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REVIEW OF HYDROLOGICAL STUDIES IN NORTH EASTERN REGION

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PREFACE

The North Eastern Region of India comprising seven states, endearingly referred as seven sisters, namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, lies between 21°57' to 29°28' north latitudes and 89°40' to 97°25' east longitudes and has geographical area of 2,55,158 sq.km (08% of India). It is the highest rainfall intensity zone of the country, an annual rainfall above 2,000 mm (going upto more than 11,000 mm) except for a small area in which the rainfall ranges between 1,000 mm and 2,000 mm. The whole region which is 70% hilly, has two principal drainage namely the mighty Brahmaputra and the Barak, both combine in Bangladesh to form the Meghna basin.

The region is yet to receive basinwise and even sub-basin wise planning for composite purpose of providing drinking water, and irrigation facility, generation of hydel power and making arrangement for industrial use with due regard to ecology and environment.

The various development problems of the region are food deficit, energy shortage, inadequate surface communication, flood, drainage congestion, deforestation, declining productivity and rapid population growth. Few wrong steps in exploitation of natural resources for short term gains could invite nature's wrath and the damages are sometimes so devastating that steady gains made over several years are undone in no time. The retaliation by nature makes us temporarily wiser but soon we tend to forget the real issues without evolving long term strategy and fixing inter-se-priority for exploitation of the natural resources in a systematic and environment friendly manner.

There are various Central Government and State Government organizations besides some NGO's are working in the field of water resources to provide solutions to varying nature of hydrological problems and to develop the water resources of the region. Some of the organizations have been setup long back in sixties and seventies and so far have been involved in a number of studies. Most of them deal with a specific type of problems and their interaction with the other departments are very much limited. In some of the cases, the same type of study may be seen to be taken up by different departments. Also, the evaluation of the methodology used in the studies and performance of the infrastructures constructed over that methodology has not been taken up so far. Any hydrological study requires a lot of meteorological and hydrological data and exact information about the availability of these data with various organizations are not known. For all these reasons and to justify a project, to evaluate its success or failure and to develop adequate technology to suit the local conditions, research inputs are very much essential. Every new study should starts from beginning but the research works must starts from the ends of the previous studies. And for this reasons the review of the earlier studies is of utmost importance not only to avoid the repetition of the work but also to evaluate analyze the shortcomings of the previous studies.

In N E Region most of the investigations and studies are undertaken on the project sites, as bare necessity to submit the project report and the picture at upper catchments which would substantially affect the project in its life time is gloomy or unknown. As a result ongoing projects throttle, oncoming projects invite quarries difficult to reply and thereby pushing the things to uncertainty.

Therefore, it has been decided to review all the hydrological studies taken in the region by any agencies governmental or non governmental and to prepare a dictionary type of the report. The various information included in this report are the purpose and year of each study, location and extent of study area with its brief description, data used, listing of specific studies and results and recommendations of the studies wherever possible. It

has been tried to collect all the studies related to hydrology and its allied fields. Besides the scheduled type of studies done by various departments, the research type of works done in academic institutions and North Eastern Regional Center of National Institute of Hydrology have also been reviewed.

The reports/literature materials have been collected by visiting library and project cell of the various organizations. National Institute of hydrology highly acknowledge the help and support provided by the authorities of North Eastern Council (Watershed Management and Flood Control), Central Water Commission, Brahmaputra Board, Central Ground Water Board, North Eastern Regional Institute of Water and Land Management, North Eastern Regional Institute of Science and Technology, Irrigation Department and Flood Control Department of Assam, Assam Remote Sensing Application Centre, Civil Engineering Department of Assam Engineering College, Meghalaya State Electricity Board and all others who provided relevant materials and support to complete this study.

The report has been jointly prepared by Sh. Pankaj Mani, Scientist-B and Sh. B.C. Patwary, Scientist-E of North Eastern Regional Centre of National Institute of Hydrology.

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ABSTRACT

In this review report, it has been tried to review all the hydrological studies done in the northeastern region of India by any agencies Governmental or non-Governmental. Sufficient care has been taken to include all the salient features of the study so that after going through the review note, an idea about the full and original studies can be obtained. The various information included in this report are the purpose and year of study, location and extent of study area with its brief description, data used, listing of specific studies and result and recommendation of the study, wherever possible. An attempt has been made to collect all the studies related to hydrology and its allied field. Besides the scheduled type of studies done by various departments, research type of study done in academic institution and research and development organisations like National Institute of Hydrology etc. has also been included

1.0 INTRODUCTION

The North Eastern Region of India comprising seven states, endearingly referred as seven sisters, namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, lies between 21°57' to 29°28' north latitudes and 89°40' to 97°25' east longitudes. It has geographical area of 2,55,158 sq.km (08% of India) and most of it is hilly. It is the highest rainfall intensity zone of the country, an annual rainfall above 2,000 mm (going upto more than 11,000 mm) except for a small area in which the rainfall ranges between 1,000 mm and 2,000 mm. The whole region which is 70% hilly, has two principal drainage namely the mighty Brahmaputra and the Barak, both combine in Bangladesh to form the Meghna basin.

While the river is endowed with vast water resource with annual flow of the Brahmaputra-Barak rivers as 585.6 BCM constituting 31% of country total surface water potential, the heighest water availability of 16,500 cum per capita and 44,180 cum per hectare and about 35 BCM of replenishable ground water resources, there is no basin or even sub-basin wise planning for composite purpose of providing drinking water, and irrigation facility, generation of hydel power and making arrangement for industrial use with due regard to ecology and environment.

The various development problems of the region are food deficit, energy shortage, inadequate surface communication, flood, drainage congestion, deforestation, declining productivity and rapid population growth. The fragility of hills further aggravates these problems by soil erosion, land slides and seismic effects generating heavy sediment load. The average soil erosion in North eastern region is about 28 ton/ha/year. This contributes high sediment load and is responsible for morphological changes in the river channel causing inconvenience of various kinds to people living in the floodplains close to wandering water courses. Few wrong steps in exploitation of natural resources for short term gains could invite nature's wrath and the damages are sometimes so devastating that steady gains made over several years are undone in no time. The retaliation by nature makes us temporarily wiser but soon we tend to forget the real issues without evolving long term strategy and fixing inter-se-priority for exploitation of the natural resources in a systematic and environment friendly manner.

The available water resources are to be utilized to maximum possible extent and formulation of developmental projects must fit in the overall plan for a basin or sub-basin, with the best possible combination of options. As far as possible, the development has to be thought of in form of multipurpose projects. The catchment treatment, environment, ecology and rehabilitation of affected people should form an integral part of the project.

1.1 Water Resources of NE-Region

NE-region of India referred as seven sisters is blessed with abundantly this gift of nature rarely available in such good measure elsewhere in the country. The region alone accounts for 1/3 rd water resources of the total water resources potential of the country. The entire region is drained by two major river systems namely.

1. The Brahmaputra river system and

2. The Barak river system

Apart from the above two river systems a few rivers which drain the part of the region are as follows:

3. The rivers of Tripura namely gumti, muhuri, manu, juri, burima , khowai, dhalai and haora.
4. The Imphal/ Manipur river system which drains the Manipur valley
5. The kolodyne river draining the south western part of Mizoram
6. Tizu sub-basin in Nagaland.

This region is a huge sprawling landmass made up of extensive countless hills and mountainous terrain that rises in the north to the snow-capped heights of the Himalayas. The physiography of the region is divided into three divisions, namely, Meghalaya Plateau, the North Eastern Hills and Basin, and the Brahmaputra Valley accounting for 13%, 65% and 22% of the total area respectively It is the highest rainfall intensity zone of the country and is richly endowed with water and other natural resources. The rains are of long duration and occur mostly between March and October. During March and April the rainfall is sporadic, but it is steady and heavy or very heavy during May and October. Mawsynram, a village, 16 km west of Cherrapunjee in Meghalaya, boasts of the heaviest rainfall in the world (annual average 11,406mm and highest recorded value even more than 24,000 mm).

Annual rainfall in north-eastern portion of Arunachal Pradesh, North-west of Dihang and north-east of Bomdila, is above 4,000 mm, but gets reduced in south-western direction. The rainfall increases in Khasi Jaintia and Garo hills (over 10,000 mm) but drops down in the north of the Brahmaputra valley (about 2,000 mm). The central parts of Meghalaya are famous for the phenomenonally high rainfall experienced there, average annual exceeding 7,000 mm. The northern and adjoining central area is in the rain shadow region having rainfall varying from 4,000 to 2,000 mm. The Imphal-Lumding region which partly lies in the rain shadow of the Mikir hill range records lowest rainfall.

It is to be noted that the entire North Eastern Region has an annual rainfall above 2,000 mm (going upto more than 11,000 mm) except for a small area in which the rainfall ranges between 1,000 mm and 2,000 mm. The number of rainy days in a year in the region is more than 100.

Brahmaputra Basin

The Brahmaputra basin extends over an area of 580000 sq.km and lies in Tibet(china), Bhutan ,India and Bangladesh. The drainage area of the basin lying in India is 194413 sq.km, nearly 5.9%of the total geographical area of the country. The basin lies in the states of Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim and West Bengal.

The water resources potential of the basin is the highest in the country while present utilisation is the lowest. As per the latest assessment, the hydro power potential of the basin is 27949 MW at 60% load factor (33% of the country's total potential) and generation so far is only 577.75 MW. Thus a large chunk of the of the hydro power potential of the sub basin remains to be tapped. Major projects on Dihang Subansiri, Kamen, Pagaladiaya have been identified for power generation

and flood protection. This basin also holds promises for transfer of water to other deficit basin /sub-basin which will reduce the flood problem in the valley also. Though Brahmaputra basin is abundant in water during monsoon season, there are certain pockets having drinking water scarcity during non monsoon season e.g. Cherapunji in Meghalaya. The main industries are forest products based wood product, paper and pulp industries oil and tea industries etc. The quality of the water in the basin is not under threat at present except for sediment load contributed by erosion in the upper catchment. Coal, lime and dolomite mining could be a source of pollution in the future.

Barak Basin

The Barak basin has its drainage area in India, Myanmar and Bangladesh. The drainage area of the basin lying in India is 26,123 sq.km. The basin lies in the state of Meghalaya Manipur, Mizoram Nagaland Tripura and Assam and forms a part of main Brahmaputra basin.

This is also a surplus water basin with almost entire potential remain unutilised. There are only a few minor an lift irrigation shemes existing in the sub basin. One of the important ongoing hydro-power development scheme is Turial project. Tipaimukh dam and Dhaleshwari projects are the other important projects. The hydro power potential of the basin is assesed as 2042 MW while installed capacity is 15MW only. The basin is prone to flood and river bank erosion. The water in this sub basin is not afected by pollution except due to erosion because of land degradation.

Other Basins

Tripura is a tiny hilly state of this region with a geographical area of about 10,486 sq.km. The state is drained by 10 major river systems namely Lonlai , Juri, Gumti, Muhuri, Manu, Burima , Khowai, Dhalai Manu Feni and Haora. All the rivers except for Muhuri and Manu Feni forms part of Barak basin. The area being in high rainfall zone, the rivers traverse through soft rocky terrains and alluvial tracts causing flash flood and bank erosion. The area adjoining Bangladesh is thickly populated and raveged by flood and erosion every year.

Manipur is small state situated in extreme end of the NE border of India. The state is like a oval shaped valley surrounded by hills on all sides. The total geographical area of the state is 22,237 sq.km, out of which the valleys ortion occupies 2,230 sq.km. The valley portion is drained by the Imphal / Manipur river system. The river network consists of 8 major rivers namely the Imphal / Manipur, Iril, nambu;, Sekmai, Chapki, Thoubal and Khuga.

The kolodyne river drains the southern part of the Mizoram and outfalls to the Chindwin river in Mayanmar.

The Tizu basin is situated in the extreme eastern end of the state bordering Mayanmar. The river Tizu drains a catchment area of about 4894 sq.km and meets the Irrawadi river in Mayanmar.

1.2 Hydrology Related Problems of North Eastern Region

Flood Management, Drainage Congestion and Erosion Problem- The NE region

particularly the Brahmaputra and Barak valleys are subjected to frequent and damaging floods almost every year. The extent of flood problem in the Brahmaputra valley is much greater than any other flood prone valleys in India like Ganga ,Narmada and Godavari because of the physiography, distribution of rainfall and basin geology. The flooding of the most part of the valley from Dhubri to Kobo for a length of 640 km with a number of villages or even a few towns is a common occurrence in the period of June to August. in **Assam**. The flood prone area is about 38 lakh ha. Heavy deforestation, shifting cultivation, reclamation of low lying areas which earlier served as detention basins and inadequate capacity of the rivers are the main reasons of floods in **Manipur**. Drainage congestion in many areas and backwater effect on the Manipur river, i.e. the Imphal river below its confluence with the Kordak river, due to rocky hump 5 km downstream of Sugnu, are additional factors aggravating the flood problem. The flood prone are in Manipur is about 0.8 lakh ha. **Tripura** hills are not very high and the valleys are not very deep. However, flash floods occur after every heavy rainfall. Though the duration of the floods is limited in upper reaches, submergence in the downstream reaches near the international border with Bangladesh continues for longer period. The flood problem in **Meghalaya**, **Nagaland** and **Mizoram**, which are hilly states, is minor in nature. Meghalaya experiences inundation and bank erosion in some locations. The major problem in Nagaland is shifting cultivation in upper reaches of the rivers likely to cause silting up of the sections of the rivers originating from this state. In **Arunachal Pradesh** the bank erosion threatens villages, town and communication networks in many reaches and soil erosion on the slopes due to deforestation, shifting cultivation and other developmental activities leads to clogging of the river channels in the foothills aggravating flood problems.

As regards the management of flood in the North Eastern Region there has been main dependence on embankments, particularly in the states of Assam, Manipur, Meghalaya and Tripura. About 27.5% of the total embankments constructed in the country lie in Brahmaputra and Barak valleys and have provided inadequate protection. Further, raising, strengthening and anti erosion measures for these embankments have proved to be very expensive. For the Pagladiya river 87.60 km of embankments were constructed at a cost of Rs. 31 lakh, but subsequently an additional expenditure of Rs. 4.42 crore was incurred on raising, strengthening, anti-erosion measures, maintenance and repairs. Construction of embankments has also caused serious problems of drainage congestion behind embankments due to high rainfall which resulted into more distress to the population in the protected area then otherwise. Even channel improvement by dredging etc., in certain reaches of some rivers has been thought of, but the cost involved is prohibitively high and disposal of dredged materials is likely to pose big problems. Drainage improvement, anti-erosion and river training works have been executed, but the flood problem by and large still exist causing serious miseries to the people.This necessitates proper study of boundary conditions of rivers like migration of meanders, shifting of channel outfall etc. Studies on river behaviors and channel processes need to be undertaken for understanding reasons for erosion and bank migration with the help of aerial photograph and satellite imageries.

The reasons of the extensive floods in the valleys are:

Meteorological situation: The mean annual rainfall over the catchment excluding Tibet and Bhutan is about 2300mm.The mean annual rainfall over the sub

catchments varies widely from 2590 mm in Siang / Dihang catchment in Arunachal Pradesh to 1735 mm in Kopili sub catchment in Central Assam. In the northern part, monsoon rainfall accounts for less than 50%of the annual rainfall, the pre-monsoon around 35%and winter rain around 10%. In the rest of the catchment towards the south 60 to 70% rainfall occurs during the monsoon period and 20 to 30% in pre-monsoon season and a small amount during the winter.

The bulk of water both for surface and ground is obtained from rainfall. In the region rainfall occurs only in the months of monsoon completed with few spells of intense and heavy rains. Therefore until and unless major portion of water derived from rainfall in a short period is stored, it obviously will go waste causing damages en route by floods.

Physiographic condition and land use :The valley width of the Brahmaputra is only 80 to 90 km between the foothills in the North and south of which the highly braided river occupies a width of 6 to 18 km in most places. The high lands along the foothills are occupied by forests and Tea gardens. As such, the remaining width occupied by villages and cultivated fields is very small and falls within the flood plains of the river thus aggravating flood damages.

Encroachment of riverine areas: Increasing encroachment of the riverine areas due to rising populations addition of infrastructural facilities like roads etc. and their ever rising aspirations has also caused increased flood damages. Assam has a total of 68,913 km o f roads which approximately occupies an area of 1,37,826 ha of precious land.

Nature of Flood Problem - The problem of floods of Assam in the Brahmaputra valley can be summarized as below:

1. Inundation of large areas due to spilling of banks by the Brahmaputra and simultaneous overflowing of banks by the tributaries.
2. Drainage congestion at the outfall of the tributaries during high stages of the river Brahmaputra causing flooding of low lying areas.
3. Excessive silt load in the river due to soil erosion and large scale landslides in the hilly catchment areas due to intense rainfall on fragile steep slopes of Himalayas result in instability of the river and erosion of its banks. The problem has been further aggravated due to high seismicity, undesirable human actions in the form of shifting cultivation, over grazing and unscientific commercial exploitation of the forest.

Drainage - The drainage problem in the Brahmaputra and Barak valley are partly due to natural causes and partly man made. Among the natural causes are, high rainfall in the basin exceeding 2000mm in most of the catchment area and precipitation of 85 percent of it during may to october; run -off is rapid and huge from steep hill slopes in Arunachal Pradesh, Nagaland and Meghalaya. These rivers carry excessive silt load and create congestion at the outfall of the tributaries due to high stage of the Brahmaputra over a long period during the rainy season. When the Brahmaputra is in flood, it not only obstructs the free discharge of the tributaries to a distance of 8 to 10 km but also causes inundation of large areas near the outfall due to the drainage blockage of the tributaries.

Man has contributed to the problems of drainage by creating obstruction in the natural flow of water by several actions like constructions of railway embankments,

roads, private bunds, obstructions put in drains and encroachment of waterway.

The main drainage congested area lies between the Brahmaputra and the two National highways which run along the river on the north and south of the river. The drainage congestion problems is confined to the states of Assam, Tripura and Manipur while the rest of the hill states generally do not face this problem.

Erosion problem- Erosion by the Brahmaputra and its tributaries has been causing considerable damages each year. The extent of loss of damage due to erosion in the valley varies from year to year depending on the severity of floods. After the great earthquake of 1950 erosion has been very severe due to excessive silt brought down by the river from the hill as a result of extensive landslides.

Geologically the Himalayas are young mountains and are unstable. The North -Eastern region is particularly unstable because of its high seismicity .On an average about eight earthquakes of magnitude higher than 5 on the Richter scale occur every year, which seriously shake the land and disturb the terrain. To add to this adverse factor rainfall in the outer Himalayas and sub mountain areas is very high. Heavy rainfall lashing on the steep slopes of the hills causes a great deal of soil erosion in the basin further disturbed numerous landslides occur. These are caused not only by earthquakes but also to a considerable extent by soil surcharged with rain water on the steep slopes which activates and facilitates landslides.

The eroded soil in the catchment area and the debris of landslides pour in to the river during rains when the river carries not only enormous discharge but also excessive silt load Under these condition the river tries to build steeper slope which in turn results in widening of bed and braiding of channels. Erosion is prominent in almost all along both the banks of the river Brahmaputra but some of the critical reaches are worth mentioning. The reaches of the Brahmaputra where erosion is acute are south Salmara downstream of Goalpara, Gumi-palasbari Moriaholo, Kaziranga and Mathala on the south bank and Majuli Sonarighat, Tezpur, Mukalmua and Dhubri on the north bank.

Seismicity - Seismically NE region is one of the most active regions of the world. A review of the seismic history for the last 200 year shows that the whole of the region has experienced major shocks. Particular mention may be made about the earthquake in 1897 (magnitude8.7) and 1950 (magnitude8.5) which are estimated to be largest in the world and caused widespread damage. Analysis of recent earthquakes data has shown that within a radial distance of 450 km from Shillong 2500earthquakes were recorded during the years 1970-75 and the level of activities continues till date. The magnitudes of these earthquakes even though small indicate the highly seismic status of the region. Due to recurring incidence of severe earthquakes the river system in this region is overloaded with sediments and consequently rendered them unstable.It is obvious that development of huge water resource potential in this region will necessitate construction of large strong project with dams of considerable heights. Differential pressure of ground water on both the river & country sides of embankments also sometimes affect its stability. High seismic status of this region may raise a question as to how seismicity would affect the height of a dam in this region and whether it will be a feasible proposition or not to go for high dams in this region. Sufficient information regarding seismic behavior in the region is not available. The detailed programme for the creation of a permanent and close seismological network in the region may be drawn to have enough information for any development works where seismological consideration is

necessary.

1.3 Approach for Water Resource Development:

The water resources development should generally be guided by priorities on problems specific projects within the basin or sub-basin observing broad policy directives discussed above. An integrated approach to meet the demand of growing population, improve socio-economic condition of the people, support other sectors of economy for balanced development and generate revenue to the state or states of the region where the project is located has to be prepared. The projects being generally capital intensive would have long gestation period. Therefore, long term development planning probably for next 50 year perspective with short, medium and long term implementation programs catering to the beneficial uses should be the approach for development. The beneficial uses of these water resources projects in the region would be for following purposes:

Drinking Water : Due to improvement in living standard and better quality of life over the years, the existing norms for domestic water supply may have to be increased by about 50% in next few years which is a negligible fraction of the total available water. Awareness about hygienic living, better water management and conservation has to be created among the communities to improve the quality of life.

Irrigation : The region has ultimate irrigation potential of 04.26 MHA of which only about 20% is presently under irrigation. The remaining irrigation potential can be realized through multipurpose projects and by exploiting ground water resources where power supply exists. Most of the area in the region is hilly, therefore, from economic and ecological considerations better farming practices like minimal tillage , use of organic fertilizers and contour farming could be useful as recommendation under Sloppy Agricultural Land Technology (SALT) by the International Center for Integrated Mountain, Development, Kathmandu. Assured irrigation for large scale cultivation of lean season crops will boost the agriculture production and can make the region surplus in food grains. Irrigation can also play an important role in popularizing terrace cultivation in hilly areas as a viable and permanent substitute to jhoom (slash & burn) farming practice.

Hydro-power : The region Offers virtually unlimited scope of hydro power development. Of the country's prognosticated hydro power potential of 84,044 MW (At 60% load factor), 31, 857 MW (at 60% load factor) is located in the region. The Brahmaputra, Barak and other rivers in the region hold a great potential for hydro - power development. These rivers have many suitable sites both for run-off the river and Storage reservoirs with benefits of flood control, irrigation, inland navigation and fisheries in additional to power generation. As per one assessment of HE potential in the country carried out by the CEA, a total of 226 schemes have been identified in the Brahmaputra and Barak River systems totaling to a hydro-potential Of 3,063 MW. The Hydro potential of 3063 MW comprises of 1780 MW on Tista and Jaldhaka rivers in West Bengal and 1283 MW On the river Tista in Sikkim .N.E Region has about 37% of country's available power potential and only about 02% of the same has been exploited so far. The energy consumption in N.E. Region from all sources viz. Industry, domestic, agriculture, commerce and others has been worked out as 3736 million units at 1995-96 level which accounts only about 1.33% of the total energy consumption in the country. The per capita energy consumption in the region

is of the order of 100 units against all India average of about 333 Units for 195-96.

Based on the present pattern of development the demand of power in the region are not very high and the installed capacity of about 1628. 95 mw is greater than the peak demand during 1996-97 , but the average deficit in meeting the peak demand exceeds 12% in the region. The existing generating station are not able to meet the peak demand due to various reasons including very low plant load factor of thermal units. According to the **Fourth National Power Plan** prepared by Central Electricity Authority in March 1997, the pace of hydropower development has to be accelerated to add 58000 MW over next 15 years. The average hydropower generation cost in NE Region is one of the lowest in the country and submergence affected population will also be less, therefore, the North-Eastern region should be able to contribute atleast 25% of the projected demand by 2012 and cumulative 25000 MW by 2025.

Navigation : The organized in-land water transport services in the Brahmaputra river was started in 1844 and are almost as old as the Rhine in Europe and Mississippi river in USA. The Brahmaputra still remains largely in its natural state. The constitution of Inland Waterway Authority of India (IWAI) in October 1986 and declaration of the Ganga & the Brahmaputra as National Waterways in 1988 have set the stage for coordinated and sustained development of inland navigation in the Brahmaputra river. The 891 km long river reach from Sadiya to Bangladesh border has now become the National Water way No.2.

The inland navigation in the region comprise of a specific type of cargo with a capacity of 119000 MT. The capacity utilized in 1996-97 was only 2117 MT (20% of the available). The passenger traffic is mainly concentrated on cross-ferrying in the Brahmaputra-Barak rivers and their tributaries. About 60,000 passengers and goods are transported everyday through ferry routes benefitting the people of entire region. The navigable length of north-eastern rivers alone is about 3880 km and there is further scope to divert a sizable traffic to inland navigation for which the waterways have to be sustained by improving the braided and unstable river reaches, increasing the draft during lean season and reducing the high velocity.

Industries : The per capita income in the region is 84% of national average. The predominance of the primary sector to the Gross Domestic Product(GDP) indicates low level of industrial development of the region. Number of large and medium scale industries in the region was only 166 till 1994 and pace of industrial development is also observed to be very low. Factors like locational disadvantage, nonavailability of adequate skilled manpower and raw materials stand in the way of rapid industrial development in the region. However, availability of water in abundance with facilities for waste disposal coupled with availability of cheap and assured hydropower may overshadow all these constraints.

Pisciculture : Few researchers have reported that from each hectare of beel area of Assam 100 kg of fish can be produced(without any scientific aid) which is regarded as the highest fish producing potential from the wet land in the country. Then these beels referred as `**Duck Factory**`, are breeding ground for numerous varieties of aquatic flora and fauna and habitat for exotic migratory birds. These wet lands are also regarded as unique natural laboratory for botanical & zoological sciences. Serious concern has been expressed the way these wet lands are being managed by the Governmental and non Governmental agencies looking at the totality and that these wet lands capable of giving quick returns and revenue are facing extinction or

turning into dumping ground of garbages polluting the atmosphere

The fish production in 1994-95 was 1,98,000 tonnes. The requirements by 2000, 2025.& 2050 @ 75 gm per day per capita will be 830 tons, 1250 tons and 1750 tons respectively. The 17 multi-purpose projects so far identified by Brahmaputra Board will create a water area of 925 sq.km on completion in a phased manner. These schemes will provide incidental benefit of pisciculture with estimated fish production of 2.75 lakh tons, 8.50 lakh tons in 2000, 2025 and 2050 respectively.

Recreation : The water bodies in controlled form offer opportunities for recreational activities like boating, motor launch racing, water skiing, river cruising, swimming, angling and bird watching etc. With panoramic landscape, lush green hill ranges and fascinating fauna and flora, the north eastern region has great prospect for promotion of tourism alongwith development of the water resources. The aspect has to be kept in view while planning the river valley projects.
(Ref: Approach for Water Resource Development in NE -Region 2050 AD, by Brahmaputra Board)

1.4 Need of Research Work

Water resource problems of the region being of very large dimension and very specific it needs a thorough and systematic study in the region. Due to recurring incidence of severe earthquakes the river system in this region is overloaded with sediments and consequently rendered them unstable. In spite of various positive aspects of embankments, the negative aspects quite often outweigh their utility as flood protection measure. Differential pressure of ground water on both the river & country sides of embankments also sometimes affect its stability. This necessitates proper study of boundary conditions of rivers like migration of meanders, shifting of channel outfall etc. Studies on river behaviour and channel processes need to be undertaken for understanding reasons for erosion and bank migration with the help of aerial photograph and satellite imageries.

Non-structural measures like flood plain zoning, real time flood forecasting, systematic training of personnel for disaster management are very much useful to reduce flood damage. It is usually expressed in many forums that there is lack of seriousness about the problem both amongst the public & public leaders and enough stress is not laid on this aspect.

To work with water resource problems, non availability of sufficient data of desired quality at short notice has been of great concern for the research institutions. The necessity of establishment of central data bank containing data collected over the years by the state & central agencies is felt to be an extremely important. Inadequacy of hydrometeorological observation net-work in the region has been expressed since long past, but improvement in this regard is far from satisfactory. To create a sound data base and formulating a full-proof water resource development project, observation net-work must be strengthened to the requirement until which it is said "ingenuity of hydrologists will continue to be tapped to estimate data of ungauged river/stream sites" when it becomes suddenly necessary to take up a water resource projects on the river/stream. Water resources management Issues in the North Eastern region also requires substantial improvement in the data collection , analytical base and its dissemination . Although a number of agencies are involved in water data collection. In the region the network has remained very poor. This may become very clear from the fact that in whole of the state of Mizoram there is no systematic recording of rainfall. Achieving improved water resources management requires a substantial upgrading of the data base and its practical application in

basin plans, environmental monitoring and assessments, and other hydrological analysis.

1.5 Scope of the Review Study

Water resource problems of the region being of very large dimension it needs enormous infrastructures & fund allocation, coordinated efforts of all the departments, extensive & intensive research and investigations; and over and above strong socio-political will to translate the ideas into reality. There are various Central Government and State Government organizations besides some NGO's are working in the field of water resources to provide solutions to varying nature of hydrological problems and to develop the water resources of the region. Some of the organizations have been setup long back in sixties and seventies and so far have been involved in a number of studies. Most of them deal with a specific type of problems and their interaction with the other departments are very much limited. In some of the cases, the same type of study may be seen to be taken up by different departments. Also, the evaluation of the methodology used in the studies and performance of the infrastructures constructed over that methodology has not been taken up so far. Any hydrological study requires a lot of meteorological and hydrological data and exact information about the availability of these data with various organizations are not known. For all these reasons and to justify a project, to evaluate its success or failure and to develop adequate technology to suit the local conditions, research inputs are very much essential. Every new study should starts from beginning but the research works must starts from the ends of the previous studies. And for this reasons the review of the earlier studies is of utmost importance not only to avoid the repetition of the work but also to evaluate analyze the shortcomings of the previous studies.

In N E Region most of the investigations and studies are undertaken on the project sites, as bare necessity to submit the project report and the picture at upper catchments which would substantially affect the project in its life time is gloomy or unknown. As a result ongoing projects throttle, oncoming projects invite quarries difficult to reply and thereby pushing the things to uncertainty. Therefore, it has been decided to review all the hydrological studies taken in the region by any agencies governmental or non governmental and to prepare a dictionary type of the report. The various information included in this report are the purpose and year of each study, location and extent of study area with its brief description, data used, listing of specific studies and results and recommendations of the studies wherever possible. It has been tried to collect all the studies related to hydrology and its allied fields. Besides the scheduled type of studies done by various departments, the research type of works done in academic institutions and North Eastern Regional Center of National Institute of Hydrology have also been reviewed. Although an attempt has been made to refer almost all the water related studies done in the region by various agencies, but it may not be possible to go through all of them because of many reasons including the accessibility of reports, time limitation to complete this review study etc. But always there is a scope to incorporate these reports if available in future.

2.0 SURFACE HYDROLOGY AND FLOOD STUDIES

2.1 Studies conducted by Central Water Commission

2.1.1 Longai Multipurpose Project (Tripura and Mizoram), 1993

Longai river basin is a part of Barak basin. The river originates from Jampui hills in Tripura and after traversing a distance of 90 km through a dense forest in hilly terrain, enters Assam near Rangamati and covers 120 km in plain before entering Bangladesh. Since the discharge carrying capacity of the river is very low, flood builds u at a very fast rate leaving little or very low scope of advance warning. The total catchment area is 1171 km2 and upto haedwork site is 483 km^2. The project is for the purpose of 10.35 GWh of power for Mizoram and flood control in Karimganj in Assam.

Hydrometeorology - There are 3 rainguage stations (in the plain area only) are Isabil, Sephinjuri and Patharkandi. In close proximity of the basin, for IMD observatory at Kailashahar (since 1952) and Dharamnagar (since 1956) daily rainfall data and is available. Evaporation studies have been done using data collected at Agartala.

There is no GD site in the basin but at Akabarpur 100 km d/s of the proposed dam one GD site is maintained by FCD of Assam and data is available for 1977-89. Two GD sites had been opened by CWC at Loipowa and Kanhmun in 1987 and continued upto 1990 only. Sediment study has also been conducted using data observed at Kanhmun during July 1989 to Jun 1990 and calculated as 1480 m^3/km^2/year. Water balancing technique has been used to arrive at monthly yield series. As long term data at Radhapur GD site over Juri river is available, Juri basin has been selected as model basin. Determination of field capacity, drainage coefficient, chaanel storage coefficient have been calculated using monthly rainfall of Dharamnagar and Kailashahar and average of two stations.

2.1.2 Tipaimukh Dam Project

The multipurpose project with power and flood control benefits is over Barak river 500 m d/s of the confluence of Tuivai river. The catchment area upto dam site is 12758 km^2 spread in states of Manipur (8936 km^2), Mizoram (2344 km^2), Nagaland (728 km^2) and Burma (751 km^2).

Data Availability: - There had been 5 stations inside the basin prior to 1978 but now it there are 41 various ORG and SSRG stations in and around the basin. Toatl 26 numbers of GD sites are in the entire basin and 5 upto dam site.

Studies:

1. Design storm
2. Design flood
3. Storm distribution
4. Maximum probable flood
5. Water quality studies (pH, DO, Hardness number, specific conductance, anionic constituents, cationic constituents, alkali metals, other toxic and trace elements), from June 1991 to Jan. 1993 at dam site, Jakuradhar, Annapurnaghat and Badarpurghat.

2.1.3 Lower Tuiphal Micro hydel Scheme, 1994

Location:

Tuiphal river basin with its catchment area of 309 sq.km lies in the Aizawl district of Mizoram state. The dam site is located at the latitude of 23°48′23″ N and longitude 93°09′20″ E. River Tuiphal is the tributory of Tuivai in Barak basin. River is 33km long and its average bed slope is 1in 100. Average rainfall in the catchment based on Aizawl station is 2132mm and varies from 2947mm maximum to 1410mm minimum.

Data Availability:

No long term rainfall data is available inside the catchment. Average rainfall in the catchment based on Aizawl station is 2132mm and varies from 2947mm maximum to 1410mm minimum. Temperature in the catchment varies from 34.4 °C maximum to 8 °C with normal temperature of 20 °C. Maximum and minimum humidity is 94% and 79% with normal value of humidity is 86%. Annual evaporation computed for the catchment is 1093mm. Design flood calculated is 3090 cumecs.

2.1.4 Laolui Micro Hydel Scheme, 1993

Location:

It is a diversion scheme over in the Laolui river, a tributary of Liklui river in the Dhaleshwari basin in the Aizawl district of Mizoram. The weir is located at latitude 23°20′03″N and 93°46′03″E. The whole catchment is in hilly region with catchment area of 42.73sq.km.Length of the river upto weir site is 12 km and the bed slope is 1:35. There is a fall of about 48m in river between trench weir and tail race location and it is proposed avail this head for power generation.

Climate:

The average rainfall in the catchment is2132mm and varies from 2947mm maximum to 1410mm minimum. The temperature in the catchment varies from 30.4 °C maximum to 8 °C with normal temperature of 20 °C. Maximum and minimum humidity is 94% and 79% with normal value of humidity is 86%. Design flood calculated is 930 cumecs.

Data Availability:

There is no rainguage station within the catchment area of Laolui river project. Except one self recording rainguage/ordinary rainguage installed by Central Water Commission, Investigating Circle, Shillong with effect from August 1988 to October 1991.

2.1.5 Lower Tuiphal Micro hydel Scheme, 1994

Location:

Tuiphal river basin with its catchment area of 309 sq.km lies in the Aizawl district of Mizoram state. The dam site is located at the latitude of 23°48′23″ N and longitude 93°09′20″ E. River Tuiphal is the tributory of Tuivai in Barak basin. River is 33km long and its average bed slope is 1in 100. Average rainfall in the catchment based on Aizawl station is 2132mm and varies from 2947mm maximum to 1410mm minimum.

Data Availability:

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2.1.6 Laolui Micro Hydel Scheme, 1993

Location:

It is a diversion scheme over in the Laolui river, a tributary of Liklui river in the Dhaleshwari basin in the Aizawl district of Mizoram. The weir is located at latitude 23°20'03"N and 93°46'03"E. The whole catchment is in hilly region with catchment area of 42.73sq.km.Length of the river upto weir site is 12 km and the bed slope is 1:35. There is a fall of about 48m in river between trench weir and tail race location and it is proposed avail this head for power generation.

Climate:

The average rainfall in the catchment is2132mm and varies from 2947mm maximum to 1410mm minimum. The temperature in the catchment varies from 30.4 °C maximum to 8 °C with normal temperature of 20 °C. Maximum and minimum humidity is 94% and 79% with normal value of humidity is 86%. Design flood calculated is 930 cumecs.

Data Availability:

There is no rainguage station within the catchment area of Laolui river project. Except one self recording rainguage/ordinary rainguage installed by Central Water Commission, Investigating Circle, Shillong with effect from August 1988 to October 1991.

2.1.7 Tuichanglui Microhydel Scheme, 1996

This is a diversion scheme over Tuichanglui river, a tributary of Tuipui/Kolodyne river in Kolodyne basin in Aizawl district of Mizoram. The catchment area is 1287 sq.km and the length of the river upto weir site is 110km. The river flows through a hilly catchment and the bed slope is of the order of 1in 200. The geographical location of the weir site is 23°15'20" N and 92°55'20" E.

Hydrology:	
Maximum precipitation	2947mm
Minimum precipitation	1410mm
Annual Average	2132mm
snowfall	nil
Temperature	8 - 30.4 °C with nominal temperature of 20 °C
Humidity	58-94 % with nominal value of 86%
Maximum probable flood	17,250 cusec (design flood)
Ten daily dependable yield	0.96 cumecs (April) to 179.83 cumecs (August)
Diversion Structure :	
type	Trench weir

Shape	Trapezoidal trough
Length	27.5m

Data Availability:
No rainguage station is available within the catchment. However monthly rainfall data is available at Serchhip since 1982. The rainguage is being maintained by Department of Agriculture, Government of Mizoram. G & D data is available for the period of April 1988 to May 1991.

2.1.8 Kamlang Hydroelectric Project, (Arunachal Pradesh), 1998

The project is located in the Lohit district valley of Arunachal Pradesh between 27°30′N to 27°55′ N latitude and 96°0′ to 96°45′ E longitude and the barrage site is at the longitude 96°23′44″ E and latitude of 27°44′26″. River originates from Sematong Bum at elevation of 4571 m. The average slope of the river bed is 1:10. Highest peak is covered with snow. The catchment area of the basin upto barrage site is 500 km^2. Average annual rainfall in the basin is 5938.55mm and average annual yield is 1758.36 Mcum while 90% and 75% dependable yield is 1218.04 Mcum and 1486.38 Mcum. Maximum and minimum observed flow is 251.34 cumecs and 3.08 cumecs. Design flood (100 year return period) was calculated as 2197 cumecs. Annual sediment load in the river is observed as 1.4 mm/year.

