Direct Impact Zones of the Emra-I & Emra-II HEPs is 76.17 and 70.96%, respectively. Based upon forest cover and Biological Richness Index, these two projects get High sensitivity Score.

Emra river is one of the tributaries where mahseer is known to migrate from Dibang river into its waters during monsoon for breeding. As the high dam of Dibang Multipurpose Project will completely check the upstream migration, mahseer no longer will be able to reach this river.

11.7 PROJECTS ON ITHUN RIVER

Three projects are planned on Ithun river with 2 on main Ithun river and one on its tributary Ithipani. Ithun river catchment also constitutes one of the pristine areas of Dibang basin. Though there are number of habitations in its catchment, forest cover is more than 81% and area under Very High and High Biological Index is 80% and fragmentation is also low.

Forest cover in Direct Impact Zones of Ithun-I, Ithun-II and Ithipani HEPs is 96.71, 94.81 and 98.36%, respectively. However due to presence of number of settlements near the proposed projects, fragmentation is higher than catchments of Emra, Mathun and Talo as area under High Fragmentation Index category varies from 15.70 to 18.41% in all three projects. Therefore, overall sensitivity score is not very significant.

Fishes form an important aquatic resource in this river. Fishes like Golden mahseer and Chocolate mahseer migrate into this river for spawning and breeding from main Dibang river. At higher altitudes river also harbours species of trouts. However as already discussed in previous sections the migration of mahseer fish will be entirely stopped by Dibang Multipurpose project.

11.8 SINGLE PROJECTS ON TRIBUTARIES

Sissiri HEP on Sissiri River

More than 86% of Sissiri river catchment is under forest. Based upon sensitivity and biodiversity value assessment Sissiri HEP falls in Low impact category and is the only project on Sissiri river which meets Dibang river only in plains.

Elango HEP on Ahi River

On Ahi river, only Elango HEP is planned, which is not yet allotted. Based upon the project location (no other data is available), its catchment is in pristine condition and mahseer is known to migrate from Dibang river for spawning and breeding.

Ashupani HEP on Ashupani River

Though Ashupani HEP has been allotted to M/s Arti Power & Ventures Pvt. Ltd. but no work has been done till to date and developer has yet to apply for ToR. As per the present layout of the project reservoir tail of the project falls within the boundary of Mehao Wildlife Sanctuary.

Anonpani HEP on Anonpani River

Anonpani small hydropower project is the only project on Anonpani, a left bank tributary of Talo river. It falls in low sensitivity/impact category and has been planned as construction power project for Etalin and Attunli HEPs by the project developer. The Forest Clearance also has been recommended by Regional Empowered Committee, Shillong of MoEF&CC.

11.9 PROJECT SPECIFIC RECOMMENDATIONS

11.9.1 Dibang Multipurpose Project

The project is in most advanced stage in basin, with environment and forest clearance in DPR and DPR is under revision due to changes proposed during environment clearance process. The project has reduced the dam height by 10 m leading to change of installed capacity from 3000 MW to 2880 MW. Environmental flow provisions as finalised during the environment clearance have been assessed by modeling study and are found to be adequate. Keeping this in view, no additional modification or changes are recommended for this project.

11.9.2 Etalin and Attunli HEPs

In addition to Dibang Multipurpose Project, these two are the only projects which have made substantial progress in terms of Survey and Investigation and preparation of environmental impact assessment study reports. Etalin's DPR has already been accorded TEC by Central Electricity Authority; EIA & EMP studies have been completed along with public consultation process and have been discussed in EAC, however, environment clearance is not recommended because basin study was not complete at that time. Adequate free flow river stretch is maintained with upstream and downstream projects in both the cases and with the provision of environmental flow recommendations, impacts of reduced flow in de-watered stretch will also be mitigated. Therefore, no changes are required for these two projects as well.

11.9.3 Emra I and Emra II HEPs

Emra I and Emra II projects have been allotted to M/s Athena Energy by GoAP vide MoA dated 02/02/2008 with the provision of developing Emra river in two or more schemes/stages. Survey and investigation have not made any significant progress. Environment clearance process has yet to start from scoping clearance stage. These two projects have been considered on the basis of the desktop information provided by the developer; however, whether more projects in the Emra basin can be sustainably develop cannot be assessed based on the limited information. Therefore, it is recommended that development of Emra basin should remain limited to two schemes in the present form. No more projects should be considered on Emra River unless a detailed basin study establishes their sustainability.

11.9.4 Malinye, Elango, Agoline and Etabue HEPs

These four projects have not been allotted yet, and therefore, not much information is available for a detailed assessment. Malinye HEP falls within Dibang Wildlife Sanctuary and there is no possibility of shifting the project downstream in order to avoid falling within the sanctuary and there is no free stretch between Malinye and Attunli HEPs according to the tail water level of the project provided by the state government matches with the FRL of Attunli HEP. Therefore based upon the location of Malinye HEP is recommended to be dropped.

Etabue HEPs diversion site is on Ange Pani and powerhouse is planned on left bank of Dri river downstream of Mihumdon HEP powerhouse (on right bank) and upstream of Agoline HEP. Diversion on Ange Pani will reduce the contribution of intermediate catchment downstream of Mihumdon diversion. As the project features are not yet final, it is recommended that at least one kilometre of free flow stretch should be maintained between FRL of Agoline and TWL of Etabue. As Agoline HEP is also not allotted, based on limited available features, it TWL is approximately giving a 970m free river stretch with Etalin FRL on Dri river. A minimum of one kilometer free flow stretch is recommended to be maintained by Agoline from the FRL of Etalin HEP.

11.9.5 Mihumdon, Amulin, Emini, Ithun I and Ithun II HEPs

Mihumdon, Emini and Amulin HEPs are with Reliance Power and Ithun I and Ithun II are with JVKIL consortium. All these five projects have taken scoping clearance which have lapsed and have not been applied for revalidation/extension by developers. No significant progress is made on DPR preparation as well. Projects have been considered and reviewed based on the PFR information and scoping clearance issued by MoEF&CC. Environmental flows have been assessed and recommended for individual project and should be incorporated in DPR during its preparation and finalisation.

