Sarma, B.; Sarma, A. K.; Mahanta, C.

Gis Based Inventory of the Rivers of Northeastern Region of India For Their Conservation and Management

GIS BASED INVENTORY OF THE RIVERS OF NORTHEASTERN REGION OF INDIA FOR THEIR CONSERVATION AND MANAGEMENT

Sarma B.[1], A K Sarma[2] and C Mahanta[3]

Abstract: *River system management requires maintaining records of large numbers of attributes and their analysis. Management and analysis of such large spatiotemporal dataset can be conveniently carried out with the help of Geographical Information System (GIS). Considering this, a GIS database system has been designed to facilitate efficient monitoring of river system of the Northeastern Region of India. The developed database is user friendly to retrieve required information through simple GIS queries and one can also develop similar database for river systems elsewhere. Designed in ArcGIS 9.1 platform it contains two major databases; river network database and water quality database. In the river network database, digital map of the stream networks has been prepared and linked with the additional databases like watershed and discharge database. In the water quality database, the secondary and primary data regarding the river water quality of the region has been incorporated and linked with the river network database. Water quality status of the rivers was assessed on the basis of primary data supported by calculation of Water Quality Index (WQI) and secondary data. The water quality database provides scope of getting information of as many as 24 important water quality parameters and location of sampling sites (119 sites).The developed GIS database is expected to help in developing better monitoring and mitigation strategies of these rivers and thereby suggest appropriate action plan and techno-management measures for the rivers of the region.*

Keywords: *GIS; River; Water quality; WQI*

INTRODUCTION

Rivers are the most dynamic features of nature; and they keep constantly changing. Rivers show wide variation in shape, size and water chemistry over time and space due to close and mutual interaction with the land that it traverses through. It is important to maintain the records of such changing river history for projection of future trends of such variables and management of the river system. This includes records of large numbers of attributes regarding the water quality, flow, water velocity, discharge, shape, size, present aquatic community etc of a river system at different temporal and spatial dimension.

[1] Senior Research Fellow, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781039,India Email: s.banasri@iitg.ernet.in
[2]Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, India Email: aks@iitg.ernet.in.
[3]Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, India Email: chandan@iitg.ernet.in

The Northeastern Region of India has numerous streams and rivers (Sarma et al., 2009). The rivers of the still at relatively pristine state, as the region have limited industrialization so far. However, with the present trend of urbanization, there is serious threat to the rivers from pollution. Also, the impact of climatic change on the water resources of an eco-sensitive region like Northeast India can be of serious concern for the scientific community (Arnell, 1999; Mujumdar, 2008). As the region's economy is highly dependent on its water resources, water resource degradation may have undesirable impact on the socioeconomic condition of the region. Thus, a GIS database of the rivers incorporating all information relevant to the rivers has become necessary to assess the existing status regarding physiographic characteristics and water biochemistry of the rivers. This paper presents development of a GIS database system to facilitate efficient monitoring and management of river system of the Northeastern Region of India.

STUDY AREA

The study area, which lies between 22^{o}N to 29^{o}N latitude and $87^{o}55^{/}$E to 98^{o} E longitude, comprises of eight states: Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Tripura and Sikkim.

The Brahamaputra is a major international river covering a drainage area of 5,80,000 sq.km, 50.50% of which is in China, 33.60% in India, 8.10% in Bangladesh and 7.80% in Bhutan. Its basin in India is shared mostly by Arunachal Pradesh (41.88%), Assam (36.33%), Nagaland (5.57%), Meghalaya (6.10%) Sikkim (3.75%) and West Bengal (6.47%) (Ojha et al., 2004). Barak is the second most important river of Northeastern India. The river originates from the Naga Hills and ultimately drains through Bangladesh to Meghna River. The study area along with the river network is presented in Figure 1.