Data Availability

Daily Rainfall data used in the hydrological analysis are for three raingauge stations as detailed below:

1. Glao Lake (within catchment) - 22.6.90 to 31.12.93.
2. Bailey Bridge (outside catchment) - 1.8.89 to 31.12.93 and hourly rainfall data has been used for the period of March 92 to December 93.
3. Kamlang Nagar (outside catchment) - 1.5.85 - 31.7.89, 1.6.90 to 31.10.90 and 1.1.91 to 31.12.93.
4. Wakro - 21.8.90 to 31.12.93.

Gauge and discharge data is available as detailed below:

1. At Bailey Bridge (4.5 km downstream of proposed Barrage) - daily discharge from June 89 to Dec. 93 and hourly gauge data for monsoon period of 1989 to 1993.
2. At 1 km downstream of barrage site - daily gauge data from Oct 89 to Oct 92 and March 93 to Dec. 93.
3. At proposed barrage site - daily gauge data from March 93 to Dec. 93.
4. Khowang site of Buri Dihing - daily discharge data from Jan 56 to Dec. 88
5. Chenimari site of Buri Dihing - daily discharge from Jan 78 to Dec. 92.

Sediment data for bailey bridge site from 11.9.89 to 28.2.1993 has been used for the calculation of annual sediment load.

2.1.9 Ranganadi Hydro-electric Project, Arunachal Pradesh

Ranganadi known as Panyor in the upper reaches form a sub basin which is part of Subansiri composite basin. Dikrang sub-basin is also part of it. The river rises from th , Defla hills in the lesser Himalaya zone of Arunachal Pradesh, follows its course through hilly terrain and across the plain of Assam and finally meets Subansiri before the latter joins Brahmaputra. Important tributaries of are Pain, Niyarkeg, Kale, Pangen and Pit. Total catchment is about 2500 km^2 of which 1950 km^2 falls in hilly terrain. The drainage pattern is sub dendritic which is characteristic of hilly mountainous region. Catchment area upto dan site is 1730 km and upto diversion dam site is 1894 km. Maximum and minimum rainfall observed in the basin are 1562 and 838 mm with the average rainfall of 1232 mm. Design flood has been estimated as 13241 cumecs.
Details of Dam (Yazali)

1. Type - rock fill, Height - 112 m, length - 410 m, Top of dam - 722 m.
2. Spillway capacity - 13241 cumecs
3. Maximum / annual runoff - 8643/1862 MCM
4. Gross storage at FRL - 529.2 MCM
5. Dead storage at MDDL - 152.2 MCM

Details of diversion dam

1. Type - concrete and rock fill, Height - 112 m, length - 221 Top of dam - 571
2. Spillway capacity - 13241 cumecs
3. Maximum / annual runoff - 5080/2048 cumecs
4. Gross storage at FRL - 21.28 MCM
5. Dead storage at MDDL - 15.58 MCM

2.2 Studies carried out in Assam Engineering College, Guwahati

2.2.1 Stochastic Model Analysis of River Brahmaputra for General of Peak Flow Sequence and its Comparison with Frequency Analysis

The study has been conducted in search for a structural model for determining the peak discharge at different recurrence interval to over come the inadequacies that arise in empirical as well as probabilistic method. For that, records of daily runoff from two gauge stations of river Brahmaputra chosen on the postulated absence of trends induced by man made improvements are analysed. Estimation of probable peak discharge by stochastic method for river Brahmaputra for which flow data for a reasonable period is available has been analysed. Also, the results obtained by stochastic method with the results of frequency analysis have been compared.

2.2.2 Regional Flood Frequency Analysis for the Barak Basin

In this work, regional flood frequency analysis is being applied taking the 8 tributaries of Barak basin for periods ranging from 14 to 21 years. The same type of study has been done by Brahmaputra Board for various periods ranging from 3 to 14 years. The data for different stations have been tested for homogeneity and a group of stations satisfying this test have been considered. This group of stations

constitutes a region and all the station data of this region are pooled and analysed as a group to find the frequency characteristics of the region.

Regional flood frequency analysis involves two major parts - the first is to develop a basic dimensionless frequency curve representing the ratio of flood of any frequency to mean annual flood against return period and other is to develop a correlation curve between mean annual flood and corresponding catchment area enabling to predict the mean annual flood at any point within the region. The combination of mean annual flood with basic frequency curve provides a frequency for any location. It is assumed that Gumbel extreme value distribution is fit well to those data series to establish preliminary frequency curve for individual station. A computer programme has been developed for computation by Gumbel extreme value distribution for finite data series and for regression analysis too.

2.2.3 Flood Frequency Analysis : Log Boughton Approach A Comparative Study

An attempt has been made in this dissertation to compare the computed design flood for a particular return period using three distribution. Distribution are namely Log Boughton, Gumbels Extreme Value, and Log Pearson Type-III distribution. Annual peak discharge values of three rivers as available are considered for analysis. It is observed that for lower value of return period computed flood discharges are nearly same with results from Log Boughton lying in between the other two distribution. For higher value of return period result of Log Boughton are on lower side in comparison to other two. Since Log Boughton distribution has an optimal solution for direct fitting of the distribution to either complete sets or subsets of annual flood data, therefore, annual floods from 33 years of Kaldia rivers are used to show the fitting of the distribution to complete as well as subset of data. For subset of data the estimated floods value does not vary much when the 2, 3, 4, and 5 lowest values are omitted in turn from the distribution. Three computer programs has been developed for computation by Gumbels Extreme Value, Log Pearson Type III and Log Boughton distribution for complete set of annual flood data.

2.2.4 Comparison of Gumbel's Method and Log-pearson Type-III Method of Flood Frequency Analysis for Rivers in North-east Region

Twenty rivers of Brahmaputra basin including river Brahmaputra have been investigated. Using Weibull plotting formula, Gumbel Extreme Value distribution and Log-Pearson Type-III distribution were fitted to each individual river having annual peak discharge data for record lengths ranging from 10 to 39 years. Goodness of fit has been tested using D-index and other least square error criteria. Gumbel method has been, in general, found to give better fit in the middle as well as both at bottom and top ends. Gumbel method has been concluded to be better fitted and more suited than Log-Pearson Type-III method for flood frequency analysis of rivers in North East Region.

2.2.5 A Study of the Flood and Drainage Problem of Guwahati

Flood and drainage problems of Guwahati are investigated and associated factors are analysed. Remedial measures proposed earlier are reviewed and new measures to relieve Guwahati from flood and drainage problems are proposed. Guwahati flood and drainage problems have been identified in two situations. One is

urban drainage problem and the other is flood congestion problems. Stress has been given on land and sever management for the remedial measures of the urban drainage problems. Concentration is given on gravity flow condition for the solution of the flood congestion problem by a system of existing and proposed drainage channels which ultimately leads the Guwahati run-off to Brahmaputra through river Kulsi.

2.2.6 Stochastic Analysis of Stream Flow Records for Generation of Peak Flow Sequence and Estimation of Monthly Flow Volume

The study intends to present the stochastic procedures in search for structural models for the time series of two hydrological process; first, prediction of peak stream flow magnitudes for different return periods and the second is determination of confidence limits for stochastically estimated monthly flow volumes. Records of daily discharge from the Numaligarh gauge station of the Dhansiri river on the south bank of the River Brahmaputra have been used for this demonstrative analysis. Absence of any trends induced by man made improvements presumed. Results obtained are mildly liberal. Since a single source of data used, generalisation not suggested.

2.2.7 Comparison of Plotting Position Formulae For Rivers in North-east Region

Selection of an appropriate frequency distribution is of utmost importance in flood frequency analysis. A particular distribution is judged on the basis of its fitting the observed data for a river basin. Plotting position of observed data series is ascertain with some empirical or semiempirical plotting position formula. Fitting of a particular data series to a distribution depends on the formula for plotting position being used.

Investigation has been done to find out the most suitable plotting position formula for Gumbel distribution. On the basis of some statistical criteria, if plotting position formulae were tested with annual flood series of 21 rivers of Brahmaputra basin having record length from 10 years to 37 years. Weibull plotting position formula is found to fit best in general for Gumbel distribution followed by Adamowski formula in the Brahmaputra basin.

2.2.8 Flood Frequency Analysis Using Annual and Partial Duration Series for the River Ranganadi and Comparison of the Statistical Methods

The problem investigated in this work is the flood frequency analysis of the river Ranganadi - one of the northern tributaries of the mighty river Brahmaputra. Attempt has been made to ascertain the best suited frequency analysis method for flood prediction in the river Ranganadi. For this, a detailed analysis based on probability and statistical methods has been carried out with the complete duration series of flow data locally available.

The yearly flood peak discharges for the river Ranganadi at 51 km from Ziro-Kimin road near Agri-farm at Yazali in Arunachal Pradesh, for a period of 27 years from the available records have been chosen for use in this analysis. For the analysis of data annual maximum series and the partial duration series have been

selected from the complete duration series. Point data analysis of both these series have been dealt with and the results obtained from each series are compared. For the flood frequency analysis with the annual maximum series data, four theoretical distribution functions, viz., Gumbel Extreme value, Log-Pearson Type-III, Log-normal and Log-Boughton distributions are considered and fitted to the observed distribution. An attempt has also been made to identify the best suitable plotting position formula from the four commonly and widely used plotting position formulae, viz., Weibull, Blom, Gringorten and Cunnane for the analysis. The D Index method is used as a measure of goodness of fit of each function to the observed sample distribution.

2.2.9 Regional Flood Frequency Analysis by Two Step Power Transformation

It is a common problem that flood frequency information is required at a site for which there are no records. Regional frequency analysis is an useful tool to estimate frequency information for an ungauged site or a site with inadequate discharge data. Experiences gained in point data analysis can be averaged to represent the frequency characteristics of the whole of the hydrometeorologically homogeneous region. Homogeneity test has been carried out to define the homogeneous region. Dimensionless regional frequency curve has been prepared giving the ratio of floods to mean annual flood against return periods. A correlation curve for mean annual flood and corresponding catchment area has been developed to obtain mean annual flood at the ungauged site.

Two step power transformation method of frequency analysis has been used to compute frequency characteristics, in which the observed data series is first transformed to satisfy the condition of skewness of a normal distribution and then, another transformation is performed along with the modification of the first transformation coefficient so that both the conditions of skewness and kurtosis of a normal distribution are satisfied for the TSPT series to the desired degree of accuracy.

Computer programs in FORTAN 77 have been developed to compute the transformation parameters itiratively and for the homogeneity test and regression analysis. Fifteen river basins of the Brahmaputra valley have been analysed and the mean flood is found to tally very closely to the 2 - year return period flood by TSPT method.

2.2.10 Comparison of Flood Frequency Analysis by Two Step Power Transformation Method And Log Boughton Methods For North East region of India

In hydrological frequency analysis the uncertainty concerning the choice of appropriate probability distribution is a problem yet to be solved. Hydrologists have done much work on it and are still in search for better frequency analysis technique. Recently, two step power transformation method and log Boughton methods have been pronounced as solutions to this problem, but which one is more suitable is yet a problem to be decided.

Attempt has been made to ascertain the best suited frequency analysis method for flood prediction in NE region of the country. A suitable computer application software has been developed for computation and to compare the fit of two step power transformation method and Log Boughton methods of flood

frequency analysis. It has been found that the two step power transformation method can transform a flood series of any degree of skewness and kurtosis to a truly normal distribution and fits the observed frequencies better than Log Boughton methods as per D-index suggested by Water Resources Council. The two step power transformation method is found to be a superior frequency analysis technique than Log Boughton methods for flood prediction especially for higher return periods.

2.2.11 Regional Flood Frequency Analysis for the Brahmaputra Basin

Attempt has been made to establish a relation between recurrence interval and discharge in ratio to mean annual flood and a correlation between mean annual flood and catchment area in the Brahmaputra Basin. It is assumed that the Gumbel extreme value distribution is fit well to those data series to establish preliminary frequency curve for individual stations. A computer program has been developed for computation by Gumbel extreme value distribution for finite data series, and for regression analysis too.

2.2.12 Computation of Unit Hydrograph of Hilly Catchment Area of Arunachal Pradesh

The aim of the study is to develop unit hydrograph of Tirap river in Arunachal Pradesh. It has been developed from rainfall discharge data available. Several unit hydrographs have been derived for future use in flood forecasting and prediction of Tirap river basin.

2.2.13 Patterns of Sediment Transport And Sedimentation in the River Burhidihing, Assam

In this study an attempt has been made to present a short analysis of the available data on hydrology and suspended sediment load of the river. Sediment load observation have been carried out on this river at Khowang gauge discharge site. The main purpose of this investigation is to study the suspended sediment transport data for last ten years obtained from Brahmaputra Board. A general review of the various problems relating to silt load for the rivers Brahmaputra and Burhidihing have been discussed. Problems of sedimentation associated with a river, such as the geometry of the cross-section of river, the pattern of flow and all other characteristics depend on the quantity and type of sediments it carries. The main problem associated with stability of a river channel, is that of the sediment transported along with the water which comprises of soil particles of various sizes ranging from very fine silt to coarse sand and gravel. Depending on its cross section, a river receives sediment load of varying quantities at different discharges.

2.2.14 Variation of Silt Characteristics in The Different Parts of a Selected Drain in Guwahati.

The drainage problem in Guwahati City is one of the burning problems at present. The topography of the city is such that the rainwater cannot drain out easily from the heart of the city. Therefore, proper planning and design is necessary for the solution of this vexed problem. but this problem is increasing day by day mainly because of improper planning of the city as well as improper design of the drainage

system. Therefore, a small part of the entire drainage system, which starts from the point "Zoo Road Tiniali" to the point "Where the Drain and The River Bharalu Meet" has been selected for study under this project work. Emphasis has been given on the problem of rapid siltation of the drain and some remedial measures have been suggested to overcome this problem of flash flood in the city.

2.2.15 Model Study for Mitigation of Disaster Due to Embankment Failure

The North Eastern part of India, being situated in the region of heavy rainfall, has been suffering from the flood disaster, even twice or thrice in a year. The construction of embankment is the common practice adopted for flood protection purpose in this region. But it has been experienced that frequent and sudden failure of embankment causes great damage to the nearby area. Therefore, it is felt that effort should be made to mitigate flood hazard through proper management rather than aiming at complete prevention of it. A prior knowledge of flood movement through model study can only lead to an efficient management of flood plain on the down stream of the embankment.

Therefore, a two dimensional mathematical model has been developed to simulate the flood wave propagation resulting from a lateral breach. The validity of the model has been checked with the help of experimental data generated in the laboratory model constructed for the purpose. Such model would also enable one to decide optimal cropping pattern by incorporating flood release from a predetermined suitable point.

2.2.16 A Study of Two-dimensional Flow Propagating From an Opening in the Rive Dike

Frequent occurrence of flood due to failure of river dike has long been a serious problem in NE region. However, it will be possible to mitigate the flood disaster if prior information regarding flood movement can be made available. This is possible through some model simulation. Therefore, a two-dimensional mathematical model for simulating flood propagation in the said situation has been developed in this study. Two-dimensional continuity and momentum equations of shallow water wave, in conservation form, have been used as the governing equations. Solution for these equations has been achieved by using two-step predictor-corrector explicit finite difference scheme. Though shock capturing scheme has been used, numerical computation has been started from an analytically computed initial profile as flow domain lies only on the downstream side of the separating barrier. For obtaining the initial flow surface, a new characteristic based analytical solution has been developed. This new analytical solution gives more realistic results in the concerned situation that other existing analytical solutions of classical dam break problem. A simple lumped model has been used for obtaining a logical breach width for river dike of Assam. This has been done on the basis of probability analysis carried out on 326 breach record, collected from various places of Brahmaputra and Barak valley.

As acquiring real data of flood propagation for this situation appears to be almost an impossible task, experimental data have been generated for verification of the proposed mathematical mode. A laboratory setup has therefore been developed for simulating flood movement on the downstream side of the river dike, due to its sudden failure. To investigate the effect of bed resistance on flood propagation, three different bed rougness have been used for the flood plain lying downstream of the

separating barrier, representing river dike. As the flood moves over the valley with a tremendous speed, recourse has been made to video-recording for obtaining data of flood movement.

Validity of the proposed model has been established on the basis of comparison of computed wave fronts and computed tip velocities with experimental results. As the flow depth in the laboratory model is very small, as compared to the real situation, calibrated value for resistance coefficient has been used in place of standard value. Both the comparisons have shown quite satisfactory agreement between experimental and computed results.

2.2.17 Prediction of Stage-discharge Relation for Alluvial Streams in North East India With Special Reference to the River Brahmaputra

Prediction of discharge for various rivers or channels is necessary for the construction of various hydraulic structures and for better utilization of water. For a mighty river like the Brahmaputra the behavior of hydraulic characteristics is too complex to be presented by simple analysis. Hydraulic resistance in alluvial channels is affected by changes in the bed configuration i.e. bed forms which occur when the discharge through the channel varies. Unfortunately, data for the bed forms for different discharges are not available. However, attempt have been made to formulate a resistance law covering a wide range of discharges. Predicted discharges based upon the methods proposed by Enstein - Barbarossa, Engelund, Alam-Kennedy, Garde-Ranga Raju, have been plotted against the observed data. Of these methods, the one proposed by Garde-Ranga Raju has been found to field closer results in lower stages while the result obtained by using Engelund's method has been found to give closer results in medium and high stages.

2.3 Studies carried out by NERC, National Institute of Hydrology

2.3.1 Application of HEC -2 Program for water surface profile determination of River Digaru at Sonapur, Assam CS(AR) –16, 1996-97.

The program HEC - 2 calculates water surface profile for gradually varied flow by standard step method. It computes the water surface elevations and related hydraulic parameters at all locations of interests for given flow values. The data needed to perform these computations include flow region, starting elevations, discharge, loss coefficients, cross section geometry, reach length etc. The effect of obstruction such as bridges, weirs and other structures in flood plan can be studied. In a single run, upto 14 profiles using the same cross section data can be computed. The program can take into account the reduction of the flow carrying capacity due to encroachments of flood plain. The computation of water surface profiles in the tributary system, if necessary, can be made after the computation in main stream.

In this report HEC-2 program has been implemented on river Digaru to compute water surface profile for several discharge condition. The reach between two bridge has been considered for study. The computed water surface elevations, critical water surface elevations, energy grade elevations and slope, velocity in the channel, flow area, top width and Froude Number in the reach have been mentioned in the report.

2.3.2 Infiltration studies: Dudhnai Sub-basin (Assam/Meghalaya) CS - 102,

1994-95.

In the requirement of long term representative studies taken up at Dudhnai sub-basin, field infiltration tests have been carried out in it with double ring cylinder infiltrometer at 23 locations under different soil and land use. Results are analysed and infiltration curves developed reflecting land use, soil type and to some extent water quality. The regression analysis has been performed for the field observations using Kostiakov (1932) type infiltration function (also compared with other available infiltration models) through multiple linear regression. The results shows large variation of infiltration rates depending upon various land uses and soil types in Dudhnai Sub-basin. While analysing the results, different models have been applied but Kostiakov's equation gives most satisfactory results with correlation coefficient of regression equation ranging from 0.87 to 0.99 in most cases confirming a good fit of the infiltration function.

2.3.3 Majuli River Island: Problems and Remedies, RN, 1996-97

Majuli, the largest river island in the world with an area of about 1245 Sq. km by old records (presently about 900 Sq. km) has been undergoing large scale erosion by the Brahmaputra floods since the great earth quake of 1950. The unabated erosion has thrown out of gear every protection measure, displaced 75,000 people, threatened existence of age old religious and socio-cultural epicenters (Satras) of 1.50 lakh odd mixed population of Assam and now challenges modern technology to understand it and suggest long lasting solution to the gigantic problem to save the great human heritage. Fury of the Brahmaputra flood is eroding Majuli in two ways; first engulfing large section of the land on the river banks along the direction of flow and the second is continuous collapse of the near vertical banks of the river. During monsoon a large part of the island is inundated by the spill waters of the Subansiri and the Brahmaputra river when they are in high spate. With Majuli reducing smaller and smaller after every flood there is growing concern amongst the technocrats, bureaucrats, public representatives and the large population for protection of the island.

This report throws light on the problems, reviews the activities to tackle it, examines various technical opinions, highlights certain recommendations to the multi-dimensional problem and suggests approach for long term solution.

2.3.4 Implementation of SCS Model in Dudhnai Sub-basin, CS-1998-99

In a predominantly agrarian country like India, water is the most vital but limited natural resource for the survival of mankind. Therefore, it has become necessary to estimate the amount of precipitation excess that flows over the surface of the earth as run-off. For estimation of runoff from a stream rainfall is an essential input. In many regions of the country rainfall record is available for fairly long period but runoff record is inadequate in most of the cases particularly on sub-watershed level. Therefore it is an urgent need to estimate the runoff with suitable model, which transform the available rainfall into runoff.

Run-off depends on a multitude of climatic and physical parameters prevailing in the watershed in which landuse, soil and moisture condition play an important role in converting rainfall into run-off. The model which incorporates these three important parameters is USDA (United States Department of Agriculture) Soil Conservation

Services (SCS) method. Land use/land cover are important required information for SCS model and this can be exactly delineated using remote sensing technology with the advent of its unique characteristics of synoptic view repetitive coverage and reliability. Hydrological Soil condition that represents the runoff potential of a particular soil, is derived from the soil resources information. Antecedent moisture condition alters the volume runoff is also taken into account in this method.

In this study, as a component part of representative basin studies at Dudhnai sub-basin SCS method has been applied to estimate basin run-off. Runoff volume has been estimated for all the nine sub-watersheds of the study area. Four sub-watersheds have been selected for water conservation measures.

2.3.5 Raingauge Network Design for Myntdu Basin, CS(AR) 1998-99.

A rain gauge network is intended to serve the general as well as specific purposes such as water supply, hydro power generation, flood forecasting, irrigation and flood control etc. In the present study, the network design for the Myntdu basin has been carried out. The basin lies in the zone of highest rainfall in the world (Cherapunjee is about 50 km from Myntdu) The rains are of long duration and occur mostly between March and October. During March and April the rainfall is sporadic, but it is steady and heavy or very heavy during May and October. Annual rainfall in the basin is over 10,000 mm. There is wide spatial variation in this small but almost all hilly catchment. Various methods have been tried which takes into account the location and type of basin and its climate, precipitation characteristics from the existing rainguage stations etc. Apart from IS-recommendations, C_v method, Key station method and spatial correlation method have been used. Based on the study certain conclusions have been made regarding the existing network accuracy, total number of additional stations to be installed in the catchment and their possible location.

2.3.6 Estimation of Design Discharge for Myntdu Leska Hydroelectric Project, 1999-2000.

The Myntdu (Leska) hydro electricity project is aimed at harnessing the water of river Myntdu and its tributaries, the Umshakiang and Lamu. This envisages construction of a dam across the river for power generation. The catchment area of the Myntdu river catchment up to the proposed dam site is 350 Sq.Km. The Meghalaya State Electricity Board desired that National Institute of Hydrology may compute the design flood for Myntdu-Leska dam. NIH proposed to compute the design flood by (i) using deterministic approach based on design storm, and (ii) probabilistic approach using flood frequency analysis.

A conceptual rainfall-runoff model, FLAPS has been used with daily isohyetal precipitation of the basin. The model was calibrated for the 1977-1992 period of observed runoff data and then it was validated for the period. The design flood peak obtained by rainfall runoff model is used with flood frequency method with the extended data.

Based on the design storm provided by IMD to the project authorities, the design flood has been estimated using the calibrated model. Also the flood frequency analysis were carried out using the peak flood series observed at Leska site. Clark's model is used with short-term data of Nukkum and Jowai. The parameter are estimated with optimization technique and the 1-Hr unit hydrograph

has been obtained. The design flood obtained for the project is as per the recent recommendations of CWC to use double bell hyetograph instead of single bell used earlier.

Design flood estimated from the distributed rainfall-runoff model is 8253 m^3/s whereas the 1000 year return flood varies from 8358 m^3/s(Ev1) to 15584 m^3/s (LN2) using flood frequency approach. In the absence of long term data log normal distribution has a tendency to be biased. If Gumbel distribution is considered 10000 year return period flood varies from 10,748 m^3 /s (extended series) to 11,644 m^3 /s (annual series). The design flood peak of 11,644 m^3 /s is suggested for adopting in the design of Myntdu (Leska) H.E project .

2.3.7 Daily rainfall runoff modeling in Myntdu Leska Basin. 1998-99

In this report, rainfall-runoff analysis has been carried out for Myntdu-Leska basin in Meghalaya using Flood Analysis And Protection System (FLAPS). The catchment area of the basin is about 350 Sq.Km and the whole basin lies in hilly parts of Jaintia. The study involves processing and analysis of rainfall and simulation of runoff. In the first part of the report the spatial and temporal pattern of rainfall experienced in the basin is analysed in detail. For this isohyetal maps prepared using monthly station rainfall are used to interpolate areal rainfall values. A total number of 252 isohyetal maps are prepared for the present project to cover the available rainfall series. In the analysis the daily mean values of rainfall were obtained using the daily isohyetal map and the results are compared with the corresponding values of mean rainfall derived following the above methodology. The comparison gave fairly good approximation between the two. Further the results of mean areal rainfall for the basin obtained using arithmetic mean, thiessen polygon method and the isohyetal method are checked for surface water balance. The later tend to give better results so the isohyetal mean is used as input in the rainfall-runoff simulation procedure. Since the rainfall record is too short, estimation of normal annual precipitation at any of the index stations was not possible. Under the circumstance, National Weather Service Method was found to be more suitable and used in this project instead of the Normal Ratio Method. Four of the major base stations viz., *Shamsam, Bataw, Jarain* and *Nukkum* in the neighborhood of the problem station was selected for this test. The data of the annual rainfall of each station and also the average rainfall of the group of base stations covering the 21 years period is used for the simulation process. The model is applied to the study area as a lumped system In the present case the model calculates the flow at the outlet of the basins for a given input, i.e. rainfall, PET. The normal PET values. The output runoff is used with the actual runoffs for calibrating model parameters. The calibrated model is then used for simulating runoff from actual rainfall values to fill up the missing series.

2.3.8 Rainfall Characteristics in Nort East India. TN - 132, 1991-92

Rainfall plays a vital role in hydrology, because all hydrological processes are directly related to rainfall. It is a unique phenomenon varying in space and time due to several factors like topography, nature of weather system, geography, aerosol content in the atmosphere and drop size distribution in cloud etc. The level of rainfall varies from place to place depending n local topography and is affected by wind

fluctuation, orientation of hill slope with respect to wind flow etc.

In this technical note characteristics of rainfall have been discussed in four meteorological sub-divisions which cover the regions of seven state of northeast India and the region of sub-Himalayan West-Bengal and Sikkim. Studies of characteristics of rainfall in Brahmaputra valley and Kulsi basin are also included. The rainfall data and other information have been collected from various Journals/reports.

2.3.9 Some Hydrological Aspects of Brahmaputra River. TR - 133, 1991-92

The Brahmaputra river in North East of India is characterized by high seasonal variability in flow, sediment transport and channel configuration. In the report some hydrological aspects of river like flood producing storms and rainfall, river stage, river discharge and sediment discharge have been reviewed with the analysed data obtained from various sources.

2.3.10 Loktak Lake Studies : Part – I, TN-108, 1993-94.

Loktak lake in Manipur plains which is of international importance where floating swamps of Keibul-Lanjao provides a last refuge for the Manipur brown antlered is causing problems of increased flooding and hinderance in the normal functions. Hydrology of the lake has not yet been studied. The study aims at describing different aspect of lake in general and the study area in particular. The different hydrological aspects of the lake have been discussed before describing the study area. The general aspects of a lake covers classification of lake, hydrology of lake, lake morphology, sedimentation, ecology of lakes etc. It has been recommended that water balance study of the lake should be undertakes to study fluctuation in water level/storage etc. A comparison of area elevation curve with the data supplied by Loktak Development Authority has been made and certain data error has been indicated. It has been proposed to study and provide proper measures on catchment treatment to effectively reduce the siltation of the lake in the second part of the study.

2.3.11 Network design of Raingauge stations for Nagaland CS(AR)-117, 1994-95

The main aim of hydrological network is to provide a distribution of stations for an area so as to measure adequately the required parameters. It is possible to determine the number of measuring stations required for certain using statistical techniques. The four different methods have been used in the study are ISI Code method, C_v method, spatial correction method and Dymond and Zawdzki Methods.

The existing raingauge stations are at Dimapur, Pfutsero, Medziphema, Heningkunglwa and Mokokchung, maintained by Nagaland State Department of Agriculture. The data used for these stations for the period 1980-1985. In the study it has been concluded that 63 no. of raingauge are required out of which 7 number are to be SSRG to represent whole region. The district wise distribution of raingauge stations has also been given.

2.4 Studies carried out by Water and Power Consultancy Services India Limited

2.4.1 Doyang Hydroelectric Project, Nagaland NEC, Shillong

(Identification report for catchment area treatment and siltation studies)

Doyang is the longest river in the Nagaland having length of 179 km with bed slope of 1:200. Catchment area is 2606 sq.km and altitude varies from 1000m to 2000m. The river originates at the height of 2700m. Chubi is its largest tributary with Dzulu nala, Phe Ru, Chiedudi Ru, Tsnyi Ru and Thagn Ru on lefy bank and Tsudze Ru, Khuono nala, and Tulo nala on right bank of the river.

Location:The catchment lies in district of Wokha, in the State of Nagaland and within the longitude 93°56′ and 94°31′ E and latitude 25°30′ and 26°26′N with 97 % of the area in Nagaland & 3 % in Manipur. Reservoir spread area is 26.06 sq.km.

Climate: Maximum and minimum annual runoff is 3095.2 M cum and 1265.3 M cum respectively. Full reservoir level is 330m with gross storage of 535 M cum while minimum draw down level is 306m with corresponding dead storage of 165 M cum. Design flood is 5977 cumecs. Dam is a rockfill type with impervious core. Elevation of the top of the dam is 338m, length is 462m. Height of the dam above deepest bed is 87.5m. Spillway is 71m long provided with 5 number of 11m long gates with crest elevation of 322m.

June to September is the summer month with temperature varies from 12°C mean minimum to 32°mean maximum. Sometimes heavy rainfall occurs in this month. Winter starts from October and continues upto February with temperature varying from minimum of 4° to Maximum of 24°C. There is no snowfall but frost is common during this period over large tracts. Heavy rainfall ocuurs in the months of May to August and varies from 2000mm to 2500mm. Thunderstorm and hailstorm are common during post and pre monsoon. November to April is generally dry period. Climate is highly depending upon the altitudinal variations.

1. Warm subtropical climate in low hills and valleys.
2. Sub mountain wet and subtropical climate in cool winter.
3. Temperate moist climate with severely cool winter in high altitudinal zone.

Land Use: Population estimated in 1994 as 66,424 in the catchment. 86% of the catchment area is under jhoom cultivation. Virgin and very thick forest is 1.61% and thick forest is 11.86%.

Data availability: Rainguage stations are at Kohima, Tsemnyu, Wokha and Mokochung. Temperature data is available for Tsemnyu for 1984 and 1985 and for kohima it is available for the year 1984 to 1988. Sedimentation studies has also been done, however, no silt data near or adjacent to dam site is available. Based on silt sample of Numaligarh (1957-62,1970 & 1973), it was esstmated a value of 1.25 hafeet/sq. mile/year.

Construction of 87.5m high rockfill dam across the Doyang river at a site 4 km upstream of Lotha bridge in district of Wokha, Nagaland. Catchment area is 2606 sq.km , effective storage is 370 M Cum with design head 67m and power capacity of 75 MW. The project was approved by planning commission in February 1983 with cost of 16922.70 lakhs and handed over to NEEPCO in March 1983 for execution. Administration approval by cabinet was given in March 1985.

2.5 Studies Carried out by Brahmaputra Board

2.5.1 Bairabi Dam Project, 1999

The project was proposed by National Hydroelectric Power Corporation, to be located at about 3.5 km upstream of foothill village of village of Bairabi in North Aizawl district of Mizoram. The project was conceived as hydroelectric project with incidental benefits of flood control navigation, pisciculture, tourism, soil conservation etc. The project envisaged on the river Dhaleswari, also known as Twalng is a tributary of Barak and has its catchment area between latitude 2250 to 2414 N and longitude 9227 to 9248 E. The river originates at a location in the southern part of Mizoram near the town of Lunglei. The catchment area of the river upto the proposed dam site is 2740 km^2. The river bed slope is comparatively mild being of the order of 1:270. The average rainfall in the catchment has been estimated to be about 3135 mm. On the basis of the available runoff data, average annual yield at the proposed dam site is 3146 MCM. The maximum observed discharge at the dam site is 1600 Cumecs.

Data Availability: Rainfall - There are nine rainguage stations in and around Dhaleswari catchment and are maintained by IMD upto 1960. These are Aizawl, Sairang, Sialsuk, Champhai, Lunglei, Sherkawn, Demagiri, Kolasib and Kawnpui. Brahmaputra Board has further collected rainfall data, however no data could be collected prior to 1986. The availability of data with Brahmaputra Board are as follows

	Station	Availability period	
		Monthly data	Daily data
1	Kolasib	1986-93	Jan 1994 - Oct 1998
2	Bairabi	1986-93	July 1997 - Oct 1998
3	Mammit	1986-93	July 1997 - Oct 1998
4	Hortoki	1986-93	July 1997 - Oct 1998
5	Phailang	1986-93	July 1997 - Oct 1998
6	Sairang	1986-93	July 1997 - Oct 1998
7	Aizawl	1986-93	1994-97
8	Serchip	1986-93	1994-97
9	Hnahthial	1986-93	1994-97
10	Siasluk	1986-93	1994-97
11	Lunglei	1986-93	1994-97

Studies:

1. Average rainfall
2. Rainguage network design

Evaporation - There is no evaporation existing at the site at present. Based on the studies conducted for Tipaimukh project and Kopilli hydroelctric project the

evaporation loss has been estimated.
Hydrological Observation:

1.	Bairabi village 3 km d/s of dam site	GD	June 1997 - Dec. 1998.
		S	since May 1998.
2.	Dam site	G	March 1997 - Dec. 1998
3.	Power House Site, 400 m d/s of dam site	G	March 1997 - Dec. 1998

Studies:

1. Development of stage - discharge curve at dam site.
2. Development of tail water rating curve at dam site.
3. Water resource assessment
4. Dependable yield estimate
5. Design flood studies
6. Sediment studies etc.

3.0 MASTER PLAN STUDIES

3.1 Studies carried out by Brahmaputra Board

3.1.1 Barak Sub Basin - Master Plan June 1995

Barak is the second largest river of North East lies between 22°32′ - 25°35′ N latitude and 92°15′ - 94°18′ E longitude. It is the part of Ganga-Brahmaputra-Meghana river system. The river originates in Nagaland, a short distance from Manipur Nagaland border. The catchment area upto Bhanga is 25,086 km^2, the two branches, the Surma and Kusiyara have an additional catchment of 1107 km^2 upto Indo-Bangladesh border. The catchment area lies in Burma -751 km and rest in India (Assam - 6562 km^2, Manipur - 9567 km^2, Mizoram - 8585 km^2 and Nagaland - 728 km^2). In addition, several tributaries drain area of Assam (662 km^2), Meghalaya (10,650 km^2), Mizoram (281 km^2) and Tripura (4688 km^2) and after flowing through areas of Bangladesh join the Barak river in Bangladesh.The catchment area upto Tipaimukh - 12,758 km^2, Bhubandhar - 13,339 km^2, Lakhipur - 14,450 km^2, Silchar (Annapurnaghat) - 18,721 km^2, Bandarpurghat - 25,070 km^2 and Bhanga - 25,086 km^2. Toatal number of tributaries are twenty, out of which eleven are wholly in India and nine flowing hrough India and Bangladesh. The river flowing wholly in India are Irang/Tuilarg(L), Makru(R) Tuivai(L), Jiri(R), Sonai(L), Chiri(R), Madhura(R), Jatinga(R), Ghagra(L), Dhaleswari or Katakhal(L), Singla(L), and tributaries flowing through India and Bangladesh are Longai(L), Juri(L), Manu & Dhalai(both L), Khowai(L), Bugi Dereng and Someswari(both R), Jadukata and UmNgi, Umiew, Umrew and UmNgot(all R), Myntdu(R), Lubha(R), and other small streams flowing in Bangladesh.

Data Availability

Rainfall: Cherapunji in Meghalaya once having the highest rainfall in the world is situated in this sub basin. Although break monsoon situation is predominant cause of rainfall and its pressure is more or less the uniform over the entire sub-basin, yet there is a variation in the amount of rainfall in different parts varied orographic conditions.

Studies:

1. Determination of annual average rainfall and its distribution in Barak basin. Maximum range varies from 2400 mm to 4000 mm.
2. Average annual rainfall with sub-catchment wise distribution
3. Seasonal distribution of rainfall and variability of seasonal and annual rainfall.
4. Frequency and pattern of rainfall
5. Rainguage network design as per WMO recommendations
6. Evaporation losses (based on data of the mesh covered evaporimeter at IMD station at Imphal and converted to open pan loss by multiplying 1.144. To obtain lake evaporation, multiplication factor is 0.82, 0.70 and 0.601 for monsoon annual and non monsoon period respectively.

Hydrological Data: on main Barak river

Station	Category	Period	Source
Tipaimukh	GD	July 1978 - Dec 1980	CWC
Bhubandhar	GD	Jan 1971 - Dec 1980	JRC
Lakhipur	GDS	Jan 1976 - Dec 1981 (GD) Jan 1956 - Dec 1962 (GDS) Jan 1975 - Jan 1977 (GDS)	FCD
PS Ghat (Sonaimukh)	GDS	Jan 1973 - Dec 1984 (GD) Jan 1981 - Dec 1984 (GDS)	FCD
Annapurnag hat	GDS	Jan 1976 - Dec 1984 (GD) Jan 1981 - Dec 1984 (GDS)	FCD
Badarpurgha t	GDS	Jan 1976 - Dec 1986 (GD) Jan 1981 - May 1984 (GDS	FCD JRC

Studies:

1. Maximum and minimum discharge of Barak river at different sites have been compiled
2. Flood frequency analysis (Gumbel distribution and Log Pearson type III distribution)
3. Silt load studies
4. Drainage problem of basin (under the headings of physiography of the area, drainage congested areas, cause of drainage problems, drainage improvement works carried out so far, performance of drainage improvement works and new proposals)
5. Flood studies in respect of physiographic aspects, modes of flood, problem areas, historic floods, high floods in recent past, extent of flooding, drainage congestion, extent of flood damage, flood moderation and flood protection, watershed management, reservoir, detention in sub-basin, improvements of river channels, cut-offs, embankments, raising of habitations above flood height, flood plain zoning, flood warning and forecasting etc have been done in details
6. Erosion problem studies.

