# Providing Solutions to Water Problems


**National Institute of Hydrology**
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# Foreword

The world is changing very fast, and, with it, the water use and requirements patterns are changing rapidly as well. One of the biggest environmental challenges that developing countries face is to balance their increasing demand with the diminishing availability of water. Increases in population coupled with the ongoing processes of industrialization, urbanization and agricultural modernization are, on one hand, leading to an ever increasing demand for water and, on the other, a decreased supply of freshwater, especially in the absence of effective mechanisms to regulate pollution. An objective and analysis of water management and development in recent years indicate that the water profession has been quite good at looking at the past and present situations, but poor at assessing possible future developments.

The hydrologist play very important role in solving water-related problems in society such as quantity, quality and water availability or basin water budgeting through application of the proper scientific knowledge and mathematical principles. They also deal with the studies concerning the municipal water supply, irrigation water supply and management, mitigation of floods and droughts, integrated watershed management, ground water recharge and solving reservoir sedimentation problems.

National Institute of Hydrology has been conducting research in the field of hydrology and water resources over the last three decades. Many important studies and strategic projects were carried out providing solution to the need-based problems in the country. With the changing scenario in the water sector, the Institute is focusing more on demand driven strategic research. The Institute is also pro-actively contributing to the knowledge dissemination, mass awareness and capacity building programmes.

It gives me immense pleasure to present to you this compilation of the results and findings of recent studies conducted by NIH. This publication is an attempt to rejuvenate the knowledge dissemination efforts of the Institute, with a flavour of 'connecting to the people'. The intent is to take the research findings to the community so that they are incited to develop interest in the scientific developments taking place in the country.

Raj Deva Singh

(R D Singh)
Director

November 7, 2012
Roorkee

# National Institute of Hydrology

The National Institute of Hydrology (NIH), established in 1978 as an autonomous organization under Ministry of Water Resources (Government of India), is a premier R&D institute in the country to undertake, aid, promote and coordinate basic, applied and strategic research on all aspects of hydrology and water resources development. The Institute has its headquarters at Roorkee (Uttarakhand). To carry out field related research covering different regions of the country, the Institute has four Regional Centers located at Belgaum, Jammu, Kakinada and Bhopal, and two Centres for Flood Management Studies at Guwahati and Patna. The Institute has established state-of-art laboratory facilities in the area of Nuclear Applications in Hydrology, Water Quality, Soil Water, Remote Sensing & GIS Applications, Groundwater Modelling and Hydrological Instrumentation.

The Institute act as a centre of excellence for transfer of technology, human resources development and institutional development in specialized areas of hydrology, and conducts user defined, demand-driven research through collaboration with relevant national and international organizations. The Institute vigorously pursues capacity development activities by organizing training programmes for field engineers, scientists and researchers, NGOs. NIH has so far completed more than 150 sponsored research and consultancy projects- the sponsors included Indian Army, PSUs, Planning Commission, National Productivity Council, State Government Departments, and central ministries of Science & Technology, Environment & Forests, Agriculture, Rural Development, etc. The Institute has undertaken a number of internationally funded projects, including those from UNDP, USAID, UNESCO, The World Bank, The Netherlands, Sweden, European Union. The Institute is presently participating in the World Bank funded Hydrology Project Phase-II.

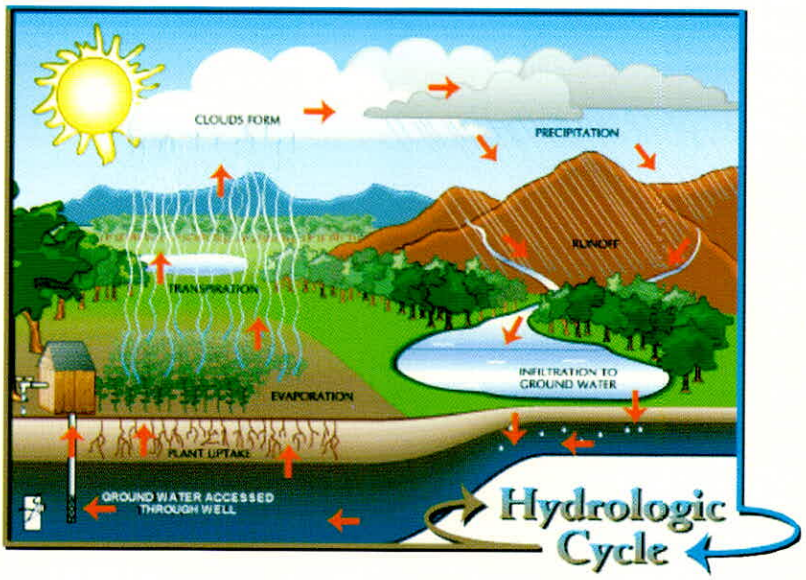
Some of the significant contributions of NIH include studies for solution of real-life problems related to augmentation of water supply and water management in cities, glacier contribution in streamflow of Himalayan rivers for hydro-electric power projects, watershed development, water quality management plan for lakes, watershed development, storm water drainage network in cities, flood inundation mapping and flood risk zoning, and water quality assessment in major cities. The Institute is actively pursuing the IEC activities and mass awareness programmes of the Ministry of Water Resources. NIH works as a nodal centre of the Ministry for effective implementation of the National Water Mission.

## VISION

Providing leadership in hydrologic research through effective R&D solutions for achieving sustainable development and self-reliance of the water sector in India

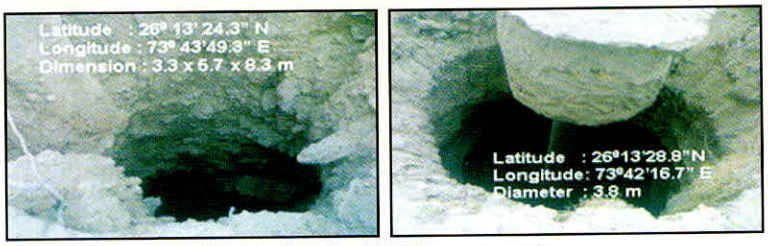
## THRUST AREAS

- Water Resources Planning and Management
- Ground Water Modeling and Management
- Flood and Drought Prediction and Management
- Snow and Glacier Melt Runoff Estimation
- Prediction of Discharge in Ungauged Basins
- Water Quality Assessment is specific areas
- Hydrology of Arid, Semi-arid, Coastal & Deltaic Zones
- Reservoir / Lake Sedimentation
- Impact of Climate Change on Water Resources
- Application of modern techniques to provide the solution to hydrological problems



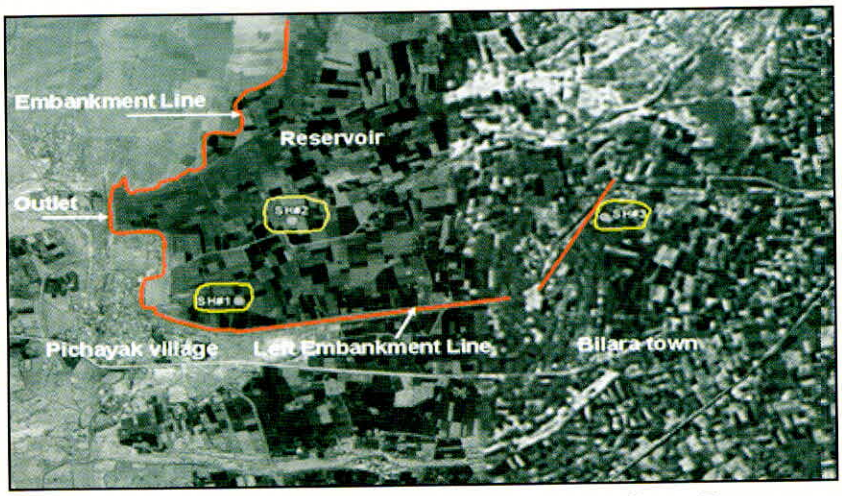
## *Hydrological and hydrogeological investigations to assess causes of seepage from the reservoir of Jaswant Sagar Dam in Jodhpur, Rajasthan*

The study was aimed to find reasons as to why the reservoir of the Jaswant Sagar dam was not able to retain water in the form of storage for a longer period as designed, and also to find reasons of excessive losses from storage of the reservoir. Jaswant Sagar is 109 years old earthen dam, across the ephemeral Luni River. Farmers have constructed 155 different categories of wells inside the reservoir area to irrigate exposed submergence areas.



Sinkholes inside the reservoir

Sub-surface formation representing limestone formation below the reservoir bed is deemed to be unfit and unfavorable to retain stored water in the reservoir. Only about 1/3rd of the water spread area along the right side of the reservoir, underneath of which sandstone formation is laid down, is deemed fit and favorable to retain stored water for a longer time. Time duration for the reservoir to be emptied for the estimated variable seepage rates and the average evaporation rate of 7.926 mm/day was estimated to be 57days, if there are no sinkholes on the reservoir bed. For the presence of sinkholes, the time duration for the reservoir to be emptied would be much less.



Sinkholes located in and around the Jaswant Sagar Dam

## *Quantification of Impact of Rainwater Harvesting on Groundwater Availability in Aravalli Hills*

The objective of the study is to analyse the hydrological impact of rainwater harvesting schemes on groundwater availability in Aravalli hills through mathematical modeling. The study area comprises the Jaisamand Lake Catchment which is located in the semi-arid region of Rajasthan in Udaipur district. The area is

marked by hilly terrain belonging to the Aravalli chain. The average annual rainfall in the region is 650 mm. The major source of water supply in the semi-arid region is groundwater, which plays a central role in the maintenance of economy and environment. Considerable emphasis has been given by various agencies for the augmentation of groundwater recharge by both traditional and modern techniques. The impact of artificial recharge schemes on groundwater was studied qualitatively in Gangeshwar watershed. It was found that as a result of recharge schemes in this watershed, the 'recovery time' on pumping water from the wells decreased and the wells yielded sufficient water to enable cultivation of third season crop. To make a systematic assessment of the effectiveness of these schemes on groundwater availability and gain an insight into the hydrological processes in hard rock terrain under semi-arid climatic conditions, data monitoring and detailed investigations including field tests were carried out in the Savana Watershed of the region. A comprehensive database was developed for Savna watershed based on field investigations and data monitored in the field. Also, field and lab experiments have been carried out to determine soil moisture retention characteristics and saturated hydraulic conductivity. In addition, pump tests in the watershed have also been carried out and groundwater samples collected from the

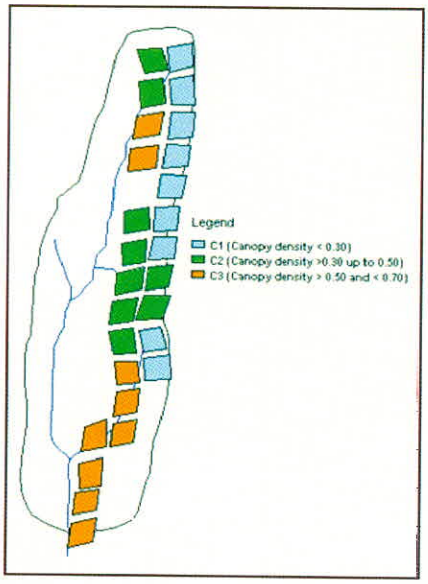
watershed for water quality analysis.