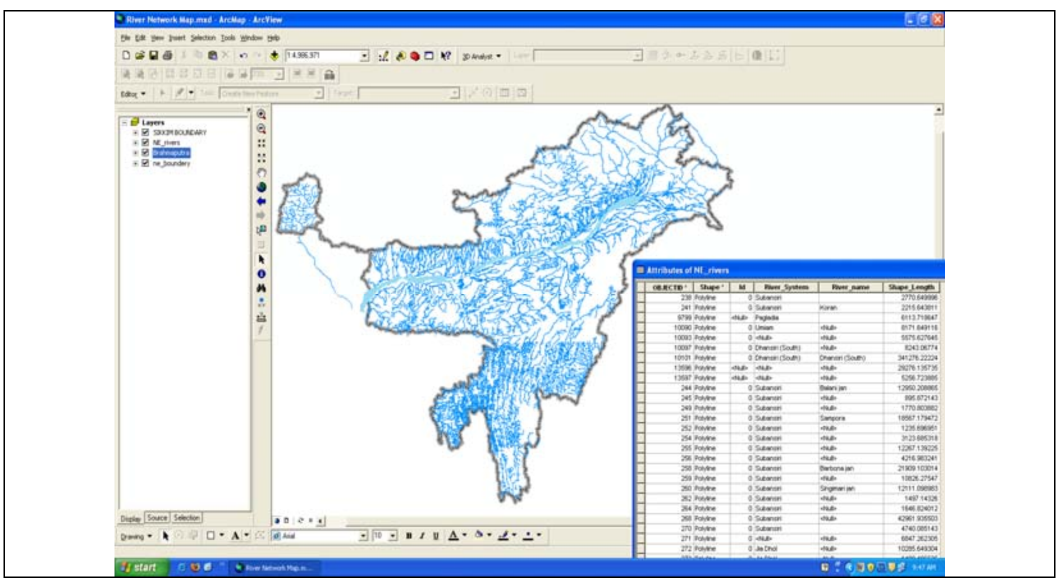

Fig. 1. River Network Database of the Study Area in ArcGIS 9.1

MATERIALS AND METHOD

Database Design

The databases were designed as individual "Feature class" in ArcGIS 9.1 with same projection system so that different layers can be overlaid. Following the projection system adopted in Survey of India (SoI) toposheets, this study adopted the Polyconic-Everest projection system. Projection and transformation of the scanned maps and imageries into real world coordinates has been done in ERDAS software. The detail of the toposheets and imageries used in the study is presented in Table 1.

The vector map of the river network was developed by digitizing Survey of India (SoI) toposheets and satellite imageries. To incorporate the geomorphologic changes of the rivers that have occurred after creation of the toposheets (1972), extensive editing, especially in the plain areas, has been done by referring to the recent imageries and final digital river network layer was prepared.

Table 1. Details of the maps and imageries used in the study

Sl. No	Toposheets	Source
1	1: 2500000 scale toposheets covering NE India	University of Berkely website
2	1:50000 scale toposheets covering NE India (1972 edited)	Survey of India
3	IRS AWiFS imagery (multispectral) of NE India Resolution:59mx59m	NRSA
4	Recent IRS LISS III imagery (multispectral) Resolution:23.5mx23.5m	NRSA
5	SRTM DEM Resolution:90mx90m	CGIAR Consortium for Spatial Information (CGIAR-CSI) website

For the river watershed database, watershed delineation was done primarily from SRTM DEM (using Hydrology tool of ArcGIS 9.1). The River water quality database and discharge database was prepared incorporating both primary and secondary data. GARMIN GPS (model: 76 CSx) with MapSource Software was used for creating GIS layers for sampling locations of the primary water quality data.