3.1.2 Jiadhal - Master Plan, 1993

River originates from the hills of Arunachal Pradesh at an altitude of 1247 m. The basin is partly snowfed. Three small rivulets viz. Siri nadi, Sika nadi and Sido nadi join together and flows as Jiadhal. It joins the Subansiri river near Bardal Gaon. The catchment lies between 9415 - 9438 E longitude and 278 - 27 45 N latitude and is located in Assam and Dhemaji and West Siang district of Arunachal Pradesh. The total catchment area is 1346 km^2 out of which 1040 km^2 is in Assam and remaining 306 km^2 is in Arunachal Pradesh. Its main tributaries are Siri nadi, Sika nadi, Kumtia and Sido nadi.

Data Availability

Rainfall - There is only ane rainguage station in Dhemaji in and around the basin.
Studies:

1. Annual average rainfall in the basin is 3500 mm.
2. Rainguage network design as per WMO recommendations

Hydrological Data - There is no G or D observation in the basin.
Studies:

1. As there is no discharge data series is available in the basin, unit hydrograph method for ungauged catchment has been used for estimating the different magnitude of flood peak, i.e. 25 years, 50 years and 100 years. For analysing these events, a CWC report on flood estimation for north Brahmaputra basin has been referred.
2. Studies on development of irrigation and pisciculture
3. Erosion, flood and drainage congestion problem

3.1.3 Gabharu Basin - Master Plan, 1992

Gabharu river originates from Kalatngpa hills of Arunachal Pradesh.The basin is located in district Sonitpur of Assam and East kameng of Arunachal Pradesh. The geographical location is 92°25′ - 93°40′ E longitude and 26°55′ - 27°0′ N latitude. The catchment area is 295.607 km^2 out of which 238.24 km^2 is in Assam and rest 57.367 km^2 is in Arunachal Pradesh. Sonairupai river (length -11km, basin area - 24.17km^2) is the right bank tributary in the upper mountainous reaches. In lower flood plain reach Gelgeli (20km, 62.89km^2) is the right bank tributary and Mara Dipota (13.5km, 35.425km2) is the left bank tributary.

Data Availability:

Rainfall - There are two rainguage stations in the catchment, viz. Bengnajuli H/W (1978-90) and Gabharu E&D compound (1978-86)
Studies:

1. Average annual rainfall and its distribution over the basin (average annual and maximum rainfall in basin are 1581.94 mm and 2401.1 mm respectively.)
2. Annual average rainfall with sub catchment wise distribution
3. 1,2,3 days maximum rainfall
4. Seasonal distribution of rainfall
5. Raingauge network design as per WMO guidelines

Hydrological Data -

1. N T road crossing - GDS - 1987-90 (silt observation 1978-87)
2. Missamari railway bridge crossing - G
3. Nabil gauge site acroo Gabharu river - G

Studies:

1. Maximum and minimum highest flood level for three sites. The maximum and minimum observed discharge at NT road crossing are 484.372 cumecs and 0.09 cumecs respectively. The annual maximum and minimum mean discharge at NT road crossing are 50.689 cumecs and 9.069 cumecs

respectively.

2. Flood waves and their duration above danger level of Gabharu river data at NT road crossing from 1978-90
3. Flood hydrology and flood frequency studies
4. Silt studies (maximum and minimum values of silt load are 0.0165 ha-m/km^2 in 1985 and 0.0004 ha-m/km^2 in 1981)
5. Development of irrigation and pisciculture have been studied
6. Study of flood drainage congestion and erosion problems in the basin

3.1.4 Bhogdoi Basin -Master Plan, 1990

River originates from Naga hills in Nagaland and flows through Mokokchang district of Nagaland and Jorhat district of Assam. The catchment area is 920 km^2 out of which 286 km^2 in Assam and 534 km^2 in Nagaland. It joins Dhansiri near its confluence with Brahmaputra, flows through Gelabeel river which runs parallel to Brahmaputra. Geographical location of the basin is 26°20′ - 26°45′ N latitude and 94°0′ - 94°30 ′E longitude. The length of the river is 160 km of which 95 km is in hills and 65 km in plain.

Data Availability:

Rainfall - There are 12 rainguage stations in the catchment but data could be collected for 10 only for the period 1971- 1988. These stations are Negheriting (1975-88), Tocklai (1970-88), Kathanibari Tea Estate (1985-88), Hunual TE (1974-88), Kamarbandha TE (1971-88), Lahpohia TE (1971-88), Sycotta TE (1971-88), Hilica TE (1973-88), Khumtai TE (1971-88) and Titabor TE (1983-88)

Studies:

1. Average annual rainfall (a a r - 2035 mm, maximum rainfall - 2734 mm), sub catchment wise distribution of average annual rainfall, seasonal distribution of rainfall etc.
2. Network design as per WMO guidelines
3. Temperature and RH observations (maximum and minimum temperature are 33.8 °C and 8.5 °C respectively, maximum RH - 97%, minimum RH - 60% and average Rh - 95%)

Hydrological Data –

Data available at AT road NH bridge crossing at Jorhat are GDS - guage data during 1976-88, discharge data during 1956-59 and 1967 onwards, and silt data during 1957-58 and 1972-84.

Studies:

1. Monthly mean, annual mean and maximum and minimum discharge and quarterly and annual yield has been computed. (average annual yield - 0.0681 Mha-m, Maximum and minimum annual yield are 0.2091 Mha-m and 0.0293 Mha-m respectively and maximum and minimum discharge at GD site are 594.30 cumecs and 0.12 cumecs respectively.), high and low water level

study, flood wave and its duration above danger level etc. have been studied.
2. Flood hydrology and flood frequency study, Flood of various return period,
3. Sediment study
4. Development of irrigation and pisciculture
5. Flood, drainage congestion and erosion problems in the basin have been studied.

3.1.5 Dudhnoi - Krishnai Basin - Master Plan, 1992

Both Krishnai and Dudhnoi rivers originate from the Garo hill range of Meghalaya, join together near a place called Domani before outfalling into Brahmaputra near Moranoi. Geographical location of the basin is 25°34′ - 26°6′ N latitude and 90°21′ - 90°53′ E longitude. The basin is located in Goalpara district of Assam and East Garo hills district of Meghalaya. The catchment area of Dudhnoi is 420 km^2 and that of Krishanai is 1195 km^2 (1294 km^2 in hills and 321km^2 in plains). Rongre (basin area - 251km^2) and chidrang (140km^2) are the right bank tributary of Krishnai and Rongma (95km^2) and Chil (66km^2) are the right bank tributary of Dudhnoi.

Data Availability:

Rainfall - There are three stations in the basin as follows:

1. Kherang head work site at Damra - Aug 1977 to Feb 1991
2. Dudhnoi - Aug 1977 to Jun 1987 and Dec 1989 to Feb 1991
3. Bumani - Jan 1974 to dec 1981

Studies:

1. Annual average rainfall with sub basin wise distribution (maximum rainfall - 2881 mm and average rainfall - 1817 mm)
2. Seasonal distribution of rainfall
3. Rainguage network design as per WMO guidelines

Hydrological Data - for Krishnai at NH bridge crossing (catchment area upto site is 986 km^2) - G & D data from 1972 to 1990 and Silt data from 1963 to 1990 is available. For Dudhnoi, at NH bridge crossing, G & D data from 1955 to 1990 and silt data from 1963 to 1990 is available.

Studies:

1. High flood levels and low water levels for Dudhnoi and Krishnai
2. Maximum, minimum and annual average discharge
3. Annual and monsoon yield of the rivers
4. Flood frequency analysis
5. Silt studies (annual silt load of Dudhnoi and Krishnai are 6.2×10^{-3} Mha-m/km^2 and 8.9×10^{-3} Mha-m/km^2 respectively)
6. Evaporation studies (based on data available at Borjhar airport, Guwahati)
7. Development of irrigation, agriculture and pisciculture etc.
8. Flood, drainage congestion and erosion problems in the basin have been

studied.

3.1.6 Jinjiram basin - Master Plan, 1993

Jinjiram river originates from Utpad hill of Goalpara and falls into Brahmaputra in Bangladesh. The basin is located in the Goalpara and Dhubri district of Assam and Garo hill district of Meghalaya. Catchment area is 3467 km^2 (975 km^2 in Assam and rest in Meghalaya). Geographical location is between 25°15′ - 26°10′ N latitude and 89°48′ - 90°35′ E longitude. It has four tributaries all on south bank viz. Ajagaur-Ghagowa (length-17km, basin area-626km^2), Rongai (25km, 430km^2), Kolo(32km, 487km^2) and Daru (14km, 102km^2). There is no north bank tributaries as Brahmaputra is in close vicinity (2 to 30 km away only).

Data availability:

Rainfall - There are seven rainguage stations, namely; Balbala, Lakhipur, Phulbari, Tikrikilla, Tura, Mankachar and Goalpara.

Studies:

1. Annual average rainfall with sub basin wise distribution
2. Seasonal distribution of the rainfall
3 Rainguage network design as per WMO guidelines

Hydrological Data - At Rongsai

3.1.7 Master Plan of rivers of Tripura (Hoara, Burima, Khowai and Dhalai), March 1991.

River system of Tripura - Almost all rivers are part of Meghana basin and have been classified in three categories:

1. North flowing rivers - Khowai, Dhalai, Manu and Juri
2. West flowing rivers - Gumti, Haora and Burigang
3. South flowing rivers - Muhari

Khowai River - River originates in Lang tharai hill ranges and formed by two hill streams known as Narichera and Romachera coming down west and south west direction from altitude of 305 and 213.4 m above mean sea level respectively. The catchment area is 1328 km^2 and length 166 km within the state of Tripura. Besides this area about 124 km^2 is also drained by tributaries which join the Khowai main stream after it enters Bangladesh. The main tributaries of Khowai river are Baluchhera, Jeelchhera, Chamalchhera, Ahiadiacherra, Bhaskarchhera, Maharanichhera, Trirupachhera, Samruchhera and Lalchhera on its right bank and Gulichhera, Nunachhera, Kukrachhera, Brahmachhera, Sarduchhera, Batekachhera, Gangraichhera and Sonaichhera on its left bank.

Dhalai River - It originates from Langtharai hill range. The river after traversing length of 66 km in India enters into Bangladesh near Kamalpur plain area. It then join river Manu in Bangladesh. Catchment area is 630 km^2 and its length is 117 km. Its tributaries are Bahurichhera, Chandraichhera, Balaramchhera, Sofemachhera, Jamthungchhera, and Surmachhera on its right bank and Kulaichhera, Daluchhera,

Nalichhera, Maharanichhera, and Kataluthmachhera on its left bank.
Manu River - River originates from Kasalang reserved forest in between Sardeng range and Jampai range at an altitude of 387 m above msl. It enters Bangladesh after traversing a length of 167 km in India at Kailashsahar and meets Kasuriya, a branch of Barak. Its catchment area is 2278 km^2.
Juri - River originates from Jampui hill range. Catchment area is 256 km^2 upto Dharamnagar near Indo-Bangladesh border. It finally meets Kasuriya river in Bangladesh. It is about 79n km long and has a total catchment area of 482 km^2. Its main tributaries are Deochhera, kAkricheera, Lalchhera, Balichhera, Pratyckraychhera, Ichailalcheera and Wakainadi.
Gumti - It is the largest basin in the state. Length of the river is 133 km and catchment area is 2492 km^2. Its main tributaries are Levachhera, Dalakchhera, Sarbhangchhera, Sangang, Pitrachhera on its right bank and on its left bank are Rambhadrachhera, Ekchhera, Chelegang, Kurmachhera, Maharanichhera etc.
Hoara - River originates from Baramura hill range and after traversing a distance of 53 km within the state it enters Bangladesh near Agartala and finally falls in river Tilash near Akhaura in Bangladesh. It has catchment area of 488 km^2. Its main tributaries are Donaigang, Ghoramaora and Debtagang on right bank and Champanadi, Dabatilachhera, Chhichumachhera and Bangeswarang on the left bank.
Burima (Burigang) - It originates from Buramura hill range. After traversing a length of 54 km, it enters Bangladesh near Durganagar. Its catchment area is 414 km^2. Its main tributary is Rangpanichhera.
Muhuri - It originates from Debotamura hill range and falls in Fenny river in Bangladesh. It is about 64 km long has catchment area of 1014 km^2. Its main tributaries are Charakbaichhera, Baikerachhera, Laugang, Pillakchhera, Abhangachhera, Tuigamarichhera, Sonaichhera etc.

Data Availability:

Rainfall - There are 11 rainguage stations in the area at Agartala, Kailashsahar, Sonamura, Belonia, Khowai, Dharamnagar, Udaipur, Sabroom, Amarpur, Kamalpur, Gunamani and Sardarpara.

Studies:

1. Determination of average annual rainfall, Maximum annual rainfall at Dharamnagar is 2594.95 mm. The maximum range of rainfall 2480 mm also occurs at Khowai and Belonia.
2. Average annual rainfall with sub-catchment wise distribution.
3. Seasonal distribution of rainfall (Mar-May 26.83%, Jun-Sept 63.12%, Oct-Nov 7.95%, Dec-Feb 2.1%)
4. Network design as per the WMO recommendation.
5. Potential evapotranspiration, Actual transpiration and water surplus calculation.

Hydrological Data - Guage and discharge site on different streams are as follows:
Juri - Radhapur (GD), Radha Hotel (GD)
Manu - Nalkata(GD), Heanchura (GD), Kailashsahar (GDS), Kumarghat (GD),Manu Bazar (G)

Deo - Kumarghat (GD), K/ghat Bridgepur (G)
Dhalai - Jirania (G), Kamalpur (GD), Ambassa (GD)
Khowai - Khowai town (GD), Teliamura (GD), Kalyanpur (GD)
Hoara (Howrah) - Town Bordwali (GD), Jirania (GD)
Burima - Bishalgarh (GD)
Gumti - Rkpur (GD), Maharani (GD), Sonamula (GD)
Muhuri - Belonia (GD), Kalashi (GD), Kakulia (G)

Studies:

1. Maximum and minimum discharge of all the rivers.
2. Quarterly annual yield of the rivers
3. Monsoon yield of rivers
4. High and low water level
5. Silt studies of river Manu at Kailashsahar
6. Flood waves and their duration over danger level for different years
7. Average annual, monsoon and lean period discharge of Gumti river
8. Ground Water Potential of West Tripura District (by CGWB)
9. Flood drainage congestion and anti-erosion studies.

3.1.8 Dikirong Sub Basin - Master Plan, 1996

The Dikirong river originates at an elevation of 2579 m near the border of Lower Subansiri district and East Kameng district of Arunachal Pradesh. The basin lies between 26°55′-27°20′ N latitude and 93°15′-94°0′ E longitude. The catchment area is 1528 km^2 (252 km^2 in Assam and 1276 km^2 in lower Subansiri of Arunachal Pradesh). Total length of the river is 145 km out of which 113 km in hills of Arunachal Pradesh and 32 km in plains of Assam. In the upper reaches of Arunachal Pradesh the river is known as Par nadi and subsequently as Dikirong. Bed slope of the river is very steep upto Harmoti (1:46) and afterwards upto outfall in river Brahmaputra it is 1:864. Its main tributaries in the hilly area are keyate nadi (length 10 km and catchment area 31km^2), Pang nadi (15km, 73 km^2), Shu pabung (23 km, 74 km^2) and Peti Nala (12 km and 29 km^2) on its left bank and Ranchi Pabung (20 km, 66 km^2) and Pachin Nadi (59 km, 295 km^2) on its right bank. Beguli Nadi (23 km, 74 km^2) is its left bank tributary and Kachilata Nadi (24 km, 46 km^2) is its right bank tibutary in the plain area.

Date Availability

Rainfall - There are four raingauge stations in the basin, Sisapathar, Harmoti Tea Eastate, Dizoo Tea Eastate and Silikhaguri.

Studies:

1 Determination of average annual rainfall (over entire basin it is 2833.8 mm while Dizoo station receives annual average maximum rainfall of 3390.2 mm and minimum at Silikhaguri is 2176.5 mm),
2 Storm analysis - due to mearge hourly rainfall data available in the sub-basin, detailed storm analysis specific to the basin could not possible. However, some studies have been done in reference to the study carried out for the NE region by

CWC in their report (no.-1/73, revised) to determine the overall precipitation pattern over the basin.

3 1,2,3 day maximum rainfall in different years.
4 Seasonal distribution of rainfall (Mar-May 22.98%, Jun-Sept 67.37%, Oct-Nov 5.84%, Dec-Feb 3.81%)
5 Rainguage network design as per the WMO recommendation.

Hydrological Data - Guage and discharge sites are as follows:

Harmoti - G - 1973 to 1987
Paadalghat - G - 1978 to 1985 (site abolished on 1.6.86)
Sisapathar - GDS - 1973 to 1994, (originally at old NT road crossing and shifted to New NT road crossing RCC bridge on 24. 6.73, silt observation started since 1976)

Studies:

1 Maximum and minimum water level at discharge sites
2 Maximum and minimum discharge at Sisapathar RCC bridge site
3 Monthly mean, annual mean, and average annual mean discharge calculation
4 Rating curve at Sisapathar site
5 Dependable yield (average annual yield - 2538.25MCM, monsoon yield - 1909.62MCM and non-monsoon yield - 628.63MCM)
6 Flood hydrology and frequency analysis
7 Annual Sediment load calculation
8 Water Balance studies
9 Developments of Irrigation, pisciculture and hydropower potential have also been studied.
10 Flood, drainage congestion and erosion problems discussed in details. Flood protection, drainage improvement and anti-erosion measures taken up so far have been assessed. Measures have also been suggested to tackle balance problems of flood and erosion.

3.1.9 Champamati Sub Basin - Master Plan, 1998

River originates on southern slopes of remote Danda ranges of Bhutan hills at an altitude of 2022 m above msl. After traversing through Bhutan territory where it is known as Bhur, it enters Kokrajhar district of Assam. Length of the river is 99.5 km and its catchment area is 1142 km^2. Its tributaries are Dhalpani (27.75km, 122.08 km^2 upto juncture with Laopani), Laopani (31km, 94.22 km^2) and Bhandarani (18.75 km, 37.19 km^2) on its right bank and Mora Bhur (21.5 km, 61.67 km^2), Sukti (14 km, 23.96 km^2), Duramari (28.75 km, 29.17 km^2), Bakra (67.25 km, 130.25 km^2), Kujia (31.5km, 83.96 km^2), Ghoga (29.5km, 64.38km^2) and Tunia (30.25 km, 73.74 km^2) on its left bank.

Data Availability:

Rainfall - There are 8 rainguage stations in the basin, namely Chapar (1982-94), Basugaon (1982-93), Bongaigaon (1983-94), Bbengtol (1982-94), Choibaro Tea Eastate (1982-93), Boitamari (1983-93), Hatisor (1983-95) and deosiri (1983-95)

Studies:

1 Average annual rainfall (3727.3 mm, anuual precipitation observed maximum 7652.8 mm at Deosiri as and minimum 2325.9 mm at Bengtol)
2 Calculation of dependable rainfall (50% dependable- 3539.5 mm 75% dependable - 3162.8 mm, and 90% dependable - 3117.3 mm)
3 Storm analysis - due to mearge hourly rainfall data available in the sub-basin, detailed storm analysis specific to the basin could not possible. However, some studies have been done in reference to the study carried out for the NE region by CWC in their report (no.-1/73, revised) to determine the overall precipitation pattern over the basin.
4 Seasonal distribution of rainfall (Mar-May 19.7%, Jun-Sept 73.3%, Oct-Nov 5.1%, Dec-Feb 1.9%)
5 1,2,3 day maximum rainfall in different years.
6 Rainguage network design as per WMO recommendations.
7 Temperature study based on data observed at 21 numbers of meteorological stations in NE region at different altitude.
8 RH study based on data collected at Guwahati airport (Annual average RH - 80.46%, max. 86.32% and min. 67.07%)

Hydrological Data:

Karigaon - GD - since 1978
Basugaon - GD - 1972-93 (discharge data 1972-77)
Bahalpur - GDS - since 1971 (discharge data 1971-93)

Studies:

1 Guage hydrograph for three guage sites.
2 Dependable yield calculation (at Karigaon site 50%, 75%, 90% and 94% dependable yield is 2248.23 MCM, 1963.59 MCM, 1711.1 MCM and 1600.2 MCM respectively and at Bahalpur site it is 3607.2 MCM, 2978.74MCM, 2465.75MCM,and 1945.91 MCM respectively)
3 Flood hydrology and flood frequency

At Bahalpur GDS site

· Maximum recorded level and discharge - cumec	38.61m	and	1503.94
· 100 year return period level and discharge cumec	39.03m	and	1867.34
· 50 year return period level and discharge cumec	38.77m	and	1676.59
· 25 year return period level and discharge cumec	38.52m	and	1484.43

At Karigaon GD site

· Maximum recorded level and discharge - cumec	66.66m	and	1224.65
· 100 year return period level and discharge cumec	69.04m	and	1316.65
· 50 year return period level and discharge	68.12m	and	1179.95

cumec
25 year return period level and discharge 67.13m and 1042.24 cumec

4 GD curves for karigaon, Basugaon and Bahalpur have been prepared.
5 Calculation of sediment load (0.034 ha-m/km^2/year based on data at Bahalpur site from 1981-91)
6 Developments of Irrigation and pisciculture have also been studied. Irrigation schemes have been suggested to irrigate 29994 ha area annually.
7 Flood, drainage congestion and erosion problems discussed in details. Flood protection, drainage improvement and anti-erosion measures taken up so far have been assessed. Measures have also been suggested to tackle balance problems of flood and erosion.

3.1.10 Jia Bharali Sub Basin - Master Plan

Jia Bharali is one of the major north bank tributary of Brahmaputra river. Out of total 229 km of its length, 166 km flows in hilly terrain of Arunachal Pradesh and remaining 63 km in plains of Assam. The catchment area of the basin is 10289 km^2. In the upper reach of Arunachal Pradesh, the river is known as Kameng river and in lower reaches of Assam, it is known as Bharali. The river follows a braided pattern in the plains of Assam. From the study of satellite data of 1973 and 1983, it has been observed that river bank line has undrgone changes near 26°46¢ N and 92°55¢ E. The left bank has shifted eastwards and the river took a convex bend. Also the river course changes from braided plan form to single channel near 26°47¢ N and 92°53¢ E. Its major tributaries on left bank in hilly region are Para river,(29km, 212 km^2), Pachi river (31km, 400km^2), Pacha river (37km, 375km^2) and Papu river (56km, 583km^2) and on right bank are Pachuk river (47km, 785km^2) and Bichom river (103km, 2240km^2). In the plain region tributaries are only on left banks and are Namiri river (24km, 203km^2), Upper Dikarai (15km, 91km^2), Khari Dikarai (20km, 105km^2) and Bor Dikarai (39km, 711km^2).

Data Availability

Rainfall - There are 9 raingauge stations in the basin namely; Balipara Tea Eastate (1978-90), Naharani TE (1978-93), Phulbari TE (1978-93), Tezpur E & D coloney (1978-93), Bomdila (1990-94), Kalaktong (1990-94), Sesuja (1990-94), Towang (1990-94) and Tippi (1985-94)

Studies:

1 Average annual rainfall (1620.4 mm in the basin, maximum precipitation observed in a day near Tezpur is 275 mm, maximum average rainfall is 2533.7 mm at Towang and minimum is 998.4 mm at Kalaktong)
2 Storm analysis - due to mearge hourly rainfall data available in the sub-basin, detailed storm analysis specific to the basin could not possible. However, some studies have been done in reference to the study carried out for the NE region by CWC in their report (no.-1/73, revised) to determine the overall precipitation pattern over the basin.
3 1,2,3 days maximum rainfall in different year
4 Seasonal distribution of rainfall (Mar-May 21.77%, Jun-Sept 64.96%, Oct-Nov

7.93%, Dec-Feb 5.34%)
5 Rainguage network design as per WMO recommendations.

Hydrologic Data:

NT road crossing - GDS - 1969 to 1993 (silt data since 1978)
Bhalukpong - G - 1978 to 1994
Silonipam - G- 1982 to 1993
Sirowani - G - 1955 to 1993

Studies:

1 Calculation of dependable yield (Maximum recorded discharge in the flood plain is 6004.87 cumecs at NT road crossing site, 50%, 75% and 90% dependable yield are 27493 MCM 23644 MCM and 22136 MCM respectively)
2 Flood hydrology and flood frequency analysis
3 G & D curve at NT road crossing site
4 Sediment study (silt load maximum annual - 2338.37 ha-m, minimum annual - 33.96 ha-m and average annual - 1782.44 ha-m)
5 Water Balance study
6 Developments of Irrigation pisciculture and hydel power have also been studied. Total of 34 numbers of hydel shemes have been identified out of which 7 are storage schemes.
7 Flood, drainage congestion and erosion problems discussed in details. Flood protection, drainage improvement and anti-erosion measures taken up so far have been assessed. Measures have also been suggested to tackle balance problems of flood and erosion.

3.1.11 Juri Sub Basin - Master Plan, 1992

Juri river originates from Jampai Tlang hill range situated between Tripura and Mizoram border. Basin is located in North Tripura district of Tripura and lies between 24°15¢-24°32¢ N latitude and 92°12¢-92°21¢ E longitude. Catchment area is 482 km^2 (110 km^2 in plain and 372 km^2 in hill) and stream length is 79 km. Catchment area upto Dharamnagar, a important town in Tripura is 256 km^2. River after traversing in Tripura enters Bangladesh and falls in Barak (Kushiara) river. Two hydroelectric projects Jalbasa Project (1.2MW) and Juri dam project at Kunjanagar (1.2MW) have been proposed by CWC.

Data Availability

Rainfall - Only one rainguage station at Dharamnagar

Studies:

1 Average annual rainfall (2595 mm in the basin)
2 Seasonal distribution of rainfall
3 Rainguage network design based on WMO recommendations
4 Calculation of Evapotranspiration and moisture surplus making use of long term average monthly minimum and maximum temperature and normal rainfall

observed at Agartala, monthly mean, seasonal and annual potential evapotranspiration by empirical formula have been calculated.

Hydrological Data:

Radhapur - GD - since 1978 (some data are not available)

Studies:

1 Average annual yield (154.45 MCM) and monsoon yield
2 85% of the recoverable resource at Dharamnagar has been worked out to be 84.15 MCM.
3 Flood Hydrology (maximum and minimum observed discharge at Radhapur is 147.45 cumec and 0.20 cumec respectively)
4 Developments of Irrigation and pisciculture have also been studied.
5 Flood, drainage congestion and erosion problems discussed in details. Flood protection, drainage improvement and anti-erosion measures taken up so far have been assessed. Measures have also been suggested to tackle balance problems of flood and erosion.

3.1.12 Kulsi Deosila Basin - Master Plan, 1991

Kulsi river originates from West Khasi hill range in Meghalaya at an elevation of about 1800-1900 m above msl. On reaching the plain, it branches into three rivers and joins again and thereafter the river is called Jaljali which meets Brahmaputra river near Mornoi. The basin is located in Kamrup and Goalpara districts of Assam and West Khasi hill and East Garo hill districts of Meghalaya.. Its geographical location is 25°32¢ - 26°7¢ N latitude and 91° - 91°45¢ E longitude. The catchment area is 3770 km^2 out of which 1595 km^2 in Assam and remaining 2175 km^2 in Meghalaya. Catchment of Kulsi is 3132 km^2 and that of Deosila is 532 km^2. Krishniya and Umsiri are the left bank tributaries of Kulsi river in the upper reaches and Batha is in middle reaches. In the lower reach Boko and Singra join the river on left bank. Marki and Singua are the tributaries of Deosila river.

Data Availability:

Rainfall - There are 5 raingauge stations in the basin, namely; Guwahati airport (1977-88), Mirza (1977-88), Chamaria (1977-88), Boko Police station (1977-88) and Ukium (1977-88).

Studies:

1 Annual average rainfall in basin (aar is 1789.84 mm, monsoon rainfall is 1149.52 mm)
2 Average annual rainfall with sub basin wise distribution
3 Seasonal distribution of rainfall
4 Maximum 1, 2, 3 day rainfall
5 Rainguage network design as per WMO guidelines
6 Evaporation losses based on data collected at Guwahati airport

Hydrological Data:

On kulsi river

Ukium site - GD - Guage data since 1956 and discharge 1964-88
Kukurmara NH crossing - GDS - from 1971-88
Kharkhari - GD - from 1975-88
Chaygaon - GD - 1973-88
Boko discharge site (tributary of Kulsi) - GD - 1976-88
On river Deosila
NH crossing site - GD - 1955-88

Studies:

1 Flood hydrology and flood frequency
2 Highest and lowest water level
3 Maximum annnual discharge, monthly and annual mean discharge (maximum observed discharge at Ukium is 18077 cumecs and minimum annual mean discharge is 44.55 cumecs, Maximum discharge observed at Kukurrmara site is 338.36 cumecs)
4 Annual yield, monsoon yield and quarterly yield (combined annual yield of three branches of Kulsi river is 2131.02 MCM, Average annual yield is 2318 MCM)
5 Development of pisciculture, hydroelectric power, irrigation and agriculture (There is a provision for hydroelectric power generation through the multipurpose project downstream of Ukium village with gross storage of 79500ha-m water. It will irrigate 18200 ha of gross command area in Kulsi - Deosila basin).
6 Flood, drainage congestion and erosion problem studies

3.1.13 Jinari Basin - Master Plan, 1992

River originates from the Selselgiri hills of East Garo hills of Meghalaya and falls in Brahmaputra near Dubapara 6 km upstream of Goalpara.. The basin is located in Goalpara district of Assam and East Garo hills of Meghalaya. Its geographical location is 25°42′ - 26° 8′ N latitude and 90°21′ - 90°42′ E longitude. Catchment area is 594 km^2 out of which 183 km^2 is in Assam and 411 km^2 is in Meghalaya. Rongkhati (length 20km and basin area 54km^2) is its left bank tributary and Nabang (11km, 38 km^2) is its right bank tributary.

Data Availability:

Rainfall - Three rainguage stations are at Goalpara, Balbala and Bajengdoba

Studies:

1. Annual average rainfall (aar - 3946.53 mm and maximum rainfall in basin - 5291.8 mm)
2. Seasonal distribution of rainfall
3. Rainguage network design as per WMO guidelines
4. Evaporation loss studies based on data available at Guwahati airport

Hydrological Data - The only observation site (GDS) is at Balbala NH crossing site,

G & D data used in the study are from 1976 to 1988 and silt data are from 1977 to 1988.

Studies:

1. Maximum and minimum discharge (annual maximum mean discharge - 38.41 cumecs, annual minimum mean discharge-11.248 cumecs, maximum and minimum observed discharge at Balbala are 132.344 cumecs and 0.41 cumecs respectively)
2. High and low water level
3. Annual, monsoon and quarterly yield (average annual yield- 617.37 MCM, monsoon yield-428.23 MCM)
4. Silt studies (average annual silt load - 0.00727 ha-m/km^2)
5. Flood frequency and flood hydrology
6. There is no provision of hydropower generation and no storage proposals.

3.1.14 Moridhal Basin - Master Plan, 1993

Moridhal river originates from lesser Himalayan range in Arunachal Pradesh at an altitude of about 1480 m above msl. It is located in Dhemaji district of Assam and West Siang district of Arunachal Pradesh. Catchment area is 929 km^2 (801km^2 is in Assam and 128 km^2 is in Arunachal Pradesh). Its geographical boundary is 27°15′ - 27°46′ N latitude and 94°17′ - 94°44′ E longitude. It traverse a distance of about 123 km through plains of Dhemaji subdivision and finally outfalls into Brahmaputra near Bali Deurigaon. Upstream of town Dhemaji, the river passes through a swampy area. It is a shallow river and has a steep gradient. The river meets with Gainadi at about 14 km upstream of NH-52 crossing. During high flood when the river Brahmaputra is in spate, the water from Gainadi enters back to Moridhal river and the flood water enters through the breach point of right bank embankment of Moridhal river. Its tributaries are Lalpulia Nadi (12km), Kanibil Nadi (14km), Sisi river (31km) and Sisi Nadi (16km).

Data Availability:

Rainfall - There is only one rainguage station at Dhemaji

Studies:

1. Annual average rainfall (3750 mm)
2. 1,2,3 days maximum rainfall
3. Rainguage network design as per WMO guidelines

Hydrological Data: There is no GD site in the basin

Studies:

1. Based on unit hydrograph principle for ungauged catchment for estimating different magnitude of flood peak; i.e. 25 years, 50 years and 100 years flood (flood estimation report for north Brahmaputra basin, sub zone 2(a) prepared by CWC has been referred).

2. Other studies like development of irrigation and pisciculture has also been delt. However, there is no provision of hydropower generation.
3. Flood, erosion and drainage congestion problems have been studied in details

3.1.15 Tongani Basin - Master plan, 1993

River originates from foot hills of Bhutan hill ranges. Two small branches namely Khaurang nadi and Angara nadi meet and known as Golanadi and aterwards Tongani. The basin is located in Darang district of Assam and Samdrupjongkher in Bhutan. Its catchment area is 237 km^2 out of which 191 km^2 in Assam and 46 km^2 is in Bhutan. The catchment area in hills is 57 km^2 and that of in plain is 180 km^2. The basin lies between 90°0′ - 92°9′ E longitude and 26°29 '- 26°55′ N latitude. Tributaries are Khaurang nadi and Angara nadi.

Data Availability

Rainfall - There is no rainguage station inside the basin. However, 5 stations for which rainfall data between 1970 to 1990 have been used in the analysis are Majuli Tea Estate, Kherkheria TE, Hatigarh TE, Chukanmati and Kowpati

Studies:

1. Annual average rainfall (2336 mm)
2. 1,2,3 days maximum rainfall
3. Rainguage network design as per WMO guidelines
4. Evaporation loss

Hydrological data - There is no GD site in the basin.

Studies:

1. Based on unit hydrograph principle for ungauged catchment for estimating different magnitude of flood peak; i.e. 25 years, 50 years and 100 years flood (flood estimation report for north Brahmaputra basin, sub zone 2(a) prepared by CWC has been referred).
2. Average annual yield has been calculated by proportional catchment method based on adjacent Noa nadi data (annual yield - 227.74 MCM).
3. Other studies like development of irrigation and pisciculture has also been delt. However, there is no provision of hydropower generation and storage potential development.
4. Flood, erosion and drainage congestion problems have been studied in details

3.1.16 Belsiri Basin - Master Plan, 1993

Belsiri originates from Kalaktangpa hill in Arunachal Pradesh. The basin is located in Sonitpur district of Assam and West Kameng district of Arunachal Pradesh. The geographical location is 92°18′ - 92°36′ E longitude 26°36′ - 27°8′ N latitude. The catchment area is 751.4 km^2 out of which 581.3 km^2 is in Assam and rest is in Arunachal Pradesh. The right bank tributaries of the river are Sapai Garmajuli (area 34.475 km^2, length 17.85km), Garjuli (45km^2, 20.5km) and Dherai

(265.63 km^2, 74km) and the left bank tributaries are Benganajuli(50.3km^2, 24.5km), Mejenjuli (7.325km^2, 9km) and Ghagar (1.7km^2, 3.25km).

Data Availability:

Rainfall- Rainfall data for four stations have been used between the period 1978-1990. They are Dhekiyajuli Block, Dherai Tea Estate, Panbari TE and Dighalijuli TE.

Studies:

1. Maximum 1,2,3 days rainfall
2. Average annual rainfall (aar - 1668 mm, maximum annual rainfall in basin - 2943mm)
3. Average annual rainfall with sub catchment wise distribution
4. Seasonal distribution of rainfall
5. Rainguage network design based on WMO guidelines
6. Evaporation loss study based on data collected at DRL Solamora station

Hydrological data:

1. Foot hills gauge site - G - 1978-90
2. NT road crossing - GDS - 1978-90
3. Bharasingre gauge site - G - 1978-90

Studies:

1. High and low water level
2. Flood waves and their duration above danger level
3. Maximum and minimum discharge over the years (average annual mean discharge - 24.9 cumecs, maximum annual mean discharge - 55.9 cumecs, minimum annual mean discharge - 5.183 cumecs, Maximum and minimum observed discharge at NT road crossing are 397.74 cumecs and 0.043 cumecs
4. Annual, Monsoon and quarterly yield (average annual yield - 727.55 MCM)
5. Flood hydrology and flood frequency
6. Silt studies
7. Other studies like development of irrigation and pisciculture has also been delt. However, there is no provision of hydropower generation and storage potential development.
8. Flood, erosion and drainage congestion problems have been studied in details

3.1.17 Ranga Nadi Basin - Master Plan, 1995

Ranga nadi originates near the border of Lower Subansiri and East Kameng district in Arunachal Pradesh. The geographical location is 93°15′ - 94°10′ E longitude 27°0′ - 27°45′ N latitude. The catchment area is 2941 km^2 out of which 700 km^2 is in Lakhimpur district in Assam and remaining 2241km^2 is in Lower Subansiri district of Arunachal Pradesh. The right bank tributaries of the river are Lorio (A- 165.62 km^2, L- 22 km), Pering (A- 455.6 km^2, L- 35 km), Niarci (A- 88.75 km^2, L- 15 km), Pepfi (A- 88.12 km^2, L- 17 km), Singra (A- 138.13 km^2, L- 30 km) and Pabha (A- 516.88 km^2, L- 25 km) and the left bank tributaries are Niyarpuna (A-

71.25km^2, L- 25 km), Keing (A- 236.88 km^2, L- 30 km), Talo (A- 143.75 km^2, L- 27 km), Kale (A- 313.13 km^2, L- 35 km) and Puriperh (A- 80 km^2, L- 17.5 km).

Data Availability:

Rainfall- Rainfall data for 9 stations have been used. They are Dizoo Tea Estate (1972-86), Lilabari (1974-84), NL Civil (1967-82), Kimin (1968-82), Yazali (1965-82), Ziro (1968-82), Did (1980-82), Parang (1980-82) and Mangio (1980-82).