### *Evaluation of water quality of rivers joining Tehri Reservoir and downstream of the reservoir*

The main aim of the study was to examine the suitability of water of the rivers joining Tehri reservoir and downstream for various designated uses and to identify possible sources of pollution and assess the actual changes in river water quality. A reconnaissance field visit of Tehri reservoir and its joining rivers has been carried out and three water samples from the reservoir were collected in the month of December 2008, May 2009 and August 2009 and analysed for physico-chemical, bacteriological parameters and metal concentrations. Results revealed that all the physico-chemical parameters and heavy metals are found within the limit prescribed for drinking water by Bureau of Indian Standards (BIS, 1991). Bacteriological contamination was observed in the river Bhagirathi and Bhilangana which may be attributed to runoff and washing off from the places of open defecation from bank in the catchment areas. Assessment of suitability of the river water for irrigation purpose revealed that the water is of good quality for irrigation purpose throughout the year as per recommended guidelines for evaluation of irrigation water quality.

### *Hydrological studies in a forested watershed - a case study on natural regeneration of sal forest in Uttrakhand*

Hydrological and micro-environmental parameters viz., soil moisture, light intensity and soil erosion are important factors that affect the natural regeneration in forests. These factors vary spatially depending on the overhead canopy density of the forest. A study was carried out in collaboration with Department of Forests, Govt. of Uttarakhand to study the effect of variation of soil moisture, light intensity and soil erosion on natural regeneration of sal (Shorea robusta) under different micro-environments due to overhead canopy of varying forest density. Experimental plots of 40m 40m size were laid under different overhead canopy densities in a small sal forested watershed in the foot hills of Himalayas in Nainital District of Uttarakhand State, India. The plots were monitored on a long term basis for soil moisture at multi depths, light intensity and natural regeneration of sal. Measurements of rainfall,



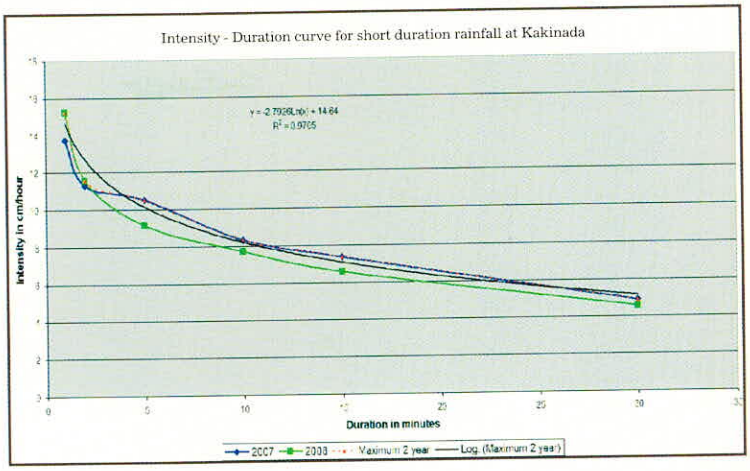

runoff and sediment yield were also made at the watershed outlet. ANSWERS, a distributed parameter, event based hydrologic simulation model was used to quantify the spatial erosion in the experimental plots. The results of the study revealed that the natural regeneration was highest under C1 (up to-0.30) canopy followed by C2 (0.30-0.50), and C3 (0.50-0.70) canopies. The C3 canopy showed the dying back of sal shoots over 4 years of study. The highest R2 value of linear regression between incremental score of plot regeneration and average soil moisture content was obtained as 0.156 for average soil moisture content during non-monsoon months at 100 cm depth. The R2 value between incremental score of plot regeneration and annual average light intensity was obtained as 0.688 which indicated that the regeneration is largely dependent on the light intensity conditions during the year. The multiple linear regression analysis between the incremental score of regeneration and the average light intensity and average soil moisture content revealed that that about 80% of variation in regeneration is explained by both the factors. Analysis of rainfall-runoff data revealed that the runoff from the watershed varied from about 5 to 15% of the event rainfall depending on the rainfall intensity. An analysis of spatial soil erosion under different canopy densities did not indicate adverse effect of erosion on the regeneration.

The results of the study amply indicated that the soil moisture and light intensity are crucial parameters for management of natural regeneration in sal forests. These results should prove useful in formulating the forest management plans that incorporate the practices to ensure adequate soil moisture and light penetration. Ensuring adequate regeneration and sustained productivity is at the heart of any scientific silvicultural system.

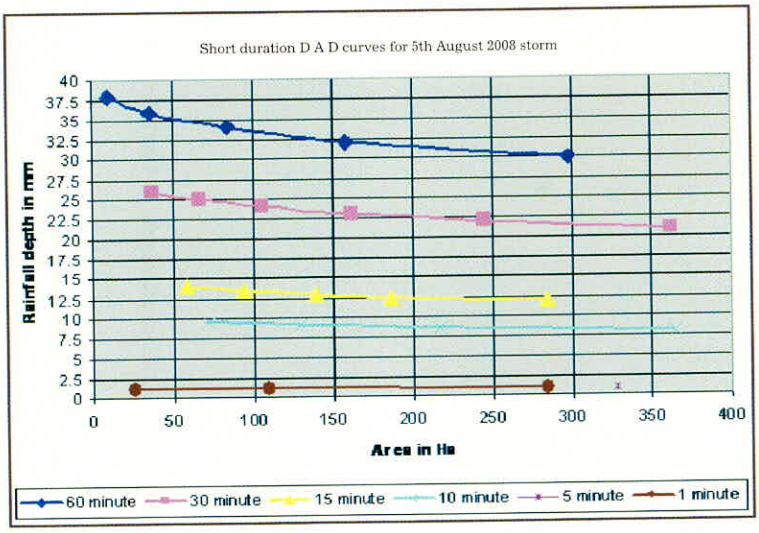
### *A study on Spatial and Temporal Hydrological Aspects for Water Resources Planning and Management of an Urban Area (Kakinada) along the Coastal Region*

The study demonstrated the importance of spatial and temporal analysis of rainfall for urban hydrological studies including groundwater. The impact of excess precipitation on urban drainage and deficit precipitation on urban water supply was evaluated with specific attention to the management of surface water and groundwater. The results of

the above study shows that 15-minute duration rainfall observed is about 50 mm at Kakinada (13 October 2005) and it is most intense 15-minute rainfall (20 cm/hour) so far observed.




To understand the rainfall recharge characteristics of urban area, groundwater monitoring is undertaken for water levels and quality at 12 locations in the city. The groundwater table is at a depth of 1.5 to 3.5 m during pre monsoon and rise by 1 to 2 m by post monsoon. From the groundwater aspect of the analysis and results, it has been concluded that there is certain impact of urbanization on the shallow unconfined aquifer in Kakinada city. With the increasing draft from the aquifer in highly urbanized areas and less recharge to it from rainfall the dependability of the shallow aquifer is under threat. There is need to rejuvenate such aquifers using artificial recharge techniques to supplement the decreasing natural rainfall recharge to the aquifer for sustainable development of the water resources in the city.




## *Groundwater Modelling Study in the Pushkar Canal Command Area in Andhra Pradesh*

There are number of ongoing projects in East Godavari District, Andhra Pradesh for irrigation purpose. After introduction of canal water there was sustained rise in groundwater table, which has lead to adopt conjunctive use of surface and groundwater. Therefore, water management practices are to be planned scientifically in ongoing projects. In this direction pre project studies were undertaken on hydro-geological conditions and on canal design and flow for Pushkar canal area and

documented. Using the said information there is need to undertake a study to understand the future scenarios of surface water and groundwater interaction in irrigated command area at typical locations of the Pushkar canal system (Fig. 1).

In the present study on groundwater flow modelling in select pilot command areas of the Pushkar canal system analysis interacted with state Irrigation authorities of Pushkar canal system and collect data and information on Talluru lift irrigation system. Also undertaken field visits to measure water levels and to collect groundwater samples for laboratory analysis. Identified a command area of 7393 acres with a geographical area of about 40 sq. km under distributaries D1 and D2 of its Left main canal (LMC) in the uplands of the Gandepalli and Jaggampeta mandals in Andhra Pradesh. Compiled information of identified pilot command area in upper

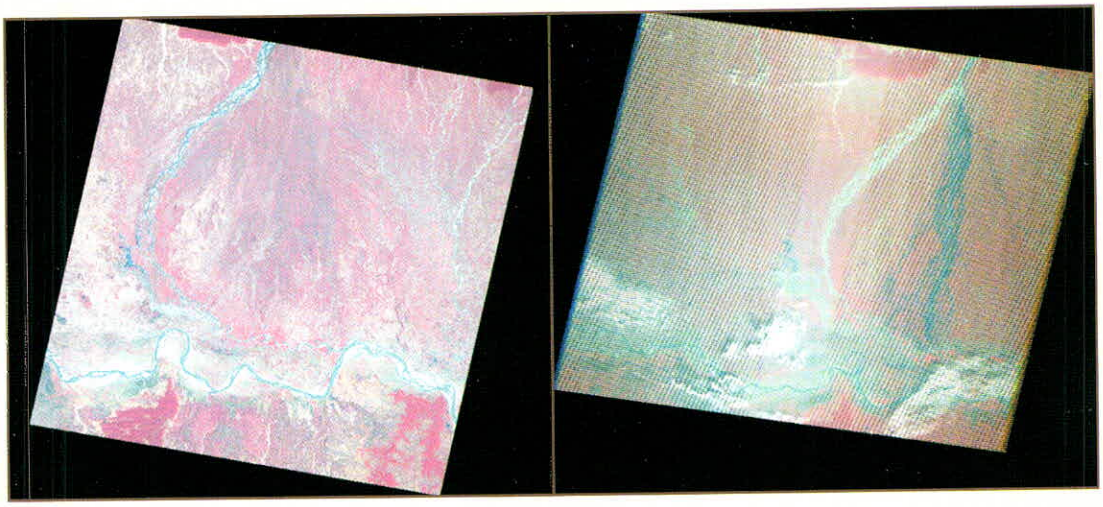

Fig. 1 Study pilot areas under Pushkar canal system

middle and lower reaches of the canal on topography, Soils, Hydrogeology, Hydrometeorology etc. During pre-project, the ground water table in the study area was very deep and at Gandepalli piezometer it was about 40 m below ground level.