11.9.6 Anonpani and Ithipani HEPs

Anonpani and Ithipani are two small projects i.e. less than 25 MW installed capacity and therefore are not covered under EIA notification. Anonpani is in advance stage and is making progress whereas Ithipani is only at PFR stage. Projects are found to be sustainable based on the present project features and environmental baseline setting, therefore, no specific recommendations have been made.

11.9.7 Ashupani HEP

Ashupani is a 30 MW proposed project on Ashupani river and the features available as of date are from PFR prepared by NHPC under 50,000 MW initiative. Project was allotted to Arti Power & Ventures Pvt. Ltd. in 2013 and no progress is made till date. Reservoir tail appears to be encroaching in the Mehao Wildlife Sanctuary. Detailed Project features are not available to verify this fact. Project is planned as inter-basin transfer where water of Ashupani will be diverted to a powerhouse on the bank of Digi Nala. This will make about 11 km of the Ashupani river, downstream of dam up to confluence with Dibang, dry but for the environmental flow. Catchment area at diversion site is only 67 sq km. It is recommended that project should be planned keeping it completely outside the boundary of Mehao Wildlife Sanctuary. Environmental flow provisions are very critical for this project where out of 28 km of the total Ashupani river length, about 11 km will be left with environmental flow only. Therefore, the environmental flow recommendations should be strictly implemented and provisions should be made in the project design in DPR itself.

11.9.8 Sissiri HEP

Sissiri HEP’s installed capacity has already been reduced to from 222 MW to 100 MW and revised DPR is under preparation. Scoping clearance obtained in 2009 has lapsed and never applied again for re-issue/revalidation. Environmental flow provisions have been assessed and same needs to be incorporated to make project environmentally sustainable. It is recommended that environment flow provisions are incorporated in the DPR at this stage as it may require some changes in terms of turbine configuration/features. It is further recommended that developer should proceed with fresh scoping clearance and environment study.

11.10 ENVIRONMENT FLOW RELEASE RECOMMENDATIONS

Detailed environmental flow assessment is done and discussed on Chapter 08. Following table summarizes final recommendation on environmental flow releases.

Summary of Environmental Flow Release Recommendations

S. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Intermediate River Length* (km)	EFR (as % of average values of corresponding season/period in 90% DY)			EFR (Minimum Absolute Values in cumec)		
						Lean	Monsoon	Intermediate	Lean	Monsoon	Intermediate
1	Dibang Multipurpose	2880	Dibang	Dibang	1.20	20 cumec throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year					
2	Etalin (Dri Limb)	3097	Dri	Dri	16.50	20.00	12.20	13.30	30.64	50.00	30.64
3	Etalin (Talo Limb)		Talo	Talo	18.00	20.00	10.00	13.30	19.52	26.17	19.52
4	Attunli	680	Talo	Talo	10.68	20.00	10.00	15.00	17.60	23.60	19.80
5	Agoline#	375	Dri	Dri	9.38	20.00	30.00	25.00	-	-	-
6	Etabue#	165	Ange Pani	Dri	3.10 **	20.00	30.00	25.00	-	-	-
7	Mihumdon	400	Dri	Dri	9.39	20.00	25.00	20.00	8.46	25.58	15.91
8	Emini	500	Mathun	Dri	6.43	20.00	20.00	20.00	22.73	54.96	42.73
9	Amulin	420	Mathun	Dri	8.62	20.00	15.00	15.00	19.02	34.48	26.81
10	Emra I	275	Emra	Dibang	6.12	20.00	25.00	20.00	14.83	48.95	21.95
11	Emra II	390	Emra	Dibang	1.30 ***	20.00	25.00	20.00	15.24	50.33	22.56
12	Elango#	150	Ahi	Dibang	-	20.00	30.00	25.00	-	-	-
13	Ithun I	84	Ithun	Dibang	6.35	20.00	20.00	20.00	7.02	18.82	10.53
14	Ithun II	48	Ithun	Dibang	4.47	25.00	25.00	25.00	6.70	18.00	10.08
15	Ashupani#	30	Ashupani	Dibang	11.10 **	20.00	30.00	25.00	-	-	-
16	Sissiri	100	Sissiri	Dibang	0.50	20% of average discharge of four leanest months (3.87 cumec) in 90% DY throughout the year through an un-gated opening along with at least one turbine running 24 hours in full/part load throughout the year					

* Intermediate River length is the distance along the river between diversion site and tail water discharge point i.e. the river reach, which will be deprived of flow due to diversion of water to HRT. Adequate environment flow will ensure that river in this reach should have sufficient water throughout the year.

** Intermediate river length is distance along the river from diversion site up to tributary's confluence with main river.

*** Intermediate river length is distance along the river from diversion site up to reservoir tail of downstream project.

Simulation Modelling could not be carried out due to non-availability of data, EFR is recommended based on Standard TOR of MoEF&CC for Hydropower projects.

References

Acreman, M. and Dunbar M.J. (2004). Defining environmental river flow requirements: a review. Hydrol Earth Syst Sci 8(5):861-876Aitchison, J.E.T. (1868). Flora of Hushiarpur district of the Punjab. *J. Linn. Soc. (Bot.)* Vol. 11: pp. 17-22.

Adoni, A.D., Joshi, G., Gosh, K., Chaurasia,S.K., Vashya, A.K.,Yadav Manoj and Verma H. G. (1985); Workbook on limnology. Pratibha Publishers C-10, Gour Nagar, Sagar-470003, India.

Ali N. and Ghosh B. (2006). Ethnomedicinal Plants in Arunachal Pradesh: Some Tacit Prospects. *ENVIS Bulletin: Himalayan Ecology*, Vol. 14(2), pp. 22-28.

Ali, S and Ripley, S.D. (1983). Handbook of the birds of India and Pakistan. Oxford (Delhi and New York).

APHA (1992). Standard methods for the examination of water and wastewater, 18th ed. Washington DC: American Public Health Association.

Arthington, A. H. and Pusey, B. J. (1993). In stream flow management in Australia: Methods, Deficiencies and Future directions, *Australia Biologist* Vol. (6): 52-60.

Arthington, A.H. and Zalucki, J.M. (eds.) (1998). Comparative evaluation of environmental flow assessment techniques: review of methods. Land and Water Resources Research and Development Corporation Occasional Paper No. 27/98. Canberra, Australia. pp 141.