River Water Quality Assessment

The river water quality data from different sources were collected as secondary data (CIFRI, 2003, Mahanta et al., 2004, Trisal et al., 2004, Hussain et al.,2006 , CPCB,2008,Girija, 2008). Besides, the present water quality status of the rivers was also investigated where analysis of about of 24 water quality parameters was carried out. Water quality analysis was done both in situ and in the laboratory using standard procedure (APHA, WEF, AWWA, 1998). Instruments used for field testing were: Eutech pH meter, Eutech TDS meter, Wagtech pH meter and conductivity meter, Wagtech Turbidity meter, VSI DO meter. Considering the time frame and dimension of the work, Wagtech Potakit (manufacturer: Wagtech International) was used to facilitate testing of some parameters in a very short time compared to the conventional laboratory procedures. The parameters that were tested with Wagtech Potakit are Nitrate, Nitrite, Ammonia, Free Chlorine, Total Chlorine, Iron, Sulphate, and Microbiological testing. Parameters investigated in the laboratory using standard methods (APHA, WEF, AWWA, 1998) were DO, BOD, COD, Iron, Nitrate-Nitrogen, Sulphate, Phosphate, Silica, Chloride, Alkalinity, Hardness, Calcium, Magnesium, Sodium and Potassium.

To understand the overall water quality status of those rivers, water quality index (WQI_a and WQI_m) was calculated following the guideline of NSF WQI (Canter, 1996) with some simplifications applicable to this study. To calculate the aggregate WQI, a weighted linear sum of sub indices (WQIa) or a weighted product aggregation function (WQI_m) is used:

$$\text{NSF } WQI_a = \sum W_i Q_i \quad (i = 1 \text{ to } n)$$
$$\text{NSF } WQI_m = \prod Q_i^{W_i} \quad (i = 1 \text{ to } n)$$

For each test, the numerical value or Q-value is multiplied by a “weighting factor” as given in Table 2.

Table 2. Water quality factors and weights (Canter, 1996)

Factor	Weight
Dissolved Oxygen	0.17
Fecal coliform	0.15
pH	0.12
Biochemical Oxygen Demand	0.10
Temperature change	0.10
Total phosphate	0.10
Nitrate	0.10
Turbidity	0.08
Total solids	0.08

Based on WQI, the following scale of acceptability, developed by NSF,USA , was used to decide the overall quality of water :
91-100: Excellent
71-90: Good
51-70: Medium
26-50: Bad
0-25: Very Bad

In this study, both WQI_a and WQI_m were calculated following the procedure described in NSF WQI(Canter, 1996), with the following modifications:

1. The nine parameters that are considered are dissolved oxygen, fecal coliform bacteria, pH, 5-day BOD, temperature change, total phosphorus, nitrate-nitrogen, turbidity, and total dissolved solids (pathfinderscience, 2009). Instead of TS in NSF WQI, total dissolved solid (TDS) is considered instead of total solid (TS) for this study. As samples for the present study being calculated from surface of the river, the characteristics high sediment load of the river were not generally reflected by the TS value present in the samples. Besides most of these suspended solids being of natural origin are generally of non toxic nature constituted mostly by silicate minerals. Based on these two aspects, since these solids contribute ionic species to the dissolved load, it was considered to include the TDS value, instead of TS value for the WQI calculation. Also, the weight factor and Q-value of TDS is considered to be same as TS described in NSF WQI (referred to Table 2)
2. All parameters are considered to have same Q values and weight factors as that of NSF WQI
3. Temperature change is considered to be nil in calculating WQI, as for the sampling stations covered under the study almost consistent temperature prevailed and there was no source of temperature deviation.
4. For fecal coliform bacteria, following scenarios are considered: For some samples, the FC test indicated presence of bacteriological contamination; however exact measurement of FC could not be done. So for those sample stations, WQI is calculated considering an average Q value for FC based on the observed cases (i.e. 65) and curves showing variation of WQI with FC (other parameters remaining same) are developed, as actual FC in these points may differ from the average observed value. Generally it is expected that most of the rivers of Northeast India are contaminated with fecal waste, so in case where our experiment did not clearly show presence of fecal coliform, we have still calculated WQI considering average FC value (i.e. 65)
5. During this study, nitrate and phosphate were found to be below detectable level (BDL) for some samples. In such cases, Q values of these two parameters were taken to be 99

For calculation of Q values for all the nine parameters, online software was used available in NSF website (*http://www.water-research.net/watrqualindex/waterqualityindex.htm*).