### *Shifting characteristics of Kosi river*

The river Kosi (also known as 'Sorrow of Bihar') is a tributary of the river Ganga. Nearly 80% of its catchment lies outside the country and the rest 20% lies in India. The portion of the catchment in India is almost flat and the river has the shifting characteristics. After entering India it travels for about 318.65 km in an alluvial plain, unloads the silt in the plains of Bihar and finally meets the river Ganga near Kursela. The river carries a mean annual discharge of 1,600 m3/sec, with monsoon discharge 10 times the lean period discharge. Sediments load of Kosi is estimated at 120 m cu.m. As one course becomes higher than the possible adjacent paths, Kosi river shifts laterally.

Shifting of Kosi from 1736 to 1964 was 112.6 km towards west. In the present study, shifting characteristic of Kosi river starting from the year of publication of SOI toposheet have been studied. The toposheets of 1936-38 on the scale of 1:250000 were used. To generate the base level information (prior to construction of Kosi Barrage project in 1954), the Landsat, MSS and TM imageries at 5 years interval from 1972 onwards have been analyzed for marking the course of river Kosi at different times. The analysis indicates that there is different trend of shifting as the river flows from north to south. Two satellite imageries in a gap of 36 years are shown below.



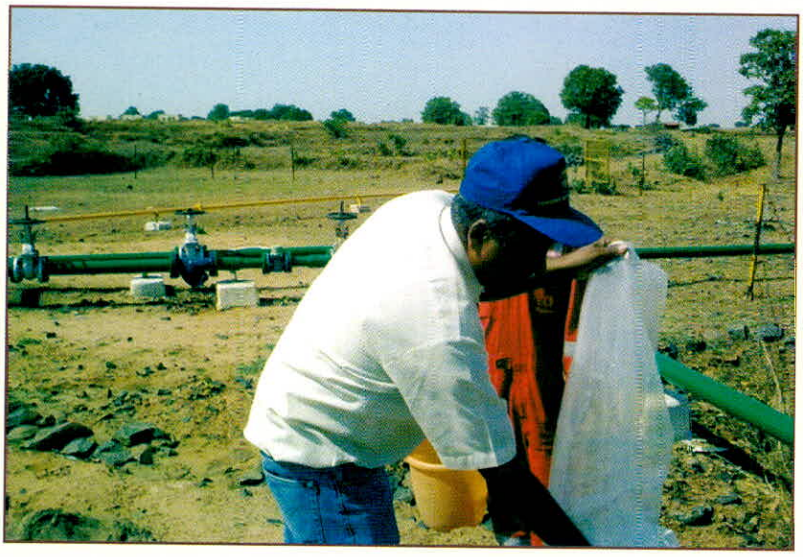
Kosi river 07 Nov, 1972 Kosi river 05 Nov, 2008

### *Rainfall-runoff modeling and water availability estimation for Rehar River at Rihand Dam and selected sites in Benas and Mehar river*

Rainfall-runoff modeling and water availability estimation are the components of the project on "Utilization of Rihand reservoir water up to designed MDDL and possibility of creating additional storage in the nearby catchments to meet requirements of thermal power plants". The study was taken up with the objectives to develop rainfall-runoff relationship and assess water availability in Benas, Gopad and Kanhar rivers. Rainfall records at various stations in study catchments and flow records at Benas river have been used to estimate water availability at two sites in Gopad and one site in Kanhar river. Rainfall-runoff modeling and water availability analyses showed that both the basins have surface water availability during the monsoon season to supplement the requirement of water for thermal power plants around the Rihand reservoir.

### *Dating of water from CBM wells and nearby tube wells by isotopic method ($^{3}H$ and $^{14}C$)*

Coal Bed Methane (CBM) is a natural gas occurring in coal seams and is a relatively new source of energy in India. Large amount of groundwater is pumped alongwith the



gas from CBM wells, especially in the early stages of production. This may create environmental problems by inducing recharge of water from the overlying leaky aquifers or surface water bodies through fractures and faults. The lowering of water table or drying of surface water bodies may impact the economic and social activities in the area. Reliance Industries Limited, Ahmedabad, awarded this consultancy project to National Institute of Hydrology to know whether the water being produced from CBM wells is connate water from coal bed of Gondwana and is not connected to ground water of the area through Isotopic analysis of water (Preferably 3H and 14 C ) from CBM wells and nearby tube wells.

The study was carried out in Sohagpur East and Sohagpur West blocks falling in Shahdol and Anuppur districts of Madhya. The study indicated: (i) the groundwater present in the shallow and intermediate aquifers (30-75 m) is generated from the recent time precipitation; (ii) the groundwater pumped from deep CBM wells is older than that use for drinking from shallow water; and (iii) the uncorrected age of groundwater abstracted through the CBM wells is >20,000 yrs.

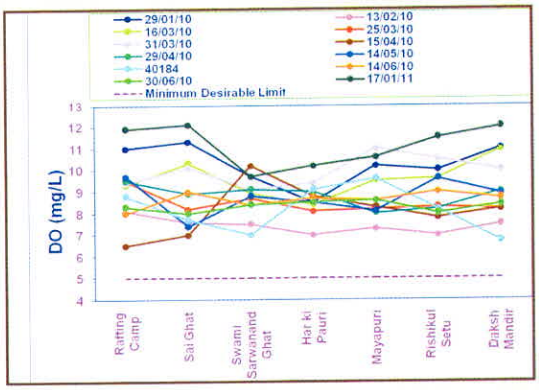
### *Assessment of Ground Water Quality in 25 Class I Cities of India*

The Central Pollution Control Board (CPCB), Delhi awarded the project study on 'Assessment of Ground Water Quality in Class I Cities of India'. In order to achieve the objectives of the study, thirty ground water samples from the Class I Cities of Guwahati, Raipur, Shimla, Jammu, Shillong, Aizawal, Kohima, Bhubneshwar, Agartala, Dehradun, Itanagar, Gangtok, Chandigarh, Panjim, Gandhinagar, Ranchi, Thiruvananthapuram, Imphal, Pondicherry, Kavaratti, Daman, Silvassa, Ratlam, Bilaspur were collected during pre- and post-monsoon seasons during 2009-11 from various abstraction sources used for drinking purpose at various depths covering extensively populated area, commercial, industrial, agricultural and residential colonies so as to obtain a good areal and vertical representation and were analysed for various water quality parameters, viz., physico-chemical and bacteriological parameters, heavy metals, pesticides and polynuclear aromatic hydrocarbons. Water samples for pre- and post-monsoon seasons ware processed as per BIS and WHO

standards to examine the suitability of ground water for drinking purpose, ionic relationships were developed and water types were identified. Spatial distribution maps were prepared in the form of contour diagrams to identify degraded water quality zones. Suitability of ground water for irrigation purpose was assessed on the basis of total soluble salts, SAR, RSC and boron content. Classification of water was made using Piper trilinear diagram, Durov plots, Chadha's diagram,U S Salinity Laboratory Classification and Gupta Classification.

## *Modelling of Pesticide Transport in Ground Water - a case study of Metropolitan City - Vadodara*

Metropolitan city Vadodara witnessed a sudden spurt in industrial activity with the establishment of Gujarat Refinery, Indian Oil Corporation. Metropolitan city of Vadodara is the industrial nucleus of the Gujarat State. During the recent study carried out by NIH, very high concentration of pesticide lindane was observed in ground water of metropolitan city Vadodara. In view of this fact, the study of the lindane migration pattern in the ground water of metropolitan city Vadodara from future projections was conceived in collaboration with Ground Water Resources Development Corporation (GWRDC), Gandhinagar, Gujarat. The objectives of the study were to develop a contaminant source identification model from point source



and characterize the contaminant (pesticide) migration pattern in the ground water in space and time for prediction purposes. To fulfil the objectives of the study, column study (experimental) was carried out to see the flow and transport of organo-chloro pesticide (Lindane) in unsaturated zone and for ground water flow modelling in saturated zone, model MODFLOW was calibrated using the field data of vadodara city. For contaminant transport modelling, the test run of model MT3D was carried out for TDS and then for pesticide for future projections along space and time for a period up to 50 years. Contaminant sources using chemographs of point sources and ground water at different locations were identified. This study highlight that River Vishwamitri and river Jambua are the main contaminant sources of ground water of Vadodara city.

### *NIH_ReSyP (NIH_Reservoir-System-Package)*

NIH_ReSyP is a WINDOWS based software package that has been developed at NIH for various kind of reservoir analysis. Different modules of the software include capacity computation, storage-yield analysis, statistical analysis of flow data, initial rule curves derivation, operation analysis of a multi-purpose multi-reservoir system for conservation and flood control purposes, hydropower analysis, reservoir routing, interpolation of elevation-area-capacity table, and inflow computation. The software is being named as NIH_ReSyP which signified NIH_Reservoir-System-Package. The software has been developed in Visual Basic and various computer programs developed in FORTRAN language at NIH have been linked. Various forms have been developed for easy preparation of data files. It will be easy for the users to select the data files and take the model runs. Results can be viewed in tabular as well as graphical form either through MS-EXCEL or through a built-in routine. It is assumed that the package will help the field engineers in carrying out various kind of reservoir analysis. The opening banner of the software is shown.