Arthington, A.H., King, J.M., O'Keeffe, J.H., Bunn, S.E., Day, J.A., Pusey, B.J., Blu¨hdorn, D.R. and Tharme, R.E. (1992). Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. In: *Proceedings of an International Seminar and Workshop on Water Allocation for the Environment*, Pigram JJ, Hooper BP (eds). The Centre for Water Policy Research, University of New England: Armidale, Australia.

Bagra K., Kento K., Kongbrailatpan Nebeshwar-Sharma Boni A. L., Uttam U. S., Debangshu N. D., (2009). Ichthyological survey and review of the checklist of fish fauna of Arunachal Pradesh, India, Check List Vol 5(2): pp 330–350.

Baker, E. C. Stuart (1913). On a small collection of birds from the Mishmi Hills, N. E. frontier of India. *Records of the Indian Museum*. Vol. 9: pp. 251–254.

Barre De Saint Venant in 1871

Barua, U., Hore, D.K., Rathi, R.S. and Das, G. (2006). Occurrence of Orchids in parts of Upper Assam Districts and Lohit and Dibang Valley Districts of Arunachal Pradesh. *Environment & Ecology,* Vol. 24 (4): pp. 736-742.

Battish, S.K. (1992). *Fresh Water Zooplankton of India*. Oxford and IBH Publishing Co. Pvt. New Delhi.

Bechara, J.A, Domitrovic, H.A., Quintana, C.F., Roux, J.P., Jacobo, W.R. and Gavilan, G. (1996). The effect of gas supersaturation on fish health below Yacyreta dam (Parana River, Argentina). In: Second International Symposium on Habitat Hydraulics (eds M. Leclerc, H. Capra, S. Valentin, A. Boudreault and Y. Côté). Québec, Canada. INRS Publisher.

Beecher, H. A. (1990). Standards for Instream Flows. Rivers, Vol. 1(2): pp 97-109.

Behera M.D., Kushwaha S.P.S. and P.S. Roy (2002). High plant endemism in an Indian hotspot – eastern Himalaya. *Biodiversity and Conservation* Vol. 11: pp 669–682.

Ben-Menahem, A., Aboudi, E. and Schild, R. (1974). The source of the great Assam Earthquake: An intraplate wedge motion. *Physics of the Earth and Planetary Interiors*. Vol. 16: pp. 109-131.

Bergkamp, G., McCartney, M., Dugan. P., McNeely, J. and Acreman, M., (2000). Dams, Ecosystem functions and Environmental Restoration. Thematic Review II.1, prepared as an input to the World Commision on Dams, Cape Town, www.dams.org

Bhaumik, M. (2010). Contributions to the Orchid Flora Vis-À-Vis Forest Types of Dibang Valley District Of Arunachal Pradesh (India). *Bulletin of Arunachal Forest Research*, Vol. 26 (1&2): pp. 58-64.

Bhaumik, M. and M.K. Pathak (2005). A new variety of *Cheirostylis chinensis* Rolfe var. *glabra* (Orchidaceae) from Dibang valley, Arunachal Pradesh, India. *Bull. Bot. Surv. India* Vol. 47(1-4): pp. 183-184.

BirdLife International (2001) Threatened Birds of Asia: *The BirdLife International Red Data Book*. BirdLife International, Cambridge, U.K.

Borah, M. M. (2004). A study on the Habitat Ecology and Diversity of Ambhibian fauna of Arunachal Pradesh. *Arunachal Forest News Journal*, Vol. 20: pp 123-133.

Borang, A. (2001). Mammalian Fauna of Arunachal Pradesh (Checklist and Distribution in Protected Areas). *Arunachal Forest News, Biodiversity Special Issue*. Vol.19 (1&2): pp 43-82.

Borang, A. (2002). Mammalian Fauna and Tribal Traditional Biodiveristy Conservation and Management Sysytem in Dehang Dibang Biosphere Reserve Area in Eastern Himalaya. *Himalayan Biosphere Reserves* Vol. 4 (1&2): pp. 55-74.

Borang, A. (2003). Checklist of Reptilian Fauna of in Dehang Dibang Biosphere Reserve in North East India. *Himalayan Biosphere Reserves* Vol. 5 (1&2): pp. 61-68.

Borang, A. and Bhatt, B.B. (2001). Checklist of Reptils of Arunachal Pradesh (North east India) *Arunachal Forest News*: *Special Biodiversity Issue*. 19 (1& 2): 132-148.

Borang, A., Bhatt, B.B., Tamuk, M., Borkotoki, A. and Kalita. J. (2008) Butterflies of Dihang Dibang biosphere reserve of Arunachal Pradesh, Eastern Himalayas, India. Bulletin of Arunachal Forest Research, Vol. 24: pp. 41-53.

Bovee, K.D. (1982). A guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. Information Paper No. 12. Washington DC: U.S. Fish and Wildlife Service (FWS/OBS-82/26).

Bovee, K.D., Lamb, B.L., Bartholow, J.M., Stalnaker, C.B., Taylor, J. and Henriksen. J. (1998). Stream habitat analysis using the instream flow incremental methodology. Information and Technology Report 1998-0004. Fort Collins, CO: U.S. Geological Survey. 130 p.

Bradka. J. and Rehackova, V. (1964): Mass destruction of fish in the Slappy Reservoir in winter 1962.-63. In Vodni Hospodarstvi. Vol 15: pp 451-452.

Brown, C. A. and King, J. M. (1999). Task 2 Report Series. Introduction and description of the workshop process. Consulting services for the establishment and monitoring of the instream flow requirements for river courses downstream of the Lesotho Highland Water Project dams. Lesotho Highlands Development Authority, Lesotho.

Brown, C. and King, J. (2000). Environmental flow assessments for rivers: A summary of the DRIFT process. *Information Report no. 01/00, Southern Waters' Ecological Research and Consulting Pty* (Ltd): Mowbray, South Africa (www.southernwaters.co.za).

Brown, C.A., Sparks, A. and Howard, G. (2000). Proceedings of the IFR Workshop and determination of associated dam yields. Palmiet River Instream Flow Assessment. Unpublished Southern Waters Report to Client: *Department of Water Affairs and Forestry. Report* No. G400-00-0499. 168 p.