THE STRUCTURE OF THE RIVER INFORMATION SYSTEM

The major component of this river information system was- the river network database and the river water quality database. Besides, additional databases like watershed database and discharge database were also included in this river information system database. These databases were made relational with the common field ("River Name"), which provides linking of the rivers with their respective water quality data at the geographical location of the sampling sites. The schematic diagram of the structure of GIS database is shown in the Figure 2.

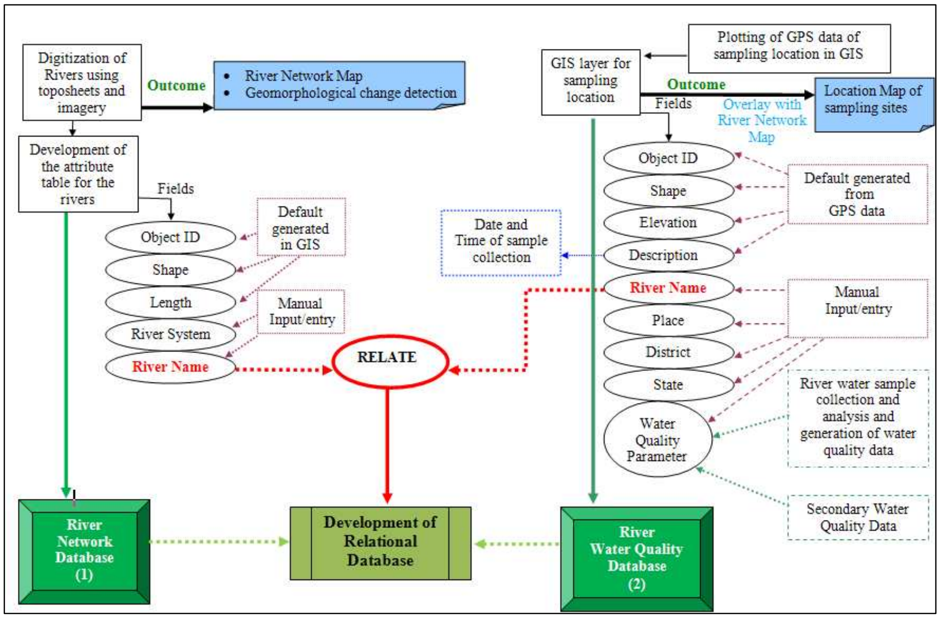

Fig.2. Schematic Diagram of the GIS Database for the Rivers of Northeastern Region of India

The River Network Database

The digital stream network map of the Northeastern region gives the geographical locations and morphological status of the rivers. Stream network data thus developed revealed that the rivers are generally meandering and sometimes braiding at the foothill areas and have experienced various morphological changes form the past time.

The river network database contains the following information:

1. A feature ID: This gets generated by default in ArcGIS for every feature at the time of digitization. This ID is unique for each and every river.
2. Shape length: Length of the river
3. River name: Corresponds to the local name of the river
4. River system: Name of the major tributary of which the stream is a part
5. Average width: Average widths of the major tributaries.

The Water Quality Database

The developed water quality database provides scope of getting information of as many as 24 water quality parameters and location of sampling sites (119 sites). The water quality database contains the following information:

1. The source of the data
2. An unique feature ID
3. Latitude and longitude of the point
4. River name
5. Place name of the sampling point
6. Date and Time of sampling
7. State where the sampling point is located

8. District where the sampling point is located
9. Water quality parameters

Some Additional Databases of the River Information System
Watershed Database

The watershed database contains the following information:

1. An unique feature ID of the watershed
2. Name of the watershed (as per the name of the river system)
3. Area covered by the watershed

River Width and Discharge Database

Average widths of rivers can be measured using the measure tool of ArcGIS from toposheets and imageries and likewise river width database may be created. Width of some major rivers in the plain area was measured in equally spaced points along the river and average of these widths was taken as the average width of the river. In GIS, a table was created with these data and linked with the GIS database of the rivers. Discharge data of some major tributaries of the region were collected from Brahmaputra Board, Guwahati, Assam and incorporated in a geodatabase table.