### *Groundwater Modelling and Surface Water - Ground Water interactions in and around Puri City*

Puri is a city of high religious importance and heritage value, details of the Puri Jagannadh Temple, rituals, fairs and festivals and related aspects are covered extensively. It is found that water levels in two wells (Ganga and Yamuna) are falling inside the Jaganatha Temple Puri, which is causing problem for temple activities. The probable causes need to be studied by undertaking modeling study of rainfall-recharge processes, surface water groundwater interactions and increasing demands

due to urbanization at basin scale. Water Samples have been collected from 3 blocks [Satyabadi, Brahma Giri and Puri Sadar] on March 2010 and November 2010. Hydrochemical analysis indicates that pH value is varying from 7 to 8.4 and conductivity is found in between 238 to 2710 mhos/cm. The EC values indicate that the shallow groundwater in Puri is not saline. Isotopes like O-18, Deuterium and water chemistry data have been used to identify the groundwater source/s. The stable isotopic signatures indicate two different sources active in the City area. Most of the handpumps carry water recharged by the surface sources as more evaporation effect is visible in isotopic signature. Few handpumps and most of the dug-wells carry groundwater whose isotopic signatures resembles with local precipitation. The groundwater recharge is taking place from North-southern direction.

*Study of Rising Groundwater Table in Jodhpur city*

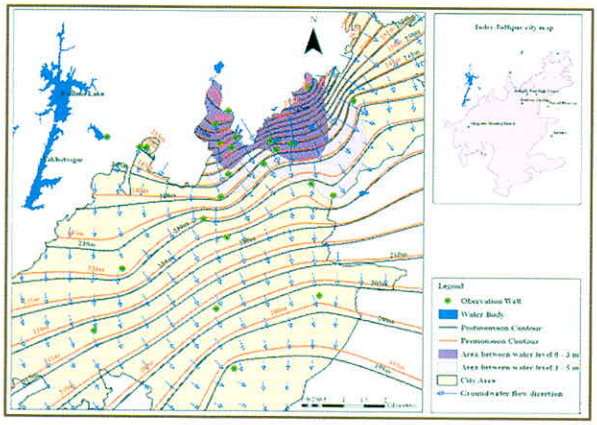
The rise of groundwater table near to the ground surface in some parts of the Jodhpur city has resulted into living hazards to the people located in the affected areas. Control and management of the rising trend of groundwater level by finding the cause and an immediate scientific solution have emerged as a challenging task for the Government of Rajasthan. To find the exact source and causes of groundwater table rise and to develop an appropriate management plan to revert back the rising trend, a study was entrusted to the Institute with the following objectives:

- Identification of cause(s) of rising ground water levels in Jodhpur city.
- Development of an effective and sustainable management plan for maintaining the water table of the area at a safe level to avoid any adverse impact on the civil structures and population of the area.

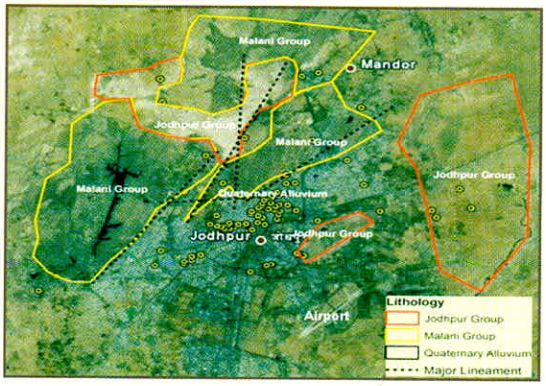
For addressing the issues, a systematic analysis of the topography, demography, geological formations, hydrometeorology-hydrology and hydrogeology, groundwater quantity and quality, sewage flows, inflows and outflows of waters to/from the Jodhpur city and from the Kailana-Takhatsagar Reservoir has been carried out. The major findings are:

(i) The waterlogged area and its extent are mainly located in the Quaternary alluvium formation below the Jodhpur city area. The Kailana-Takhatsagar and the Jodhpur city areas are located on two distinct geological units. These formations have different hydro-geological properties and hence, cannot be considered as a single system.

(ii) The possibility of seepage from the Kailana-Takhatsagar Reservoir entering the waterlogged area was investigated making use of the contour maps assuming that the Kailana-Takhatsagar Reservoir is not hydraulically connected with the aquifer underneath the Jodhpur city, and the Kailana-Takhatsagar Reservoir is hydraulically connected with the aquifer underneath the Jodhpur city. It is inferred that groundwater flow from the Kailana-Takhatsagar side is not causing water logging in the waterlogged area. For the latter case, it is noted that the direction of flow lines is not towards the waterlogged area. Thus, whether the Kailana-Takhatsagar Reservoir is hydraulically connected with the aquifer underneath the Jodhpur city or not, the seepage from the lake is not flowing towards the waterlogged area in either situation.



(iii) The measurements and analyses of the sewages data of the year 2009 indicated sewages disposal of about 37% of the supplied water through three major sewerage systems, i.e., Airport drain, Polytechnic Institute drain and Nandri sewage treatment plant drain.




(iv) The source of water logging and rise in groundwater level in some parts of the city area appears to be due to return flow of water from water supply system and from the source other than the sewage waters. In some pockets, the seepage from sewage system cannot be ruled out.

*Suggested measures:*

1. As the first and foremost remedial measure, it was suggested to regulate the

quantity of water being supplied to the city area at the source itself, i.e., regulation of water from the Kailana-Takhatsagar Reservoir. The regulation needs to be based on per capita per day water requirement basis. The Jodhpur city being located in the arid and water scarce region, about 110 liters per capita per day could be taken as the guideline. Industrial water requirements are to be included separately. For 110 lpcd supply, the quantity of water requirement for the estimated population of 11,08,950 in the Jodhpur city for the year 2010 is worked out to be 268.69 lac gallon per day, which will reduce the quantity by about 35% over the quantity supplied (521.7 lac gpd) in the year 2009,

2. In the affected area, the water supply lines need to be thoroughly checked to find the locations of leakages, and suitable remedial measures to stop the leakages need to be taken up. The sewages/drainage lines in the affected area need to be properly sealed to stop seepage, if any,

3. The terrain being undulating, the area being an urban area, the requirement of lowering the water table by 4m, minimum depth of alluvium being 2m, all these aspects do not promote provision of a usual horizontal sub surface drainage system. However random sub surface drainage trench of 4m depth, filled with coarse sand and gravel can be constructed to control the rising water which can be led to a collector caisson, from where water can be pumped out,

4. Provision of vertical drainage system i.e., by pumping the water from the aquifer in the problematic area looks feasible; as drainage wells can be constructed with least interference in the urbanized area. The pumping rate and schedule can be controlled, the number drainage wells can be increased in a locality as required, and already such practice has been initiated in the area, all these factors favor provision of vertical drainage. In region of low transmissivity area (<30 $m^2$/day ), large diameter wells of 0.5m can be constructed, and

5. There are three large ponds, namely, Baiji Ka Talab, Fateh Sagar, and Gulab Sagar located near to the problematic area. The pond beds are more or less impervious, or if necessary, these can be made impervious by lining. The pumped water can be discharged to these ponds through conveyance pipe. From these ponds surface channel can be constructed to convey the water stored in the pond to the existing surface drainage system through gravity. These waters can be used for agricultural irrigation purposes. It should not be mixed with sewage waters.

### *Impact of sewage effluent on drinking water sources of Shimla City and suggesting ameliorative measures*

During 2006-07, a mass levels Jaundice due to influx of pollutants/bacteria in the drinking water have been reported in Shimla Town, India. After discussion with the officials of Himachal Pradesh, it was found that the assessment of impact of sewage effluent on drinking water sources of Shimla city is the real problem and needs to be

assessed scientifically and thus, this study was taken by NIH as PDS under Hydrology Project Phase-II. The main objectives of this project were (a) analysis of hydrological, water quality, & basin characteristics of Shimla city, (b) assessment of water quality variables in drinking water sources and sewage effluent, (c) analysis of pollutant / source identification (location) of sewage influx in drinking water, (d) impact assessment of sewage effluent in drinking water source and (e) suggesting possible remedial measures for its removal and dissemination of knowledge and findings to field engineers and common people.

The drainage area of Shimla City, which consist of part of Satluj and Yamuna sub-basins. Two watersheds falls in Satluj river sub-basin, while one watershed fall in Yamuna river sub-basin. In this study, watershed characteristics are evaluated for problematic (Sanjauli - Malyana Zone) area of Shimla City lying under Yamuna (Fig. 1) basin using SWDES and ERDAS/ILWIS Software's.

Figure1: Sewer Network map of Study Area (Sanjauli - Malyana Zone)

Samples were collected for Pre & Post Monsoon period of 2010-11 from the: groundwater, surface water, WTP and STP at different locations (See pictures). Sampling and analysis for various physico chemical and bacteriological parameters (pH, EC, TDS, Ca, Mg, Na, K, HCO3, Cl, SO4, NO3, PO4, F, BOD, COD, total coliform, fecal coliform, etc.) of the study area were carried out. Drinking water quality data were analyzed on quarterly basis using standard methods (APHA, 1995). Verification for efficacy of sewerage network of Sanjauli - Malyana Zone had been carried out by using Bentley SewerCAD software. The salient conclusions and recommendations of this study are:

1. Sewerage network installed in Sanjauli Malyana region is sufficient for designed sewage load and elevation profile indicates smooth flow of sewage.
2. Contamination of natural stream supplying water to Ashwani Khud WTP is due to-poor connectivity of habitation with the sewerage network.

3. The groundwater of Shimla city was found to be of Ca-Mg-HCO3 type having temporary hardness.
4. The important sources of contaminations of water resources reduced efficiency of Malyana STP.
5. The WTP needs modification to provide safe water.
6. It is recommended to install solids contact type Clarifier / Actiflow with an option for in built sludge recirculation in order to get rid of organics and microbes during pretreatment (Equipment cost - 15 Crores INR).
7. Septic tank system should be discouraged and sewerage facility should be provided.
8. Anoxic tank for removal of nitrate should be considered in order to reduce the nitrate concentration in drinking water supplied from Ashwani Khud WTP.
9. It is recommend to continuously recycle the settled sludge along with periodic removal of biomass from the system.
10. Proper operation of WTP & STP by its proper evaluation/ audit will minimize the disease outbreaks. This can be achieved by proper training of the operators and valuing their critical role.