Studies:

1. Maximum 1,2,3 days rainfall
2. Storm analysis based on CWC report 1/73 revised
3. Average annual rainfall (aar - 2336.3 mm, maximum rainfall recorded at yazali in 24 hours is 342.7 mm)
4. Seasonal distribution of rainfall
5. Rainguage network design based on WMO guidelines

Hydrological data: The observation sites are:

1. Pahumaraghat at NH 52 crossing - GD - guage since 1973, discharge 1973-1992
2. At Yazali 41 km from Kamini (Dam site of Ranganadi Hydroelectric Project) - GD - guage-1956-61 and 1972 onwards and discharge 1957-62 and 1973-90

Studies:

1 High and low water level
2 Flood waves and their duration above danger level
3 Maximum and minimum discharge over the years (Maximum observed discharge at Pahumaraghat is 1635.59 cumecs)
4 Annual, Monsoon and monthly yield (average annual yield - 727.55 MCM)
5 Flood hydrology and flood frequency
6 Sediment studies (maximum and minimum annual sediment load at Pahumaraghat are 373.98 and 48.91 ha-m respectively with average annual 150.58 ha-m)
7 Flood, erosion and drainage congestion problems have been studied in details
8 Other studies like development of irrigation and pisciculture power production etc. have also been discussed. There is a proposed hydroelectric project known as

Ranganadi hydroelectric project. The salient features of the project are:

1 Location - in Lower Subansiri district of Arunachal Pradesh (93°49′ E and 27°20′N)
2 Catchment upto Yazali dam site - 173000 ha
3 Catchment upto diversion dam site - 189400 ha
4 Maximum observed flood - 1529 cumecs
5 Design flood - 13241 cumecs
6 Rainfall - maximum 1562 mm, minimum 838 mm and average 1232 mm

Stage I (under construction)

1 Maximum annual runoff - 5080 MCM

2 Minimum annual runoff - 2048 MCM
3 Maximu water level - 567.5 m
4 Full reservoir level - 567 m
5 Gross Storage at FRL - 21.28 MCM
6 Dead Storage at MDDL - 15.58 MCM

Stage II (Proposed), Yazali reaservoir
1 Maximum annual runoff - 8643 MCM
2 Minimum annual runoff - 1862 MCM
3 Maximu water level - 717.5 m
4 Full reservoir level - 717 m
5 Gross Storage at FRL -529.2 MCM
6 Dead Storage at MDDL - 159.2 MCM

3.1.18 Bharalu Basin -Master Plan

Bharalu river originates in Meghalaya hills and enters Guwahati city from south eastern corner where it is known as Bahini upto Guwahati Shillong (GS) road crossing. Near Rukmanigaon, it meets with local drainage channel and thereafter, it is known as Bharalu. The Bharalu flows parallel to GS road and through the city area Dispur, Zoo road, Laichit Nagar, Ulubari, Rahabari, Bushnupur and finally outfalls into Brahmaputra at Bharalumukh. Its catchment are is 469 km^2 and covers part of Kamrup district of Assam (414km^2) and East Garo hills (55 km^2) of Meghalaya. Total length of the river is 40 km out of which 15 km is in Meghalaya and 25 km is in Assam Geographical location of the basin is 26°8′ - 26°15′ N latitude and 91°38′ - 91°57′ E longitude. The tributary of Bharalu river is of significant importance.

Data Availability

Rainfall - Only one raingauge station at Guwahati airport. Data from 1986 -1991 has been used in the study.

Studies:

1 Anuual average rainfall (1864 mm), Maximum rainfall in the basin is 2189 mm.
2 Seasonal distribution of rainfall
3 1,2,3 day maximum rainfall
4 Rainguage network design
5 Evaporation loss

Hydrological Data:
At NH 37 crossing - GD - from 1977 to 1978

Study:

1 Flood drainage congestion and erosion problems. Flood and erosion problems reported to be negligible. There is no proposal for storage and irrigation development etc.

3.1.19 Brahmajan Basin -Master Plan, 1993

River orginates from Dafala hills. The catchment area of 92 km^2n is spread over Sonitpur district of Assam and Lower Subansiri district of Arunachal Pradesh. Geographical location of the basin is 2645 - 27 N latitude and 9325 - 9330 E longitude. Chengelijan (basin area -8km^2 , length - 5.1km) is the right bank tributary while Tupung nadi (6.75 km, 5km^2) and Kekuri nadi (3.75km, 1km^2) meet the river on its left bank.

Data Availability:

Rainfall - The various stations for which data of the period 1982-92 have been in the study are Dafflagar Tea Estate, Bholaguri TE, Nirmala TE and Bormajan TE.

Study:

1 Average annual rainfall is 2584 mm and maximum rainfall in the basin is 3534.7 mm.
2 Sub basin wise rainfall distribution.
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall
5 Rainguage network design
6 Evaporation loss

Hydrological Data: Only gauge site is at NH crossing for which data have been used from 1982-92.

Studies:

1 High and low water level
2 Discharge calculation based on similar adjacent catchment of Borgang
3 Flood frequency analysis
4 Studies regarding development of irrigation, pisciculture, agriculture and water supply. However, there is no proposal for power generation and storage.
5 Flood, drainage congestion and erosion problems have also been discussed.

3.1.20 Giladhari Basin - Master Plan, 1993

The river originates from Alka hill of Arunachal Pradesh at an Altitude of about 500 m and falls in Brahmaputra near Panpur. Catchment area is 670 km^2 and spread over Sonitpur district in Assam and East Kameng district of Arunachal Pradesh. Length of the river is 61km out of which 50.8km is in Arunachal Pradesh and rest in Assam. Geographical location of the basin is 26°40′ - 26°57′ N latitude and 92°55′ - 93°10′ E longitude. Monai nadi (basin area 116km^2, length 28km) and Chnota Giladhari (176km^2, 19km) are the right bank tributaries and Diring (125km^2, 26km) and Majuli (66km^2, 27km) are on the left bank.

Data Availability

Rainfall The three stations for which data have been used are Majuli Ghar Tea Estate (1983-92), Pratap Ghar Tea Estate (1983-92) and Biswanath (1974-91).

Studies:

1 Average annual rainfall is 1917.33 mm.
2 Sub basin wise rainfall distribution.
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall
5 Rainguage network design

Hydrological Data: One GD site is at NH crossing where Guage data is available since 1980 and discharge since 1981.

Studies:

1 Monthly water level,
2 Maximum and minimum discharge (81.359 and 0.220 cumecs)
3 Annual maximum discharge, monthly and annual mean discharge
4 Average Monsoon yield (139.08 MCM)
5 Other studies like irrigation pisciculture and agriculture development. However, there is no proposal for power generation and storage.
6 Flood, drainage congestion and erosion problems have also been discussed.

3.1.21 Gadadhar Basin - Master Plan, 1993

The river originates from the marshy land in the alluvial plain Srirampura and Gassaigaon in Assam, flows southwards and ultimately falls into Brahmaputra near Dhubri. Catchment area of 610 km^2 is spread over Kokrajhar and Dhubri districts of Assam. Geographical location of the basin is 26°02′ - 26°26′ N latitude and 89°50′ - 90°02′ E longitude. Silai is the only tributary of the river, which meets the mainstream at Gauripur.

Rainfall- The two stations are Mornoi and Dhubri for which data have been used.

Studies:

1 Average annual rainfall is 3459 mm and maximum rainfall is 4545 mm.
2 Sub basin wise rainfall distribution.
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall
5 Rainguage network design
6 Evaporation loss

Hydrological Data: There are two Guage site one at Moterjhar and other at Targhat where Guage data is available upto 1883. Silt data at Moterjhar from 1977 to 1982 has also been used in silt study.

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge (182.75 and 4.58 cumecs)

3 Average Annual , quarterly and monsoon yield (average annual yield 729.86 MCM)
4 Silt study (average silt load is 0.0006 ha-m/km^2/year)
5 Other studies like irrigation pisciculture and agriculture development. However, there is no proposal for power generation and storage.
6 Flood, drainage congestion and erosion problems have also been discussed.

3.1.22 Subansiri Basin - Master plan, 1993

River originates in the snow cloud peaks of Karkang Shabota, Bara and Mata in Bhutan at an elevation of about 5389 m above msl. Total catchment area is 28,200 km^2 out of which 1200 km^2 is in Assam, 15,800 km^2 is in Arunachal Pradesh and remaining in Bhutan. About 4000 km^2 of the drainage area of Subansiri falls in perpetual snow. Geographical extent of the basin is 27°0′ - 29°0′ N latitude and 91°45′ - 94°45′ E longitude. The tributaries of the Subansiri are Nye chu (Subansiri), Char chu (L), Jume Chu (L), Chayal chu (R), laro chu (L), Sang chu (L), Tsani chu (R), Kamala, Sichir (L), Situr (L)Sigenr (L), Singenr (R), Kurungr (R), Peinr (R), Parsenr (R), and Sipura (R) in the hilly areas. Bogi nadi (R) meets the river in the plain area.

Data Availability:

Rainfall - There are 18 rainguage station spread over the basin for which data have been used. These are - NL Civil Hospital (1967-82), Ananda Tea Estate (1971-91), Gerukamukh (1983-91), Khabulighat (1984-87), Lilabari airport (1974-84), Lohit IB (1972-87), Bahadurchuk (1984-87), Gensi (1983-91), Raga (1979-86), Muri (1983-90), Daporijo (1982-91), Tamen (1978-90), Damporijo (1983-91), Nyapin (1979-97), Liromoba (1982-90), Daring (1982-88), Damin (1983-88) and Ziro (1968-82).

Studies:

1 Average annual rainfall is 2754.48 mm and maximum rainfall is 4768.81 mm.
2 Sub basin wise rainfall distribution.
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall in different years
5 Rainguage network design

Hydrological Data: The data for following sites have been used:

1 Tamen - GDS - 1978-91
2 Daporijoo - GDS - 1978-91
3 Gerukamukh - GD - 1977 -91 (site established in 1973 and sifted 2 km u/s in August 1977)
4 Chouldhowaghat - GDS - 1956-91
5 Dhalghat - G - 1976-91
6 Khabulighat - GDS - 1964-91

Studies:

1 Flood hydrology and flood frequency

2 Maximum and minimum discharge (18789.54 and 129.4 cumecs at Chouldhowaghat)
3 Monthly, annual and mean discharge (maximum monthly mean discharge - 6972.49 cumecs, average annual mean discharge - 2031.73 cumecs at Chouldhowaghat)
4 Maximum and minimum water level
5 Flood waves and theor duration above danger level
6 Average Annual , quarterly and monsoon yield (average annual yield 5.206 Mha-m)
7 Silt study (average silt load is 0.072 ha-m/km^2/year)
8 Other studies like irrigation pisciculture and agriculture development. There is a provision for hydropower generation of 4800 MW, 2.3 km u/s of Gerukamukh village on Assam Arunachal Pradesh border with design discharge of $28.5x10^3$ cumecs, including flood control storage potential of 1.4 M ha-m at 334 m FSL.
9 Flood, drainage congestion and erosion problems have also been discussed.

Salient features of Subansiri dam :

1 Location of dam - 4 km u/s of Gerukamukh village in Arunachal Pradesh near Assam border,
2 Catchment area upto dam site - 27000 km^2
3 Maximum observed discharge - 18799 cumecs
4 Minimum observed discharge - 130.58 cumecs
5 Average annual yield - 52700 MCM
6 Gross storage - 1.34 M ha-m
7 Live storage - 1 M ha-m

3.1.23 Depota Basin - Master Plan, 1993

Depota river originates from Charduar reserved forest of Assam. Catchment area of 295.7 km^2 is in Sonitpur district of Assam. 52.83 km^2 basin area is in hill and rest in plain. The hilly portion of the river is known as Monsajuli. Geographical extent of the basin is 26°37′ - 26°55′ N latitude and 92°35′ - 92°46′ E longitude.The left bank tributaries of the river are Bindukuri (basin area 15.8km^2 and length 11km) and Bimalajan (basin area 5.225 km^2 and length 7 km) and Borjuli (basin area 40.175 km^2 and length 4 km) and Ghagra 'N' (basin area 20.425 km^2 and length 18 km) are on the right bank.

Data Availability:

Rainfall - One raingauge station is at Bindukuri for which data is available from 1980 to 1992

Studies:

1 Average annual rainfall is 1921 mm.
2 Sub basin wise rainfall distribution.
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall in different years
5 Rainguage network design

6 Evaporation loss based on data at Defense Research Laboratory, Jorhat)

Hydrological Data:

1 Naimukh guage Site - G - 1980-92
2 NT road crossing - GD - 1980-92
3 Bindukuri guage Site -G - 1980-92

Studies

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge (45.086 and 0.084 cumecs at NT road crossing)
3 Monthly, annual and mean discharge (maximum monthly mean discharge - 33.27 cumecs, average annual mean discharge - 7.67 cumecs at NT road crossing)
4 Maximum and minimum water level
5 Flood waves and their duration above danger level
6 Average Annual , quarterly and monsoon yield (average annual yield 0.0159 Mha-m)
7 Other studies like irrigation pisciculture and agriculture development. However, there is no proposal for power generation and storage.
8 Flood, drainage congestion and erosion problems have also been discussed.

3.1.24 Tipkai Basin - Master Plan, 1993

Ganga and Joyma combined stream is called Sankhos. Just about 5 km before reaching national highway, the Sankhos is joined by a small stream called Tipkai, originating in the Mahamaya reserved forest. The Sankhos is thereafter called Tipkai upto its outfall into Brahmaputra at Mojharchar. The catchment area is 1744 km^2 out of which 1572 km is in Kokrajhar and Dhubri district of Assam and remaining 172 km is in Bhutan. Geographical location of the basin is 26°03′ - 26°52′ N latitude and 89°30′ - 90°14′ E longitude. The tributaries of the river are:

1 The Hel, or Gangia, it meets Joyma at Sapatgram (originating in Bhutan)
2 The Pekua or Geruphella or Joyma
3 The Longa, left bank tributary of gangia
4 Laska, left bank tributary of Sankhos (Tipkai)
5 The Hel (not as no 1), left bank tributary of Sankhos (Tipkai)
6 Tipkai, right bank tributary of Tipkai

Data Availability:

Rainfall: The four stations inside the basin are Gossaigaon, Kachugaon, Dotma and Fakiragram and one outside station is Bilasipara.

Studies:

1 Average annual rainfall is 3264 mm and maximum rainfall is 3606.61mm.
2 Sub basin wise rainfall distribution.
3 Seasonal distribution of rainfall

4 Rainguage network design
5 Evaporation loss based on data at Guwahati airport for 1975-83)

Hydrological Data: The observation sites are:
1 Khoraghat - GDS - 1982-91 (silt data for 1981-90)
2 Saptagram - G - 1982-91

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge (3233.75 and 30.07 cumecs at NH crossing)
3 Maximum and minimum water level
4 Average Annual , quarterly and monsoon yield (average annual yield 7685.41 MCM)
5 Silt studies (silt load 0.035 ha-m/km^2/year)
6 Other studies like irrigation pisciculture and agriculture development. However, there is no proposal for power generation and storage.
7 Flood, drainage congestion and erosion problems have also been discussed Erosion problem in the basin is severe.

3.1.25 Sankhos Basin - Master Plan, 1993

The river originates from the snow clad greater Himalayan ranges at Tibet at an elevation of about 7300 m above msl. In Bhutan it is called Mo chu and Gangadhar in plains of Assam beyond Srirampur.River length is 214 km in Bhutan and 107 km in India. Catchment area is 10345 km^2 out of which 9560 km^2 is in Bhutan and remaining 785 km^2 is in Kokrajhar and Dubri district of Assam in India. Geographical location of the basin is 26°43′ - 28°18′ N latitude and 89°24′ - 90°30′ E longitude. The right bank tributaries of the Sankhos river are Nabe Rang chu, Hietsha chu, Ruri chu, Piso chu, Kamga chu, Tache chu or Cher chu, Budda chu, Dagagua chu, Ragnu chu, Sami and Home khola. The left bank tributaries are Paya chu or Pe chu, Tang chu, Kangkha chu, Hera chu, Lara chu, Buri chu, Chan chu, kali khola, Dhanese khola, Nijula and Sunderi.

Data Availabilty:

Rainfall - There are total Eight stations, five in Bhutan and three in India. Punakha, Phodrang, Tagedzong, Chirang and Dronagaon are in Bhutan and Jamuduar, Srirampur and Golakganj are in India.

Studies:

1 Average annual rainfall is 2862.72 mm.
2 Seasonal distribution of rainfall
3 Rainguage network design

Hydrological Data: The observation sites are:

1. Jamuduar - GD - 1972-91
2. Srirampur - GDS - 1972-91 (catchment area upto Srirampur is 9923.43 km^2)

3. Golakganj - G - 1972 - 91.

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge (3152.69 and 62.63 cumecs)
3 Maximum and minimum water level
4 Average Annual , quarterly and monsoon yield (average annual yield 17169.9 MCM)
5 Silt studies (silt load 0.464 mm/year over the catchment)
6 Other studies like irrigation pisciculture and agriculture development. There is proposal for one multipurpose reservoir for hydroelectric power generation of 1525 MW and irrigation etc. The salient features of Sankhos dam are:

- Dam near Korabari with two power hoses, drainage area upto dam site is 9700 km^2
- Mean annual rainfall in watershed is 151 cm.
- Average yield - range of variation - 21784 MCM (1979-80) to 10977 MCM (1965-66)
- Average annual yield - 16902 MCM
- Design annual yield - 14715 MCM
- Maximum and minimum observed flow are 3408 and 87 cumecs respectively
- Inflow design flood (100 year return period) - 9100 cumecs
- Diversion design flood - 6960 cumecs
- Annual Sediment load - 8.13 MCM/year

7 Flood, drainage congestion and erosion problems have also been discussed Erosion problem in the basin is severe.

3.1.26 Beki Manas Aie Basin - Master Plan, 1991

The river originates from hills in Tibet. Total catchment area is 41350 km^2 spread in Tibet and Assam in India. 35550 km^2 of catchment is in hills and 5800 km^2 is in plains. Geographical location of the basin is 26°13′ - 28°35′ N latitude and 90°27′ - 92°27′ E longitude. The river system id devided into three part; Choulkhowa river system, Beki-Manas river system and Aie river system. The tributaries of Beki river are Buradia, Mora Pagladiya, Tihu, Kaldiya, Pahumara, Polla and Choulkhowa. The tributaries of Manas river are Kanamakra, Dulani, Bhalukadoba and Burisiri and Buri Aie is the tributary of Aie river.

Data Availabilty:

Rainfall - There are total ten stations inside the basin for which data have been used for period 1982-88. These are Bhawanipur, Barpeta road, Barpeta, Sarbhog, Bijni, Manikpur, Bongaigaon, Mathanguri, Hatisar and Rupahighat

Studies:

1 Average annual rainfall.
2 Average annual rainfall with sub basin wise distribution.

3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall
5 Rainguage network design
6 Evaporation loss study (Guwahati airport data)

Hydrological Data: The observation sites are:

1 Beki NH crossing - GDS - 1962-88
2 Manas NH crossinh (NT road crossing) - GDS - 1955-88
3 River Aie railway bridge site - GDS - 1972 – 88

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge
3 Maximum and minimum water level
4 Silt studies (silt load at Pahumara 28 ha-m/year, in Beki Manas 1817 ha-m/year and Aie 1576 ha-m/year)
5 Other studies like irrigation pisciculture and agriculture development. There is proposal for one multipurpose project near Mathamguri in bhutan at 4 km u/s of India-Bhutan border.
6 Flood drainage congestion and erosion problem study

3.1.27 Dhansiri (South) Basin - Master Plan, 1996

River originates from Laishang Peak on the southwest corner of Nagaland. It meets Brahmaputra river at Dhamsirimukh. Total length of the river is 352 km in Assam Nagaland and Manipur. Catchment area is 10305 km (7515 km^2 is in hills and 2790 km^2 is in plains). Geographical location of the basin is 25°21′ - 26°42′ N latitude and 93°10′ - 94°37′ E longitude. The left bank tributaries are Deopani (L-38.64 km, A-221.05 km^2), Nambor (L-45.28 km, A-127.12 km^2), Kaliyani (L-89 km, A-1319.28 km^2) and Doigurung (L-64.4 km, A-389.23 km^2).The right bank tributaries are Diphupani (L-48.3 km, A-619.62 km^2), Diyung (L-201.25 km, A-4571.63 km^2) Galdbil and Bhogdoi (L-161 km, A-920 km^2) and Kakadanga (L-67 km, A-1099.88 km^2).

Data Availabilty:

Rainfall - Stations are Numaligarh Tea Estate (1971-92), Khoomatai TE (1971-92), Bokajan CCI/TE (1971-92), Kohima (1984-91), Sarupathar GDS Block (1971-92), wokha TE (1971-92), Bogidholla TE (1973-92), Borpathar / Porajan TE (1980-92).

Studies:

1 Average annual rainfall (aar - 1805.6mm and average monsoon rainfall - 1158.1).
2 Storm analysis (based on CWC report 1/73)
3 Average annual rainfall with sub basin wise distribution.
4 Seasonal distribution of rainfall
5 Rainguage network design

Hydrological Data: The observation sites are:

1 Bokajan - G-
2 Golaghat - GD - since July 1978
3 Numaligarh - GDS - GD since 1946, silt data 1971-80
4 Kuruabahi - G

Studies:

1 Gauge discharge curve
2 Flood hydrology and flood frequency
3 Maximum and minimum discharge (at Numaligarh max. and min. are 2091.85 cumecs and 3.96 cumecs respectively)
4 Maximum and minimum water level
5 Flood waves and their duration above danger level in different years.
6 Monthly, annual and monsoon yield (average annual yield - 6784.71 MCM, 90%, 75% and 50% dependable yield are 3740.13 MCM, 4752.72 MCM and 6254.37 MCM respectively)
7 Hydrological network design
8 Silt studies (silt load at Pahumara 28 ha-m/year, in Beki Manas 1817 ha-m/year and Aie 1576 ha-m/year)
9 Other studies like irrigation pisciculture, hydropower and navigation etc. There are eight numbers of hydro power generation schemes (5 are storage and 3 are runoff the river schemes).
10 Flood drainage congestion and erosion problem study (flood plain area - 2368 km^2, area prone to 25 year return period flood - 398 km^2, agricultural area affected during normal and high flood - 1200 ha and 37920 ha respectively, low lying/wet area in basin - 21,357 ha, No drainage congestion and erosion is observed at 32 number of sites).

3.1.28 Barnadi Basin - Master Plan, 1992

The river originates from Himalayan range in Bhutan at an elevation of about 914.4 m above msl. 739.23 km^2 of Catchment area is spread over Kamrup and Darrang district of Assam and Bhutan. Basin area in India (Assam) is 611.95 km^2 and that in Bhutan is 127.28 km^2. Geographical location of the basin is 26°12′ - 26°52′ N latitude and 91°43′ - 91°54′ E longitude. The tributaries (only rght bank) of the river are Barnadi (A-478.85 km^2, L-112 km), Kalpani (A- 189.24 km^2, L-52.5 km) and Dimila (A-71.14 km^2, L-28 km)

Data Availabilty:

Rainfall - only one station is at Bhergaon Tea Estate (1878-90)

Studies:

1 Average annual rainfall (aar - 2037 mm and maximum rainfall - 2427 mm).
2 1,2,3,days maximum rainfall in different years
3 Seasonal distribution of rainfall
4 Rainguage network design

5 Evaporation loss (Guwahati airport data)

Hydrological Data: The observation sites are:

1 Jalukbari rly bridge - G- June 1978 -1990
2 Lenga gauge site - G - Jan 1980 -1990
3 NT road crossing - GDS - Jan 1978-1990

Studies:

1 Gauge discharge curve
2 Flood hydrology and flood frequency
3 Maximum and minimum discharge, monthly and annual discharge (annual max. and min. mean discharge 25.279 cumecs and 5.283 cumecs respectively, at NT road crossing maximum observed discharge 230.482 cumecs, average annual discharge 14.06 cumecs, minimum observed discharge 0.051 cumecs)
4 Maximum and minimum water level
5 Flood waves and their duration above danger level in different years.
6 Monthly, annual and monsoon yield (annual average yield 405.075 MCM)
7 Silt studies
8 Other studies like irrigation pisciculture, hydropower and navigation etc. However, there is no proposal for storage and hydel power.
9 Flood drainage congestion and erosion problem study

3.1.29 Gaurang Basin - Master Plan, 1992

The river originates from Chirang reserved forest in Bhutan. The Saralbhanga river originating in Bhutan hills is also known as Gaurang in its lower course. The river has history of frequently changing its course. 1023 km^2 of Catchment area is spread over Kokrajhar and Dhubri district of Assam and Bhutan. Basin area in India (Assam) is 834 km^2 and that in Bhutan is 189 km^2. Geographical location of the basin is 26°12′ - 27°0′ N latitude and 90°10′ - 90°22′ E longitude. The tributaries of the river are Samukha and Tarang

Data Availabilty:

Rainfall - There are 4 stations inside the basin and 2 are outside it. These are Bilasipara, Kokrajhar, Fakiragram, Haltugaon, Basugaon and Dotma.

Studies:

1 Average annual rainfall (aar - 3123.07 mm and maximum rainfall - 3485.34 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall
4 Rainguage network design
5 Evaporation loss (Guwahati airport data)

Hydrological Data: The observation sites are:

1 Kokrajhar rly bridge crossing - GDS- since 1955, DS discontinued in 1978.

2 Bamungon NH crossing - GDS - since 1978

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge, (Maximum and minimum discharge observed at Kokrajhar rly bridge crossing are 1756.3 and 3.11 and that observed at Bamungon NH crossing are 2493.4 and 8.15 cumecs)
3 Maximum and minimum water level
4 Flood waves and their duration above danger level in different years.
5 Monthly, annual and monsoon yield (annual average and monsoon yield at Bamumgaon are 4312.255 and 3576.37 MCM respectively)
6 Silt studies (1981-90 data has been used, silt load - 0.031 ha-m/km^2/year)
7 Other studies like irrigation pisciculture, hydropower and navigation etc. However, there is no proposal for storage and hydel power.
8 Flood drainage congestion and erosion problem study

3.1.30 Na-Nai Basin - Master Plan, 1992

The river originates from foothills of Bhutan ramnge of Himalaya called kalapani hills. 859.52 km^2 of Catchment area is spread over Darrang district of Assam and Jonkhar district of Bhutan. Basin area in India (Assam) is 654.92km^2 and that in Bhutan is 204.6 km^2. Geographical location of the basin is 26°15′ - 27°45′ N latitude and 90°0′ - 91°45′ E longitude. The left bank tributaries of the river are Mangari (L-15.75 km), Hagguri (L-13.25 km), Hadurma (L-13.5 km) and Dwigaj nadi. Dimakuchi (L-22.5 km) and Nanai chara (L-24.25 km) meets the river on its right bank.

Data Availabilty:

Rainfall - The 4 stations are Khandajan IB compound (1980-89), Dimakuchi Tea Estate (1978-90), Makuli Khonda H/W (1978-87) and Paneri TE (1978-90).

Studies:

1 Average annual rainfall (aar - 1722 mm and maximum rainfall - 2171 mm).
2 Average annual rainfall with sub catchment wise distribution
3 1,2,3 days maximum rainfall in different years
4 Seasonal distribution of rainfall
5 Rainguage network design
6 Evaporation loss (Guwahati and Tezpur airport data)

Hydrological Data: The observation sites are:

1 NT road crossing - GDS - 1978-90
2 Tangla PWD road crossing - G- 1978-90
3 Nai Nadi E & D Bridge site - G - 1978-90

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge, (annual maximum and minimum 283.128 and 124.068 and that maximum and minimum observed discharge at NT road crossing are 239.189 and 0.365 cumecs respectively)
3 Monthly and annual mean discharge
4 High and low water level
5 Flood waves and their duration above danger level in different years.
6 Monthly, annual and monsoon yield (annual average 594.042 MCM)
7 Silt studies
8 Other studies like irrigation pisciculture, hydropower and navigation etc. However, there is no proposal for storage and hydel power.
9 Flood drainage congestion and erosion problem study

3.1.31 Jhanji Basin - Master Plan, 1990

The river originates in Naga hills at an altitude of 1415.86 m above msl. 1349 km^2 of Catchment area is spread over Sibsagar and Jorhat district of Assam and Mokokchung district of Nagaland. Basin area in Assam is 476 km^2 and remaining 873 km^2 is in Nagaland. The length of the river is 108 km. The tributaries of the river are Muning nadi (A-160 km^2 in hills), Tori nadi (A-184 km^2 in plain)and Teok (A-218 km^2, L-38.5 km).

Data Availability:

Rainfall - The 5 stations are Seleng Tea Estate (1971-88), Teok TE (1971-88), Naginijan TE (1973-88), Baisa TE (1972-88) and Amguri TE (1980-88).

Studies:

1 Average annual rainfall (aar - 2342 mm and maximum rainfall - 2711 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall
4 Rainguage network design

Hydrological Data: The observation site is:

NH bridge crossing - GDS - 1978-90, gauge since 1948, discharge since 1971 and silt data in 1956-58 and since 1972. Data used in the study are gauge 1963-88, discharge 1971-88 and silt data 1956-58 and 1972-88.

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge, (maximum and minimum observed discharge at NH bridge crossing are 643.77 and 0.14 cumecs respectively)
3 Monthly and annual mean discharge (maximum monthly mean discharge 53.26 and average annual mean discharge 24.82 cumecs respectively)
4 High and low water level
5 Flood waves and their duration above danger level in different years.
6 Annual and quarterly yield (annual average 0.0783 M ha-m, maximum and

minimum yield are 0.1108 and 0.0458 M ha-m)
7 Silt studies (average silt load - 0.017 ha-m/km^2/year)
8 Other studies like irrigation pisciculture, hydropower and navigation etc. However, there is no proposal for storage and hydel power.
9 Flood drainage congestion and erosion problem study

3.1.32 Dhansiri (North) Basin - Master Plan, 1993

The river originates from foothills of Himalaya called Khempajuli hills situated in Bhutan and Kalaktangpa hills in Arunachal Pradesh. 955.96 km^2 of Catchment area is spread over Darang district of Assam, West Kameng in Arunachal Pradesh and Jonkher district in Bhutan. Basin area in Assam is 622.88 km^2, 102.48 km^2 in Bhutan and remaining is in Arunachal Pradesh. . Geographical location of the basin is 26°30′ - 27°03′ N latitude and 92°0′ - 92°17′ E longitude. The length of the river is 76 km. The left bank tributaries of the river are Betali nadi (A-179.125 km^2 L-34 km), Ajagar (A-50.9 km^2 L-36.5 km) and right bank tributary is Mora Dhansiri (A-104.25 km^2 L-67 km)

Data Availability:

Rainfall - The 4 stations are Nonoi Para Tea Estate (1978-90), Kowpati TE (1978-90), Dhansiri TE (1978-90) and Chikanmati TE (1978-90).

Studies:

1 Average annual rainfall (aar - 1876.58 mm and maximum rainfall - 2263.14 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall in different years
5 Rainguage network design

Hydrological Data: The observation sites are:

1 Dhansiri outfall - G - 1978-90,
2 Rowta railway bridge - G - 1978-90
3 NT road crossing - GDS - 1978-90

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge, (maximum and minimum observed discharge at NT road crossing are 982.74 and 1.97 cumecs respectively)
3 Monthly and annual mean discharge (mean annual maximum and minimum discharge 611.18 and 4.10 cumecs respectively)
4 High and low water level
5 Flood waves and their duration above danger level in different years.
6 Annual and quarterly and monsoon yield (annual average 2002.576 MCM)
7 Silt studies maximum silt load - 0.0250 ha-m/km^2 in 1978 and minimum silt load of 0.0001 ha-m/km^2 in 1987)
8 Other studies like irrigation pisciculture, hydropower and navigation etc. There is

a flow irrigation scheme. A barrage has been constructed at Bhairabkunda at the juncture of Assam, Bhutan and Arunachal Pradesh. One micro hydel project of 20 MW is also under construction. The salient features of the project are:

- ·Catchment area upto headwork - 450 Sq.miles
- ·Normal annual rainfall average - 2454.98 mm and maximum annual rainfall - 3439.5 mm, minimum annual rainfall - 1920.2 mm
- ·Minimum observed discharge - 13.433 cumecs, Maximum observed discharge - 3142.66 cumecs
- ·Maximum design flood - 3400 cumecs

9 Flood drainage congestion and erosion problem study

3.1.33 Dhikhow Basin - Master Plan, 1995

The river originates from Naga hills at an altutude of 1800 m in Zunheboto district of Nagaland. Catchment area is 4022 km^2. Geographical location of the basin is 26°05′ - 27°05′ N latitude and 94°27′ - 95°18′ E longitude. The length of the river is 236 km. The tributaries of the river are Phomchi (A-319 km^2 L-23 km), Yangmun (A-2418 km^2 L-78 km), Namdang (A-432 km^2 L-45 km) and Darika (A-207 km^2 L-40 km)

Data Availability:

Rainfall - The 8 stations are Sibsagar E & D (1971-92), Amguri (1980-92), Ligiriphukuri (1971-92), Lakhimijan (1971-92), Maduri (1971-92), Bihubar (1971-92), Santak (1971-92) and Barbam (1971-92).

Studies:

1 Average annual rainfall (aar - 2492.9 mm and maximum rainfall - 2967.2 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall
4 Storm analysis based on CWC report 1/73 revised
5 1,2,3 days maximum rainfall in different years
6 Rainguage network design
7 Evaporation study (Jorhat data)

Hydrological Data: The observation sites are:
Sibsagar NH bridge crossing - GDFS - gauge since 1948 with some gap, discharge since 1956 except 1959-62, silt 1956-58 and 1972-84

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge, (maximum observed discharge at NH crossing are 1378.89 and floods of 100 year, 50 year and 25 year return period are 1652.08, 1496.34 and 1342.73 cumecs)
3 Monthly and annual mean discharge.
4 High and low water level
5 Gauge discharge rating curve at Sibsagar NH bridge crossing
6 Flood waves and their duration above danger level in different years.

7 Annual, monthly and monsoon yield.
8 Silt studies average silt load - 0.0182 ha-m/km^2/year
9 Hydrological network design
10 Other studies like irrigation pisciculture, hydropower and navigation etc. There are three identified hydel schemes, two storage project and one runoff river schemes. Salient features of Dhikow dam projects are:

- ·Location of dam site - is 26°43′ N latitude and 94°50′ E longitude, u/s of Naginimara.
- ·Catchment area upto dam site - 3000 km^2
- ·Average annual discharge at dam site - 114.75 cumecs.
- ·Average annual yield at dam site - 3618.75 MCM.
- ·Average annual silt Load at dam site - 0.0398 ha-m.

11 Flood drainage congestion and erosion problem study

3.1.34 Buroi Basin - Master Plan, 1993

The river originates from eastern Himalayan range namely Dafla hills of East Kameng district of Arunachal Pradesh. Catchment area is 791 km^2 out of which 137 km^2 is in Sonitpur district of Assam and remaining in East Kameng district of Arunachal Pradesh. Geographical location of the basin is 26°45′ - 27°15′ N latitude and 93°15′ - 93°35′ E longitude. The length of the river is 62.5 km. The left bank tributaries of the river are Dalang nadi (A-10 km^2 L-9.5 km) and Pam nadi (A-256 km^2 L-30 km). Helem nadi (A-31.25 km^2 L-24 km), Bihmori nadi (A-25 km^2 L-17 km) and Papum nadi (A-272 km^2 L-26 km) meet the river on its right bank.

Data Availability:

Rainfall - The 5 stations are Behali Tea Estate, Borjuli TE, Bedeti TE, Helem TE and Seijosa for which data from 1980 to 1991 have been used in the study.

Studies:

1 Average annual rainfall (aar - 2188.56 mm and maximum rainfall - 2882 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall
4 1,2,3 days maximum rainfall in different years
5 Rainguage network design

Hydrological Data: The observation site is at NH crossing - GD - 1981-91

Studies:

1 Flood hydrology and flood frequency
2 Maximum and minimum discharge, (maximum and minimum observed discharge at NH crossing are 1079.11 and 2.036 cumecs
3 Monthly and annual mean discharge. (annual average mean discharge - 56.686 cumecs and maximum monthly mean discharge - 159.235 cumecs)
4 High and low water level

5 Annual, monthly and monsoon yield (average annual yield - 0.179 Mha-m)
6 Other studies like irrigation pisciculture, hydropower and navigation etc. There is one Papum Pam hydel schemes (100 MW) at 22 km distance from NH 52 with catchment area 460 km^2, reservoir area 58 km^2 and available head 130 m. Detailed study of the project has been done by NEEPCO.
7 No flood, drainage congestion and erosion problem in this basin.

3.1.35 Burhi Dehing Basin - Master Plan,

Burhi Dehing river, south bank tributary of Brahmaputra river, is a combination of two main river namely Neo Dehing and Burhi Dehing. Neo Dehing river originates from Singpho hills near India - Mayanmar international border and northern range of Patkai hills in Arunachal Pradesh. Flood plain of basin lies in Tinsukia and Dibrugarh district of Assam and rest of the basin area is in hilly catchment of Tirap, Changlang, and Lohit district of Arunachal Pradesh. Catchment area is 8730 km^2. Geographical location of the basin is 26°46′ - 27°45′ N latitude and 94°42′ - 97°12′ E longitude. The tributaries of Neo Dehing river are Dirak (A-97 km^2) on left bank and Namdapha (A-651 km^2), Deban (A-183 km^2) and Sanglai (A-350 km^2)on right bank. Right bank tributaries of the Burhi Dehing are Sessa (A-350 km^2), Telpani (A-93 km^2), Tingrai (A-275 km^2), Tipling (A-100 km^2) and Digboi (A-200 km^2) and Disam (A-200 km^2), Namsang (A-380 km^2), Dirak (A-150 km^2), Tirap (A-1100 km^2), Namphuk (A-940 km^2) and Namchik (A-500 km^2) meet the river on its left bank.

Data Availability:

Rainfall - There are 21 stations in the basin for which data from 1971 to 1988 have been used in the study. These are Anandabag, Balijan, Borborwah, Bagapani, Chabua, Deohal, Dinjan, Hapajan, Jaipur, Khowang, Langkasi, Mohanbari, Mragarite, Mohadeobari, Namdeng, Namrup, Naharkatiya, Panguri, Phulbari, Romai and Wlton.

Studies:

1 Average annual rainfall (aar - 2421 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall (pre-monsoon 25.83%, monsoon 63.25%, post monsoon 6.8% and winter 4.12%)
4 1,2,3 days maximum rainfall in different years
5 Storm analysis.
6 Rainguage network design as per WMO guidelines.