Bunn, S. E. and Arthington, A. H. (2002). Basic principles and consequences of altered hydrological regimes for aquatic biodiversity. *Environmental Management. Vol.* 30(4): 492–507.

Bunn, S. E. and Arthington, A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. Environ Manage Vol. 30: pp. 492–507.

Chakraborty, S. and Sen, A. K. (1991). Mammals of the Mehao Wildlife Sanctuary (Dibang Valley District, Arunachal Pradesh) with remarks on their status. Rec. zool. Surv. India. Vol. 88 (3&4): pp. 263-285.

Champion H.G., Seth S.K., (1968). *A revised survey of the forest types of India*. Govt. of India Press, Nasik.

Checklist of Endemic Plants of Arunachal Pradesh. ENVIS Centre on Floral Diversity. Botanical survey of India, Ministry of Environment and Forests, Government of India. indiabiodiversity.org/**checklist**/show/194.

Chetry, D. and Chetry, R. (2007) Current Status and Conservation of Primate in Dibang Wildlife Sanctuary in the State of Arunachal Pradesh, India. *Project Report*. Supported By The Rufford Small Grants Foundation ("RSGF").

Chetry, D., Chetry, R., Ghosh, K., and Chetry, D. (2007). Primate survey in Dri valley in Dibang Valley Wildlife Sanctuary, Arunachal Pradesh, India. Tiger Paper. Vol. 34 (4): pp 23-26.

Chetry, R., Chetry, D. and Bhattacharjee, P.C. (2012). Status and conservation of Eastern Hoolock Gibbon Hoolock leuconedys in Assam, India. Journal of Threatened Taxa Vol. 4(13): pp. 3183–3189.

Choudhary, R.K. (2008) A Preliminary Report On Floristic Diversity Of Dihang Dibang Biosphere Reserve Of Arunachal Pradesh. *Bulletin of Arunachal Forest Research*, Vol. 24 (1&2): pp 29-34.

Choudhury A. (2010). Mammals and birds in Dihang-Dibang Biosphere Reserve, Arunachal Pradesh. Tigerpaper Vol. 37 (4): pp. 1-4.

Choudhury, A. (2010). *The Vanishing herds: the wild water buffalo, Guwahati*: Gibbon Books & Rhino Foundation (supported by COA,Taiwan and CEPF/ATREE).

Choudhury, A. U. (1994). A new Crane- migration route discovered. Asian Wetland News 7(1):18 p.

Choudhury, A. U. (1995) White-winged Wood Duck in Mehao and Pakhui Sanctuaries, Arunachal Pradesh. IWRB TWRG Newsletter 7: 12.Choudhury, 2000 Spotbill Pelican

Choudhury, A. U. (1996) Survey of the White-winged Wood Duck and Bengal Florican in Tinsukia district and adjacent areas of Assam and Arunachal Pradesh. The Rhino Foundation for Nature in NE India. Guwahati. 82 p.

Choudhury, A. U. (2000) The Birds of Assam. Gibbon Books and WWF-India, NE Regional Office, Guwahati.

Choudhury, A. U. (2003) The mammals of Arunachal Pradesh. Regency Publications, New Delhi.

Choudhury, A. U. (2010). Mammals and birds in Dehang-Debang Biosphere Reserve, India. LAP Lambert Academic Pub., Saarbrücken, Germany, 104 p.

Choudhury, A., (2006). A pocket guide to the birds of Arunachal Pradesh. 1st ed. Pp. 1–109. Guwahati: Gibbon Books & The Rhino Foundation for Nature in NE India

Chowdhery, H.J. (1998). *Orchid Flora of Arunachal Pradesh*. Bishen Singh Mahendrapal Singh, Dehra Dun.

Conservation Assessment and Management Plan (CAMP) Workshops Report (2003). Medicinal Plant species of conservation concern identified for Arunachal Pradesh (AR).

http://envis.frlht.org- ENVIS Centre on Conservation of Medicinal Plants, FRLHT, Bangalore.

Conservation Assessment and Management Plan (CAMP) Workshops Report (1998), Freshwater Fishes of India, Hosted by National Bureau of Fish Genetic Resources (ICAR), Lucknow 22-26 September 1997. Edited by Sanjay Molur and Sally Walker. Published by Zoo Outreach Organisation.

Curits, J. T., (1959). The vegetation of Wisconsin. Univ. Wisconsin Press, Madison.

Curtis, J. T. and McIntosh R. P.,(1950). *The interre-lations of certain analytic and synthetic photosocio- logical characters*. Ecology. Vol. 31: pp.434-455.

Daniel Mize, Ripin Taba and Hirendra Nath Sarma (2014), Species Diversity of Birds in Dihang-Dibang Biosphere Reserve, Arunachal Pradesh.

Dasgupta, S., Kumar, M and Chatterjee G., (1997). Report on the systematic mapping of eastern Arunachal Pradesh, Dibang valley, Arunachal Pradesh, Unpub. Prog. Rep. F.S. 1996 – 97.

DWAF (1997). White paper on a National Water Policy for South Africa. Department of Water Affairs and Forestry, Pretoria.

Dynesius, M. and Nilsson, C. (1994). Fragmentation and Flow Regulation of River Systems in the Northern Third of the World. Science Vol. 266: pp. 753–762.

Ebel, W.J., Tanonaka,G.K., Monan, G.E., Raymond, H.L. and Park,D.L. (1979). The Snake River Salmon and Steelhead Crisis: its Relation to Dams and the National Energy Shortage. Northeast and Alaska Fisheries Center, National Marine Fisheries Service, Seatle, Wasington, USA.

Edington, J. M. and Hildrew A. G. (1995). Caseless caddis larvae of the British Isles. A key with ecological notes. Freshwater Biological Association Scientific Publication No. 53: 134 p.

Edmondson, W.T. (1959). *Freshwater Biology*. John Wiley & Sons, New York.

Environmental Impact Assessment of Dibang Multipurpose Project (3000MW), Arunachal Pradesh. National Productivity Council, Guwahati. *Prepared for* National Hydro Power Corporation Limited (NHPC Ltd.).

Fauna of Arunachal Pradesh, State Fauna Series (2006). Editor-Director, Published by the Director, *Zoological Survey of India,* Kolkata. 13(Part-l) 1-396.

Fleming, R. L. 2006. Notes on some Butterflies and Natural History of the Siang Valley, Arunachal Pradesh, India.