Ashwani Khud Water Treatment Plant (WTP)

Malyana Sewerage Treatment Plant (STP)

Dhalli WTP

## *Assessment of Groundwater Resources & Development Potential of Yamuna Flood Plain, NCT, Delhi*

The existing sources of water all over the country are under heavy stress to meet the gross water requirement for all uses of our people. However, there is a scope for improving the situation by optimizing the demand and supply requirements, ensuring judicious distribution and optimum consumption of appropriate quantity and type of water for a particular use. In National Capital Territory of Delhi, Delhi Jal Board (DJB) is responsible for supply of water to all the users. Due to limited availability of surface water and in general saline groundwater, DJB is not able to fully meet the municipal needs of the State. Therefore, to increase the supply of water, DJB is contemplating a scheme to extract groundwater from the Yamuna River Floodplain. A consultancy project was awarded to NIH, Roorkee with the objectives, (i) Estimation of groundwater resources in the Yamuna floodplains, (ii) Estimation of groundwater development potential in space and time through ground water simulation studies, (iii) Assessment of the impact of groundwater extraction from floodplains on hydrological regime, and (iv) Assessment of groundwater quality vis-a-vis availability of drinking water.

In this study, a four layer 3-dimensional groundwater model for the Yamuna Floodplain and adjoining area has been developed using Visual Modflow. All data related to river discharge and cross sections have been collected and incorporated into model (See figures 2 & 3). The subsurface layers have been defined using the lithological data. Model has been calibrated using the five year water level data collected from CGWB. The scenarios for recharge of Yamuna Floodplain at low, medium and high flood levels were developed. Impact of large scale pumping on groundwater and surface water regime also studied through groundwater modeling of the floodplain aquifer.

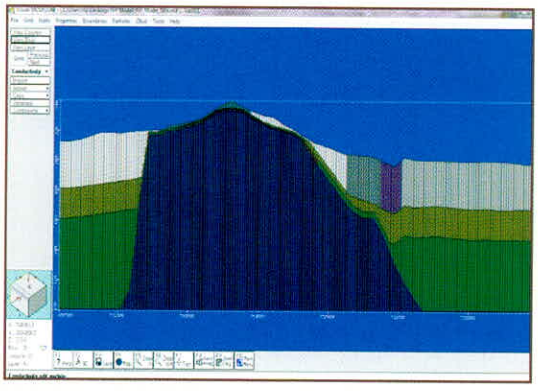


Figure 2: Cross section of the Model

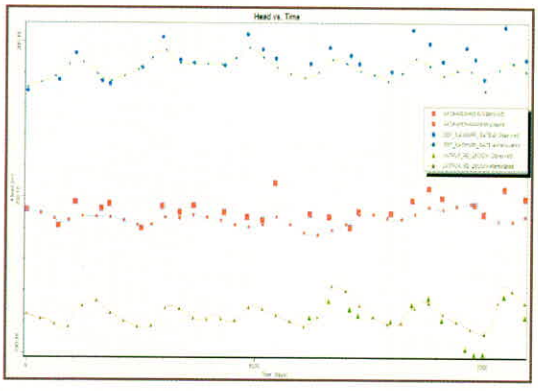



Figure 3: Calibration of Model

## *Water availability study and supply-demand analysis in Kharun sub-basin of Seonath basin in Chhattisgarh state*

Chhattisgarh, a newly born state is exploiting its water resources mainly for development of irrigation schemes, domestic supply and industrial supply. The state is facing the problem of water scarcity in rural as well as in urban areas to meet various water demands. Present PDS study deals with the problems of water scarcity being faced by Chhattisgarh state. It envisages the assessment of drought situation in the basin, rainfall runoff modeling, water availability assessment and study of supply demand scenario for the formulation of strategies for future water resources development and management in Kharun river basin.

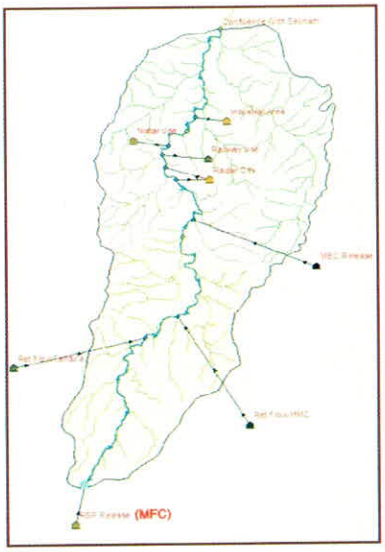


Figure 1: Schematics of Kharun River MIKE BASIN Model

The Rainfall Runoff model was developed for Kharun river using observed flow data of Patherdihi G/d site having catchment area 2442 km2, using MIKE11 NAM model. The coefficient of determination (R2) value of model calibration and validation were observed as 0.858 and 0.764 respectively, which indicated the good agreement between the simulated and observed catchment runoff in terms of the peak flows with respect to timing, rate and volume (Figure 1). It could be concluded that model is capable to generate extended runoff time series in Kharun basin. The Efficiency Index was obtained as 81% which shows that the choice of the model parameters was relevant and the model was found simulating the stream flow with accuracy.

The flow regime in Kharun river is strongly influenced by regulation operations associated with water transfer from Ravishankarsagar reservoir to Kharun and its supply for various usages through the series of anicuts. The Kharun River Basin Model was developed in MIKE BASIN to generate the virgin or regulated flows at required locations (Figure 2). The water availability assessment in the river under regulated and non-regulated indicated that the Kharun river is originally a intermittent river having flow during monsoon season and 2-3 months thereafter. Under the natural virgin condition, the river has no flow during January to May at even at 60% probability. The river has sufficient annual water yield but due to lack of big storage structures, the water demands in the basin cannot be fulfilled by the river. The water supplemented from Ravishankarsagar reservoir and other sources to Kharun river is being supplied to Raipur city, railways and industrial area through the series of anicuts. Thus the river experiences flow throughout the year under regulated flow condition.

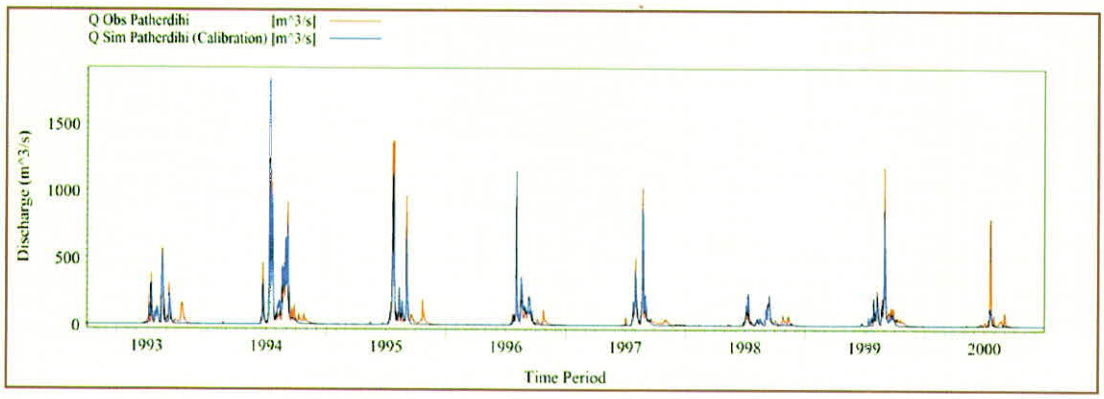



Figure 2: Comparison between observed and simulated discharge using MIKE11 NAM Rainfall Runoff Model

The water from Kharun river is being utilized mainly to meet domestic and industrial water demand, which are expected to be boost up in next few decades due to rapid population and industrial growth. The present domestic water demand of Raipur city is 41.28 MCM which will become 94.67 MCM by the year 2050-51. From the analysis of Ten-Daily Period flow volumes at various probability levels at Patherdihi, it was observed that, the quantity of water available in the river during lean period till the beginning of monsoon season is due to the water added from various sources to the river to meet its demands. From the supply-demand analysis it was observed that, when the water surplus volume becomes zero, the deficit begins and vice-versa. The river water deficit increases with increase in demand and increase in probability level of assured water supply. The development of future supply-demand scenarios, amount of water deficit at various probabilities is important for development and planning of water resources in Kharun river basin (Figure 3). It sets guidelines for addressing various issues such as demand management in the river basin, planning of water supply at appropriate level of probability, selection of flow volume of reasonable dependability and providing assured water supply to meet the total demands being fulfilled from the river.

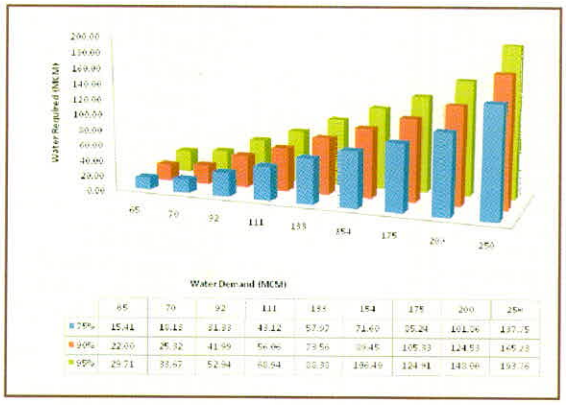



Figure 3: Additional water supply required to meet the water deficit at various probability levels

## *Acid Mine Drainage in Coal Mining Areas of Meghalaya*

Acid Mine Drainage (AMD) is recognized as one of the most serious environmental problem in the mining industry. The problem of acid mine drainage has been present since mining activity began thousands of years ago. Mining activity has disrupted the

hydrology of mining areas so badly that it is extremely difficult to predict where water would eventually re-emerge. Acid mine drainage can have severe impacts to aquatic resources, can stunt terrestrial plant growth and harm wetlands, contaminate ground water, raise water treatment costs and damage concrete and metal structures. Therefore, coal-mining operations must meet strict environmental regulations concerning mining techniques and treatment practices.