Hydrological Data: The observation sites are at
1 Khowang 20 km u/s of the confluence of the river with Brahmaputra - GDS - since 1956
2 Naharkatia - GDS - since 1956. Data used in the study are for Khowang site for period 1956-93

Studies:

1 Flood hydrology and flood frequency (Gumbel distribution and Log Pearson type

III)
2 Maximum and minimum discharge,
3 Monthly and annual mean discharge
4 Silt load study (0.050 ha-m/km^2/year)
5 Annual, monthly and monsoon yield (average annual yield - 11906.93 MCM)
6 Flood, drainage congestion and erosion problem of the basin has been discussed in details. The drainage system of the entire upper Assam region was seriously disturbed after 1950 earthquake resulting in reduction of the conveyance capacity of the river channel. In the master plan, different measures have been suggested to tackle flood, drainage congestion and erosion problems.

3.1.36 Kopili-Lalang Basin - Master Plan,

Kopili-Kalang river system is a combination of two main river Kopili and Kalang. Kopili river originates from Barail range in North Cachar hills while the Kalang which is a spill channel of Brahmaputra originates from Brahmaputra at a place called Kalangmukh near Jakhalabandha. Both the rivers combined together at Hathiamukh (Jagibhakatgaon) in Morigaon district in Assam and then meets the Brahmaputra at kajalimukh. About 30 km u/s of Jagibhakatgaon, a cut channel called titamari joins the Kopili at Chaparmukh with the Kalang at Raha. The off take point of the Kalang at Kalangmukh was closed in 1964, since then the flow in Kalang is insignificant. However, during flood season, the Titamari channel carries a part of the Kopili flow in Kalang and hence a substantial flow is available in it d/s of Raha. The landuse pattern in the basin has been prepared by Assam Remote Sensing Centre based on Satellite imagery of 1993. Catchment area is 20068 km^2 (hill-15868 km^2 and plain-4200 km^2) located Assam and Meghalaya. Geographical location of the basin is 25°12′ - 26°34′ N latitude and 91°34′ - 93°40′ E longitude. The tributaries of Kopili river are Diyung and Jamuna on right bank Amring, Borpani-Lutumai and killing on right bank. The left bank tributaries of the Kalang river are Misa, Dizu and Haria-Nonoi and Digaru. There is no right bank tributary of Kalang river.

Data Availability:

Rainfall - There are 57 stations in the basin but data could be collected for 34 stations only for the period from 1971 to 1992 and have been used in the study. These are Amsoi, Borapani, Bakulia, Burigonga, Chapana, Kellyden, Diphu, Hojai, Hatimura, Jaijuri, Kharikhana, Kalibor, Kondoli, Kaki, Lumding, Loongsoong, Motiapahar, Nagaon, Rangamati (Silghat), Saluna, Sagunbahi, Tapatjuri, Udmari, Lengting, Kanpur, Kathiatoli, Kheroni, Dizoo valley, Dharamtul, Nilbagan, Na-pani and Rangagarh. For some of stations data are not available for some period.

Studies:

1 Average annual rainfall (aar - 1690.1 mm).
2 Average annual rainfall with sub catchment wise distribution
3 Seasonal distribution of rainfall (pre-monsoon 349.4, monsoon 1163.5, post monsoon 132.1 and winter 45.2mm)
4 Evaporation loss
5 Storm analysis.
6 Rainguage network design as per WMO guidelines.

Hydrological Data: The observation sites on the main stream and its important tributaries are:
Kopili river - Kheroni (G), Kalighat (G), Kamrup (G) and Dharamtul (GDS).
Kalang river - Silghat (G), Nagaon (G), Raha (G), Jagibhakatgaon (GD) and Kalangpar (G).
Killing - Auguri (G), Amlighat (G), Naldhara (G) and GKTE (GDS).
Haria- Borkola (GDS), Hariaghat (G) and Hariamukh (G).
Borpani- Madhapara (G), Baithalomgsu (G) and Basundhari (G).
Digaru- Sonapur (GDS), Nartup (G) and Kasutali (G).
Missa- Missa and NH crossing (GDS)
Dizu- Dizu NH crossing (GDS)
Nonoi- Tulasimukh (G)

Studies:

1 Flood hydrology and flood frequency (Gumbel distribution and Log Pearson type III)
2 Maximum and minimum discharge,
3 Monthly and annual mean discharge
4 Silt load study (0.011 ha-m/km^2/year)
5 Annual, monthly and monsoon yield (average annual yield - 9023 MCM)
6 Flood, drainage congestion and erosion problem of the basin has been discussed in details. The drainage system of the entire upper Assam region was seriously disturbed after 1950 earthquake resulting in reduction of the conveyance capacity of the river channel. In the master plan, different measures have been suggested to tackle flood, drainage congestion and erosion problems.

3.1.37 Puthimari Basin - Master Plan,

Puthimari river originates from Himalayan ranges in Bhutan near 25°12'' N latitude and 91°34' E longitude at an altitude of 3750 m above msl. The river is known as Oontang river and traverses 8 km from its origin at a gradient of 420 m/km and then gradient become mild 51 m/km in next 24 km stretch. For remaining 32 km gradient is 25.4 m/km upto foothills of Bhutan. In plain slope is mild 1.9 m/km and here river is known as Jia Barnadi. The river is named as Puthimari near Nagrijuli Tea Estate. The miidle portion of the river is braided and meandering, mostly embanked and bed slope ranges from 1:1100 - 1:6500. Then lower most portion of the river system is known as Lokhaitara and this reach passes through a number of beels, swamps with interconnections with Sessa river. This part may be treated as back water zone of Brahmaputra. Catchment area is 1787 km^2. Geographical location of the basin is 26°10' - 27°18' N latitude and 91°27' - 91°50' E longitude. The tributaries of the river are Sukla ans Sessa the left bank.

Data Availability:

Rainfall - There are 7 stations in the basin for which data had been collected for the period from 1977 to 1988 and have been used in the study. These are Magarjuli Tea Estate, Rangia, Hajo, Goibargaon, Mowkata, Goreswar and Kamalpur

Studies:

1. Average annual rainfall (aar - 1749.6 mm).
2. Dependable rainfall (75%and 90% dependable rainfall are 1123.1and 1042.7 mm respectively)Average annual rainfall with sub catchment wise distribution
3. 1,2,3 days maximum rainfall in different years
4. Seasonal distribution of rainfall (pre-monsoon 27.12%, monsoon 64.92%, post monsoon 5.86% and winter 2.1%)
5. Evaporation loss (based on Guwahati airport data)
6. Storm analysis.
7. Rainguage network design as per WMO guidelines.

Hydrological Data: The GDS observation site is at NH/railway bridge crossing and data is available for period 1958-93 (silt data from 1971-90).

Studies:

1 Flood hydrology and flood frequency (Gumbel distribution and Log Pearson type III)
2 Maximum and minimum discharge, (maximum recorded flood 1588.38 cumecs)
3 Monthly and annual mean discharge
4 Silt load study (0.072 ha-m/km^2/year)
5 Annual, monthly and monsoon yield (average annual yield - 4803.66 MCM)
6 Flood, drainage congestion and erosion problem of the basin has been discussed in details. The drainage system of the entire upper Assam region was seriously disturbed after 1950 earthquake resulting in reduction of the conveyance capacity of the river channel. In the master plan, different measures have been suggested to tackle flood, drainage congestion and erosion problems.

3.1.38 Disang Basin - Master Plan, 1996

The river originates in the patkai hill ranges in Tirap district of Arunachal Pradesh. River is Known as Tisa at its source and Disang or Dilli in middle reach and Disang in its lower reach. Basin is located in Assam, Arunachal Pradesh and Nagaland. Geographical location is between 26°36′20″ - 27°18′50″ N latitude and 94°34′35″ - 95°32′45″ E longitude. Catchment area is 3890 km^2 out of which 1938 km^2 (L-187.5 km), is in plain and remaining 1952 km^2 (L- 65.5 km) is in hills. The gradient of the river in different stretch are:

- Disangmukh to Akhaia Deodhai Gaon (64 km) - 1: 8162
- Akhaia Deodhai Gaon to Nahar Pukhuri (100 km) - 1: 4438
- Nahar Pukhuri to Dilli rail bridge (10 km) - 1: 1341

The river length is 61 km in Arunachal Pradesh, and 192 km in Assam. The tributaries of the river are Safari (L-71.12 km, A- 350 km^2), Taukok (L-85.1 km, A- 279 km^2), Tinan (L- 117.6 km, A- 170 km^2), Tiruju (L- 33 km, A- 199.4 km^2), Tewai (L- 27.5 km, A- 499 km^2) on the left bank and Balama (L- 28.8 km, A- 97 km^2), Dimau (L- 92 km, A- 390 km^2), Diroi (L- 77 km, A- 620 km^2) and Tarat (L- 37.5 km, A- 163.8 km^2) on right bank.

Data Availability:

Rainfall - There are 23 raingauge stations in the basin but data for only 20 raingauge stations could be collected. These are Dilli Tea Estate (1976-79), Borhat TE (1979-94), Barasali TE (1979-94), Namrup TE (1981-94), Umtara TE (1986-94), Mahkhoti TE (1981-94), Sepon TE (1970-94), Rajmai TE (1991-94), Rajabari TE (1981-94), Dekhari TE (1981-94), Domardalang TE (1981-94), Sonari TE (1980-94), Rajgarh TE (1981-94), Karangani TE (1981-94), Saffery TE (1980-94), Naphuk TE (1980-94), Krishnabehari TE (1981-94), Thowrah TE (1975-94), Longding (1991-95), Charaideo TE (data not available), Moran state dispensary (data not available), Mathurpur (data not available) and Pongcham (1990).

Studies:

1. Average annual rainfall (aar - 2562.3 mm).
2. Dependable rainfall (75%and 90% dependable rainfall are 1123.1and 1042.7 mm respectively)Average annual rainfall with sub catchment wise distribution
3. Storm analysis based on CWC report no. 1/73 revised
4. 1,2,3 days maximum rainfall in different years
5. Seasonal distribution of rainfall (pre-monsoon 24.24%, monsoon 62.97%, post monsoon 7.73% and winter 5.05%)
6. Temperature, relative humidity and evaporation loss (based on data at Mohanbari, maximum evaporation loss 130 mm during June and 59 mm during December)
7. Rainguage network design as per WMO guidelines.

Hydrological Data: The observation sites are:

1. Dillighat Station - G - since 15.5 1971 FCD & CWC.
2. Nangalamore - GDS - 7.7.1989 (D&S), FCD and 15.5.1971 (G) CWC.
3. NH Crossing (Rajabari) - GDS - FCD (discharge data-1965-88)
4. Akhoiphutia - G - FCD

Studies:

1. Flood hydrology and flood frequency (Gumbel distribution and Log Pearson type III)
2. Maximum and minimum discharge, (maximum and minimum observed discharge at Nangalamore 1069 and 5.30 cumecs respectively)
3. Monthly and annual mean discharge (annual mean discharge at Nangalamore 152.32 cumecs)
4. G & D curve
5. Silt load study (0.0228 ha-m/km^2/year)
6. Annual, monthly and monsoon yield (average annual yield - 4803.66 MCM)
7. Flood, drainage congestion and erosion problem of the basin has been discussed in details. Some of the salients features of study are:

   - Flood plain area - 1938 km^2
   - Flood plain area prone to 25 years return period - 656 km^2
   - Drainage congested area in Diman sub basin - 134 km^2
   - Drainage congested area in Dini sub basin - 134 km^2

- Ground water resources utilizable for irrigation is 1610.082 MCM
- Land use study done by Assam Remote Sensing Centre

3.1.39 Pagladiya Basin - Master Plan, 1996

Pagladiya river is one of the major tributary of Brahmaputra on its north bank. The river originates on southern slopes in hills of Bhutan at an altitude of 3000 m above msl. After traversing through the Bhutan territory it enters the Nalbari district of Assam near Chowki. It meets Brahmaputra near Lowpara village. Geographical location is between 26°36'20" - 27°18'50" N latitude and 94°34'35" - 95°32'45" E longitude. Catchment area is 1674 km^2 out of which 1251 km^2 is in India and remaining 423 km^2 is in Bhutan. The catchment area in hills are 465 km^2 (423 km^2 in Bhutan and 42 km^2 in India). The river length is 196.8 km out of which it flows from a length of 19 km in the hilly tracts of Bhutan and the rest 177.8 km in Nalbari district of Assam. The tributaries of the river are Mutunga (L- 30 km, A- 130 km^2), Dimla (L- 25.5 km, A- 48.75 km^2), Nona/Mutunga (L- 63 km, A- 268 km^2) and Chowlkhowa (L- 75 km, A- 538 km^2) on the left bank. Joha river (L- 28.8 km, A- 97 km^2) flows along the the right bank of the Pagladiya and outfalls in Brahmaputra independently as Baralia nadi and because of its small catchment it has been included in Pagladiya basin.

Data Availability:

Rainfall - There are 10 raingauge stations in the basin are Darrang (1975-94), Moneka TE (1988-94), Uttarkuchi (197-94), Gaibargaon (1975-94), Narjuli TE (1975-94), Kumarikata (1988-94), Masalpur (1975-94), Nalbari (1975-94), Rajabari TE (1981-94), Dekhari TE (1981-94), Domardalang TE (1981-94), Sonari TE (1980-94), Rangiya (1977-94) and Hajo(1975-94)

Studies:

1. Average annual rainfall (aar - 2317.6 mm).
2. Dependable rainfall (50%, 75% and 90% dependable rainfall are 2225.2,1789.3 and 1573.1 mm respectively)
3. Average annual rainfall with sub catchment wise distribution
4. Storm analysis based on CWC report no. 1/73 revised
5. 1,2,3 days maximum rainfall in different years
6. Seasonal distribution of rainfall (pre-monsoon 27.3%, monsoon 65%, post monsoon 5.4% and winter 2.3%)
7. Temperature, relative humidity and evaporation loss. Attempts have been to correlate the temperature with altitude in NE region of India by the analysis of data collected at 21 number of different stations at varying altitude spread in NE region.
8. Rainguage network design as per WMO guidelines.

Hydrological Data: The observation sites are:

1. At Talkuchi/Hahkata GDS - guage since 1970 and discharge 1968-94, silt since 1964.
2. NT road crossing - GDS - Gauge 1957-94 and discharge since 1957

3. Bijalighat - D - 1990-95
4. Goldighat- G - FCD

Studies:

1. Flood hydrology and flood frequency (Gumbel distribution and Log Pearson type III)
2. Maximum and minimum discharge, (maximum observed discharge at NT road crossing 1737 cumecs)
3. Monthly and annual mean discharge
4. G & D curve
5. Silt load study (at Talkuchi/Hahkata 0.017 ha-m/km^2/year and at NT road crossing 0.11 ha-m/km^2/year
6. Annual, monthly and monsoon yield (average annual yield - 4803.66 MCM)
7. Other studies like irrigation pisciculture, hydropower and navigation etc. There is a proposal for a multipurpose scheme.
8. Flood, drainage congestion and erosion problem of the basin has been discussed in details.

3.1.40 Manu Basin - Master Plan, 1997

Manu river system is a combination of two important rivers of North Tripura district namely Manu and Deo. It originates from the Kasalang reserved forest in between Sardeng Mura and Jampai ranges at an altitude of 387 m above msl. The river slope in hilly region is 1:255 and in plain 1:2250. The river predominantly flows in the northern direction and crossed the Indo-Bangladesh border near the town Kailashahar. The river traverse a length of 140 km in India and flows through the plains of Bangladesh for about 140 km. The river Manu outfalls into the Kushiyara, the southern channel of Barak river system at Manumukh in Bangladesh. Geographical location is between 26°36′20″ - 27°18′50″ N latitude and 94°34′35″ - 95°32′45″ E longitude. Catchment area is 2278 km^2. The tributaries of the river are Chhamanu chhara (L- 28.6 km, A- 132 km^2) and Kathal Chhara (L-10.5 km, A- 27 km^2) on the left bank. Deo river (L- 107 km, A- 908 km^2), Mandhal Chhara (L-16.7 km, A- 62 km^2), Rwahart Chhara (L-17.9 km, A- 46 km^2), Chailengtha Chhara (L-26.5 km, A- 94 km^2), Kanan Chhara (L-12.8 km, A- 58 km^2) and Laxmi Chhara (L-19.3 km, A- 54 km^2) meet the river on its left bank.

Data Availability:

Rainfall - The 3 raingauge stations managed by State Agriculture Department, Tripura, are Kailashahar, inside basin (1975-95), Dharamnagar, adjacent basin (1975-95) and Kamalpur, adjacent basin (1975-95)

Studies:

1. Average annual rainfall (aar - 2540.46 mm).
2. Average annual rainfall with sub catchment wise distribution
3. Storm analysis based on CWC report no. 1/73 revised
4. 1,2,3 days maximum rainfall in different years
5. Seasonal distribution of rainfall (pre-monsoon 33.87%, monsoon 55.65%, post

monsoon 8.02% and winter 2.46%)

6. Temperature, relative humidity and evaporation loss (based on data collected at Agartala airport, PET 1314 mm, AET 1171, Water Surplus 1205 mm).
7. Rainguage network design as per WMO guidelines.

Hydrological Data: The observation sites are:

1. Kailashahar - GDS - CWC - 1983-95, silt since 1991 onwards
2. Kumarghat - GD - State Government, 1968-95
3. Nalkata - GD - State Government, intermittent
4. Manu Bazar - G - State Government, 1987-95

Studies:

1. Flood hydrology and flood frequency (Gumbel distribution and Log Pearson type III)
2. Maximum and minimum discharge, (maximum observed discharge at Kailashahar 1633.49 and at Kumarghat 32.97 cumecs)
3. Monthly and annual mean discharge
4. G & D curve
5. Silt load study (at Kailashahar 0.022 ha-m/km^2/year)
6. Annual, monthly and monsoon yield (average annual yield at Kailashahar-2472.8 MCM)
7. Other studies like irrigation pisciculture, hydropower and navigation etc. There is a proposal for a multipurpose scheme.
8. Flood, drainage congestion and erosion problem of the basin has been discussed in details.

3.1.41 Master Plan of Brahmaputra river - Main Stream, 1986

The Dihang river travels about 52 km from Pashighat before two major rivers namely the Dibang and Lohit join it opposite Kobo located in its west River is known as Tsangpo in Tibet, the Siang or Dihang in Arunachal Pradesh and Jamuna in Bangladesh. The river length is 2906 km out of which 1625 km is in Tibet, 918 km in India and remaining 363 km in Bangladesh. It drains an area of 580000 km^2 above its confience with Ganges near Goalundo in Bangladesh. The catchment within Tibet - 293000 km^2, India - 195000 km^2, Bhutan - km^2, and Bangladesh - 47000 km^2. The state wise distribution of the catchment in India is 81424 km^2 in Arunachal Pradesh, 70634 km^2 in Assam, 10803 km^2 in Nagaland, 11667 km^2 is in Meghalaya, 7300 km^2 in Sikkim and 12585 km^2 in West Bengal. Basin has a maximum east west length of about 1540 km and a maximum north south width of about 682 km along longitude 93° E. Upper portion of the basin lying in Tibet (China) mostly in narrow valleys in mountain range , in Bhutan, Sikkim, Arunachal Pradesh, Nagaland and Meghalaya in hills and in Assam and West Bengal in hills, forest, tea gardens and fertile plains. In Bangladesh, the catchment is lying in fertile plains and delta areas.

The gradient of the river within Tibet reach is 1:385, between Indo-China border and Kobo in India is 1:515, Kobo and Dhubri is 1:6990 and within Bangladesh is, for 1st 60 km from India border 1:11340, next 106 km stretch 1:12360, next 92 km 1:27200 and next 105 km 1:37700.

The north bank tributaries (20 nos.)of the Brahmaputra river are The Simen,

Jiya Dhol, Subansiri, Burai, Bargang, Jia Bharali Gabharu, Belsiri, Dhansiri, Noa Nadi, Nanai Nadi, Bar Nadi, Puthimari, Pagladiya, Beki, Manas, Champamati, Gaurang, Tipkai and Sankhos. On north of the Brahmaputra rainfall is heavier and the hills are less stable and more liable to soil erosion and land slides, therefore north bank tributaries carry large silt discharge. The Brahmaputra river is closer to the hills on the southern side as if the river has been pushed southward over the geological period by the more numerous and heavier silt carrying north bank tributaries. Characteristic of north bank tributaries:

1. Have steep slopes and shallow braided channels for a considerable distance from the foothills and in some cases right upto the outfall.
2. Have boulder, pebble and course sandy bed and carry a heavy silt load.
3. Generally have flashy floods.

South bank tributaries are (13 nos.) Dibru, Burhi Dehing, Disang, Dikhu, Jhanji, Dhansiri, Kopili, Kulsi, Deosila, Dudhnai, Krishnai, Jinari and Jinjiram. The characteristics of south bank tributaries are:

1. Have comparatively flatter grades and deep meandering channels almost from the foothills.
2. Have beds and banks composed of fine fine alluvial soil.
3. Have comparatively low silt charge.

Drainage Congestion Problem

Brahmaputra valley receives water the surrounding hills of Arunachal Pradesh, Nagaland and Meghalaya through numerous tributaries, large and small. The rainfall is high being of the order of 2800 mm per annum in Arunachal Pradesh and over 2000 mm in Nagaland and Meghalaya. The rainfall in the plain is also high ranging from 1100 mm in the rain shadow area near Lanka to 2125 mm in Kamrup district. It is during monsoon season, June to September, that most of drainage problem arises as the shallow tributaries not only contributes to floods in the Brahmaputra but also overspills their banks flooding the country side already drenched with rainwater. The high stage in Brahmaputra creats drainage congestion at the outfall of tributaries leading to prolonged inundation of the countryside. During the rainy season, the tributaries bring substantial quantity of silt, most of which is carried to Brahmaputra. When silt laden water in the tributaries overspill the banks, the heavier fraction in the silt are dropped near the banks, thus progressively raising the banks above countryside. The spill water flows farther on the low lying hinterland. Over a period of time, a depression is formed between two adjacent tributaries and a drainage line develops to carry the spill water of the tributaries and the surplus local rainwater. This drainage line also suffers from congestion near its outfall during high stage of the receiving tributaries of Brahmaputra.

Large scale inundation during the rainy season in the valley is a recurring feature. The silty spill water from the tributaries, however, contributed to land building and to some extent to fertility of land. But prolonged submergence of arable land adversely affected the land use and called for steps to minimise the duration and depth of inundation. The difficulty got aggravated in lower Assam after earthquake of 1897 and in upper Assam after earthquake of 1947 and 1950, when the regime of Brahmaputra and most of the tributaries was upset raising bed level and

consequently flood heights, change in their course and an abnormal increase in silt charge.

Cause

Natural Cause:

1. High precipitation in basin and 85% of it in monsoon season (during May to October)
2. Steep hill slopes of Arunachal Pradesh, Nagaland and Meghalaya,
3. Excessive silt load,
4. High stage of Brahmaputra over a long period during rainy season causing congestion at outfall of tributaries; it obstructs free discharge of tributaries and its water backs up into tributaries to a distance of 8 to 10 km causing inundation of large areas near the outfall.
5. Water hyacinth which hampers drainage of land (this is a pernicious weed widely infects pods, bils, drains, streams and all other places where there is a accumulation of water in Brahmaputra valley.

Man Made Cause:

1. Construction of railways and roads,
2. Building of embankments,
3. Building of private bunds,
4. Obstruction put in drains and
5. Encroachments on waterway of drains.

The actual area submerged in any year depends upon the maximum flood level in Brahmaputra during the year and duration of its high stage. The extent of submerged area is under two categories; flooding of large areas near the outfall of tributaries and flooding of local depression in valleys called bils. The main drainage congested area lies between Brahmaputra and two National Highway which run along it on the north and south of river. The belt of congested area is about 5 km wide on either side. The worst affected area are located on the u/s side of the outfalls of the tributaries where pockets are formed between the main river and the tributaries and which under the prevailing condition do not lend themselves to a feasible drainage arrangements. The condition on the d/s side are different as the accumulated water there can be carried away through a drain behind the main embankment or by diversion of a natural drainage channel to another channel. The details of the basin wise drainage congested area along the main stream are given below:

Tributary	Locality	Area affected (km^2)
South Bank		
Burhi Dehing	Laura, Jamira and Sessa	300
	Demow	226
	Deroi	86
Dikhu	Konwarpur	112
	Namdang	10

Tributary	Locality	Area affected (km^2)
Jhanji	Jokaisuk	100
Bhogdoi	Gelabil	5
Kalang	Sonai Basin	300
Kulsi	Rangapai	147
North Bank		
Sisi	Bhereki Bil	96
Subansiri	Zengrai Ratanpur	134
Ranganadi	Pakamia	16
Dikrang (Phoba)	Sispathar	12
Dikarang (Solengi)	Mora Pichalamukh	8
Ghiladhari	Panpur	144
Nanoi	Sipajhar and Rainakuchi	62
Puthimari	Sessa	59
Pagladiya	Barbhag	56
Pahumara	Barpeta	180
Beki Manas	West of Barpeta	

3.1.42 Report on the Erosion Problem of Majuli Island, 1997

Majuli, the largest river island in the world, is situated in the upper reaches of the river Brahmaputra between chainage 435 and 520 km from Indo-Bangladesh border. The island extends for a length of about 80 km east to west and about 10 to 15 km along north south direction. It lies between latitude 2645 N to 2710 N and longitude 9340 E to 9435 E. It covers and area of about 875 km^2. The revenue records shows that the area of the island during 1950 was 1246 km^2. The island is bounded by the river Subansiri on north-west, the Kherkatia-Suti (a spill channel of Brahmaputra) on north east and main river Brahmaputra on south and south-west. The average height of the island varies from 85 to 95 m above mean sea level. The existence of Majuli is threatened by severe bank erosion and flood inundation. The southern sore of island along the main Brahmaputra river is worst effected. The Brahmaputra Board invited a team of experts for inspecting the main erosion spots in the island, investigating causes of erosion, making presentation and discussions, drawing short, medium and long term measures to effectively combat erosion in a systematic manner. The team comprises of professionals in hydrology, river mechanics, geomorphology, hydraulics and mathematical modelling, flood management and soil conservation etc. participated in exercise. The general view of the expert was that the river being a dynamic entity, its behaviour can not be predicted with certainty. The team deliberated the following issues to be taken up for scientific studies of the problem:

1. Acquisition of data; geographical data, hydromet data,geomorphological studies etc.
2. Hydraulic modelling; Physical model studies, part-width models, mathematical modelling etc.

The protection measures like anti erosion work and embankment reconstruction has been divided into short term, medium term and long term measures. The vulnerable sites for each type of measures and special engineering structures suitable for it has also been suggested.

4.0 IRRIGATION STUDIES

4.1 Studies carried out in Assam Engineering College, Guwahati

4.1.1 A Critical Review of the Irrigation System in Assam

In this work an attempt has been made to give a physiographic account of the state of Assam, its water resources, land use pattern, the existing agricultural practices etc. and to present the following analysis of the existing Irrigation system in the state:

1. A picture of both the completed and on going irrigation Schemes of the state along with an analysis of the level of utilisation of the created potentials.
2. A comparative study of the development of Irrigation in other states of the country. Vis-a-vis the development in the state of Assam and
3. The comparative study of the efficiency of scheme of different categories like FIS., LIS, DTWI and STWI schemes.

4.1.2 Investigations on Crop Water Requirements For Humid Water Sheds in North Eastern Region

Investigation is aimed for determining water requirements and irrigation needs of crops, for humid watersheds in North Eastern Region. Studies have been made using four methods to estimate the reference crop evapotranspiration using a Computer Program. Modified Penman method is found to be more realistic. Effective rainfall is computed using Dastane's Method. Crop evapotranspiration for five crops grown in the region viz. Paddy (Boro), Paddy (Amam), Sugarcane, Cotton, Maize and Potato have been computed. Using the effective rainfall and computed crop evapotranspiration, irrigation requirements for the above mentioned crops for various development stages have been computed.

4.1.3 Design of Sprinkler Irrigation System For Bishnupur Tea Garden Area of Sapekhati, Sibsagar

Sprinkler Irrigation can be used for almost all crops and for most soil. This method is becoming increasingly popular in India in regions of water scarcity where available water is insufficient to irrigate the command area by surface irrigation. Sprinklers also being increasingly used for irrigating high valued plantation crops.

The existing sprinkler systems in different tea gardens of Assam are not based on the climatological and soil investigations. So, an attempt has been made on the design of an optimal sprinkler irrigation system considering the climatic behaviors and soil texture.

Data regarding rainfall, humidity and mind velocity have been collected from Bishnupur tea garden and other climatological data have been assembled from Zoklai Experimentation station, Jorhat. The soil character has been examined and evapotranspiration of tea crops has been calculated with the help of climatological data of the concerned garden. Then, sprinkler irrigation system has been designed for two plots of Brihnupur Tea garden area.

4.1.4 A Study on Design of Sprinkler Irrigation System for Tea Gardens of

Assam (A Case Study of Monabarie Tea Estate)

An attempted has been made on the design of an optimal sprinkler irrigation system considering the climatic behaviour and soil texture. Data regarding rainfall, humidity & wind velocity has been collected from Monabarie tea estate along with the soil samples and the soil character has been examined. The evapotranspiration of tea crops has been calculated with the help of climatological data of the garden as per their garden records and then a sprinkler irrigation system has been designed for Behupukri division of Monabarie tea estate.

4.2 Studies carried by Central Water Commission

4.2.1 Tsurang Irrigation Project, Nagaland, 1997.

The project is a runoff the river scheme over river Tsurang , a tributary of Brahmaputra river in the Mokakchung district of Nagaland. The river length in Nagaland is 90 km and flows 40 km in Assam in the name of Bhogdoi (also known as Disai in Assam). The Barrage site is located at the latitude of 26°28'14"N and longitude 94°21'02" E. The catchment area is 326 sq.km.

Hydrology:

Average annual rainfall		1854mm
Average annual evaporation		1290mm
Temperature	1	2-32 °C
Annual yield at 50% dependability		356 M cum
75% dependability		255 M cum
90% dependability		218 M cum
Maximum yield		499 M cum
Minimum yield		129 M cum

Flood:

50 year return flood	1026 cumecs
100 year return flood	1134 cumecs (design flood)
SPF	1132 cumecs

Barrage:

Submergence area	1.95 sq.km (EL-153m)
Reservoir capacity	4.9 M cum (EL-153m)

Irrigation:

Gross command area	1755 ha
Culturable command area	1500 ha (85.7% of GCA)
Net irrigable area	1350 ha (90% of CCA)
Gross irrigable area	1878 ha

Data Availability:

Category	Period	Station	Source
Gauge	July 90-Dec 93	GDS 4.65km d/s of barrage site.	CWC
	Aug 71-Jun 88 Jan 89- Jul 89 Oct 89- Dec 93	AT Road crossing site d/s of barrage	Brahmaputra Board
Discharge	July 90-Dec 93 Aug 71-Jun 88 Jan 89- Jul 89	GDS 4.65km d/s of barrage site. AT Road crossing site d/s of barrage	CWC Brahmaputra Board
Sediment	Sept 90- Oct 93	GDS site 4.65km u/s fo barrage	CWC
Rainfall	July 90-Jun 93 1970-80 1974-88 1971-88	GDS site 4.65km u/s fo barrage Tocklai Hunwal Sycotta	CWC Brahmaputra Board Brahmaputra Board Brahmaputra Board

4.2.2 Tenuyiphe Land Leveling cum Irrigation Development, Dhipu River Command Area, Nagaland

The objective of the project is to develop irrigation potential by trapping the surplus runoff from Diphu river at the existing diversion weir near Chamukedima village. The catchment area of 1730 ha is laying between 25°45′ - 25°49′ N latitude and 93°43′ - 93°49′ E longitude. The area comprises of foothills mainly dissected by gullies adjacent to the hills. Topography is gentle and sloppy. Slope varies from 0 -4 % in the entire command area.Average temperature in the catchment is 22.5 C while maximum and minimum is 36 C and 9 C respectively. Average annual rainfall at Dimapur is 1600 mm while state average is 2307 mm. Number of rainy days is about 105-110 days. 80% of the rainfall occurs during May to November. December to April is generally dry.

Irrigation - The following measures have been suggested for irrigation:

- Renovation of existing weir in Diphu,
- Construction of headwork for diverting water from Diphu area towards project area,
- Construction of main channel from headwork to command area,
- Construction of distributaries,
- Necessary drop structures according to topographic condition and cross drainage woks etc.

Supplementary irrigation by lift irrigation has also been proposed. CGWB has prepared techno feasibility report in Dimapur Sugermill area 3 km away from the project area during September 1978. Water table is available 3-4 m below ground level. It has been suggested that a open well of 3 m dia fitted with motor and pumpset will be sufficient for 2 ha of land.

4.3 Studies carried out by Irrigation Department, Assam

4.3.1 Puthimari Irrigation Scheme.

The river Puthimari is one of the north bank tributories of the Brahmaputra. This river originates from the foot hills of Bhutan. The river Puthimari flows in southern direction. After crossing the N.F. Railway line and NH - 31 near Puthimari village, the river flows in the south-west direction for a length of about 16 miles . Then it joins the Brahmaputra river near leopara. The region lying on the southern side beyond the foot hill area is quite high and has comparatively steeper gradient. As such the rain water drains out quickly through the natural drainage and the present rain fed crops in this vast area cannot derive expected benefit from the rain water. Moreover, the rainfall is erratic and so the crops cannot get timely requirement of water from the rainfall. Also, the crops suffer from occasional drought . Therefore, this irrigation project has been proposed to extend irrigation facilities to a gross area of 50,375 Acres better agricultural production and to improve the economic condition of the poor people of the locality. Design discharge has been calculated using Dicknnel formula.

Data Availability: There is discharge data collection at N.H.Grossing since 1966; while at the H.W. Site which is about 40 km. U/S , (H.W. the is a flood forecasting centre of C.W.C).,where we can have W.L. since 1972 during flood time , So, after drawing stage discharge curve at Ok-aldonga site , dischage has been determined the with the available W.L. at the peak period. The availability calculation has been made with the discharge records so obtained for the flood time while the lean period discharge is considered at N.H. crossing. The discharge has been calculated by Gumbel's method as modified, by Ventochow and Regional flood frequency study. Moreover, the discharge is checked by applying unit hydro graph method in which the isoleytes are considered as published by the IMD.

Soil Survey Report of commended area of Puthimari Irrigation Project - The Soils are : Piedmont zone : - 80% of the soils of the piedomont zone belong to the various families of Typic Udorthents, out of which members of coarse and fine loamy families of Typic Udorthents, are predominant followed by coarse loamy over sandy and fine loamy over sandy through contrasting particle size class families . There are other intrusions in families level mostly belonging to strongly contrasting particle size classes but they are very minor with isolated occurrence. Other associated soils belong to various family and subgroup of the great group Hapludalfs and Udipsmments. The Soil of the pidomont zone are moderately to strongly acidic, deep, well drained with moderately rapid permeability. Soluble salts in soil is very low and there is no salt hazard . The soil occur on gently sloping uplands (1-3%) which are slight to moderately eroded.

4.3.2 Rupahi Irrigation Scheme (Medium), 1996

The Irrigation scheme is envised with a view to bring under irrigation a vast area of the North Kamrup Rangia (Now under Barpeta District). It has been proposed to construct a weir across the river Rupahi near Bhuyapara. The gross commanded area of the scheme is 3992 ha and the net commanded area in 3552 Ha. The annual Irrigation area is 5668 ha. The catchment area of the river upto head works is 78.40

sq. mile and the weir is designed for flow discharge of 25000 cusec at the same time keeping a provision for clearing a super flood of 30,000 cusec by providing sufficient free board. The main canal taken off from the right bank of the river is about 670M in length.

4.3.3 Rupahi Irrigation Scheme (Medium)

The river Rupahi is a perennial channel which originates from Himalayan foot hills of Bhutan between elevation 100-1500 m and flow towards south direction and it joints the river Pahumara in Kamrup (now Barpeta) district of Assam. The river Rupahi contributes about 1/4th of the discharge of the river Pahumara. Like most of the river on the northern bank of the Brahmaputra, the river has wide and shallow channels with a step bed grade immediately from the foot hills and extends for a considerable length before entering in the lower plains where is meandered and flows down with a flowing bed grade. In the central region the river is shallow and the bed consists of small pebbles.

Data availability - G.D.Site - Discharge data of Rupahi river near Head works site is available from the year January,1972. G.D. site is at the N.H. crossing at about 15 miles downstream of the proposed head work site and between these two sites a bigger stream named Pahumara has joined the river Rupahi. From the available discharge of Rupahi river, it is seen that it contributes 25% of the combined discharge at N.H. crossing assuming that the discharge is combined discharge of Rupahi and Pahumara at N.H. crossing. For some of the months discharge data of Pahumara are not available. In that period discharge has been calculated by taking average of the data for their preceding and succeeding years of data of the months. The maximum discharge of the Head work is taken as 20,000.00 cusecs.

Rain fall:- The raingauge station of the Rupahighat of Rupahi river is established in June 1973. Dumni tea estate raingauge station is the nearest raingauge station from the Head work site of the Rupahi Irrigation scheme.

4.3.4 Regional Jiri Irrigation Project, 1997

(Study Carried out by Irrigation and Flood Control Department, Manipur)

To harness the available inflow of the Jiri river at or near about Leingangpokpi at Jiribam this irrigation scheme has been conceived at the initiative of North Eastern Council. The total annual irrigation potential created under the project is of the order of 9,775 ha. The basin area of 755 km^2 is bounded by 24°49′23″ to 25°15′23″ N latitude and 93°10′16″ to 93°28′26″ E longitude. The length of the river from origin upto confluence with barak river is138 km while upto barrage site it is 109 km. Weighted mean slope of river is 0.000621. Mean annual rainfall in the basin is 1720 mm.

Data availability - Actual hydro-meteorological data collection for the jiri river has been started since 1981 and continued till today. However, the yield of the Jiri River Basin with respect to the proposed site of the irrigation diversion structure has been made according to the observed gauge and discharge records maintained at the site for the period from 1981-86. The observed rainfall records at Jirighat Tea Estate outside the catchment, 4.40 km from the proposed site (1968 to 1986) and Leingangpokpi (1981-1986) have been extensively used. To derive a Mathematica

model to correlate between the rainfall and runoff for the Jiri basin with respect to the proposed diversion structure, the rainfall at Leingangpokpi, is however first linearly extended from the rainfalls at Jirighat tea Estate for the remaining period up to 1980. With the so generated rainfalls, the curvilinear relationship between the runoff and rainfall, applicable to the basin was established and it comes to be

$$R = 0.0008828xP^{2.120436}$$

where R. and P are respectively the runoff and rainfall in cm. The relationship is statistically acceptable as the co-efficient of the corelation is 0.958. With this extended data the yield of the Jiri river is generated for the same period up to 1980. Using the above relationship the yield series applicable for this project for a period of 19 years from the jiri river is 75,078.471 ha-m and whereas the 90% and 100% yeilds are 49,777 and 33,687 ha-m respectively. For the purpose of considering the safety of the diversion structure to be erected on the Jiri River the design flood discharge for 100 years return period had been evaluated from the unit hydrograph method and its value has been work out to 2580 Cumecs.