Gandhi, H. P. (1998). *Freshwater diatoms of Central Gujarat – With a review and some others*. Bishen Singh Mahendra Pal, Dehradun.

Gaston, K. J. (1991). How large is a species geographic range? Oiko. Vol 61: pp 434-438.

Gibji, N., Ringu, N. and Oyi Dar, N. (2012) Ethnomedicinal Knowledge among the Adi tribes of Lower Dibang Valley District of Arunachal Pradesh India. International Research Journal of Pharmacy. Vol 3 (6). Pp 223-229.

Gibji, N., Ringu, N. and Oyi Dar, N. (2013) Phytogeographical Observations from the ADI Tribes Inhabited Areas of Lower Dibang Valley District, Arunachal Pradesh (India). Science and Culture. Vol 79 (9-10). Pp 396-402.

Gibji, N., Ringu, N., and Dai N. O. (2012). Ethnomedicinal knowledge among the Adi Tribes of Lower Dibang Valley District of Arunachal Pradesh, India. International Reasearch Journal of Pharmacy. Vol. 3 (6): pp. 223-229.

Gippel, C.J. and Stewardson, M.J. (1996). Use of wetted perimeter in defining minimum environmental flows. In: Leclerc, M., Capra, H., Valentin, S., Boudreault, A. & Côté, Y.

(eds). Ecohydraulics 2000. Proceedings of the 2ndinternational symposium on habitat hydraulics. Québec, June 1996. INRS-Eau, Quebec City, Canada.

Godoy, M.P., (1985). Aquicultura. Actividade multidisciplinar. Escadas o outras facilidades para passagens de peixes. Estaçoes de piscicultura. Florianopolis, Brasil.

Gogoi, M.J. (2012). Butterflies (Lepidoptera) of Dibang Valley, Mishmi Hills, Arunachal Pradesh, India. *Journal of Threatened Taxa* Vol. 4(12): pp. 3137–3160.

Grimmett, R., C. Inskipp and T. Inskipp. 1998. *Birds of the Indian Subcontinent*. London: Oxford University Press. 384p.

Grimmett, R., C. Inskipp and T. Inskipp. 2011. Birds of the Indian Subcontinent. London: Oxford University Press. 528p.

Groshens, T. P. and Orth, D. J. (1994). Transferability of habitat suitability criteria for small mouth bass, *Micropterus dolomieu*. Rivers. Vol 4(3): pp. 194-212.

Growns, I. and Kotlash, A. (1994). *Environmental Flow Allocations for the Hawkesbury-Nepean River System: A Review of Information*. (Australian Water Technologies EnSight: Sydney.) Report No. 94/189. 55 p.

Holden, P.B. and Stalnaker, C.B. (1975). Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. In: Transactions of the American Fisheries Society. Vol. 104: 217-231.

http://avibase.bsc-eoc.org/avibase.jsp. Avibase –a database system for managing and organizing taxonomic concepts

http://www.algaebase.org/ AlgaeBase is a Global Species Database of information on all groups of algae.

http://www.fishbase.org Fishbase: A Global Information System on Fishes.

http://www.nethan-valley.co.uk/insectgroups.doc

http://www.theplantlist.org. International Plant Names Index

Hubbs, C. and Pigg, J. (1976). The effects of impoundments on threatened fishes of Oklahoma. Annals of the Oklahoma Academy of Science. Vol. 5: pp. 133-77.

Hustedt, F. (1943). Neue und wenig bekannte Diatomeen. Ber. Deutsch. *Bot. ges*. Vol. 61: pp 271-290.

Hustedt, F. and Jensen, N. G. (1985). *The Pennate Diatoms*. Koeltz Scientific Books, Koenigstein. 918 p.

Indian State of Forest Report (2013). Forest Survey of India, Minsistry of Invironment and Forest Govt. of India, Dehradun.

Indian State of Forest Report (2015). Forest Survey of India, Minsistry of Invironment and Forest Govt. of India, Dehradun.

International Union for Conservation of Nature (IUCN) Red List of Threatened Species 2015. http://www.iucnredlist.org/apps/redlist/search.

Jha, K. K., Chetri K., Ghosh T., and Jha V.C. (2014), Distribution of an endangered fish species, *Chaca chaca* (Ham.- Buch.), in Arunachal Pradesh, India: A biodiversity hot spot. International Journal of Biology and Biological Sciences Vol. 3(3), pp. 023-030, Vol. 3(3), pp. 23-30.

Jowett, I. G. (1997). Instream flow methods: a comparison of approaches. Regulated Rivers: Research and Management 13: 115-127.

Karr, J.R., Fausch, K.D., Angermeier, P.L., Yant, P.R. and Schlosser, I.J.. (1986). Assessing biological integrity in running waters: A method and its rationale. Illinois Natural History Survey, Special Publication.

Katti, M., Singh, P., Manjrekar, N., Sharma, D. and Mukherjee, S. (1992). An ornithological survey in eastern Arunachal Pradesh. *Forktail* 7: 75–89.

King, J. M. (1996). Quantifying the amount of water required for aquatic ecosystems. Water law review. Discussion document for policy development. Report for the Department of Water Affairs and Forestry. August 1996. Freshwater Research Unit, University of Cape Town, Cape Town. 31p.

King, J. M. and Louw, M. D. (1998). Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. *Aquatic Ecosystem Health and Management* Vol 1: pp 109–124.

King, J. M. and Tharme R. E. (1994). Assessment of the Instream Flow Incremental Methodology and Initial Development of Alternative Instream Flow Methodologies for South Africa. *Water Research Commission Report* No. 295/1/94. Water Research Commission: Pretoria, South Africa.

Krammer, K. (2003). Diatoms of Europe. Volume 4: Cymbopleura, Delicata, Navicymbula, Gomphocymbellopsis, Afrocymbella. 530 pp. A.R.G. Gantner Verlag K.G.

Krammer, K., Lange-Bertalot, H. (2000), *Süßwasserflora von Mitteleuropa. Band 2/5. Bacillariophyceae. Part 5*. English and French Translation of the Keys. Gustav Fischer Verlag, Stuttgart.