LINKING OF DIFFERENT DATABASES OF THE IN GIS

The various primary data generated and secondary data collected have been incorporated in different layers in GIS. All these layers are linked with the digital river network layer. A view of the linking of the rivers with their respective water quality is presented in Figure 3.

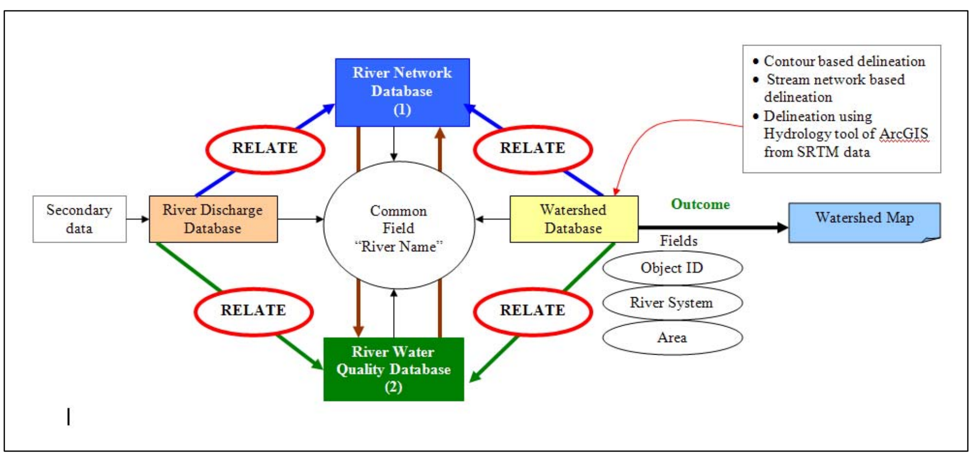

Fig. 3. Linking of Different Databases in GIS

This linking provision, using the 'relate' tool of ArcGIS, enables the information of different databases to superimpose with each other. This helps in relational analysis of geomorphological and biochemical features of the river system. Besides, GIS provides various query tools with which one can also retrieve other information like number of streams, their names, lengths or other related information like width, discharge, water quality etc shown by a particular watershed. A view of the linking of different databases with the river network layer is presented in Figure 4.