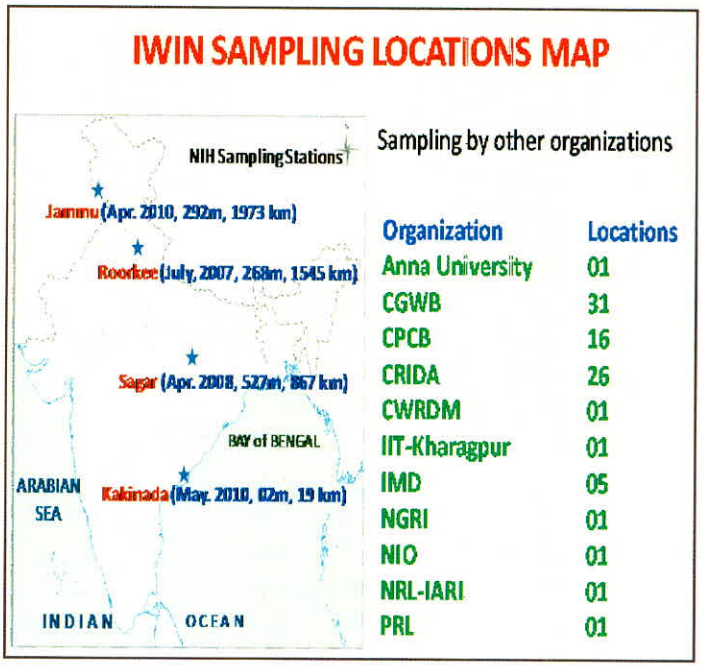
This report summarizes water quality of rivers and streams in the coal mining areas of Jaintia Hills Districts of Meghalaya and discusses some of the associated problems including adverse impacts on aquatic biota. Some of the most common treatment and containment mechanisms are listed and briefly described in the report. A few environmental management strategies that can be useful in mitigation of the environmental problems and rehabilitation of degraded ecosystems of the area have also been suggested.

*National programme on isotope fingerprinting of waters of India (IWIN)*

NIH has undertaken this dynamic research project of national and international importance to address the onset and withdrawal of monsoon and its regional dynamics along with other participating central agencies viz., A.U., CGWB, CPCB, CRIDA, CWRDM, IIT-Khargpur, IMD, NGRI, NIO, NRL-IARI and PRL. Samples are collected by NIH from 7 sites (Roorkee, Sagar, Jammu, Kakinada, Tezpur, Kanpur and Manali) and member organizations collect samples from 85 sites all over India. The location map of the NIH-IWIN sample collection sites is shown in the following figure.

The isotopic correlation among the IWIN sampling stations Roorkee, Sagar, Jammu and Kakinada were shown with special emphasis on the correlation between Roorkee and Sagar. Three more sampling stations at Tezpur University, Assam, IIT-Kanpur and Manali have also been established for collection of Ground Level Vapour (GLV) samples. A total of 1154 samples were collected from April, 2011 to September, 2011 from Roorkee, Sagar, Kakinada, Jammu, Tezpur, Kakinada, Kanpur and Manali and out of which 650 number of samples have been analysed. These include GLV,

rainwater, groundwater and river water. Using GLV - isotopic time series data (2007-11). The significance of the isotopic composition of GLV in identifying arrival and departure of monsoon and shown its significance in monitoring the climate change which is also reflected in the change in winter temperature and reduction in sustaining the maximum temperature. To extend the objective of study from ground based to vertical profile (500-1000m), balloon based new experiments was recently initiated.




*Environmental flows in river basins: a case study of Bhadra River*

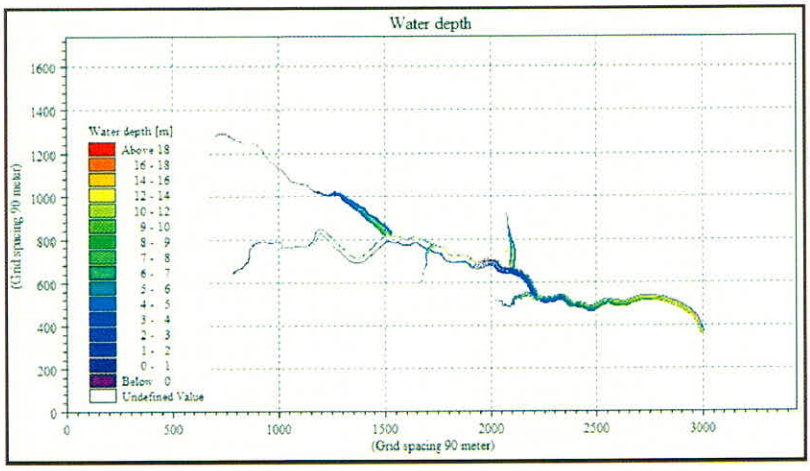
The Bhadra river originates in the Western Ghats range, and flows east across the Deccan plateau, joined by its tributaries the Somavahini, Thadabehalla, and Odirayanahalla. The river flows through the Bhadra Wild life sanctuary. A dam was built across the river near Lakkavalli. The Bhadra meets the Tunga river at Koodli, a small town near Shimoga. The combined river continues east as the Tungabhadra, a major tributary of the river Krishna, which empties into the Bay of Bengal.

This study utilizes, the secondary data pertaining to climatology, general features, water quality which were collected from the existing literature and also from various academic institution which conducted studies. Inflow and out flow data of Bhadra reservoir was collected from WRDO, Bangalore. Field investigations were also carried out along the stretch of the Bhadra river downstream of Bhadravathi town to understand the ecological and hydrological impact. Surface water samples from the river and Ground water samples around Bhadravathi town were collected. Dissolved Oxygen (DO) and Biochemical Demand (BOD) were monitored in the field. Laboratory analysis was carried out to determine major cations and anions. DO, pH and temperature were determined in the field and BOD5 was determined in the laboratory. Using the collected samples, the analysis was carried out as per the Standard Methods for examination of water and wastewater (APHA, 1992). The flow rate at each point was measured using a float method and measured cross-sectional area of flow.

Maintaining the minimum flow is a pre-requisite to keep the ecological balance as a part of river basin management. In this study, Tenant Method was adopted for the assessment of environmental flows. The present study analyses the state of water quality (in terms of DO- BOD) in the Bhadra sub-basin by using QUAL2K Model of USEP. The results obtained through the modeling helped to understand the ecological conditions existing in the river basin.

### *Flood inundation mapping and risk assessment in a reach of river Ganga using MIKE FLOOD.*

The River Ganga between Buxor to Hathidah (Rajendra Bridge) for a length of 251.2 km has been taken up for the purpose of flood inundation mapping. In this stretch, the major tributaries joining the river on its left bank are Ghaghara and Gandak while Sone and Punpun joins on right bank. The lengths of tributaries from their respective gauging sites to the confluence with river Ganga have been considered for developing the model. The study has been taken up with the objectives to i) prepare flood inundation maps for the river reach, ii) prepare flood hazard maps for the river reach, iii) prepare flood risk zone maps, iv) predict flood inundation and flood hazard areas for various stages of river flow and v) predict the flood risks associated with different return periods of flooding.



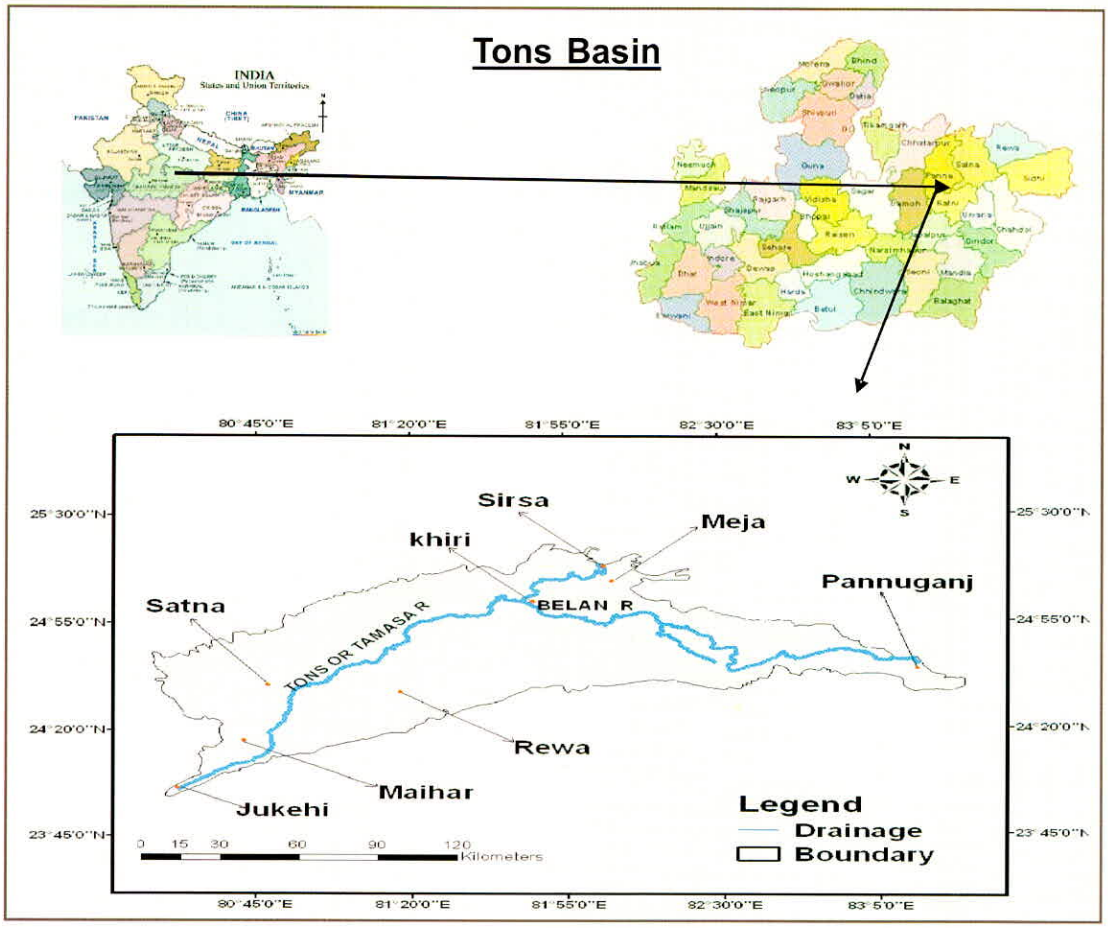

Water depth for 2-yr return period flood

From the satellite data, the flow path of river Ganga and its tributaries are delineated while the river cross sections observed by CWC is used for developing 1-D flow model. The DEM prepared from Survey of India toposheets of 1:50,000 scale and is used for generating bathymetry for 2-D model. The coupled model is used for estimating the inundation corresponding to flood of various return periods.