Krishna, M. C., Awadhesh Kumar, Ray, P. C., Sarma, K., Devi, A. and Khan, M.L. (2012), Impact of road widening on wildlife in Namdapha National Park, Arunachal Pradesh, India: a conservation issue. *Asian Journal of Conservation Biology*, Vol. 2 (1): pp. 76–78.

Lakra, W. S., Sarkar, U. K., Gopalkrishnan, A. and Kathirvelpandian, A. (2010), Threatened Freshwater Fishes of India. Published by National Bureau of Fish Genetic Resources (ICAR), Lucknow. 25 pp.

Lange-Bertalot, H., Cavacini, P., Tagliaventi, N. and Alfinito, S. (2003). Diatoms of Sardinia. Rare and 76 new species in rock pools and other ephemeral waters. In: Iconographia Diatomologica (H. Lange-Bertalot, ed.), 12, 1-438. Koeltz, Königstein.

Laskar B.A, Das D. N. and Tyagi B. C. (2009), Growth performance of the chocolate mahseer *Neolissocheilus hexagonolepis* (Mc Clelland) in pond system in Arunachal Pradesh. Indian J. Fish., Vol. 56(1): pp. 55-59.

Laskar, B.A, Roy S, Bagra, K & Das D. N. (2010), Mehao lake of Arunachal Pradesh: A biological Treasure, Science & Culture: Vol. 76 (1/2): pp. 59-61.

Lightfoot, G. S. (1940). On the occurrence of Hume's Wedge-billed Wren (*Sphenocichla humei* Mandelli) in the Aka Hills, Assam. J. Bombay Nat. Hist. Soc. 41: 418-420.Macan, T. T. 1979. A key to the nymphs of the British species of Ephemeroptera with notes on their ecology. *Scient. Pubis Freshwat. biol. Ass.* No. 20: 1-80.

Magurran, A. E. (2004). Measuring Biological Diversity. Oxford: Blackwell Science.

Mahanta P.C., Sarma D. and Dutta R. (2012), Ecological Status and Fishery Potential of Deopani: a Coldwater Stream of Arunachal Pradesh. The Clarion, Vol 1(1): pp 37-45.

Maheswaran, G. (2012). Fauna of the Protected Areas of Arunachal Pradesh: 1-14. Published by Director, ZSI, Kolkata.

Malanson, G.P., (1993). Riparian Landscapes, Cambridge University Press, United Kingdom, 296 p.

Management Plan of Mehao Wildlife Sanctuary 2011-12 to 2015-16. Mehao Wildlife Sanctuary Division, Roing, Arunachal Pradesh.

Mann, J. L. (2006). Instream flow methodologies: an evaluation of the Tennant method for higher gradient streams in the national forest system lands in the western U.S. Master of Science thesis. Colorado State University, Fort Collins.

Mao, A. A., Gogoi, R. and Apang, O. (2009). Study of Rhododendron species of Mayodiya, Lower Dibang Vlaeey, Arunachal Pradesh, India. *Bulletin of Arunachal Forest Research*, Vol. 25 (1&2): pp 93-99.

Maran, S. (2007). Débits environnementaux et Gestion Intégrée des Ressources en Eau: étude de cas du fleuve Vomano (Italie). Dans UICN-Med, 2007. Estimation et disposition des debits environnementaux dans les cours d'eau méditerranéens. Concepts, méthodologies et pratique émergente. Disponible sur Internet: http://www.iucn.org/places/medoffice/cdflow/conten/2/pdf/2_2_Italie_MedEC.pdf.

McAllister, D.E., Hamilton, A.L., and Harvey, B. (1997) Global Freshwater Biodiversity: Striving for the Integrity of Freshwater Ecosystemsî, in Special Edition of Sea Wind-Bulletin of Ocean Voice International, 11(3): 1-140.

Metzeltin D., Lange-Bertalot H., Garcia-Rodriguez F. (2005). Diatoms of Uruguay compared with other taxa from South America and elsewhere. – *Iconographia Diatomologica* Vol. 15: pp 1–736.

Milhous, R.T. (1982). Effect of sediment transport and flow regulation on the ecology of gravel bed rivers. In. Hey, R. D., Bathurus, J.C. and Thorne, C.R. (eds.) Gravel bed Rivers. John Wiley, Chichester.

Milhous, R.T. (1998). A review of the physical habitat simulation system. In *Hydroecological Modelling*. Research, Practice, Legislation and Decision-making, Blazˇkova´ S ˇ, Stalnaker C, Novicky´ O (eds). Report by US Geological Survey, Biological Research Division and Water Research Institute, Fort Collins, and Water Research Institute, Praha, Czech Republic. VUV: Praha; pp 7–8.

Milhous, R.T., Updike, M.A. and Schneider, D.M. (1989). Physical Habitat Simulation System Reference Manual—Version 2. *Instream Flow Information Paper* 26. USDI Fish and Wildlife Services, *Biology Report* Vol 89(16).

Misra, R. (1968). *Ecology Work Book*. Oxford & IBH Publication, New Delhi.

Mitchell, C., 1995. Fish Passage Problems in New Zealand. In: Proceedings of the International Symposium on Fishways '95. Gifu, Japan.

Mize, D., Taba, R., and Sarma, H. N. (2014). Species Diversity of Birds in Dhiang-Dibang Biosphere Reserve, Arunachal Pradesh. *The Ecoscan*. Vol. 8 (1&2): pp. 77-84.

Myers, N. (1988). Threatened biotas: 'hotspots' in tropical forests. *Environmentalist*. Vol. 8, pp. 187–208.

Nandy D.R. (1980). Tectonic patterns in north eastern India. *Indian Journal of Earth Sci*. Vol. 7: pp. 103-107.

Nath, P. and Dey S.C. (2000), Fish and fisheries of North East India (Arunachal Pradesh). Narendra Publishing House, Delhi. 217 p.

Nautiyal, P and Nautiyal, R. (2002). Altitudinal variations in the relative abundance of epilithic diatoms in some glacier and spring-fed Himalayan tributaries of Ganga (Ganges) river system in the Garhwal region. In *Proceeding of the 15th International Diatom Symposium, Tokyo, eds. J. John,* Perth: ARG Gantner Verlag K.G. pp: 143-151.