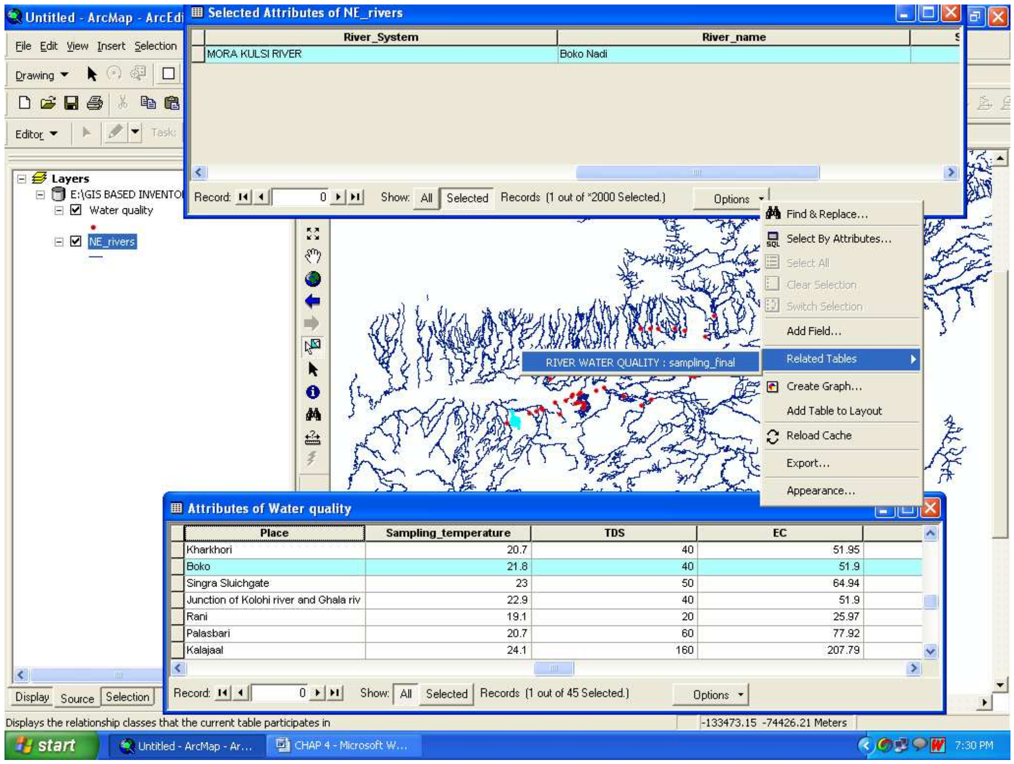

Fig. 4. A view of the linking of the rivers with their respective water quality in ArcGIS 9.1

GENERAL OBSERVATIONS ON WATER QUALITY OF THE RIVERS

River water of the region is generally alkaline with high bicarbonate, sulphate and dissolved silica concentration. DO, BOD, fecal coliform and turbidity are common violating parameters (according to BIS guideline) for most of the rivers. Though seasonal and spatial variation of water quality can be significant (due to monsoon with high discharge and non monsoon with low discharge), this could not be evaluated due to the large area to be covered within short duration.

The sediment load is significant for the rivers of the region (Mahanta et al., 2004) leading to high turbidity values. Sediment load in rivers raises the channel bed and thus leads to flood during monsoon, exhibiting a particular water quality profile. Sediments in rivers generally come with the surface runoff from the degraded watersheds. To protect the rivers from high sediment load, conservation of watershed is very essential. Proper planning and management need be prioritized for developments in hilly watersheds, to ensure lesser release of sediments to the rivers.

Results of Water Quality Index Calculation

The WQIa values ranged from 59 to 95 with a mean value of 81 (with standard deviation 6.9) and WQIm values ranged from 37 to 94 with a mean value of 76 (with standard deviation 11.6).

Among the 119 samples collected under the project, 26% of samples were found with WQIa below 80. 10% samples were found with WQIa between 59 to 70 (i.e. medium), 86% of samples were found with WQIa between 72 to 89 (good) and 4% samples were found with WQIa between 91 to 95 (excellent).

WQIm values were found as 6% below 50, 9% below 60, 23% below 70 and 52% below 80. Also 6.7 % of samples were found with WQIm 37 mg/L to 50 (bad), 19% between 51 to 70 (i.e. medium), 71% between 71 to 90 (good) and 2.5 % between 93 to 94 (excellent).

Although the rivers have not been worst impacted by pollution so far, rivers flowing through urban areas are highly threatened. The WQI values show a medium water quality for several rivers of urban areas (eg. Kalbhog River, Basistha River, Borapani River, Hoara River, Senapati River and Nambul River). This "medium" water quality of these rivers needs immediate attention, particularly considering the pristine background status of the region. Almost all rivers of the region have high water discharge in monsoon and this plays a very important role in dilution of polluting effluents coming to the rivers. Pollutant concentration in river water often becomes critical when the water volume in the river decreases during dry season. Considering this, control of the pollutant generation processes from the watershed area is of main concern for the rivers of this region.