4.3.5 Dekadong Irrigation Scheme (Medium), 1985

Original project report has been prepared considering the discharge data at Head Work for a period from 1967 to 1973. In the revised project report the data for the period from 1967 to 1983 were considered. During this period data were not continuous and there were some missing period Viz.1967, 74,75 and the part of 83. Now entire data from 1967 to 1983 has been considered in the project report. The computation of discharge for the missing period as mentioned above are worked out from rainfall run off relationship.

Silent feature of the work:-
G.C.A. = 5603 Hect.
C.C.A. = 4941 Hect.
Type of dam = Head Work (Barrage)
No. of river sluice = 13 No.
Capacity of sluices = 26.14 Cumecs.
Irrigation outlet = 180 No.
Commanding outlet = 720 No.
H.F.L.72.40 M = 70.00 (Computed)

Water is proposed to be utilized for irrigation only. There is no storage normal seepage loss in canal considered. Estimated design discharge based on partial duration method is 340 Cumecs.

Soil Survey of Command Area - Dekadong command lies in the Brahmaputra basin and the soil formation is allumial deposit of recent origin. The proposed crop pattern of Dekadong Irrigation project has been based on the preliminary reconnaissance survey carried out by state Agricultural Department. The soil have been classified into five groups.

Group A - Silty loam to silty clay loam.

Group B - Loamy sand clay loam.
Group C - Loam to sandy clay loam.
Group D - Fine sand to clay loam.
Group E - Loamy sand to sandly loam.

The slope is gentle and has been natural drainage as sub water logging problem is very loss.

4.3.6 Burisuti Irrigation Project (Medium), 1991

The river Manas Burisuti is major north bank of Brahmaputra tributaries. The catchment area of Burisuti is 200 km^2 upto the proposed head work site at panbari. The command area of the scheme extends on both bank of river of the Burisuti. The entire command area is bounded by latitude 26°37'- and 26°30' and longitude 90°45' and 90°53'. The object of the project is to supplying controlled water to a vast cultivable area in the Kokrajhar district and soma of the neglected villages bordering Barpeta and Kokrajhar district and to improve the existing cropping pattern and also to ensure irrigation to the field against vagaries of rainfall.

The catchment area of the river upto thr proposed head work site is 200 km^2, a portion of which falls in Bhutan territory. `The average annual rainfall in the command area is of order of 277 cm. But the distribution of rainfall is not uniform. The location of the gauge-discharge site is just at d/s confluence of Gobardhana and Burisuti. Yearly peak discharge of the river Burisuti is obtained from the available gauge and discharge data from the year 1971 to 1986. From this gauge and discharge data "stage-discharge curve" is plotted and corresponding to the maximum probable flood (as determined by the various methods of design flood estimated) high flood level is determined at discharge site. The maximum discharge so far observed is 294.29 Cumecs in 1972.

The maximum discharge is calculated by various method of design flood estimated namely i) Unit Hydrograph method ii) The various empirial formula iii) Gumbel's method of flood frequency analysis iv) Ven-Te-Chow's method of parstal modification v) Modified method of Gumbel's flood frequency analysis i.c. Regional flood frequency ethod.

However, the maximum discharge of obtained by unit hydrograph method is considered for designing the head works which is worked out to be 1550 Cumecs for 100 years flood.

4.3.7 Doyang Irrigation Project (Major)

The Doyang river is the largest tributary of river Dhansiri, a major tributary of river Brahmaputra. The catchment area of Doyang is 1699:88 $Mile^2$ upto the proposed head work site at Kachamari. The commanded area of the scheme is on the right bank of river Doyang and falls under Golaghat and Jorhat District. An area of 2100 ha will be commanded in the left bank under Golaghat District. The entire commanded area is bounded by latitude 26°22' and 26°33' and longitude 93°55' and 94°10'. The river rises near Mao-thana in Nagaland and flows a northeastern course for 45 miles when it abruptly turns to the northwest and passes the main ranges of hills. After flowing for 12 miles in this direction it again turns at right angle and flows for 20 miles in southwest direction and again turns sharply to the northwest. After emerging from hills, it receives the largest tributary, the Rengma. Beyond this confluence, the river more or less flows in a northerly direction and

ultimately joins the river Dhansiri at Doyangmukh about 8 miles upstream of Golaghat Town. The Doyang receives all the drainage from the main ranges of hills between Rengma & Wokha while its tributory, the Bagti, a stream of about 25 miles in length, drains the valley between the inner and outer range of hills between Dhansiri and Sonigaon. As per observation, maximum & minimum discharge of river Doyang as available at P.W.D. cold weather bridge at Jamuguri about 9.00 km downstream of proposed H/W site are given below :-

Maximum observed	113.60 Cumecs in July'1980
Mimimum observed	7.297Cumces in Feb'80

Calculation of flood discharge

- Dickon's Formula - 3,032.63 Cumecs
- Ryve's Formula - 2,665.60 Cumecs
- Max . Observed discharge at cold weather bridge at Jamugurihat about 12 K.M. D/S of proposed H/W site - 3,145.0 Cumecs, therefore, Super flood = 1.2 x 3,I145 = 3,774 Cumecs, say = 3,775 Cumecs, which has been taken as design discharge.

4.3.8 Garufella Irrigation Project(medium)

The source of the river is the foot hills of Bhutan consisting of main stream Pakua and Jakati. The stream Pakua originating from Danese and Deoralian peak of Bhutan hills flows towards south direction through the forest and meets the stream Jakati orginating from Salikhar peak of Bhutan hills and traversing about 22 km from the Indo-Bhutan boundary. The river is named Garufella after the confluence point of river Pakua and Jakati. The length of Garufella river is about 25 km from its origin to the proposed head work site. The width of the river at head work site is about 70 m. The catchment area of the river is about 277 km^2 from its source up to the proposed head work site.

The command area falls within Kokarajhar district located in the west of Assam state. The entire area lies within the Brahmaputra valley. The gross command area of the project is 7950 ha, cultivable command area is 7130 ha and net Irrigated area will be 6200 ha.

The head works site has been proposed about 3.5 km up stream of lateral road crossing. The location of the gauge-discharge site is in between the proposed head work site and lateral road crossing. Yearly peak discharge of the river has been obtained from the available gauge and discharge data from the year 1971 to 1987. From this gauge and discharge data rating curve has been plotted and high flood level is determined at discharge site. The maximum discharge obtained by regional flood frequency analysis is considered for designing the H/W which is work cut to be 1424 Cumecs for 100 years flood frequency.

4.3.9 Simen Irrigation Project (Medium), 1990

The catchment area of the river Simen upto proposed head work site is calculated to be 662.673 km^2 and most of the portion falls in Arunachal Pradesh. The

Simenmukh region, the confluence point of the three tributaries is hardly 5km from the railway bridge and is just at the foot hills. The river runs in the Arunachal Pradesh in there different directions i.e. to-wards south, south east and south west takes a direct direction towards south when it enters the plains of Assam. The river Simen received discharge from the catchment of the Himalayan ranges, in between the rivers Demow on the west, Dikhari on the east.

As per observation maximum and minimum discharge of the river Simen at the proposed head work site is given below -

- Maximum observed : 3700 cumec on 15/9/84
- Minimum observed : 8.03 cumec on 2/2/87

For the recast project report, the design flood is arrived at on the basis of the calculation for 100 year peak flood which is the highest and stands at 4690 Cumecs and it is worked out as per CWC guidelines. The Head Works axis is fixed at a distance of 800m down stream of permanent Railway bridge over river simen and 400 m down stream of RCC bridge on NH-52.

4.3.10 Borolia Irrigation Scheme (Medium), 1978.

River Borolia is one of the north bank tributaries at the Brahmaputra. The river originates from the subsoil water near Negrijuli TE, flowing for a distance of about five miles it meets another stream named Balti. The stream Balti originates from the foothill of Bhutan. The stream practically dries up in the winter. The river Borolia after it originates for sub soil water, flows in south western direction for a length of about 15 miles and then flows towards south. It crossed the N.F.Railway line and N.H.31 at about 25th and 26th miles of its course respectively. The river is then flows south western direction and out falls into the river Pagladiya near Bijulighat (Dosoutimukh). The river Borolia is found to be a stable one and there is no sign of decaying it. The river is a very ancient one. There is specially mentioned in the Rigveda about this river and the river goes by the name "Ballava". The stream has a continuous flow all throughout the year. The catchment area is about 46.4 mile^2 and this is between the longitude 91° 25′ and 91° 40′ E and it is between the latitude 26° 37′30″ and 26° 40′30″ N.

The project aims at supply of controlled water from the west area of the North Kamrup region for coping with the watering needs of the crops. It will further serve as a protection against occasional drought and will also promote double cropping which otherwise could not be carried out . It is proposed to construct a weir across the river Borolia near Pub-Kachukata village to tap about 500 Cusecs of water for irrigation purpose. The gross command area of the scheme will be 31,400 acres while net irrigation area will be 22,000 acres and CCA will be 24,000 acres.

The discharge data of the river Borolia at proposed head work site at Pub-Kachukata is available from the year 1971 onwards. The discharge data of the river at NH crossing near Rangia which is about 15 mile d/s of the proposed headwork site is available from the year 1966. For the purpose of calculating the water availability , the discharge at Pub-Kachukata has been considered.

The design discharge of the head work is taken as 657.00 Cumecs considering once in a hundred years. But a provision of 850 Cumecs is being made for supper flood. The design discharge is calculated by Gumbel's method and modified by Van-Te-Chow method.

The rainfall in the command area is not uniform. The maximum precipitation

occurs during monsoon period from May to October. Again within the monsoon period from the south west monsoon is sometimes delayed considerably affecting the sowing of Kharif crops and again it so terminates much earlier causing damage to kharif crops and also made the showing of Rabi crops difficult or uncertain. The raingauge data are collected from the neighbouring Raingauge station of Nagrijuli TE and Rangia IB, P.W.D.

4.3.11 Kollonga Irrigation Scheme

This region extendes from the South eastern Hill tracts of Karbi Anglong towards North West on the left bank of river Kollonga and cast on the right bank covered by dry alluvial area of almost regular grade. The general ground along is from North East to Western side of the area . The area includes some portion of Rongkhang Reserve forest where cultivation has already been started by tribal people has also been included in the commanded area.

The original H/W was designed for a maximum discharge of 110 Cumecs on the basis of previous discharge records of Kollonga river. But the highest flood had occurred in the month of May/88 causing damage to the guide bund etc. of the existing H/W . The observed discharge on the date of occurrence of flood was 708 Cumecs. Now it is proposed to extend the H/W with design discharge of 800 Cumecs.

The Kollonga is a perennial river in the area of the proposed scheme. It originates from the south western tracts of the Karbi Anglong at an altitude of about 427m and flows down towards north along the boundary of Rongkhong Reserve forest and passes into plain area. The R.L. of foot hills is 91.5 m and finally joins the River Kapili at Kollonga Mukh. The river Kapili is a major tributary to the river Brahmaputra in the south bank.

The catchment area of the river Kollonga upto the proposed H/W site is 150 km^2 and is rainfed during monsoon and the lean discharge is comparatively low. There is no raingage station either within the catchment area. The rain fall data is collected from 1969 at a place named Donkamokam 2.56 km away from the boundary of the commanded area on the north west side. The Dist. of rainfall is also observed un-uniform during the year. The rainfall during the winter season is being considered to be negligible. The average annual intensity of rainfall is also appears to be much lower than that of the average annual intensity of rainfall in other districts. Of the state of Assam although the rainfall is low 75% chances of occurrence on 10 days basis has been considered from the daily rain gauge date collected at Donkamokam raingage station from 1969 to 1973. The daily discharge data near the proposed Head Works site have been collected from the year 1962. The available discharge on 75% dependable availability on 10 days basis has been considered from the discharge data for the year 1962 to 1974. The minimum discharge on this basis is found to 0.727 Cumecs in the month of March and the maximum discharge data 3.90 Cumecs in the month of August.

4.3.12 Jamuna Irrigation Project (Modernization)

The project area comprising of both the command area and the catchment area is situated in the central part of the south Brahmaputra basin bounded by latitude 25°42′14″ and 26°14′26″ N and Longitude 92°48′30″ and 92°42′10″ E . The project region is situated in the rain shadow area of the Khasi and Jayantia hills

and Barail ranges. While the catchment area is situated in the eastern part of the rain shadow area, the command area occupies the central part of it and receives scanty rainfall. The general elevation of the project area ranges from 1150 m to 62 m.

The Jamuna river is one of the major right hand tributaries of the river Kopili and it takes its origin in the southern slopes of Khunbaman Parbat near Dombukse village in the Karbi Anglong district at an elevation of about 1128 m. The total length of the river is about 131 km and it drains an area of about 3958 km^2.

Climatological data only of temperature and pan evaporation of the command area were compiled by the Irrigation department in their observation station at Sitalmari and Hojai, respectively on daily basis, for the following periods.

1. Temperature data at Sitalmari from August/78 to March/85.
2. Pan evaporation data at Hojai from Jan/80 to June/93.
3. The India Meteorological Department has an observatory at Lumding just outside the southern boundary of the catchment area and in close proximity to the command area. from the climatological data table of the IMD for this observatory relating to temperature, humidity, wind and rainfall normals and extremes etc. based on observation from 1931 - '60' requisite data have since been collected and are given in table 5.2 to table 5.14 . Studies on potential evapotranspiration for Assam has since been done by the Central Ground Water Board and has been incorporated in their Hydro-geological Atlas of Assam.

In the original project report, rainfall studies were made from the data collected from raingage stations at Dimpur, Lumding, Diphu and Bakulia for the period 1923 -56, 1923 -57, 1952 - 55 and 1957 - 58 respectively. Both Lumding and Dimapur are outside the catchment area. Diphu is within the catchment area and Bakulia is on the boundary. From the above data average rainfall of the Jamuna catchment area upto Bakulia for the year 1923 to '58 was computed by isohyetal method and was founded to be 1528 mm. For the command area daily rainfall data have been collected by the Irrigation department. At the following raingauge stations located within or at the boundary of the command area for the period indicated.

1.	Hojai	from January '76 to Dec. '93
2.	Nilbagan	from January '76 to Dec. '93
3.	Khaki	from May ' 76 to Dec. '93
4.	Sitalmari	from August '76 to Dec. '93
5.	Bakulia	from May '76 to Dec. '93

Hydrological data & water availability - for the purpose of assessment of water availability at least 10 years daily discharge data are required for the type of project under consideration. However , discharge data were very much short at the time of preparation of the original project report in 1961. There was no gauge discharge site near the Barrage site and data from the Gauge discharge site at Doboka near the confluence with Kopili as mentioned by the Assam PWD were available from march/56 to Sept./58 only. From this series, discharge data at Bakulia Barrage site were computed on proportional catchment area basis and out of the 3 years available data average year and year of 75% availability were identified for final assessment of water availability which was too inadequate.

However, for the present, discharge data have been available for much longer

period. A gauge discharge site was established at about 2.5 km. about the barrage site in 1959. But data have been available only from May'69 to June'93. Some data gaps of very short duration have been filled up by arithmetic interpolation.

5.0 WATERSHED MANAGEMENT AND SOIL CONSERVATION

5.1 Studies carried out by Project Preparation and Monitoring Cell, North East Council

5.1.1 Umtongphar Watershed Management Project, 1984.

The 4500 ha area watershed is located in the central Plataea of East Khasi hill district of Meghalaya and lies between 25°25′ to 25°30′ N and 92°0′ to 92°7′ E. The watershed is situated about 50 km away from Shillong and in administrative jurisdiction of Mawkynrew block. Topography of the basin consists of rolling and steeply dissected high hills with the elevation varying from 1100 m to 1522 m. Annual average rainfall in the basin is 2400 mm. The basin is drained by Umtongphar stream through different tributaries. The drainage pattern is dendritic. Detailed soil and water conservation measures have been planned in the project area as per the site requirement like bench terracing, terrace outlet, peripheral channel construction, gully control structure, loose rock check dam, stone masonry check dam, earthen check dam, drop spillway etc. Irrigation has been proposed for 500 ha area.

5.1.2 Shinga-Tsusang Watershed Management Project, 1982.

The first watershed management project for Nagaland prepared by NEC lies in the district of Mokokchung covering an area of 40 km^2 within the catchment of Milak river between latitude 26°38′ to 26° 45′ N and 94° 35′ to 94° 38′ E. Shinga-Tsusanga is the main river and Yenha, Inchoohang, Shite-Sheyong, Naha, Tsokamba, Sangartacha and Limbansibo are its tributaries. The watershed is spread over three villages and its 75% area is the in the valley of Shinga-Tsusnga stream and remaining in the hills. Elevation ranges from 300 - 900 m. There is no meteorological observation within the radius of 50 km. Average rainfall in the watershed is 2000 - 2500 mm and temperature varies from 5°C in winter to 25° in summer in hilly portion while in valley it is 12°C in winter to 30° C in summer. The minimum discharge is sufficient to irrigate 300 ha area and it has been proposed to construct two diversion wiers on the main strem and two channels on either side of it. Recommendations for soil conservation have been made in the report as terracing, gully control and stream bank erosion control like blanket protection, revetment, diversion structures, jetty(spurs) etc.

5.1.3 Maharanicherra Watershed Management Project (Dhalai Sub-watershed), North Tripura, 1983.

It is one of the pilot project of in the catchment of river Khowai in West Tripura district of Tripura. Maharanicherra, the tributary of Khowai river, originates from Jampni hill ranges, flows northward through hilly region in its meandering courses and ultimately meets Khusiara river in Bangladesh. Watershed covers an area of 4820 ha and lies between 23°52′ to 23°58′ N and 91°36′ to 91°47′ E. Watershed is generally hilly with flat cultivable land along stream bank. 60% area is hillock and rest is in plain hillock. Elevation ranges from 47.5m to 181m. Drainage pattern is dendritic. About 1050 ha area is in reserve forest and 3775 ha has been proposed

for different watershed management programme. Detailed soil survey has been conducted in the area and based on study of morphological, physical and chemical characteristics of the soil thirteen soil series have been identified. in the area. Soil and water conservation measures have been proposed through following methods:

- Terracing - Peripheral channels, graded budding, bench terracing, diversion bund, terrace outlet etc.
- Gully control measures - Vegetation, check dam, brush wood check dam, wooden check dam, brick masonry check dam.
- Marshy land reclamation - Surface drainage, subsurface drainage etc.
- Bank protection works - Bamboo mat protection works below low water levels, Bamboo retaining walls, Jetties (spurs).

Pisciculture will be developed in small tanks to meet requirement of fish and to give addition income to the people. Assured irrigation has also been proposed for 800 ha. Surface irrigation is not feasible total lean discharge is not sufficient to cover the available irrigable area. Construction of barrage across the river is also proved to be costly and will take lot of valuable valley land. Therefore, lift irrigation schemes have been suggested for irrigating the valley by constructing infiltration galleries just below the bed levels of the river and to pump out water to a service reservoir with distribution system with gravity flow.

5.1.4 Lowangleima Watershed Management Project, Imphal, Manipur, 1986

The basin lies between 24°52′39″ to 24°57′36″ N latitude and 93°48′28″ to 93°55′ E longitude under Sadar hill subdivision of Senapati district and Imphal West. Lowangleima / Sheirak stream originates at an altitude of 2100 m on the hills of soft sedimentary rocks. The bare steep slopes with unconsolidated sediments and high rainfall accelerate soil erosion on a large scale apart from causing landslip and landslide. Therefore stream carries more silt load along with water and creates more flood and siltation in valley land. Average width of the river is 20 m. The total stream length is 14.88 km (7.68 km in hills and 7.2 km in valley land). Elevation ranges from 800 to 2331 m. Lowangleima stream with about 50 streamlets is a tributary of Nambul river which finally flows into Laktak lake.

The watershed observes humid tropical climate with wet summer and dry winter. Average maximum and minimum ranges are 24-26 °C and 10-12 °C respectively. December is driest and coolest with minimum temperature of 1 °C for 3-4 days every year. Pre-monsoon starts during March and April with full monsoon during May to September and retreading monsoon in October and November. Average mean rainfall is 13,650 mm. The rainfall, relative humidity and temperature data are available from 1961 to 1971.

Soil and Landuse survey - Soil survey organisation of the state has identified six series and 4 land capabilities classes.

Soil and Water conservation -The following recommendations have been made:

1. 167 ha under bench terracing according to soil depth, slope of land and type of soil and rainfall.
2. For stream bank erosion control Blanket protection works, revetment and retaining wall and guide bund have been proposed.
3. 50 numbers of bush wood check dam, 15 numbers of drop structure at major

gullies and 15 numbers of drop spillway to avoid undercutting and bank erosion during high floods have been proposed.
4. 20 numbers of stone masonry check dams to harvest rainwater from the upper reaches have also been proposed.

Irrigation - Irrigation development in watershed management project, where ground water resources are limited to valley land only, consists drop inlet weir, ogee drop inlet weir, head works, water harvesting structures, cross drainage structures at footpaths and streams, drop structures linked channels, earthen channels and distributing channels.

5.1.5 Hirhiri Barpanjan Watershed Management Project, Karbi Anglong, Assam, 1986.

Hirhiri and Barpanjanare tributary of Kalyan river which meets Brahmaputra near Dhansiri mukh. The catchment lies between 26°29'-26°32' N latitude and 93°40' to 93°46' E longitude and covers an area of 2300 ha. The maximum length and width of watershed is 9600 m and 5300 m respectively. Area comprises of hills, rolling and alluvial plains and river terraces and flood plains. Mean summer and winter temperature are 29-32 C and 18-25 C respectively. Mean annual rainfall is 1819.86 mm and occurs maximum during May to October. Maximum and minimum humidity is 85% and 50% respectively. Rainfall and temperature data are available at Bokhial from 1981-83.
Soil survey - Area has been classified into 5 soil series based on study of morphological, physical and chemical characteristics.
Soil and Water Conservation Programme - The following recommendations have been made:

1. Land development by graded budding (162 ha), land leveling (113 ha), Bench terracing 5-15% slope (126 ha).
2. Gully control measures by bush wood check dams (22 nos.), loose rock check dams (14 nos), stone masonry check dams (7 nos.)and drop spillway (6 nos.).
3. Stream bank erosion control measures by earthen bunds along stream bank, plantation along bank slopes of individual streams, semi permanent protection wall in vulnerable sites.
4. Hydrology and sediment monitoring programme has been proposed by fixing one stage level recorder, constructing a weir, installing raingauges etc.

Irrigation - The followings have been proposed:

1. Construction of 3 numbers of storage structure in the project area with a view to retain the optimum amount of water in soil profile and also detaining the runoff water to provide irrigation, to recharge ground water and reduce peak flow and thus irrigates 220 ha of agriculture land and also to develop pisciculture.
2. The diversion weir has been proposed over the Borpanjan stream in the watershed area to command an area of 70 ha. It will raise the water level by 0.5 m above bed level of the stream.

5.2 Studies carried out by Agriculture Finance Corporation Limited

5.2.1 Rangacherra Watershed Management Project, 1983.

Project has been prepared with the objective of optimization of available land, soil and water resources for achieving higher productivity with the participation and involvement of beneficiary farmers. The project also attempt transfer of technology for improvement of overall socio-economic condition of target groups, minimization of area under jhoom cultivation by gradual introduction of settled agriculture and provision of activities allied to agriculture. Project area is about 2200 ha and is located at a distance of 90 km from Agartala on the bank of river Dhalai, which is one of the tributaries of river Barak. It is a mountainous watershed with a number of hills and mounds covered with primary as well as secondary bamboo forest. Jhoom cultivation on hill slope or tilla land is common practice. Elevation ranges from 60 m to 345m. Streams flows in northerly direction. Lembucherra, Rangacherra and Chandraicherra and few other small rivulets are directly draining into Dhalai river. Stream carries water throughout the year. Streams are generally second order in nature. Drainage texture is 1 km in 20 ha and drainage density is one in 3ha. The stream Lembucherra is an example of 'river piracy' which was once a tributary of stream Chandraicherra. The valley land around stream have been developed for agriculture activities.

Climate is sub-tropical and sub-humid. Area is only 300 km away from way of Bengal. Maximum temperature does not rises above 40 °C. May is the hottest month. From June temperature starts falling and in winter comes down to 6 °C but never below zero. Mean annual rainfall is 2555 mm (in village Ambassa)

Water table in the foot hills is only 1-2 m deep and is fluctuating seasonally. Water table rarely falls below 4 m even in summer. Rainfall data for Ambassa is available for the period of 1973-81.

Soil Survey - Soil survey was conducted for the entire project area to find out the land use capability and soil association details. According to survey, the area has been divided upto 10 type of soil series and associated in 4 types of soil association. Soil survey carried out in area of 2182 ha, out of which 290 ha is Lunga (foothills) land, 412 under Tilla land, 990 ha under forest land and 390 ha Orchard land. There are over 118 ha land under jhoom cultivation, over 118 ha under wet land cultivation and 250 ha land under rain-fed. Various development activities have been recommended and included in watershed development and management programme are:

1. Soil conservation measures especially in tilla land providing facilities for rainfed agriculture and also intensification of horticulture crops.
2. Provision of minor irrigation facilities in the Lunga land including river lift irrigation schemes.
3. Land development in tilla land for optimizing available water resources.
4. Provision of minimum infrastructure facilities for fisheries development.

Soil Conservation Measures - Recommendations are as follows:

1. Diversion and graded bunds,
2. Peripheral drainage channels in tilla and lunga land,
3. Bamboo checks in the tilla land and steep slope and

4. River bend protection along Dhalai (one km).

Minor Irrigation Development - Recommendations are as follows:

1. Improvement of existing river lift irrigation system (already in operation near Ambassa irrigates 20 ha land),
2. Provision of flow irrigation through diversion bunds (53 units), submersible weirs (4units) covering an area of 240 ha,
3. Construction of provision of hydraulic structures, drainage crossings (165 units), drop structures (55 units) etc.
4. Repair and maintenance of various civil works and items for period of three years.

5.2.2 Teirei Watershed Management Project, Mizoram, 1984.

5676 ha project area is located in Mamit sub-division of Aziwal West district of Mizoram and lies between 23°52′ to 24°56′ N and 92°22′ to 92°30′ E. Teirei (Pakwa) rivers originates in south hills of Mizoram and drains in the river Dhaleswari /Tlawng. The average hill height is 900 m. The main valley area having a width of 1-2 km runs between two steep hills ranges in north south direction. five number of rivulets (known as Lui) namely Darlak, Bowangva, Pi-Dhari, Nalzawl and Akabama originating from uphills springs and sometimes creating deep gorges between the hills.

Climate - Nearest meteorological observation station is Kolasib centre. The area is extremely cold in winter. Average temperature is in January 17 °C, April - June 25-26 °C. Minimum temperature recorded during January is 6 °C (RH - 85%) at night and 29 °C (RH - 23%) during day time. Rainfall is of high intensity causing problem of stagnated water in depression and low laying areas. Average rainfall is 2540 mm at Kolasib centre. It is around 2600 mm spread over April to October. Winter is rainless. Average number of rainy day is 158 days in a year.

Soil Survey - Soil survey prepared by soil survey unit of Department of Agriculture, Government of Mizoram, shows 10 soil series. Other hydrological data like daily and monthly evapotranspiration, stream flow characteristics, sediments rates are not available.

Soil Conservation - The following recommendations have been made:

1. Land shaping (plot to be shaped and leveled)
2. Bunding of field boundary
3. Bench terracing
4. Peripheral drain at the juncture of foothills and flat lands to carry the runoff from the hills to nearest natural drains
5. Bamboo brush wood check dams have been proposed in all the existing gullies to help in reducing the slope of gullies, silt retention and thereby introducing natural process of leveling.
6. Water harvesting measures by construction of cross bunds and deepening to be used foe pisci-culture and irrigation purposes.
7. Minor irrigation development by construction of masonry small dams at Darlak Lui and by lift irrigation schemes. Three schemes one each at Darlak, Bongva and

Naizawl by construction of intake well in Teirei river, having total command area of 60 ha has been proposed. Also indigenous devices like swing, basket, Don and Persian wheel for lifting water from strems has been proposed.

8. Field drains have been proposed for about 398 ha flat land.

5.2.3 Barak Watershed Management Project, Tuijang sub-watershed, Thomlon, Manipur, 1981.

The project area is over river Tuijang (one of the tributary of Barak) in Manipur South district. The area is 2289 ha, almost rectangular in shape. The terrain is rough and rugged. Elevation ranges from 180 to 1100 m. Almost 60% of the basin is having slope >50%. Area is covered completely by Bamboo and mixed forest. 200 ha area is under jhoom cultivation. Climate is pleasant and salubrious. Winter is from November to February. January is the coolest month. April and May is the hottest month with peak temperature 28 °C. Rainy season is from April to September. Average annual rainfall is 2655.9 mm recorded at Thanlon. Relative humidity ranges from 60 -100 %. Rainfall data at Thanlon from 1970 to 1979, temperature and relative humidity data from 1976 to 1978.

Soil Survey - Soil and landuse map has been prepared at the scale of 1:15,000 and seven soil series have been established by State Soil Testing Laboratory of Manipur.

Watershed Management Programme - Soil and topographic survey shows forest cover as 1879 ha, Land suitable for bench terracing for agriculture - 50 ha, Horticulture - 160 ha and Jhoom land - 200 ha. Bench terracing, graded bunds and diversion bunds, bamboo check dams and rockfill dams have been recommended for soil and water conservation measures.

5.3 Studies carried out by NERC, National Institute of Hydrology

5.3.1 Geomorphological Study of Myntdu Leska Basin, CS, 19997-98

Hydrogeomorphological parameters of drainage network provide simple means, specially in mountainous and ungauged catchments to develop empirical rainfall-runoff relationships, synthetic hydrograph parameters and to develop regional Geomorphological Unit Hydrograph. In this case study, a map of Myntdu river basin is prepared from 1:50,000 scale toposheet. The map is digitized using Calcomp digitizing tablet in AutoCAD. The geomorphological parameters consisting of linear, areal and relief aspects of the drainage network the basin in which further consultancy work is to be taken up, have been worked out and presented in this report.

While reviewing the various methods of estimation of hydrogeomorphological parameters in hydrological studies, an attempt has been made to estimate these parameters using the facilities of AutoCad and by devloping some computer programs which can handle DXF files (ASCII format) of AutoCad.

The quantitative estimates of the geomorphological parameters for the basin would be utilised for the development of Geomorphological Instantaneous Unit Hydrograph for the basin and there by development of rainfall-runoff relationship for further studies.

5.3.2 Hydrological Soil Classification of Dudhnai Sub-Basin :(Assam/Meghalaya) Part - II CS(AR) – 7, 1996-97.

Hydrologic soil classification at Dudhnai sub-basin for an area of 476 km^2 has been made based on the regional information collected from various agencies supplemented by own field and laboratory experiments on the soil samples collected from time to time. In requirement of various soil classification systems, soil properties together with other information have been studied and grouped into different classes as a reference base for future hydrologic studies of the basin. Iso resistivity of the basin has been mapped for the available electric sounding data, at a depth of five meter and the results are interpreted for water bearing stratum of shallow sub-surface. Soil water retention curves for different soil compositions have been analysed from the results of bar pressure plate and interpreted for the soil water retention characteristics. Statistical methods have been applied after selecting three descriptive variables from the soil parameters to study the clusters and their deviation.

5.3.3 Soil Water Conservation with Special Reference to NE Region . SR, 1995-96.

Northeastern region is one of the richest areas in soil and water resources. Due to management problems, the region is yet to put these vast resources into some beneficial uses worth the name and rather chronically suffers from devastating floods or drainage congestion in the valley and acute shortage of even drinking water or large scale erosion in the hills. This report in an attempt to review the problems and methodologies in details, analyze it for applicability and suggest suitable remedial measures.

5.3.4 Hydrological Soil Classification of Dudhnai Sub-Basin: Assam/Meghalaya, Part - I, CS(AR)-220, 1995-96

The Dudhnai sub-basin of about 500-km^2 area on south bank of the river Brahmaputra has been selected for long term representative basin studies. Point infiltration tests, Guelf Permeameter tests for hydraulic conductivity and flux potential etc. have been conducted at various locations in respect of different land uses. Soil samples have also been collected from test sites and tested in laboratory to relate the results to soil types. Because of inaccessibility of the upland only 50% of the basin area has been covered for investigations. It has been proposed that these results would be used in the subsequent hydrologic studies to model the basin.

5.3.5 Hydrometeorological Aspects of Dudhnai Basin (Assam/Meghalaya) CS(AR)-181, 1994-95

Dudhnai basin has been selected as representative basin for long term and short term fundamental research in 1994. A meteorological observatory has also been set up and commissioned and instruments like SSRG, ORG, sunshine recorder, pan evaporimeter, soil temperature thermometer and stevanson's screen assembly etc. has been installed. An Automated Weather Station has already been procured and very soon will be installed there.

The prevailing hydrometeorological factors of the sub-basin, and some investigation results have been discussed so as to provide for a reference base for other studies to continue.

5.4 Studies carried out in Assam Engineering College, Guwahati

5.4.1 Water Balance Study for Krishnai Watershed

The work involves the feasibility study of water resources for Krishnai watershed: in Goalpara District, Assam. The catchment area under study in 933.88 square km and extends on both the banks of the river Krishnai. Allocation to optimal land resources has been done prior to the water balance study by applying Two Phase Simplex Method, a technique for solving linear programming problem in order to maximize the net return keeping in view water availability as the main constraint along with some other secondary but necessary constraints. The existing and the proposed cropping intensity have been taken as the base of comparison. The study of water availability has been carried out by thirteen years of monthly discharge and nine years of monthly rainfall data. The gross irrigation requirement (GIR) for all the proposed crops throughout the year is the only value to which the available discharge is compared to have the water balance statement. It can be precluded that the available water is, at no stage throughout the year becomes insufficient to grow the proposed crops.

5.4.2 Computer Model for Computation of Submerged Distance and Submerged Depth of Pagladiya River Basin

In the study, a computer model has been developed for about 30 kms.reach of the river Pagladiya (a major tributory of Brahmaputra river), which could enable one to know beforehand the distance of submergence at any section and depth of submergence at any point for Pagladiya river basin within the reach under consideration.

5.4.3 Planning of Land-use Pattern and Conservation Measures for a Micro-watershed in Nalbari District

The basic principle of land-use planning in watershed management project is to use the land according to its capability and treat the land according to its need. A methodology has been evolved based on USDA Soil Conservation Service (1965) and All India Soil and Land-use Organisation (1971) for land classification, land-use and land treatment measures planning for watershed management in rain-fed region. Studies have been conducted on a micro-watershed in Nalbari District in Assam.

In order to prepare a contour map of the area a topographic survey has been done using grid system. Also field investigations have been done to determine soil parameters, external land features, socio-economic conditions, climatic and hydrologic characteristics of the watershed. A soil map has also been prepared for the area.

5.4.4 Computer Model For Computation of Submerged Area on the Upstream of a Barrier

In the study, an attempt has been made to develop a computer model for the

computation of submerged area on the upstream of a barrier. This proposed computer model is to used for selecting the height of weir, barrage etc. with the consideration of environmental loss.

5.4.5 Project Report on Hydrological Investigation of Tuijang Sub-watershed, Manipur

The Tuijang Sub-watershed is under Barak Watershed. Barak Watershed extends in the states of Manipur, Nagaland, Mizoram and Assam in India and a portion of watershed lies in Myanmar. About 87% of total catchment distribution in India lies in the states of Manipur and Mizoram.

Manipur is geographically a distinct entity consisting of plain valleys surrounded by high hills. The border hills from themselves in H - 9 parallel folds with altitude varying between 1000 m to 2500 m above the mean sea level. The state is bonded on north by Mega hills, on the east by the and the upper chindwin district of Burma, in the by the chin hils (Burma) and the Mizoram and on the west by the Cacher district of Assam. Name of the block under survey is Thanion Development block. Its location is in between 24^0 15'30" N to $24^0$19'30" N and 93^0 13'0" E to 93^0 17' 0" E longitude under topographic sheet No. 83/3 and 83 H/7.

Investigation and analysis of the Tuijang Watershed management project has been contemplated by the North Eastern Council in north eastern region. The job of investigation has ben given to the Agricultural Finance Corporation Ltd., Bombay, who in collaboration with the Assam Engineering College, Guwahati, has taken up the work of investigation.

Required statistical data of hydrology and physiography are not readily available in the respective departments of the state government. However, data pertaining to the hydrology of the site or surroundings have been made available through agencies like Directorate of Agriculture and Horticulture (Imphal), Central Water Commission (Imphal), Forest Department (Imphal) and Public Works Department (Imphal). The toposheets for the site have been made available from Irrigation Department (Imphal) with contours at 20 m interval which could only be enlarged to get the idea of the topography of the site, no other map is available.

Another problem is the non availability of data pertaining to water discharge data for all the years round. The time of investigation which is limited to only 8 weeks (19th July to 15 September, 1979.) Is not sufficient to collect the necessary data for different seasons. Soil samples have been collected at the site and tested.

Land use map has been prepared and superimposed on the enlarged topomap within the available hydrologic data. The proposed land water resources development sites have been marked in the proposed land use sheet and development plans are also in the report.

5.4.6 Management of Baladi Watershed in North Kamrup

The study has been carried out for a small agricultural watershed of Baladi river in North Kamrup, Assam. The data requird for the analysis have been collected from the Borolia Irrigation Project and Directorate of Geology and Mining, Assam. The study has been made by applying photo-interpretation technique.

In the study attempts have been made to study the hydrological parameters by photo interpretation method and its effect on the watershed. The object of the present study is essentially on finding the ways and means to obtain a reasonable

value for the runoff factor and thereby to be able to calculate run off values at different periods of the year.

5 4.7 Experimental Investigation on Soil Loss in the North Cachar Hill Areas of Assam

An attempt has been made to compute numerical values to some of the fixed factors involved in the "Universal Soil Loss Equation" designed for quantifying the soil loss from a given area of hilly watershed in the North Eastern Region of India. Field experiments at three different plots of land of known area, topographical features and cover complex, to quantify the soil loss caused by measured amount of rainfall falling on the areas, are conducted. From these measured amount of soil loss and rainfall, an attempt is made to compute numerical values to Rainfall Erosivity Index "R" and Soil Erodibility Factor "K" involved in the "Universal Soil Loss Equation" in a bid to apply the equation for soil loss analysis in the hill areas of NE region of India. The computed values of "R" and "K" is recommended for hill areas of NE region to apply for quantitative assessment of soil loss under the given set of conditions.