Nautiyal, R. and Nautiyal, P. (1999). Altitudinal variations in the pennate diatom flora of the Alaknanda-Ganga river system in the Himalayan stretch of Garhwal region. Pages 85-100, In: *Proceedings of Fourteenth International Diatom Symposium* (S. Mayama, M. Idei and I. Koizumi, eds.), Koeltz Scientific Books, Koenigstein.

Nayar M.P. and Sastry A.R.K. (1987). *Red Data Book of Indian Plants*. Botanical Survey of India, Calcutta. Vol.I.

Nayar M.P. and Sastry A.R.K. (1988). *Red Data Book of Indian Plants*. Botanical Survey of India, Calcutta. Vol.II.

Nayar M.P. and Sastry A.R.K. (1990). *Red Data Book of Indian Plants*. Botanical Survey of India, Calcutta. Vol.III.

Nilsson, C. and Grelsson, G. (1995). The Fragility of Ecosystems: A Review. *Journal of Applied Ecology*, Vol. 32 (4): pp.677-692.

Pandit, M. K. and Babu, C. R. (1998). Biology and conservation of *Coptis teeta* Wall. – An endemic and endangered medicinal herb of Eastern Himalaya. *Environmental Conservation*. Vol. 25(3): pp. 262 – 272.

Paul, A., Khan, M. L. Arunachalam, A. and Arunachalm, K. (2005). Biodiversity and conservation of rhododendrons in Arunachal Pradesh in the Indo-Burma biodiversity hotspot. *Current Science*, VOL. 8 (4): pp 623-634.

Pawar, S. and Birand, A. (2001) A survey of amphibians, reptiles, and birds in Northeast India. CERC Technical Report #6, Centre for Ecological Research and Conservation, Mysore.

Pennak, R. W. (1953). *Freshwater Invertebrates of United States* (2nd edition). John Willey & Sons, New York.

Petts, G.E., (1988). Impounded rivers, Chichester,UK: John Wiley & Sons Ltd Publishers. 326p.

Poff, N. L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E. and Stromberg, J.C. (1997). The natural flow regime. A paradigm for river conservation and restoration. *Bio Science* Vol. 47: pp. 769–784.

Prasad, B. N. Misra, P. K. (1992). *Freshwater Algal Flora of Andaman & Nicobar Islands*. Bishen Singh Mahendra Pal, Dehradun.

Prasad, S. N. (1996). A Rapid Assessment Of Bio-Diversity Using Remote Sensing/Geographic Information System Techniques In Mehao Wildlife Sanctuary (Mishmi Hills) Arunachal Pradesh. SACON report. www.sacon.in/pulication/reports.

Prater, S.H. (1980). *The Book of Indian animals*. Third ed. *Bombay Natural History Society*. Bombay, 428 p.

Puckridge, J. T., Sheldone, F., Wlaker, K. F. and Boulton, A. J. (1998). Flow variability and ecology of large rivers. Marine and Freshwater Research. Vol. 49: pp 55-72.

Rama Shankar, Singh VK & Rawat MS, (1993). Medicinal plants of Divang valley (AP) social forestry and afforestation, *Bull Medico Ethnobot Res*, Vol. 14 (3&4): pp. 144-149.

Rangini, N., Lodhi, M. S., Samal, P.K., Sharma, S., Dhyani, P.P. (2013). Review of Fauna of Dehang-Debang Biosphere Reserve, Arunachal Pradesh (India). Nature and Science. Vol 11 (9). pp 8-13.

Rao, A. N. (2010). Orchid Flora of Arunachal Pradesh - An Update. *Bulletin of Arunachal Forest Research* Vol. 26 (1&2): pp. 82-110.

Rao, A. N. (2010). Orchid flora of Arunachal Pradesh- An update. Bulletin of Arunachal Forest Research Vol 26 (1 & 2): pp. 82-110.

Rawat, V. K., Sahu, T.R, Dixit. R. D., (2005). A Preliminary account of the Pteridophytes from Mehao Wildlife Sanctuary, Arunachal Pradesh, I*ndia. Jour. Econ. Tax. Bot*. Vol. 29(4): pp. 1-4.

Raymond, H.L., 1979. Effects on Dams and Impoundments on the Migration Rate of Juvenile Chinook Salmon and Steelhead Trout from the Snake River, 1966-1975. In: Transactions of the American Fisheries Society. Vol. 108 (6): 509-29.

Reimer, C.W. (1962). Some aspects of the diatom flora of Cabin Creek Raised Bog, Randolph Co., Indiana. Proceedings of the Indiana Academy of Science Vol. 71: pp. 305-319.

Rethy P., Singh B., Kagyung, R., and Gajurel, P.R. (2010). Ethnobotanical studies of Dehang-Debang Biosphere Reserve of Aruncahal Pradesh with Special refrence to Memba tribe. India Journal of Traditional Knowledge. Vol. 9(1): pp 61-67.

Richter, B.D, Baumgartner, J.V., Powell, J. and Braun, DP. (1996). A method for assessing hydrological alteration within ecosystems. *Conservation Biology* 10.(4): 1163–1174.

Ripley, S. D., Saha, S. S. and Beehler, B. M. (1991) Notes on birds from the Upper Nao Dihing, Arunachal Pradesh, Northeastern India. Bull Brit. Orn. Club 111(1): 19-28.

Rodgers, W.A. and Panwar, H.S. (1988). Planning a Wildlife Protected Area Network in India. Vol. 1 and 2. A report prepared for the Department of Environment, Forests and Wildlife, Government of India at the Wildlife Institute of India, Dehradun, 608p.

Rodgers, W.A., Panwar, H.S., & Mathur, V.B. (2002). Wildlife Protected Areas in India: a Review. Wildlife Institute of India, Dehradun.

Roy, P. (2013). *Callerebia dibangensis* (Lepidoptera: Nymphalidae: Satyrinae), a new butterfly species from the eastern Himalaya, India. Journal of Threatened Taxa (www.threatenedtaxa.org) Vol 5 (13): pp 4725-4733.

Sangha, H. S., and Naoroji, R. (2007). New and significant records of birds in Arunachal Pradesh, north-east India. *Forktail,* Vol 23: pp. 179-181.

Sarma D., Dutta R, Baruah D., Kumar P., Tyagi B.C. and Mahanta P.C. (2012). Coldwater lakes and rivers in Arunachal Pradesh, India, Directorate of Coldwater Fisheries Research, Bulletin No.19.