### *Study on integrated water resources management of sub-basin to cope with droughts*

This river basin experience Dry sub-humid climate and receives average annual rainfall of about 1022 mm. The Ton River flows through undulating topography. Major share of the water is used by agricultural followed by domestic supply and industries.

This area experiences the recurrence of drought, unprecedented economic losses and great suffering to the affected areas, reduced agricultural production and famine threat, limited and scarce water resources, huge water demand for agriculture, increased demand at a rapid rate due to demographic shifts and lifestyle changes objectives to: (a) develop inventory of drought events and water resources in the study area/region (b) classify zones vulnerable to drought in the study sub-basin (s) (c) identify strategy to use surface and groundwater resources in drought situations (d) study the water budgeting and water availability in the study basin/sub-basin (e) evaluate alternative means for minimizing adverse impacts of droughts, and (f) to device integrated water management strategies for minimizing water stress on crops, human and animal life during drought situation.




It has been found that (1) average Frequency of drought occurrence in the basin is once in every five years (2) maximum deficiency of seasonal & annual rainfall experienced in the basin in the order of 60% and 58%, respectively (3) dry spells of more than two weeks duration often cause water stress to rainfed crops during monsoon (4) frequency of dry spells occurrence is once in every two year on an average

(5) Maihar, Nagod, Mauganj and Hanumana blocks in the basin are relatively more vulnerable to sever water shortages during drought events (6) there is no major/medium storage schemes in these blocks (7) lean season water supply in these blocks largely depends on the ground water (8) Govindgarh tank and Bansagar canal

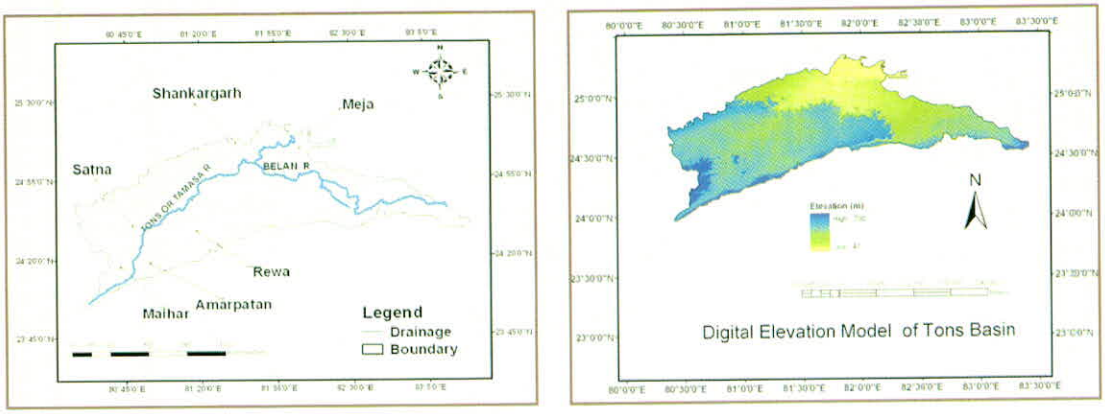
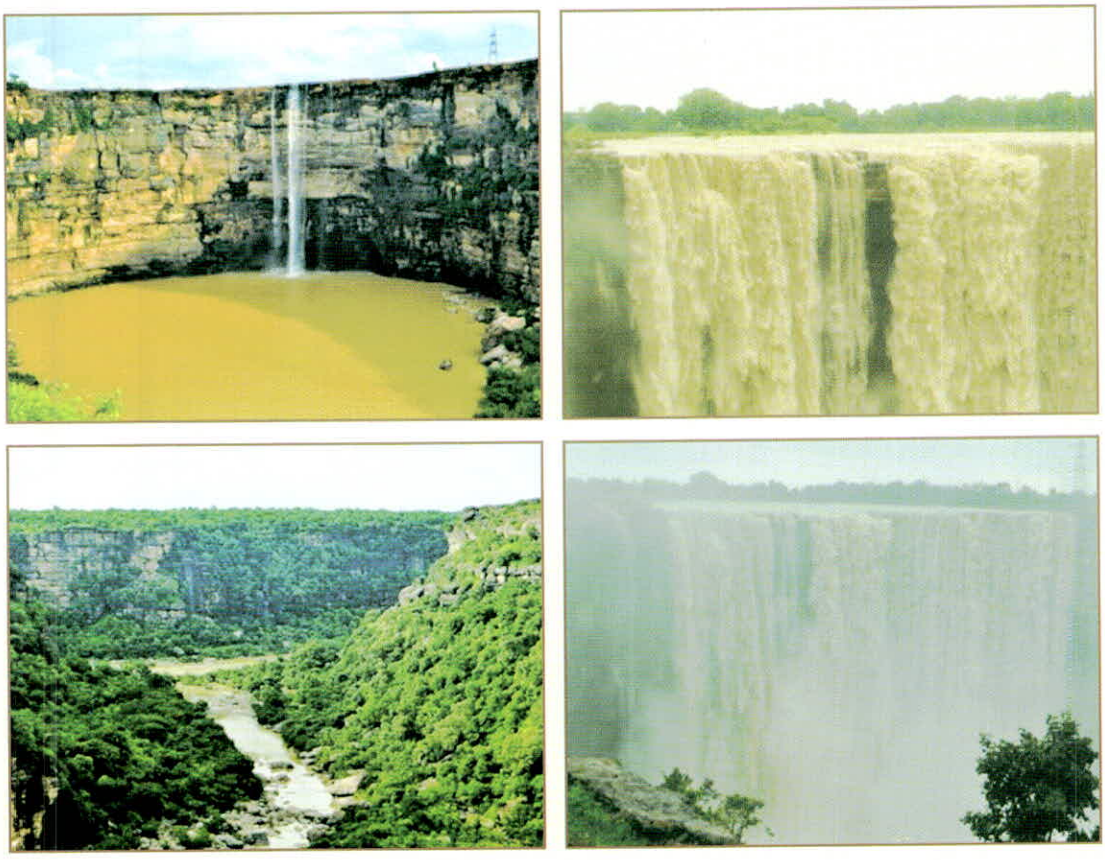



Figure: Drainage map of Tons basin



Tons Chachai fall after river tamas abated/ Spate

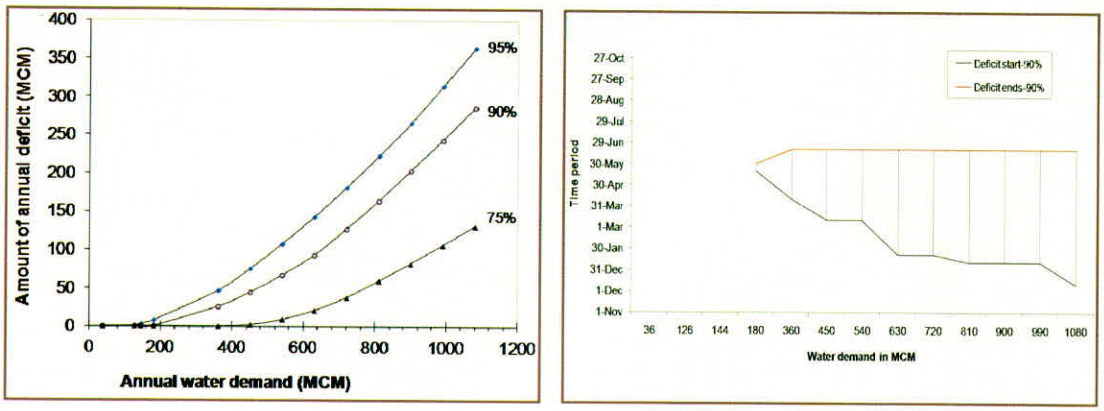
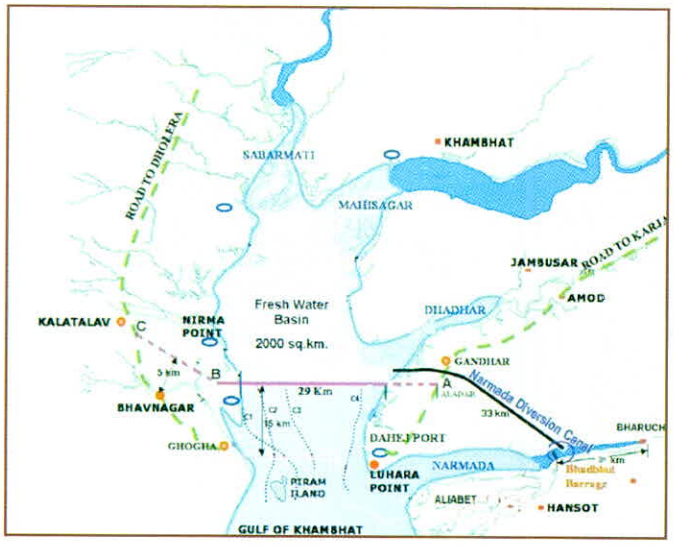



Figure: Demand-Deficit Relationship for Tons at Satna Site

can be the strategic sources for water supply in parts of Rewa, Rampur and Sirmaure, Blocks during drought (9) seasonal rainfall during the monsoon has shown insignificant declining trends while in winter season increasing trend have been found in all the RG station (10) estimates of ETo show decreasing trends and require careful verifications of results. ETc for paddy and Soyabean are more than Effective rainfall and need supplemental irrigation to save from critical dry spells (11) stream flow records show substantial depletion in lean season flow at Satna and Meja Road sites in Tons river and (12) there exist significant potential for storage of monsoon runoff to meet lean season water supplies in vulnerable blocks .