6.0 ENVIRONMENTAL HYDROLOGY

6.1 Studies carried out by NERC, National Institute of Hydrology

6.1.1 Ground Water Quality Monitoring and evaluation in and around Greater Guwahati - (Assam). part - I, Preliminary, CS(AR) 200, 1995-96

In Greater Guwahati rapid industrial and population grown has taken place during the last decade. The adverse effect on water quality because of this urbanisation has been the concern of the people. Samples from twenty three dug wells, representing the shallow unconfined aquifer were collected in pre and post monsoon season of 1994 and 1995 and analysed for various physical parameters, viz., temperature, PH, conductivity, % light transmission, oxygen reduction potential, total dissolved solid etc. The findings of the water quality tests on the representative time variant samples should be useful to have a first hand knowledge about the quality standards of ground water which is the source of drinking water for a vast populations of elite citizen of the locality.

6.1.2 Ground Water quality Monitoring and evaluation in and around greater Guwahati CS(AR) - 1997-98 Part-II, Chemical Analysis

The water quality of greater Guwahati is presented based on the physio-chemical characteristics of thirty samples collected on grid pattern. The various parameters analysed include pH, electrical conductivity, temperature, DO, TDS, alkalinity, Hardness, Na^{+}, K^{+}, Mg^{++}, Ca^{++}, NO_3^{-}, SO_4^{-2}, Cl^{-} and F^{-}. The results have been compared with water quality standards prescribed by BIS and WHO. Various parameters like Kellye's ratio, sodium absorption ratio, residual sodium carbonate, Magnesium hazards, Sodium % and permeability levels have been determined to evaluate the suitability of Ground Water for irrigation purpose. The study shows that water at some places require treatment before using for drinking purpose. An attempt has also been made to classify the quality of ground water on the basis of stiff pattern diagram, piper trilinear diagram, USSL classification, Gibbs variation classification, Durove trilinear classification, Doneer's classification and Wilcox classification. As per the stiff classification, most of the samples were found to be of either Mg-HCO3 type or Mg-Cl type. In the Piper's trilinear diagram, ground water samples of the study area fall in the Ca+Mg-HCO_3 and Ca+Mg-SO_4 hydrochemical facies. According to the USSL classification of irrigation water, samples fall under water type C2-S1 (medium salinity and low SAR) and few samples fall under C3-S1 (light salinity and low SAR) and C1-S1 (low salinity and low SAR) type. Gibbs variation diagrams show that the litho units of the area mainly control the chemistry of ground water. According to Doneer's classification most of the samples are class-I type for irrigation use. As per the Wilcox classification, most of the samples are excellent to good class and few are good to permissible. Durove's trilinear classification shows that in cation type, majority of the samples are Mg++ and intermediate type while, in anion type, samples fall in HCO_3^{-}, and intermediate category.

6.1.3 Ground Water Quality in Greater Guwahati, Assam with preference to Trace elements, CS(AR) 1998-99.

Degradation of ground quality due to heavy metals has received considerable attention during recent years. Pollutants are being added to the ground water system through human activities and natural processes. Solid waste from industrial units is being dumped near the factories, which is subjected to reaction with percolating rainwater and reaches the ground water level. The percolating water picks up a large number of heavy metals and reaches the aquifer system and contaminates the ground water. The quality of ground water is dependent on the geological, climatic, environmental, biological and other anthropogenic activities. Several reports are available which indicate that samples collected from shallow aquifers show higher concentration of heavy metals than those from deeper aquifers did. In the study, the various elements analysed include Cu, Co, Cd, Fe, Zn and Pb. The trace elements of ground water samples have revealed that the concentration of iron in ground water is much higher than the tolerance limit prescribed for drinking water. The samples have been collected for four periods and concentration of trace elements have been determined in laboratory and results have been tabulated.

7.0 LAKE STUDIES

7.1 Studies carried out by Water and Power Consultancy Services India Limited,

7.1.1 Umiam Barapani Reservoir Project, Meghalaya.

The reservoir on the Wah Umiam river at Barapani built up in 1965with a gross storage of 1,47,000 acre feet at maximum reservoir level of 3220 feet and water spread area of 2570 acre. While preparing the project no detailed studies were conducted, during 1958-59 for silt load estimation. The minimum reservoir level was kept at 3150 ft to give a dead storage of 32,000 acre. However, during the last 25 years due to development activities in the catchment silt load has increased manifold. It is, therefore, studied to assess the extent of siltation and storage still available for the project, so that suitable remedial measures could be taken for arresting further deterioration of situation.

Location: The basin is located between 25°27′ - 25°42′ N and 91°20′ - 92°15′ E in the East Khasi district of Meghalaya. The catchment area is 221.5 sq.km. The peak height in the basin is Shillong peak (1983m) while the general altitude variation is from 1200m to 1500m. Length of the concrete dam is 195m with top width of 7.3m. Height of the dam from the deepest foundation is 73.2m. Area of reservoir at maximum water level (981.46m) is 1015.8 ha. Minimum draw down level is 960.12m. Live storage and dead storage are 141.8 M cum and 39.4 M cum.

Climate: Monsoon starts from May and continue upto mid October. The average rainfall in the basin is 2667mm. Mid October to February is winter and March to April is summer. The temperature varies from 25 °C maximum to 4.5 °C minimum.

Data Availability: Two rainguage stations, one at one at Shillong (average rainfall 2455mm) and other at Barapani (average rainfall 2800mm). Temperature data is available for Shillong station for the period of 1981 to 1984.

Results of the Project Report are:

1. Sediment deposit during 25 year is 11703 acre-feet as per hydrographic survey conducted during 1989-90.
2. The dead storage of 32,000 acre-feet has now become 25,130 acre-feet, indicating a reduction of 6,870 acre-feet (21%). The live storage register a decrease of 4,833 acre-feet (4%). The average annual rate of siltation in reservoir works out to be 5.47 acre-feet/sq.mile.

Recommendations of the Project Report are:

1. Multiple vegetation
2. Protection of existing forest and raising of new forest plantation.
3 To control Potato Bun cultivation and promotes safe methods to ensure protection of soil and increase yields.

4. Efforts to stop jhoom cultivation.
5. Land settlement to be carried out.

7.1.2 Development of Loktak Lake (Identification Report), Manipur

Identification report has been prepared with the objective to suggest the ways and means for prevention of its deterioration and also further rejuvenations. Loktak Lake is the biggest natural lake in the eastern India, 38 km south of Imphal. The lake is connected by Imphal river on its eastern side by means of natural channel known as **"Khordak Cut"**. The lake area is 278 km^2 (at water level at 768.5 m above msl) but during exceptional high rainfall inundates additional 120 km^2. During 1966 area was 490 km^2 (at water level of 771.83 m above msl). Lake is gradually deteorating over the years and losing its storage capacity because of siltation which is accelerated with the profuse growth of water hyacinth and other weeds affecting fish production.

7.2 Studies Carried Out by NERC, National Institute of Hydrology

7.2.1 Loktak Lake Studies : Part – I, TN-108, 1993-94.

Loktak lake in Manipur plains which is of international importance where floating swamps of Keibul Lanjao provides a last refuge for the Manipur brown antlered is causing problems of increased flooding and hinderance in the normal functions. Hydrology of the lake has not yet been studied. The study aims at describing different aspect of lake in general and the study area in particular. The different hydrological aspects of the lake have been discussed before describing the study area. The general aspects of a lake covers classification of lake, hydrology of lake, lake morphology, sedimentation, ecology of lakes etc. It has been recommended that water balance study of the lake should be undertakes to study fluctuation in water level/storage etc. A comparison of area elevation curve with the data supplied by Loktak Development Authority has been made and certain data error has been indicated. It has been proposed to study and provide proper measures on catchment treatment to effectively reduce the siltation of the lake in the second part of the study.

8.0 REMOTE SENSING STUDIES

8.1 Study Carried Out by National Remote Sensing Agencies, Hyderabad.

8.1.1 Brahmaputra Flood Mapping and River Migration Studies- Airborne Scanner Survey 1980

The objective of the project is to map the area adjacent to main stream of Brahmaputra river system in regard to geomorphology and current hydrologic land use cover and to obtain a mosaic of multi-spectral scanner imagery covering this area for studying the river migration status and the effectiveness of the existing flood control works and to suggest improvements. The area has been surveyed during Nov-Dec 1978. Planning and developments of the flood plains for minimizing damages have been suggested in the report. It has been further recommended to carry out repetitive survey to monitor changes in landuse, river channels and banks and associated features to provide a base for estimating the response of the rivers to flood events.

8.1.2 Satellite Remote Sensing Survey of Meghalaya 1985

The project has been carried out using Landsat data (dated 26.1.1982) to prepare the soils, drainage, forest and landuse/landcover maps of Meghalaya state so that necessary steps could be initiated for soil conservation, afforestaion and optimal landuse planning. The project aimed to provide baseline resource information. In the report Digaru river basin originating from the northern slopes of Meghalaya has been selected for analysis like land classification, land and water resources evaluation, landuse/landcover assessment for optimal development and management of river basin. The morphometric characteristics calculated for the study area is:

1. Basin area - 516 km^2
2. Basin perimeter - 168 km
3. Basin length - 34 km
4. Basin configration (A^2/L_b) - 0.0183
5. Elongation ratio - 0.7
6. Length of main stream - 61 km
7. Cum. length of stream - 1143 km
8. Drainage density - 2.21 /km
9. Drainage texture - moderate
10. Drainage pattern - dendritic/sub dendritic
11. Stream order - 4
12. Four Land Systems are hills, valley, upper river plains, lower river plains (flood plain) and Residual hills.

8.1.3 Satellite Remote Sensing Survey of Lower Barak Watershed in Assam, 1982

The objective of the study is to procure valuable information on flood plains, landuse, soils, forest, geology and geo-morphology of the lower Barak river basin. The data used in the study is MSS Landsat dated 15.4.1978 on 1:1 million and 1:500000 scale. The following maps have been prepared:

1. Hydrologial landuse map on 1:250000 scale
2. River system map of lower Barak basin at 1:250000 scale
3. Forest resource map at 1:250000 scale
4. Geological map at 1:250000 scale
5. Geomorphological map at 1:250000 scale
6 Soil association map at 1:250000 scale
7. Flood plain land use of the part of the project area map at 1:250000 scale

The hydrological land use and land cover categories are:

A Agriculture land
   1. Agriculture land, post harvest mainly paddy
   2. Pre harvest seasonal crops
   3. Agriculture land prone to flood/water logging

B Water/Wetland/Swampy areas
   1. Deep clear water in Auna Beel/Barak river
   2. Shaoolw water mainly in tributaries river
   3. Water in Sone Beel
   4. Highly turbid water in fields depressions/Hoar /Beel
   5. Marshy land, adjoining field depressions/Hoar/Bell areas

C Forest and Vegetaion
   1. Miscellaneous vegetaion mainly in plains
   2. Dense forest, wooded areas in hills
   3. Scrubs.degraded forest
   4. Forest plantation
   5. Current jhooming

D Others
   1. Cloud
   2. Cloud and hill shadow
   3. Unclassified.

8.2 Studies Carried out by Assam Remote Sensing Application Center

8.2.1 Landuse / Landcover Mapping with special reference to shifting cultivation in Karbi Anglong and North Cachar Hills district, Assam, Indian, 1995

The objective of the report is to prepare land use/land cover maps of Karbi Anglong and North Cachar Hills Districts of Assam showing the spatial extent and distribution of landuse categories on 1:50,000 scale. And also to prepare a slope map with micro watershed boundaries for two districts To estimate the different categories of land use/land cover and analyse the change in shifting cultivation area for two time periods i.e. 1987 and 1994 and encroachment into the primary and secondary forests.

Data used - The image used for this study corresponds to landsat TM for 1986-87 and IRS LISS II for 1993-94. For watershed delineation atlas of landuse and soil survey, SOI toposheets have been used. For slope SOI toposheets on 1:50,000 scale has been adopted

Brief Methodology - Visual interpretation techniques have been used.

End results - Watershed wise slope and landuse statistics for both seasons for both districts has been derived, Change detection statiscs from 1987 to 1994 for both districts have been derived, Map out put of landuse/land cover for 1987 and 1994 for both districts along with watershed, slope and change detection map.

Conclusions - Increase in areal extent of current jhum thereby changes from 1987 to 1994 in both the districts, Cycle of jhuming is 5-7 years in a particular place, Considerable degradation of primary forest, Considerable decrease in area of pure bamboo from 1987 to 1994 and in some places cycle is 3 to 4 years instead of 7 years, Increase of scrub land indicates lose of soil fertility.

8.2.2 Wasteland Mapping Project Phase-V on 1:50,000 scale, 1998 (On-going)

The objectives of the study is to create a digital database in GIS environment for wasteland in addition to base details, watershed boundaries and village boundaries

Data Used - IRS LISS II FCC on 1:50,000 scale, NRIS Code book All India landuse and Soil Survey atlas and SOI toposheets for watershed codification, Thana Maps for village boundaries and NIC data

Brief Methodology- Methodology as mentioned in manual of procedure for preparation of wastelands digital database using Remote Sensing and GIS techniques. Digitization has been carried out with the help of local entrepreneur

End Results - To be given in forms of digital database along with district report with statistic of wasteland categories district-wise, toposheet-wise,watershed-wise

8.2.3 NRIS National (Natural) Resource Information System for Kamrup district, 1998 (on-going)

The objectives of the study are to generate digital database of various themes, to integrate the thematic information in GIS environment and to derive local specific action plan and to generate query shells for decision making

Data used - Multidate satellite data (IRS) Collateral data are SOI toposheets, NIC data, Thana maps, Meteorological data, relevant reports etc. NRIS Code Book (Node design & standard), Department of Space

Brief Methodology- Standard visual image interpretation technique and digital database in GIS environment

8.2.4 Integrated Mission for Sustainable Development (Imsd) for Puthimari Watershed, Kamrup District (1992-97)

The objective of the study is to draw locale-specific action plan for sustainable development of the region

Data used - IRS - 1C data, SOI. Toposheets, NIC Socio-economic data, Census Operation data Meteorological data, Ground Water data etc.

Brie Methodology - Remote Sensing and conventional data were used to analysis the resource potential of the Region and accordingly action plan for land resource and water resource was developed. Themes that were studied are - Landuse, soil, Slope, Geomorphology, Hydrology, Rainfall

End Results - For Puthimari watershed, Kamrup district 13 Land Resource Developments Schemes and 7 water Resource Development Schemes have been suggested

8.2.5 Ground water investigation in Tea Growing areas of Barak Valley (1993-94)

The objectives of the studies is to map the ground water potential zone and also to prepare water table map.

Data used - IRS - IB, LISS - II, Band 2,3&4 geo-coded

Brief Methodology - Different geomorphological units have been identified from the statistic image and geomorphological map has been prepared. Water level data have been collected from the existing dug wells available in the study area. Then groundwater potential zones and water table maps have been prepared

8.2.6 Ground water production mapping in four Tea Gardens of Upper Assam (1997-98)

The objectives of the studies is to map the groundwater plantation map for different seasons

Data used - IRS - IB, LISS - II, Band 2,3&4 geo-coded

Brief Methodology - Different geomorphological units have been identified from the statistic image and geomorphological map has been prepared. Water level data have been collected from the existing dug wells available in the study area. Then groundwater potential zones and water table maps have been prepared

8.2.7 Drainage Congestion study of 3 sub basins of Brahmaputra & Barak - using satellite data

The objective of the study is to demarcate flood prone areas, and identify breaches in embankments

Data used - Landsat TM data and IRS data

Brief Methodology - Visual Interpretation and ground Survey

End Results - Flood prone areas of Subansiri Basin, Pagladia basin and Barak Basin have been demarcated. Erosion prone and cultivable zones of others lying within the basin have been located

8.2.8 Land Resource mapping of Kamrup and Kokrajhar district on 1:50,000 scale using satellite data (on going)

The study has been carried out with the objective to map landuse and soil on 1:50,000 scale.

Data used - Landsat TM data and IRS data

Brief Methodology - Digital, visual interpretation technique and ground Survey

End results - Not yet completed

8.2.9 Wet lands of Assam : A Study using Remote Sensing Technique (1994-1997)

The project is first of its find in the entire NE. Region. The objectives of the

study are to identify and delineate the Wetlands of Assam, to classify them and estimate the area under each category of wetland and to develop a computerised database on wetlands of Assam

Data used - Remotely sensed satellite data of landsat-5 (TM) and IRS - 1B (LISS II) have been used

Brief Methodology - Visual interpretation technique has been employed to identify and map the wetlands which was followed by ground verification and areas have been estimated after the final maps are prepared on 1:50,000 scale for all the 23 districts of the State.

End Results - In all, 3513 wet lands were identified and mapped and computerized data base was developed for all these wetlands. A total of 1012.31 sq.km. is covered by the wetlands of Assam. In addition to this, a qualitative assessment of turbidity levels of water and invasion by aquatic weeds was also made using satellite data which was incorporated into this wetlands.

Salient Features - The study also reveals distribution of wetlands in different districts of Assam. From the study it is found that Nagaon district has the highest number of wetlands (1379 in numbers) while Morigaon has the maximum area under Wetlands (116.58 sq.km)

8.2.10 Land mass Dynamics and Rhino Habitat Suitability analysis in Kaziranga National Park, Assam, 1997

The objectives are to investigate the State of erosion and dynamics of land mass of 30 years (1968 tc 1997) in the park and to evaluate the habitat inevitability for Rhinoceros, in Kaziranga National Park.

Data used - Survey of India toposheets, Satellite date of lands at 5 TM and IRS -1B FCC was used in the years 1967-68, January 1990 and January 1997 respectively Ancillary data were supplied by Directorate of Park at Bokakhat.

Brief Methodology - Visual interpretation of satellite data followed by filed work and ground data collection. This was followed by field of data analysis, area calculation, processing and application of Geographical information system modelling.

End results - The study reveals that 61% of the park area is covered by tall grass while 25% is by wood lands 6% by water bodies and beels and 3% by short grasses. Also, there in a change in the total area of the park from 1967 to 1997 which is estimated at 428.9 sq.km in 1967, 400.2 sq.km in 1990 and 407.9 sq.km in 1997. The study also reveals that about 26% of the park area is highly suitable for Rhinoceros while 45% of the park areas is least or unsuitable,.

Other information - Continued investigation is required to assess the damage caused

by recurrent every year, using Remote Sensing Technique.

8.2.11 Integrated Study of Wetlands of Goalpara District of Assam using Remote Sensing and GIS, (on-going since Jan, 1997)

The objectives of the study are to identify and delineate the Wet lands of the districts from satellite data though visual interpretation and digital image processing, to study the areal spread and seasonal changes of watershed area of the beels, to estimate turbidity levels, sociao-economic survey around selected wetlands.

Data used - Satellite data of IRS -IB (LISS II) of the year 1996-97 (October and December) and digital data on CCT for the same seasons.

Brief Methodology - Visual interpretation followed by ground verification and field data collection, training site selection for digital classification and application of GIS and finally area estimation.

End results - Wetlands maps on 1:50,000 scale, Digital Output, Area Statistics and GIS Output.

8.2.12 Land cover Mapping of four Elephant Reserves of Assam, (on-going since Oct,1998)

The objective of the study is to prepare land cover Map of four elephant reserves of Assam on 1:50,000 scale, to estimate the density of vegetation and to estimate areas under each vegetation cover type.

Data used - IRS-IB (LISS II) and ID LISS III data and SOI toposheets have been used.

Brief Methodology - Visual interpretation followed by field verification, sampling and sample data collection, final mapping and area calculation

End results - Land cover map with vegetation density on 1:50,000 scale.

8.2.13 Projects Recently proposed by Assam Remote Sensing Application Center are:

8.2.14 Computersied Database for Nalbari District,Assam submitted to DST (NRDMS), New Delhi.

8.2.15 Integrated study of Major Wetlands of goalpara district using Remote Sensing and GIS Techinque, submitted to the Dept. of Environment and Forests (NNRMS), New Delhi.

8.2.16 Preparation of land Resources Map of Kamrup District, Assam by Digital

Analysis of satellite data, submitted to State Landuse board (SLUB),Assam

8.2.17 Habitat Suitability Study of Elephants in selected Elephant reserves of Assam, submitted to the Dept . of Forest, Govt. of Assam.

8.2.18 Satellite Mapping of Degraded Lands in Assam (District-wise) on 1 : 50,000 scale submitted to the State Landuse Board (SLUB), Assam.

8.3 Studies carried out in Assam Engineering College

8.3.1 Estimation of Runoff Using Remote Sensing Data "A Case Study at Dudhnai Sub-basin"

Aim of this study is to estimate runoff of a watershed by SCS method using landuse/landcover information from the satellite imagery. For this purpose Dudhnai sub-basin is selected for investigation. Imagery of IRS-1B used for determining landuse/landcover information of the basin. Rainfall data collected from IMD and hydrological soil map collected from National Bureau of Soil Survey, Jorhat have been used for run-off estimation. Objective of the study are to identify and interpret the landuse/landcover of the study area with the use of high resolution IRS data and to compute the runoff volume of the study area on a sub-watershed basis with the use of SCS run-off method.

8.3.2 A General Study of the Kulsi Watershed for its Management Through Photo Interpretation Technique

The work has been carried out as qualitative study of the nature and behavior of a watershed from aerial photographs and to suggest management practices to improve the quality of the watershed.

The stream chosen for the study is the river Kulsi. Originating from the lake"Ukium"(Meghalaya), it flows down a narrow valley to the wider plains through Chaygaon and collecting waters of many streams and lakes, finally meets with the Brahmaputra at Nagarbera. The study contains the studies made on different aspects affecting the management of a watershed and the inferences arrived at.

8.4 Studies carried out by NERC National Institute of Hydrology

8.4.1 Flood Plain Mapping of Phulbari area using Satellite data (Assam/Meghalaya). CS(AR) – 23, 1996-97

Flood is a natural calamity in which most parts of the NorthEast states are ravaged. Management of the problem in these disastrous flood affected areas often requires flood plain mapping for protection and resource development.

The report attempts to map the flood plain of the area with the remote sensing data for which IRS - IA & IB FCC at 1:50,000 scale has been used. Analysis has been carried out from the delineation of satellite data of pre and post monsoon

periods of 1988, 1992 and 1996. Survey of India toposheet (1961) has been compared with the latest satellite data for the study of bankline migration of Brahmaputra river at Phulbari area. Extensive site visit has been made for ground truth verification and interpretations from imageries were supplemented.

8.4.2 Soil Classification using Remote Sensing Technique: Phulbari Area , CS, 1997-98

Proper survey characterization of soils and soil classification are essential for efficient management of land resources. This is mostly being done on the basis of ground based survey and soil sample analysis. With the advent of remote sensing satellites with improved spatial & spectral resolution, it is now possible to classify soils to a good extent on the basis of color, tone, texture, mineralogy and content of organic compounds in soils. An effort in this direction to classify soils of Phulbari area that has been ravaged by the Brahmaputra floods since long and where some anti erosion works by other agencies are ongoing. For the purpose, two different IRS imagery data of April,1989 and February,1996 have been used for identification of different soil types. To supplement the works, soil samples were also collected from different soil horizons present in physiographic units and subjected to physi-co-chemical tests. On the basis of site characteristics and physico-chemical analysis carried out, soils of the study area have been classified into five different families. Wherever parameters other than analyzed in the report were also required help of NBSS & LUP map was taken.

8.5 Studies by Space Application Centre, Ahmedabad and Brahmaputra Board, Guwahati.

8.5.1 Erosion at Kaziranga National Park, Assam, 1999

Kaziranga National Park is situated at about 240 km east of Guwahati. It is of rough oval shape and has an extent of about 45 km long and 15 km wide at its broadest point covering an area of about 430 km^2. Its northern side is bounded by Brahmaputra river and on south, it flows almost parallel to the NH-37. Hills of Karbi Anglong occur south of the park. In addition to the rhinoceros, the park is characterised by several other wild animal including wild buffalo, elephants, swamp deer, hog deer, wild boar, tigers etc. and also has a rich variety of about 400 species of birds. The terrain of Kaziranga National Park comprises the flood plains of Brahmaputra river, in general is flat and characterised by sheer forest, tall elephant grass, water ways, beels and swamps. During monsoon, entire area inundated due to flood water of river Brahmaputra and its tributaries and causes heavy erosion and wildlife is lost. Assessment of the erosion occurring at the park is very difficult task when it is done following ground based conventional methods. It is time consuming and almost impractical when it is required to be done repetitively. Synoptic view offered by remote sensing satellites has made the task comparatively east and fast as it provides detailed information of the terrain with reasonable accuracy and in almost real time. Repetitive information on Brahmaputra river configuration obtained periodically from satellite data has been used in the present work to study the dynamic aspect of the river behaviour causing sever erosion in the park. Satellite data of the years 1987, 91, 93, 94, 96, and 98 have been interpreted at 1:50,000

scale and integrated with the base map prepared from the topographic maps of th survey years 1967-68. The interpretation was collated with the ground information available in the form of reports and maps also data collected during field visits.

The work has led to identify and delineate the areas of the park which have undergone changes along the bankline due to dynamic behaviour of the river. The river has attacked different areas during different period. It has been observed that the advancement of the bankline of the river on the park has resulted into 37.80 km^2 loss of land during the period of about 30 years. While advancing the bankline on the park area the river also has shown retreat of its bank line in some areas thus making available in all 8.93 km^2 spread over different stretches along the south bank of the Brahmaputra river. It has been noticed that the erosion is more predominant on the eastern as well as western side of park. In addition to bankline changes, it has also been observed that the progressive changes has occurred in the main stream channel and other active water courses, sandbars etc. Possible approach for arresting bank erosion have been suggested for critical areas under active bank erosion. Probable areas for extension of Kaziranga National Park has also been worked out which need further detailed investigations before taking up necessary measures.

9.0 GROUND WATER

9.1 Studies carried out by Central Ground Water Board

9.1.1 Ground Water Conditions In The North Eastern State

The significance of groundwater to satisfy the growing needs of increasing agricultural output in the northeastern region has been realised recently. In fact the agro-economic growth of the entire region depends mainly on agricultural production.

The various studies/ activities of Central Ground Water Board can be classified into: -

- Systematic hydrogeological surveys.
- Integrated Ground Water Development and Management studies.
- Exploratory drilling and first approximate resource evaluation studies.
- Water Balance studies.
- Short term water supply investigations.
- Monitoring of groundwater regime.
- Technology Mission for source finding of drinking water in problematic villages.
- Determination of chemical quality of groundwater for drinking, irrigation and industrial uses.
- Pollution studies.
- Estimation of groundwater resource potential.
- Geophysical studies relating borehole logging, water table condition, quality of water.
- Photogeology and Remote sensing studies.
- Artificial recharge studies.
- Conjunctive use studies.Hydrology Project.
- Documentation of Hydrometeorological, Hydrological, Hydrogeological and hydrochemical data and issuance of scientific reports and atlases.
- Imparting training on all aspects of groundwater training through Rajiv Gandhi National Ground Water Training and Research centre.

Under exploration programme, initially two rigs had been deployed for exploratory work in the region. In order to gear up the work 3 more rigs have been added up. In addition to these rigs one more Japanese rig deployed in bouldary formations of the region in the year 1991.

Based on the results of systematic hydrogeological survey and exploratory drilling, areas suitable for ground water exploration have been delineated. The completed wells were handed over to the state Government authorities for immediate utilization i.e., for irrigation purposes. Briefly the state-wise summarized results of exploration and survey are given below:

ASSAM

The state of Assam which has the largest areal extent of unconsolidated alluvial formation with high potentialities of ground water development had been chosen to be completed first by way of systematic hydrogeological surveys and thus the entire state was covered.

Till the end of March 1999, 158 exploratory drilling were completed in Kamrup, Nagaon, Sibsagar, Jorhat, Sonitpur, Darrang, Barpeta, Golaghat, Nalbari, Cachar, North Cachar, Dibrugarh, Tinsukia, Karbi Anglong, Hailakandi, Karimganj, Morigaon, Goalpara and Dhubri Districts of Assam.

Of these, a total number of 87 numbers of wells have been handed over to the State Government departments for utilization. The construction of deep tube-wells in Assam has brought an awareness among the people and the Government for planning irrigation through ground water, particularly in Brahmaputra valley.

Exploratory drilling taken up by the Central Ground Water Board in the Silchar, Karimganj and Hailakandi valleys of Cachar, Karimganj and Hailakandi districts have testified to the existence of 20 to 30m of saturated fine to medium sand occurring within the depths of 50m.

Shallow tubewells yielding about 30 to 35 m^3/hr., can successfully be constructed around Baskandi, Sonaimukh and Silkuri areas by and large the shallow aquifers exist only in areas in the vicinity of Barak river and tend to pinch out towards southern part of the valley. Cavity wells can successfully be constructed in such areas as well.

ARUNACHAL PRADESH

The Himalayas and Naga-patkai ranges in Arunachal Pradesh constitute about 90% of the total area of the state. Except the Sub-Himalayan range rising to heights of about 1700m. only. The plants and low hilly areas found in Siang, Lohit, Tirap, Lower Subansiri districts prove ground water worthy. The rock types in such areas comprise hard grey sandstone to silty clays pebbly sandstone, silt-stone and boulder beds. The unconsolidated sediments comprise gravels, pebbles, cobbles and boulders set in a matrix of coarse to fine grained sand and silt.

The Central Ground Water Board has covered the entire state by way of systematic hydrogeological surveys both by conventional and non-conventional method followed by limited field checks in case of non-conventional method.

Exploration and first approximate resource evaluation studies had been initiated in Kanubari area of Tirap district, Lower Subansiri, Papampare, Lohit and Changlang districts in recent years. Till date 16 exploratory wells have been drilled in Aurnachal Pradesh.

MANIPUR

The state was entirely covered by systematic hydrogeological surveys. Central Ground Water Board, North Eastern Region had taken up exploration at 15 sites. The clayey and silty nature of the water bearing sediments encountering within the top 50 to 60m depth has adversely limited the construction or open wells and

except in Imphal valley where few number of wells have been observed.

Exploration carried out so far has however indicated the limited potentialities of Ground Water development in the Manipur state. The water bearing sediments are generally very fine to medium sand and as such the yield prospects of tubewells are limited.

MEGHALAYA

The state of Meghalaya, the abode of clouds, is a hilly terrain mostly covered by hard crystalline rocks except in south western parts where semi-consolidated shale, sand-stone and limestone overlie the crystalline basement in West Garo Hills district, Central Ground Water Board delineated valley fills where unconsolidated sand and gravel occur in limited areal extent. The entire state has, however, been covered by systematic hydrogeological survey.

Central Ground Water Board has so far constructed 46 numbers of exploratory wells in West Garo Hills and Jaintia Hills.

MIZORAM

Mizoram is essentially a hilly terrain with a very rugged topography. The hills are steep and separated by river which flow either to the north or south creating deep gorges in between north-south trending hill ranges. The regional geology is represented by repetitive succession of arenaceous and argillaceous sediments south of Tertiary age which occur in relatively higher and lower grounds respectively.

The still youthful nature of the rivers in narrow valleys is mainly responsible for the absence of unconsolidated sediments in the valleys. Thus the lack of granular alluvial material and the predominantly argillaceous nature of the country rock have limited the scope for development of ground water in Mizoram.

The Central Ground Water Board has covered the entire state by systematic hydrogeological surveys. Exploratory drilling was initiated in three places of Aizawl districts.

NAGALAND

Nagaland like other bordering states of Assam is basically a hilly terrain with undulating topography. The Central Ground Water Board has covered the entire state of Nagaland by way of systematic hydrogeological surveys. Based on the surveys areas found suitable for the development of ground water through open well have been demarcated.

Central Ground Water Board in a bid to asses ground water resources in valley areas of Nagaland embarked upon exploration programme in Dimapur, Jaluki and Longnak valleys.

Central Ground Water Board has constructed 7 deep tube wells around Dimapur.

TRIPURA

From the ground water point of view Tripura comes next to Assam in the region. The semi-consolidated Tertiary formations of Tipam Group constitute the main hydrogeological units in the state. These formations consist of friable sandstone, clayey sandstone, sandy shales and shales. These formations are tightly folded into a series of anticlines and broad synclines running parallel to the regional strike of N-S to NNW-SSE. The anticline corresponds to the hilly ranges and the synclines corresponds to the broad valleys in the state.

Intensive hydrogeological surveys and exploratory drilling have been carried out in various synclinal valleys of the state. Entire state has been covered by means of systematic hydrogeological studies. Exploratory drilling have been carried out in Dharmanagar, Kailasahar, Kamalpur, Khowai, Amarpur, Agartala, Belonia and Subroom valleys covering an area of 5160 sq.km. Total 48 exploratory bore hole have been drilled in Tripura.

Monitoring of Ground Water Regime in NE Region

The periodic water level measurements is carried out four times in a calendar year, to monitor ground water regime. Barring Mizoram, all six states are covered under this study. Trend of variation, long term fluctuation and dynamic resources are calculated consequent upon this study.

Technology Mission For Source of Drinking Water in Problem Villages

The Board renders help to the state departments by way of carrying out survey for problem villages. Recommendations are being provided for constructions of suitable ground water structures whereever necessary by giving feasibility reports.

9.1.2 Determination of Chemical Quality of Ground Water For Drinking, Irrigation And Industrial Uses, Pollution Hazards in Industrial Belts

Chemical laboratory of Central Ground Water Board, NER Guwahati has been carrying out the detailed hydrochemical determination from ground/surface water samples throughout the seven states of the region. In addition to this, samples received from various organization/state government/departments are also analyzed.

A number of network stations has been established throughout the region and samples of these are collected annually to determine the change in concentration of different parameters due to various physical changes (rain, drought, flood, erosion etc.).

In addition to routine work, chemical laboratory carried out the pollution study of ground water in different areas viz. Digboi refinery, Guwahati city, Bongaigaon, Jagiroad paper mill and report was submitted/published to make an awareness in the field among the people of the region.

9.1.3 Geophysical Study Relating to Borehole Logging, Resistivity Survey

Geophysical studies have been carried out in the field of borehole logging and also resistivity survey in some selected areas of Assam, Meghalaya and Mizoram state. Borehole logging has been carried out for determination of resistivity and self potential of granular horizons down to a depth of 300 metres bgl. Based on comparative study of field observation and logging interpretation, aquifer zones are delineated and selected for tapping. In Manipur state, saline zones have been detected at some boreholes sits viz. Waikhong area of Thoubal district.

Resistivity survey adopting slumberger method has been carried out in Aizawl district, Mizoram, Jaintia Hills district and East Garo Hills districts, Meghalaya to know the thickness of over burden as well as bed rock topography.

The Central Ground Water Board, North Eastern Region time to time estimates dynamic ground water resource potential of the Region based on methodology adopted by Government of India. And the estimates provided to state organizations for planning irrigation potential.

Other the above studies some of the studies carried out by Central Ground Water Board and whose cross reference were found at different library are listed below;

1. Progress report on systematic hydrological studies of tribal sub plan area covering portion of goalpara district, March 1978.
2. Report on investigation for augmentation of water supply to Narengi cantonment and Basishtha army hospital, June 1978.
3. Note on hydrological investigation for improvement of water supply to railway colony, Lumbding, June 1978.
4. Basic data report and exploratory borehole drilled at Banskandi, Cachar, July 1978.
5. Systematic hydrological studies in portion of Nagaon and Mikir Hills district, August 1977.
6. Systematic hydrological studies in portion of Sibsagar district, Assam, October 1977.
7. Report on systematic hydrological survey in portion of tribal sub plan area of Goalpara/Kamrup district, December 1976.
8. Basic data report on Exploratory borehole drilled at Narangabari, Goalpara, July 1978.
9. Basic data report on Exploratory borehole drilled at Kalajor, Cachar, August 1978.
10. Basic data report on Exploratory borehole drilled at well-7 of Sarangingaon, Sibsagar, June 1978.
11. Basic data report on Exploratory borehole drilled at Kumargaon, Sibsagar, March 1978.
12. Basic data report on Exploratory borehole drilled at Narangabari, Goalpara, July 1978.
13. Basic data report on Exploratory borehole drilled at Rajabahar, Sibsagar, October 1978.
14. Progress report on systematic hydrological studies of tribal sub plan area

covering portion of Goalpara/Garo hills district, February 1978.

9.1.4 Ground Water Resource and Development Prospects in Dibrugarh District, Assam, 1984

The district of Dibrugarh in the upper reaches of Brahmaputra basin of Assam, has total net sown area of 2.2 lakh ha, and only about 0.21 lakh ha are under double cropping due to lack of irrigation facilities. Detailed hydrogeological investigation carried out by state and Central agencies have revealed the consistency and persistence of rich aquifer system down to a depth of 200m. The aquifer system can be broadly divided in to two group; First within 50 m below ground level and second between 50 to 200 m below ground level. The studies classified the district into three sector, both for shallow and deep aquifer zones, depending upon prevalent ground water situation. The sectors near the Brahmaputra river are characterised by high transmissivity while the sector in the southern part by the lower transmissivity. Ground water development prospective in the district with respect to the above sectors has been discussed in the report with recommendations regarding design aspects of tube wells and selection of optimum pumping systems. Areas suitable for different types of ground water development structures have been demarcated. A program of 14,040 shallow tube wells is recommended in the first instance. As regards the feasibility of tube wells 220 tube wells with average discharge of 100 m^3/hr are recommended to be constructed. Thus a total command of 44,800 ha of paddy land can be brought under assured irrigation through shallow tube wells and deep tube wells in the district.

9.1.5 Ground Water Resource Potential and Development Prospects of North Lakhimpur District, Assam, 1987

North Lakhimpur district is predominantly an agricultural area with a geographical area of 5646 sq. km. The net cropped area of the district constitutes 1,64,094 ha with gross cropped area of 2,09,578 ha giving a cropping intensity of 127% of the net sown area, those covered by assured irrigation constitutes 16512 ha i.e. only 10% of the area. The total land holdings in the district is 1,16,000 ha with an average land holding of 1.46 ha. Although the area receives abundant rainfall, the bulk of it occurs mostly in a limited period i.e. from June to September, leaving the winter months dry and devoid of soil moisture. As a result of this water stress occurs in the crops, thereby necessitating supplementary irrigation. The second constrains in the agriculture production of the district particularly during the Kharif season is the menacing flood in the low lying areas of the flood plain along the Brahmaputra river, because of which farmers have to take cultivation during Rabi seasons i.e winter months.