Sarode, P.T. and Kamat, N.D. (1984). *Fresh water Diatoms of Maharashtra*, Saikripa Prakashan, Aurangabad.

Shankar, R., Singh, V. K., and Rawat, M. S. (1993). Medicinal Plants from Dibang Valley (A.P.)-Social Forestry and Afforestration. *B.M.E.B.R.*, Vol. XIV (3-4); pp. 144-149.

Singh, T. P., Singh, S. and Roy, P.S. (2003). Assessing *Jhum*- Induced Forest Loss in Dibang Valley, Arunachal Himalayas – A remote Sensing Perspective. iJournal of the Indian society of remote sensing. Vol 31 (1): pp. 3-9.

Singh, Tarun P. and Singh, S., (2012). Plant Species Diversity and Endemism at Dihang Diabang Biospehere Reserve and its surroundings, Eastern Himalaya Biodiversity Hotspot. *Asain Journal of Biodiversity*. Vol. 3: pp. 1-22.

Smakhtin, V. and Anputhas, M. (2006). An Assessment of Environmental Flow Requirements of Indian River Basins. Research Report. International Water Management Institute P O Box 2075, Colombo, Sri Lanka.

Soils of Arunachal Pradesh for Optimising Land Use (1997). NBSS Publ. 55b, ISBN:81-85460-42-6.

Sparks, R. E. (1992). Risks of altering the hydrologic regime of large rivers. *Predicting Ecosystem Risk: Advances in Modern Environmental Toxicology* (eds. J. Cairns, Jr., B. R. Niederlehner & D. R. Orvos), Princeton Scientific Publishing Co., Princeton, New Jersey. Vol. 20: pp. 119-152.

Sparks, R. E. (1995). Need for ecosystem management of large rivers and floodplains. *BioScience*. Vol. 45: pp. 168-182.

Stalnaker, C.B, Lamb, B.L., Henriksen, J., Bovee, K. and Bartholow, J. (1995). The instream flow incremental methodology: A primer for IFIM. National Ecology Research Center, National Biological Service. *Biological Science Report* 29. 44 p.

Stattersfield, A. J., Crosby, M. J., Long, A. J. and Wege, D. C. (1998). Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. *BirdLife Conservation* Series No. 7. BirdLife International, Cambridge, U.K.

Stevens, H. (1914) Notes on the birds of upper Assam. *J. Bombay Nat. Hist. Soc*. Vol. 23: pp 234-268.

Sumit Sen. (2008). Checklist of Birds; Mishmi hills and adjoining areas. Birds of India. http://www.kolkatabirds.com/mishmi/mishmiclist.htm.

Sundaram, B., Verma, S, Venkataraman, A. and Sukumar, R. (2003). The Asian elephant (Elephas maximus): its habitat, status and distribution in Arunachal Pradesh, India. Gajah Vol. 22: pp 45-49.

Tennant, D. L. (1975). Instream flow regimens for fish, wildlife, recreation and related environmental resources. *US Fish Wildl Serv. Billings* MT, 30 p.

Tharme, R. E. (1996). *Review of International Methodologies for the Quantification of the Instream Flow Requirements of Rivers*. Water law review final report for policy development for the Department of Water Affairs and Forestry, Pretoria. Freshwater Research Unit, University of Cape Town, South Africa.

Tharme, R. E. (2003). A global prospective of Environment Flow assessment: emerging trends in the development and application of environment flow methodologies for rivers. *River Research and Applications* Vol 19: pp 379-442.

Tharme, R. E. and King, J. M. (1998). Development of the Building Block Methodology for Instream Flow Assessments, and Supporting Research on the Effects of Different Magnitude Flows on Riverine Ecosystems. *Water Research Commission Report* No. 576/1/98.

Ward, H.B. and Whipple, G. C. (1959). *Freshwater Biology* (New York: John Wiley and sons).

Weeks, D. C., O'Keefe, J.H., Fourie, A. and Davies, B.R. 1996 A pre-impoundment study of the Sabie-Sand River system, Mpumalanga, with special reference to predicted impacts on the Kruger National Park. Vol. I: The ecological status of the Sabie-Sand River system. WRC report no. 294/1/96. Water Research Commission, Pretoria.

Welcomme, R.L., 1985. River Fisheries. FAO Fish. Tech. Pap. No. 262

Werum, M. and Lange-Bertalot, H. (2004). Diatoms in springs from Central Europe and elsewhere under the influence of hydrogeology and anthropogenic impacts. *Iconographia Diatomologica*, 13 A.R.G. Gantner Verlag K.G. , Ruggell, 480 p.

Wipfli, M. S., Richardson, J. S. and Naiman, R. J. (2007). Ecological linkages between headwaters and downstream ecosystems: transport of organic matter, invertebrates, and wood down headwater channels. *Journal of the American Water Resources Association,* vol. 43(1): pp. 72-85.

Zhong, Y. and G. Power, 1996. Environmental impacts of hydroelectric projects on fish resources in China. In: Regulated Rivers: Research and Management. Vol. 12: 81-98.

PHOTO PLATES

Dibang Basin


Pine Forest


Semi-evergreen Forest


Mathun River


Dri River


Talo River


Dibang River


Sissiri River


Ithun River

Plant species

Hedychium spicatum and *Musa balbisiana*

Bambusa tulda

Rubus ellipticus

Arundo donax

Bidens pilosa

Nephrolepis auriculata

Marchantia polymorpha

A species of Lichen

Black Lored Tit (*Parus xanthogenys*)

Spangled Drongo
(*Dicrurus hottentottus*)

Orange-bellied Leafbird
(Choloropsis hardwickii)

Rufous-bellied niltava
(*Niltava sundara*)

Grey Treepie (*Dendrocitta formosae*)

White Wagtail (*Motacilla alba*)

Black Bulbul (*Hypsipetes leucocephalus*)

Chestnut-headed Bee eater
(*Merops leschenaultia*)


Paris Peacock (*Papilio paris paris*)


Common Rose (*Pachliopta aristolochiae*)


Purple Sapphire (*Heliophorus epicles indicus*)


Common Silverline, (*Cigaritis vulcanus*)


Circe (*Hestima nama*)


The Commodore (*Limenstis danava*)

Vegetation Sampling

Water Sampling