CONCLUSION

Analysis, management and updating of a large database can be carried out quite efficiently with the use of GIS. GIS database for the rivers of Northeast India has been developed to ensure better monitoring and protection of the rivers through appropriate action plan and mitigation measures.

The developed GIS database provides scope of incorporating as many as 24 important water quality parameters and some important physical dimensions such as width and length, names of the streams and names of the river systems to which a particular stream belongs to. Also, databases of watershed, discharge and width provide additional information to this database system. All these layers are linked with the GIS layer for the rivers, so that users can get information about water quality of any river by making a query in GIS accordingly. The steps that one needs to follow for developing this database are user friendly and one can develop his/her own database for a new river system following the steps presented in this study.

Analysis of primary and secondary data of river water quality and evaluation of WQI has revealed that the water quality of some of the rivers passing through urban areas is threatened. Considering the pristine status of the rivers of this region, it is suggested that due emphasis towards water quality management should be given, so that further degradation of water quality of these rivers can be prevented. Monitoring and updating of the GIS database developed in this study can be taken up on a regular basis by the concerned agencies for keeping the information update.

ACKNOWLEDGEMENT

The authors would like to thank Ministry of Environment and Forest (MoEF),Govt. of India for their financial support in this research work.

REFERENCES

APHA, WEF, AWWA .1998. Standard method for the examination of Water and wastewater, 20th ed., APHA, Washington, DC,USA.
Arnell, N. W. 1999. Climate change and global water resources, *Global Environmental Change*, 9, S31-S49.
Canter, L. W. 1996. Environmental impact assessment, second edition, Mc Graw Hill Series in Water Resources and Environmental Engineering, ISBN 0-07-114103-0.
CGIAR. Consortium for Spatial Information (CGIAR-CSI):http://srtm.csi.cgiar.org/
CIFRI .2003. Ecological status and fishery potential of riverine fisheries resources Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura, Project Report published by Central Inland Fisheries Research Institute (ICAR), Northeastern Regional Centre (CIFRI).
CPCB.2008. Central Pollution Control Board, http://www.cpcb.nic.in/
Girija, T. R. 2008. Water quality modeling in an untreated effluent dominated urban river, Unpublished PhD Thesis submitted to Department of Civil Engineering, IIT Guwahati 2008.
Hussain, M.F., Ahmad, I., and Konhauser, K.O .2006. Major ion and heavy metal chemistry of Pachin River (Itanagar)-Levels and Sources, *Journal of Environ. Science & Engg.*, 48-1P,27-34.
Mahanta, C. and Subramanian, V. 2004. Water quality, mineral transport and sediment biochemistry, V.P. Singh et.al. (eds.)*The Brahmaputra Basin Water Resources*, 376-400. Kluwer Academic Publishers, printed in Netherland.
Mujumdar, P.P.2008. Implications of climate change for sustainable water resources management in India. *Physics and Chemistry of the Earth*, 33, 354–358
Ojha, C.S.P. and Singh, V.P. 2004. Introduction, V.P. Singh et.al. (eds.)*The Brahmaputra Basin Water Resources*, Chapter 1, 1-16, Kluwer Academic Publishers, printed in Netherland
Pathfinderscience.2009.http://pathfinderscience.net/stream/cproto4.cfm, browsed on 02-06-2009.
Sarma, A.K., Mahanta, C., Sarma, B., Bormudoi, A., Borah, B. and Pathak, N. 2009 .GIS based inventory of rivers of northeastern region of India. *Report submitted to National River Conservation Directorate (NRCD), Ministry of Environment and Forest (MoEF), Govt. of India* by Dept. of Civil Engg., IIT Guwahati.
Trisal, C.L. and Manihar, T. 2004. LOKTAK-THE ATLAS OF LOKTAK LAKE. published by Wetlands International-South Asia Programme and Loktak Development Authirity,41-52, ISBN: 81-87408-02-2.