Hydrogeologically the entire district is underlain by unconsolidated alluvial materials composed of sands of various grades, pebbles, cobbles and boulders with silt and clays. Depending upon the distribution of the sediments, their granulometric parameters and physiography of the area, the district is divided in three sectors. Sector A confined to the flood plain area of the Brahmaputra and its tributaries, viz Subansiri, Dikirong and ranga Nadi. This sector is confined to the central and southern parts of Narayanpur, Bihuparia, North Lakhimpur, Bordoloni, Dhakuakhana, Dhemaji and Murkonselek blocks of the district. The area is underlain by sands of

various grades with occasional gravel and pebble with minor thickness of clay bands in a localised area. The aquifer material forms more or less a single horizon down to 160 m. The hydraulic conductivity is found to be 50 to 70 m/day indicating high yield potential of the saturated horizons. Shallow tube wells constructed 30m tapping 10 to 15 m of aquifer horizon are capable of yielding 30 to 35 m^3/hr for drawdown less than 2 m. Deep tube wells constructed within 120 m tapping depth tapping 40 to 50 m aquifer horizons are found yielding 150 to 300 m^3/hr for drawdown upto 8 m. Sector B constitutes northern part of Bihupuria, Naoboisha, North Lakhimpur, Bordoloni, Dhemaji, Murkongselek is identified. This area occurs immediately above flood plains areas as terrace deposits having undergone partial denudation. The area is underlain by pebbles, boulders with silt and sand and clay capping on top. The aquifer materials forms as a single horizon down to 150 m, with hydraulic continuity, in spite of large variation in grain size. Tube wells constructed down to 120 m tapping 35 to 40 m of saturated horizon are found capable of yielding 100 to 120 m^3/hr for reasonable drawdown. The general water level in the sector is found to be 3 to 5 m during lean period along the fringe areas of sector A, however in the northern part water levels/piezometric heads are found to be as much as 8 m. Because of this shallow tube wells are not considered feasible. However, along the fringe areas of sector A where limited sand horizon of 10 to 15 m occurs above boulder zone, twin tube wells can be constructed with yield of 25 to 30 m^3/hr. Sector C forms the hilly terrain of North Lakhimpur and Bordoloni blocks and hence not considered suitable for ground water development. Based on the water level fluctuation data of network hydrograph stations established by Central Ground Water Board in the district, adopting methodology of "Ground Water Estimation Committee 1984", annual gross recharge of 282356 ha-m has been estimated for the district with a utilisable resource of 240002 ha-m. The present net draft on account of existing structures is estimated to be 2884 ha-m only indicating ground water development to be below 3% in the district. Based on the all India delta figure of 0.65 m, the gross irrigation potential is estimated to be 369233 ha with a net potential of 184611 ha. As against this the shallow tube wells feasible in the district are estimated to be 20620 with a net command area of 61,920 ha. In addition to this tentatively 200 deep tube wells are considered in the district with a total command of 8000 ha. Thus in all 69,920 ha of land could be brought under assured irrigation through development of shallow and deep ground water structures in the district.

9.1.6 Hydrology and Ground Water Development Potential of Tripura, 1978

Intensive hydrogeological survey and exploration have been carried out mainly in West Tripura district comprising Agartala and Khowai valleys. Few exploration have also been carried out both by CGWB and State Government Agencies in South and North Tripura districts. Based on the lithology of these boreholes hydrogeological sections have been drawn to study the distribution of aquifer systems inn Tripura. Based on the reconnoitery traverses and data available with the help of some drilling already carried out in Tripura by central or state agencies, attempt has been made to compile district wise ground water potential. In order to assess the quality of ground water in Tripura, water samples from open wells, shallow and deep tube wells have also been collected and analysed. Complete chemical analysis have been carried out for about 28 water samples, collected from permanent observation wells (network stations) established by CGWB

in the state and also from some of the tube wells. Partial chemical analysis have been carried out for about 270 water samples collected from various part of the state during regular hydrological surveys. To check the suitability of water for irrigation, determination of Sodium Absorption Ratio (SAR) test has been done. It has been found that water is of excellent class for irrigation use. Also the utilization of water resource in the state has been discussed.

10.0 RECOMMENDATIONS

After review of numerous reports covering almost all field of hydrology related studies, following recommendations are made:

1. Almost all studies have been done as per the prevailing guidelines and state of art methodology. Some of the studies even have been done twenty - thirty years back. With the passage of time technology has changed much. But it seems no organisation has made any comparisons of the concluded results at the time of study with the actual observations that are being recorded or found at present. If such observations are made, not only the project potential can be better utilised but also it will give a very specific field for researchers.

2. A number of research type studies have been done but it always lacks details about its implementation in actual work. All research studies which are found to be more scientific and rational than its earlier alternatives should illustrate its field application. If some new methodology or formulae are being suggested for some basin or region, after suitable calibration and validation, these should also be used during future studies while preparing detailed project reports etc.

3. The region is having a lot of hydrological problems including floods, drainage congestion, erosion and siltation etc. which have been discussed in details in previous chapters. A number of studies have been carried out for flood and drainage related problems and also remedies have been suggested and implemented. But still the studies in the area of silt problems are lacking. Of course, silt load observations are being made and studies have been done for almost all major streams in the region, no specific studies have done to suggest some methods to trap or minimise the silt load in a stream. In addition to measures like soil conservation and watershed management in the entire basin engineering solutions are also possible to reduce the silt load in the streams. For that some experimental studies should be planned in which silt traps are to identified in the course of (tributary) streams on the principle of detention tank (considering the bed slope and may be some weir type structures have to be constructed) and providing provision for excavating the trap every year during lean discharge period.

4. The north east region being very active seismically, its effect on water resource projects has to be studied in details. No study has been done so far which either shows the seismicity on the height of dam or suggests anything about suitability of high rise dams in this region. In fact such type need the complete seismic behaviour of the region for which permanent and close seismological network has to be created in the region.

5. During the flood season when Brahmaputra river is in high spate, it backs up its tributaries and make them spill near their outfall. Due to this many cases has been observed where several river join together and form pockets. Suitable hydrological and hydraulic studies and measures for disposal of the

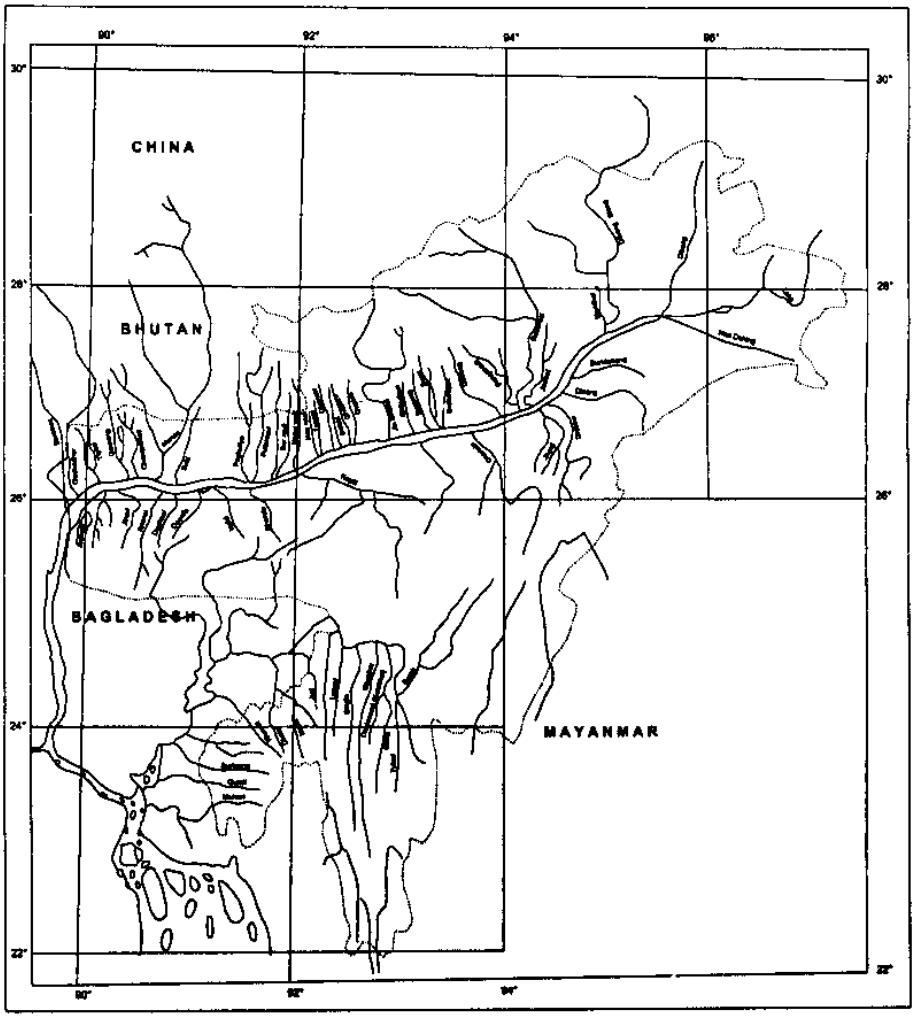
flood congestion in such pockets are required to be taken up.

6. It has been mentioned in many reports/studies that modern/latest techniques could not be used mainly because of lack of data. Studies related to hydrological and meteorological network design is to be taken up and also efforts should be given to established permanent observation stations in the entire area. Also the data collection should be thought of on permanent basis, not only for the preparation of individual projects but also for their regulation for better utilisation of water resource in future years. All data collecting agencies should be trained to collect and record the data in standard format and a centralised data bank for the region should be established.

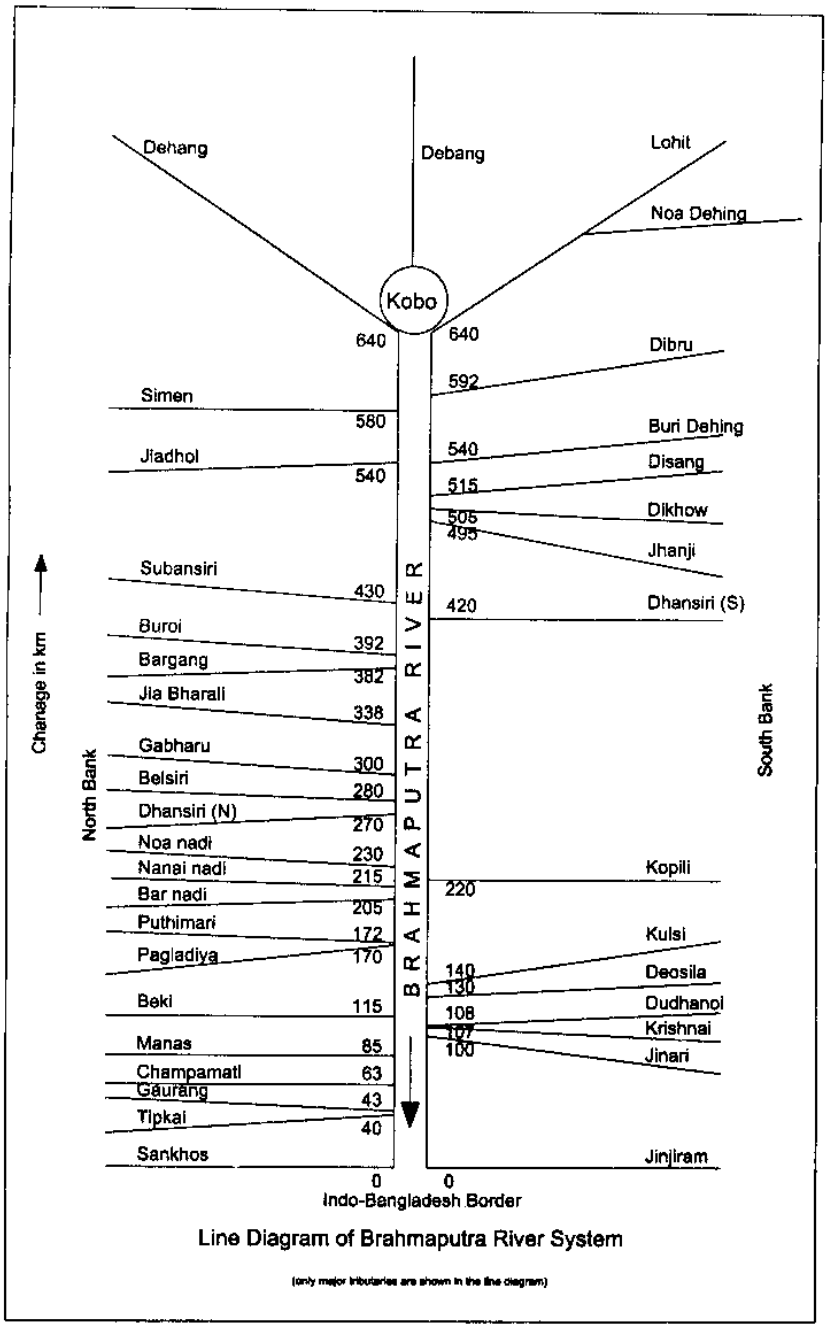
7. Representative and experimental basin studies should be given due importance to understand the complex interaction of the hydrological processes and also for studying the effects of changes in the catchment on the hydrological regime.

8. Water resource sector being highly interdisciplinary in nature and technological developments in this area being quite rapid, it is highly desirable to have a good co-ordination between various agencies working in water sector and it's allied field for providing better understanding of complex processes and real life problems.

APPENDICES

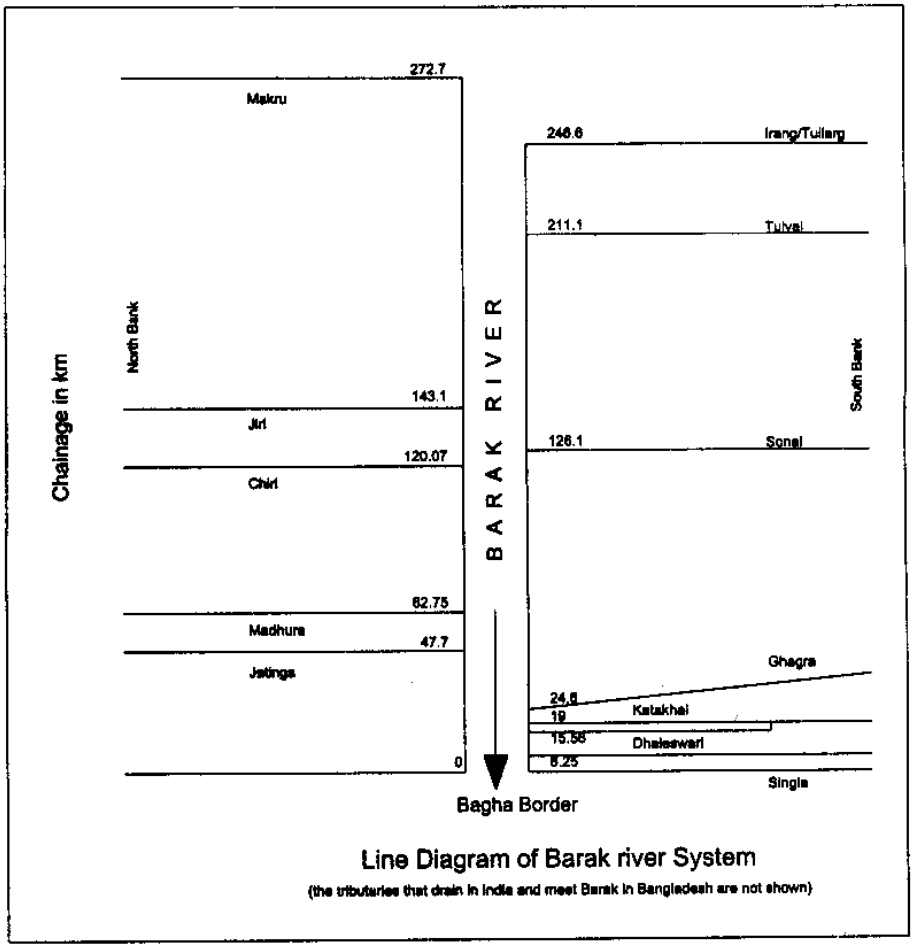


River Systems in North Eastern Region



Line Diagram of Brahmaputra River System

(only major tributaries are shown in the line diagram)



Line Diagram of Barak river System

(the tributaries that drain in India and meet Barak in Bangladesh are not shown)

Note on the Flood in Brahmaputra and Barak Basins in 1998
(Source: Hydrological Observation Circle, Guwahati)

1. Meteorological condition

During May, 98 : A cyclonic circulation lay over Assam upto 1.5 km above sea level (asl) on 16.05.98 and a fresh cyclonic circulation lay over Northeast (NE) Assam and adjoining area on 22nd May extending upto 2.1 km asl. An upper air trough passed between centre of circulation upto 1.5 km asl. On 23rd and 24th the circulation persisted in the same area. Another circulation lay over Manipur and adjoining areas between 0.9 and 2.1 km asl on 28th and persisted on 29th. On 30th it moved and lay over NE Assam and adjoining areas in lower tropospheric levels. Rainfall was isolated over the jurisdiction due to the above system, mainly on 22nd and 23rd for the first time and 30th and 31st, May, 1998 for the second time. It was also heavy at some sites.

During June, 98: On 1st June, a cyclonic circulation lay over NE Assam and adjoining areas extending upto 2.1 km asl. The southwest monsoon had further advanced into rest part of the NE India. A circulation lay over NE Assam and adjoining areas in lower level. The southwest monsoon has advanced into Arunachal Pradesh too, on 6th June, an upper air trough passed from the centre of the cyclonic circulation from NE Assam upto 0.9 km on 7th. A trough on sea level chart on 9th, existed from centre of low pressure that existed over Bihar plateau & adjoining Sub-Himalayan West Bengal, upto Manipur. The circulation persisted over Assam and neighbourhood on 10th upto 1.5 km asl and on 11th upto 0.9 km asl. On 12th it became insignificant. On 14th the circulation over Assam and adjoining area had became less marked, on 17th a trough ran from the centre of the system that existed over North Madhya Pradesh and adjoining East MP to NE Assam across Bihar plains and sub-Himalayan West Bengal, extending upto 0.9 km asl. On 18th the circulation over NE Assam persisted extending upto 0.9 km asl on 19th, 20th and 21st June. On 23rd June, the monsoon trough apparently ran from Rajasthan to NE Assam. On 24th, it disappeared from the region. On 29th, a feeble circulation lay over Assam and adjoining areas extending upto 0.9 km asl. It persisted over the same areas on 30th June also.

During July, 98 : southerlies and Southwesterlies (air current) prevail over Assam and adjoining states on lower tropospheric level, on 1st July. On 3rd, another low pressure area lay over Assam and adjoining areas. A trough on sea level chart between the main low pressure area at Orissa, West Bengal to Assam. On 4th, a trough in lower levels ran from Bihar Plateau to Nagaland, extending upto 1.5 km asl. It persisted on 5th to 7th July. On 8th, the cyclonic circulation that existed on the previous day, became less marked. On 9th a circulation lay over Assam and adjoining areas between 0.9 and 2.1 km asl. On 13th, a secondary trough ran from the centre of the low pressure that existed over Eastern UP and neighbourhood, to Nagaland, extending upto 1.5 km asl. On 14th, an upper air trough ran from the same system to NE Assam extending upto 0.9 km asl. The monsoon was vigorous over Arunachal Pradesh and active over Assam and Meghalaya. On 15th a trough with vertical extending upto 0.9 km asl. On 17th it persisted withan embedded circulation over NE Assam and adjoining areas extending upto 0.9 km asl. On 18th, the circulation over NE Assam became less marked, but the monsoon trough continued to extend upto East Arunachal Pradesh. On 19th, 20th and 21st also the

monsoon trough passed from Punjab to Arunachal Pradesh with embedded circulation over Assam and adjoining areas extending upto 0.9 km asl on 22nd, on 23rd, 24th, the monsoon trough ran from Punjab to Nagaland and on 26th upto East Arunachal Pradesh. A circulation lay over Assam and adjoining areas on 27th, extending upto 0.9 km asl and persisted on 28th, 29th. On 31st, a feeble circulation lay over Assam upto 0.6 km asl.

During August, 98 : The circulation over Assam and adjoining areas that existed on 31st July, persisted on 1st and 2nd August also with circulation upto 0.9 km asl. On 4th the monsoon trough passed ran from Punjab to Nagaland. A circulation lay over Assam and adjoining area on 7th extending upto 1.5 asl. On 8th, the circulation over Assam and adjoining area that existed on the previous day became less marked. On 11th, a secondary trough ran from Bihar Plateau to East Arunachal Pradesh across Meghalaya and Assam. On 12th, an upper air trough ran from the centre of the circulation over U.P and Bihar to East Arunachal Pradesh across Sub-Himalayan West Bengal, Assam and Meghalaya with vertical extension upto 3.6 km asl. The circulation that existed on 16th August, over Assam areas became less marked on 17th, monsoon trough on sea level chart ran from Punjab to NE Assam on 17th. On 18th a secondary trough ran from Bihar plains to East Arunachal Pradesh and upto Nagaland on 19th. On 24th, a trough in low levels upto 0.9 km asl ran from Bihar plains to East Arunachal Pradesh. On 25th, a circulation lay over West Assam and adjoining Sub-Himalayan West Bengal extending upto 0.9 km asl. On 26th it persisted and on 27th, it extended from East M.P to East Arunachal Pradesh. On 28th, it ran upto West Arunachal Pradesh across Bihar plains and SHWB extending upto 1.5 km asl. On 29th it ran from Punjab to East Arunachal Pradesh across Bihar Plains, SHWB, Assam and Meghalaya. On 30th and 31st too it persisted from Punjab to East Arunachal Pradesh.

During September, 98 : On 1st a circulation lay over Assam and Meghalaya extending upto 0.9 km asl. On 2nd, a secondary trough in the lower levels extended from Central Bihar to West Arunachal Pradesh. On 3rd, it persisted over the same region, on 4th, the trough in lower levels ran from eat M.P. to Northeast Assam across Bihar plains and sub-Himalayan West Bengal with embedded cyclonic circulation over Northeast Assam and adjoining Arunachal Pradesh extending upto 1.5 km asl. On 5th, it ran from East U.P. to Nagaland and on 6th, it persisted over the same region. On 7th it became insignificant. On 9th, a feeble trough lay extended upto Nagaland from the main system that prevailed over North Orissa and Bihar plateau. On 10th, it extended upto Northeast Assam upto 0.9 km asl. On 12th, a circulation lay over Northeast Assam and neighbourhood, extending upto 0.9 km asl. On 16th September a circulation lay over Tripura and adjoining Mizoram extending upto 2.1 km asl. On 17th it moved and lay over North Bangladesh and neighbouring Assam and Meghalaya region. On 18th, the system moved towards Bihar plains and neighbourhood with extending upto 3.6 km asl. A feeble circulation lay over North-east Assam and adjoining Nagaland, on 18th. On 21st, the circulation over East Assam and adjoining Arunachal Pradesh was seen as feeble trough over same area. On 22nd, a trough from the main system that existed over Madhya Pradesh ran upto West Arunachal Pradesh extending upto 0.9 km asl. On 23rd, it ran from Rajasthan to East Arunachal Pradesh, extending upto same height, with embedded circulation over Assam. On 24th, it persisted. On 25th, the circulation over Assam and Arunachal Pradesh persisted. On 26th and 27th, the circulation persisted. On 29th, it became insignificant.

During October, 98 : On 2nd October Cycer lies over West Assam, Meghalaya between 2.1 km asl to 4.5 km asl. A trough in lower level ran from the centres to Mizoram. On 6th South West Monsoon has withdrawn from Assam and adjoining states.

Annual/Seasonal Rainfall in Meteorological Sub-Divisions

Meteorological Sub-divisions	Geographical area (sq.Km)	Forest Area (1976-77) (Sq.Km)	Annual Rainfall (mm)	Seasonal Rainfall (June-Sept) (mm)
Arunachal Pradesh	83580	51540	2997	2085
Assam and Meghalaya	101010	36840	2497	1624
Nagaland, Manipur, Mizoram and Tripura	70460	31190	2314	2092
Sub-Himalayan West-Bengal and Sikkim	N.Av	N.Av	2779	2172

(Source: Central Water Commission, New Delhi (1987), 'Annual and Seasonal Rainfall in different Meteorological Sub-divisions of India'. A Brochure on Water Resources of India, pp. 02)

Stations Showing Heavy Rainfall in N-E India

Station	State	Meteorological sub-division	Mean annual rainfall (cm)	Elevation (m)	Period of record
Cherrapunji	Meghalaya	Assam and Meghalaya	1102	1313	1902-1975
Mawsynram	Meghalaya	Assam & Meghalaya	1221	1401	1941-1969
Denning	Arunachal Pradesh	Arunachal Pradesh	528	698	1929-1949
Buxa	West Bengal	Sub-Himalayan west Bengal & Sikkim	532	N A	1891-1968

(Source : NIH Publication 'Distribution of precipitation with elevation', TR-45, NIH, Roorkee, India)

NORMAL ANNUAL AND SEASONAL RAINFALL IN THE DISTRICTS OF METEOROLOGICAL SUB-DIVISIONS.

Name of Met Sub-Divisions	Name of District	Normal Rainfall in mm	
		Annual	Seasonal (June-Sept.)
Arunachal Pradesh	Tirap Frontier Tract	4142.1	2742.8
Assam & Meghalaya	Goalpara	2801.3	944.6
	Kamrup	2125.4	1391.8
	Darrang	2194.0	1464.0
	Nowgong	1717.8	1168.5
	Sibsagar	2197.0	1391.1
	Lakhimpur	2929.7	1938.5
	Cachar	3293.9	2041.5
	United Mikir and North Cachar Hills	3071.6	1853.4
	Garo Hills, United Khasi	2735.0	1909.0
	Jayantia Hills	6344.9	4749.6
Nagaland, Manipur, Mizoram & Tripura	Naga Hills	2377.3	1581.8
	Manipur	2389.2	1578.7
	Mizo Hills	2821.9	1927.6
	Lusai Hills Tripura	2100.7	1325.2
Sub-Himalayan West-Bengal and Sikkim	Cooch Behar	3201.3	2454.8
	Darjeeling	2994.1	2407.8
	Jalpaiguri	3944.7	3090.1
	Malda	1540.3	1209.7
	West Dinajpur	1734.8	1281.6
	Sikkim.	N.Av	N.Av.

(Based on records from 1901-1950,Source: Memories of IMD, 1961

Damage report of Floods in Assam from 1982-98

Year	Area Affected (ha)	Crop area Affected (ha)	Population affected	No. of human life lost	No. of cattle lost
1982	6863226	3549127	1423029	16	27
1983	694999	126346	2121273	20	1574
1984			-3869262	48	-
1985	920410	132400	3251640	78	833
1986	426000	322200	2345000	13	242
1987	3077800	989100	10483000	127	-
1988	4650000	133500	12677000	232	4621
1989	744000	371000	2643000	39	3086
1990	488179	207143	1692222	28	4767
1991	997000	348100	5307000	113	21627
1992	231133	42744	996417	12	58
1993	1248829	215053	5360502	72	1356
1994	52609	24937	176622	7	95
1995	722661	398980	5599125	74	6087
1996	1001460	246333	3076625	42	3
1997	7534069	102943	2750624	28	1961
1998	972328	288900	4698458	105	7814

(Source: CWC Flood damage Report of Assam Annexure VI)

District wise Ground Water Resource Potential in Assam

Sl No.	District	Gross Resource (MCM)	Utilisable Resource (MCM)
1	Barpeta	1154.50	981.33
2	Bongaigaon	626.00	532.10
3	Darrang	1161.72	987.46
4	Dhemaji	1028.57	874.28
5	Dibrugarh	1111.74	944.98
6	Dhubri	1219.06	1036.20
7	Goalpara	577.39	490.78
8	Golaghat	1120.76	952.65
9	Jorhat	944.68	802.98
10	Kamrup	1042.63	886.24
11	Karbi Anglong	2094.46	1780.29
12	Kokrajhar	971.67	825.92
13	Lakhimpur	714.54	607.36
14	Morigaon	401.76	341.50
15	Naogaon	1361.73	1157.47
16	N.C. Hills	1119.88	952.90
17	Nalbari	881.16	748.99
18	Sibsagar	1157.68	984.03
19	Sonitpur	1557.17	1323.59
20	Tinsukia	1226.73	1042.72

(Source: CGWB, Guwahati)

Ground Water Potential in the North Eastern Region

(in Cubic km/year)

Sl. No	State	Total replenishable ground water resource	Provision for domestic industrial & other uses	Available ground water resource Major, Medium & Minor Irrigation	Net draft	Balance ground water potential available for exploitation	Level of ground water development (%)
1	2	3	4	5	6	7	8
1	Arunachal Pradesh	1.44	0.22	1.22	0.00	1.22	
2	Assam	24.72	3.71	21.01	0.94	20.07	4.48
3	Manipur	3.15	0.47	2.68	Negl	2.68	negl
4	Meghalaya	0.54	0.08	0.46	0.02	0.44	Negl
5	Mizoram	-	-	not assessed	-	-	-
6	Nagaland	0.72	0.11	0.62	Negl	0.62	negl
7	Tripura	0.66	0.10	0.56	0.19	0.38	33.43
	Total NE states	31.23	4.69	26.55	1.15	25.41	4.33
	All India total	431.89	70.93	360.96	115.17	245.79	31.92

(source: water and related statistics by CWC, June, 1996)

Statewise Achievement of Irrigation Potential; (Created and Utilised) in North Eastern (1992-93)

Sl No	State	Major and Medium (surface)		Minor						Grand	
				Surface		Ground		Total		Total	
		P	U	P	U	P	U	P	U	P	U
1	2	3	4	5	6	7	8	9	10	11	12
1	Arunachal Pradesh	...	...	66.0	57.0	2.1	2.1	68.1	59.1	68.1	59.1
2	Assam	182	114	403.0	344.2	180.1	128.1	583.1	472.3	765.1	586.3
3	Manipur	62	53	50.9	41.8	0.4	0.4	51.3	42.2	113.3	95.2
4	Meghalaya	...	...	35.9	30.0	9.2	9.2	45.1	39.2	45.1	39.2
5	Mizoram	...	...	11.0	9.3	...	...	11.0	9.3	11.0	9.3
6	Nagaland	...	...	65.0	55.8	0.9	0.9	65.9	56.7	65.9	56.7
7	Tripura	2	2	72.3	64.5	19.6	19.6	91.9	84.1	93.9	86.1
NE Total		246	169	704.1	602.6	212.3	160.3	916.4	762.9	1162.4	931.9
India Total		31128	26616	11619.1	10404.5	40261.8	37494.3	51880.9	47898.8	83008.9	74514.8

P = potential created, U = potential utilised

(source: water and related statistics by CWC, June, 1996)

Statewise Ultimate Irrigation Potential in NE Region (Thousand Hectare)

Sl No	State	Major & Medium Surface Water	Minor irrigation			Irrigation Potential (Major, Medium & Minor)	UIP in ha per thousand person
			Surface Water	Ground Water	Total		
1	Arunachal Pradesh	-	150	18	168	168	194
2	Assam	970	1000	900	1900	2870	128
3	Manipur	135	100	369	469	604	329
4	Meghalaya	20	85	63	148	168	95
5	Mizoram	-	70	Not assessed	70	70	101
6	Nagaland	10	75	Not assessed	75	85	70
7	Tripura	100	100	81	181	281	102
Total NE states		1235	1580	1431	3011	4246	145.57
Total (all India)		58475	17378	64050	81428	139903	167.00
% NE Region		19.91	44.56	14.83	30.43	27.37	
% all India		53.23	66.86	62.86	63.71	59.33	

% : percentage of potential created upto the end of 1992-93 to ultimate potential.

(source: water and related statistics by CWC, June, 1996)

Address of Organisations and Consultants Working/Dealing in Water Resources Sector

1. Chief Engineer(B & B Basin)
Central Water Commission,
Jamir Mansion,Nongshilliang,
Shillong - 793 014.

2. The General Manager,
Brahmaputra Board,
Basistha, Beltola,
Guwahati - 781 028.

3. The Chief Engineer,
Irrigation & Waterways Directorate
Govt. of West Bengal
Calcutta - 700 001.

4. The Advisor, (IFC&WSM)
North East Council Sectt.,
Shillong - 793 001.
Meghalaya.

5. The Chief Engineer,
Irrigation, Assam
Chandmari, Guwahati-781 003.

6. Director,
Central Ground Water Board,
NE Circle
GS Road,Tarun Nagar (near Rajeev Bhavan)
Guwahati - 781 005.

7. Director, Technical Education
Assam, Kahilipara
Guwahati - 781 006.

8. The Chief Engineer & Secretary,
Deptt. of irrigation,
(Govt. of Sikkim),
Kazi Road,
Gangtok - 737 103.

9. The Chief Conservator of Forests,
Govt. of Assam
Basistha, Beltola - 781 028.

10. The Director,
NERIWALM,
Dolabari,
Tezpur-784 027, Assam.

11. The Director,
ICAR,
Barapani - 793 103
(Meghalaya)

12. The Professor & Head,
Civil Engg. Deptt.,
Assam Engg. College,
Guwahati - 781 013.

13. The Chief Engineer,
Irrigation & Flood Control Department
Govt. of Arunachal Pradesh
Itanagar - 791 111.

14. The Chief Engineer,
Irrigation and Flood Control Department
(Govt. of Manipur), PWD Building,
Kuyatang,
Imphal - 795 001.

15. The Chief Engineer,
Flood Control Deptt.,
Chandmari,
Guwahati - 781 003.

16. Chief Engineer
Public Health Engg. Deptt
Hengrabari, Guwahati-781 005

17. Chief Engineer
Minor, Irrigation, Assam
Chandmari, Guwahati-781 003

18. The Director,
Agriculture Deptt.,
Khanapara - 781 022.

19. Prof.C P Sinha
Head, Civil Engg.,NERIST
Itanagar, Arunachal Pradesh

20. The Head,
Assam Remote Sensing Application Center,
R.G. Barauh Road,
Guwahati - 781 024.

21. Director, Design
Irrigation, Assam
Chandmari, Guwahati-781 003

22. The Director,
Deptt. of Agriculture,
New Agricultural Complex Building
Fruit Garden, Shillong-793 003.

23. The Joint Director,
Deptt. of Irrigation,
Govt. of Nagaland,
Kohima - 797 001.

24. The Superintending Engineer,
Hydrological Observation Circle,
Central Water Commission
Nabin Nagar, Guwahati-24

25. Addl.Chief Engineer(Civil)
Me.S.E.B., Barapani-793 103
Meghalaya

26. Superintending Engineer(Civil)
Design & Inv. Circle, Me.S.E.B.,
Barapani-793 103, Meghalaya

27. Addl. Chief Engineer,
WAPCOS (india) Ltd.
Chandan nagar. Guwahati - 28

28. The Project Officer
Loktak Lake Development Authority
Imphal, Manipur

29. Assistant Executive Enginner,
Dhangiri Project Division (irri.)
Canal - I,
Udaiguri,
Darrang (assam)

30. Ex. Engineer,
Cachar Irrigation Division,
Badarpur (Assam)

31. Executive Engineer
North Lakhimpur
E & D Division,
North Lakhimpur
Assam

32. Executive Engineer
Pahumara Rupahi Division,
(Irrigation),
Sarupeta,
Assam

33. Ex. Engineer
Tangla Div.(Irri.),
P.O. - Tangla,
Assam

34. Ex. Engineer
Karbi Anglong Irrigation Division,
P.O. - Bakulia,
Assam

35. Ex. Engineer,
Irrigation $_{135}$division Kokrajhar,
Distt. kokrajhar,
Assam

36. Addl. Chief Engineer
Cachar and Hills Flood Control
Silchar - Assam

37. Asstt. Executive Engineer
Aryapatti,
Silchar - Assam

38. Asstt. Engineer
Karimganj Flood Control Divn.,
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39. Assistant Executive Engineer
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40. Secretary,
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41. Executive Engineer (Agr)
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Assam-782460

Storage Potential in Brahmaputra Valley

Name	Run-off (M ha-m)			Storage (M ha-m)			Peak flow (cumecs)	Catchment area (km^2)		Distance of dam site from confluence (km)
	Monsoon	non-monsoon	Total	Dead	Live	Total		upto dam site	upto confluence	
Dam on south bank tributaries upto and including Noa Dihing										
Noa Dihing	0.186	0.084	0.27	0.014	0.024	0.038	729.00	1719.00	2600.00	100.00
Disang	0.29	0.13	0.42	0.02	0.06	0.08	1093.00	1095.00	3950	65
Dikhu	0.31	0.11	0.42	0.02	0.08	0.1	1378.85	3266	4372	74.5
Jhanji	0.12	0.05	0.17	0.005	0.025	0.03	643.77	570	1349	60
Dayang of Dhansiri	0.154	0.066	0.22	0.03	0.12	0.15	2296.00	2606	4550	60
Kopili khandong	0.084	0.042	0.126	0.024	0.059	0.063		1256		
Kopili Umrong	0.088	0.044	0.132	0.002	0.016	0.018	1942	1318	15000	230
Lower Kopili	0.050	0.026	0.076	0.007	0.032	0.039		760		140
Amring	0.069	0.035	0.104	0.006	0.036	0.042		684		124
Kulsi (khri)	0.16	0.07	0.23	0.017	0.034	0.051	323	800	4005	70
Other tributaries										
Lohit	2.37	1.33	3.7	0.185	0.331	0.516		19100	23400	150
Dibang	2.33	1.06	3.39	0.15	0.47	0.62	11190	10350	12270	80

Name	Run-off (M ha-m)			Storage (M ha-m)			Peak flow (cumecs)	Catchment area (km^2)		Distance of dam site from confluence (km)
	Monsoon	non-monsoon	Total	Dead	Live	Total		upto dam site	upto confluence	
Subansiri	3.78	1.49	5.27	0.4	1.0	104	18799	27000	37700	95
Jia Bharali	1.82	0.77	2.59	0.14	0.51	0.65	9939	9980	14450	120
Pagladiya	0.073	0.027	0.1	0.004	0.01	0.014	1733	570	1820	70
Puthimari	0.177	0.073	0.25	0.03	0.04	0.07	861	1180	1787	70
Manas	2.96	0.86	3.82	0.20	0.72	0.92	10840	29400	38176	153
Dihang (Siang)										
Dihang (Siang)	11.74	6.16	17.9	1.15	3.55	4.7	29.643	247500	249500	100

(Source: Master Plan of Brahmaputra Main Stem, Brahmaputra Board)

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