## *Vetting of Water Availability studies of the Gulf of Khambhat Development Projects (Kalpasar Project)*

The Kalpasar project visualizes a gigantic fresh water lake-dam to be created by closing the Gulf of Khambhat (in the Arabian Sea) and thereby harness the excess water of Narmada, Mahi, Sabarmati, Dhadar rivers and other small rivers for generating tidal power, irrigation, drinking and industrial purposes. A road link will also be set up over dam to reduce the distance between Saurashtra and South Gujarat. The project has been sponsored by Narmada, Water resources, Water supply, and Kalpasar Department, Govt. of Gujarat with objectives to review the water availability study of Gulf of Khambhat Development

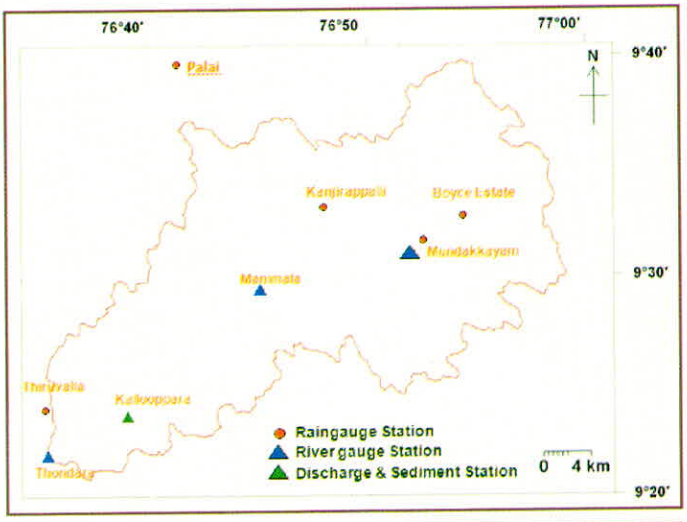


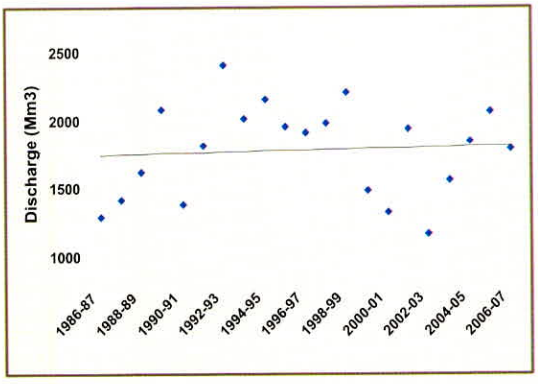
Project carried out by the Central Designs Organisation (CDO), Govt. of Gujarat. The envisaged objectives are: (a) to check the database development for the study, and (b) to check the methodology adopted in the study, computational steps, model runs taken, and the results obtained.

The CDO, Gandhinagar has carried out studies for different river basins and the reports were provided to NIH for the observations. After detailed studies of the reports and after discussing various aspects with the officials of Gujarat Government during the field visit in August/ September 2010, the comments on the studies were submitted to the Kalpasar Department. The database for the study has been revised and for some basins, major changes have been introduced in the methodology.

### *Integrated water resource management for Manimala River basin, central Kerala*

The project addresses various aspects of the water resources problems within the Manimala river basin. This study was accomplished to fulfil the following objectives: (a) to make a detailed study of Manimala river basin to gain knowledge about the soil, land use, geology, meteorology and hydrology (b) to assess the adequacy of the existing gauge network to completely represent the hydrological characteristics of the basin (c) collection and anlyses of historical hydro-meteorological data (d) to assess water demand under existing and future conditions (e) to develop alternatives and strategies to manage water resources (f) to evolve strategies to protect the water



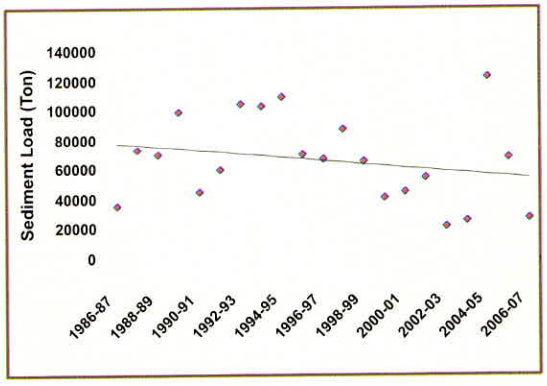




Figure: Trend in Discharge and Sediment Load at Kallooppara (CWC)

Figure: Application of Mike - Basin to Manimala

quality (g) to identify existing and future water resource infrastructure needs and to develop plans to address them.

Analysis of Sediment Data reveals that average annual sediment yield estimated for this basin was 74.50 t/sq. km, average annual discharge was 1732 Mm3, average annual sediment load was 54458.3 ton (monsoon (SW and NE) months yields 91 % of the discharge and 92 % of sediment load) and sediment yield rate (Denudation rate) was 0.05 mm/year. Sediment load shows large decreasing trend corresponding to an almost steady trend in discharge values. This may be due to large sand mining prevalent in the river basins.

| Utilisable Water Potential | | | |
|---|---|---|---|
| | Surface (MCM) | Ground (MCM) | Total (MCM) |
| **Manimala Basin** | 888 [835 (M) and 53 (NM)] | 245 [123 (M) and 122 (NM)] | 1133 [958 (M) and 175 (NM)] |
| **High Land** | 348 | 108 | 456 |
| **Mid Land** | 540 | 55 | 595 |
| **Low Land** | | 82 | 82 |

Analysis of Groundwater data reveals that pre-monsoon level data indicates not much reduction in water levels over the years. Subsequently, the average water level fluctuation was 0.75 to 3.5 m for lowland region, 0.6 to 5 m for midland region, and 0.8 to 4.2 m for highland region.

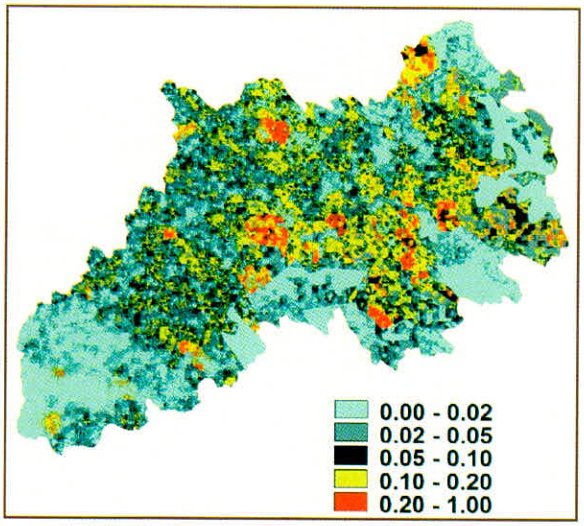


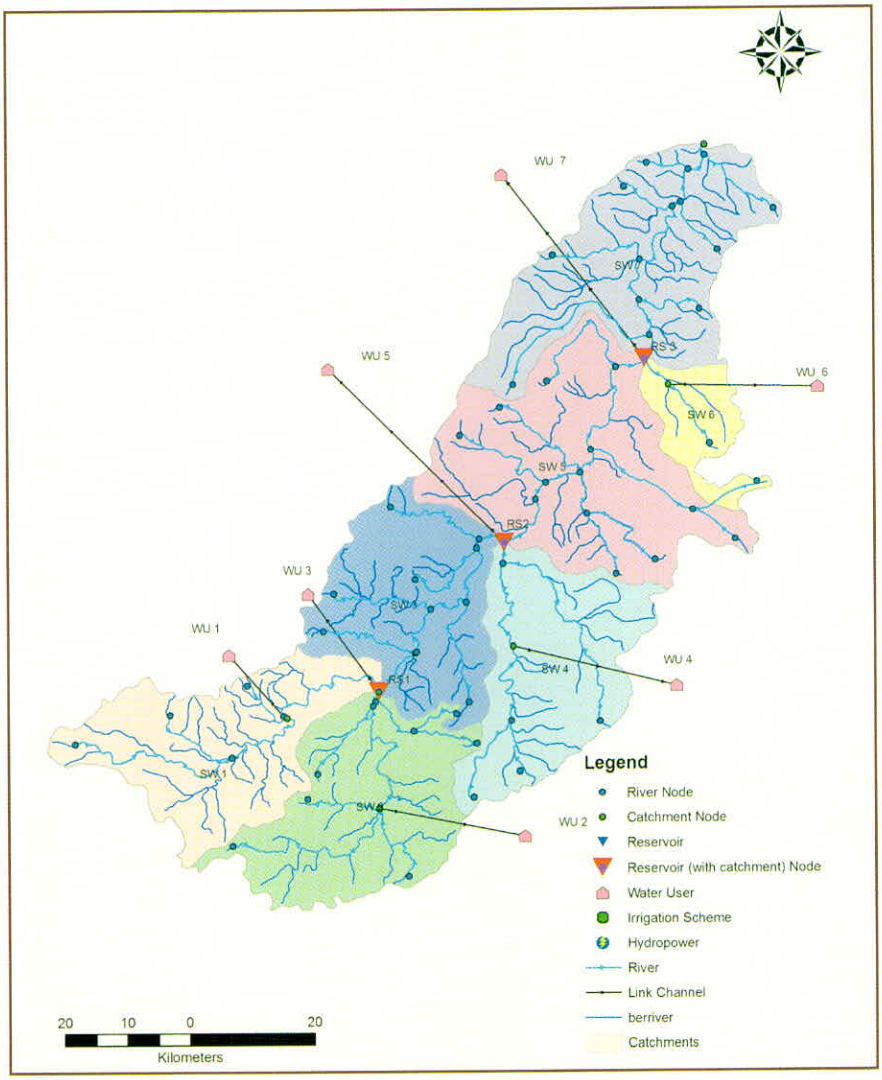

Figure: Soil Erodibility Index Map for Manimala Basin

Ground water quality monitoring that was done at 21 stations for 5 seasons reveals that low pH in few stations in few locations, large iron concentration at Erumely, Kanjirapally, Moncombu (0.6 to 2.0), and high EC (1140) and sodium (102) at Ramankary. Similarly, surface water quality that analyzed at 19 observation stations reveals that Chemical parameters are within permissible limits, coliforms are present in excess (+1100) at all stations along the river and DO shows low values at Kanjirapally, Erumely, Chenapady and Vazhoor stations.

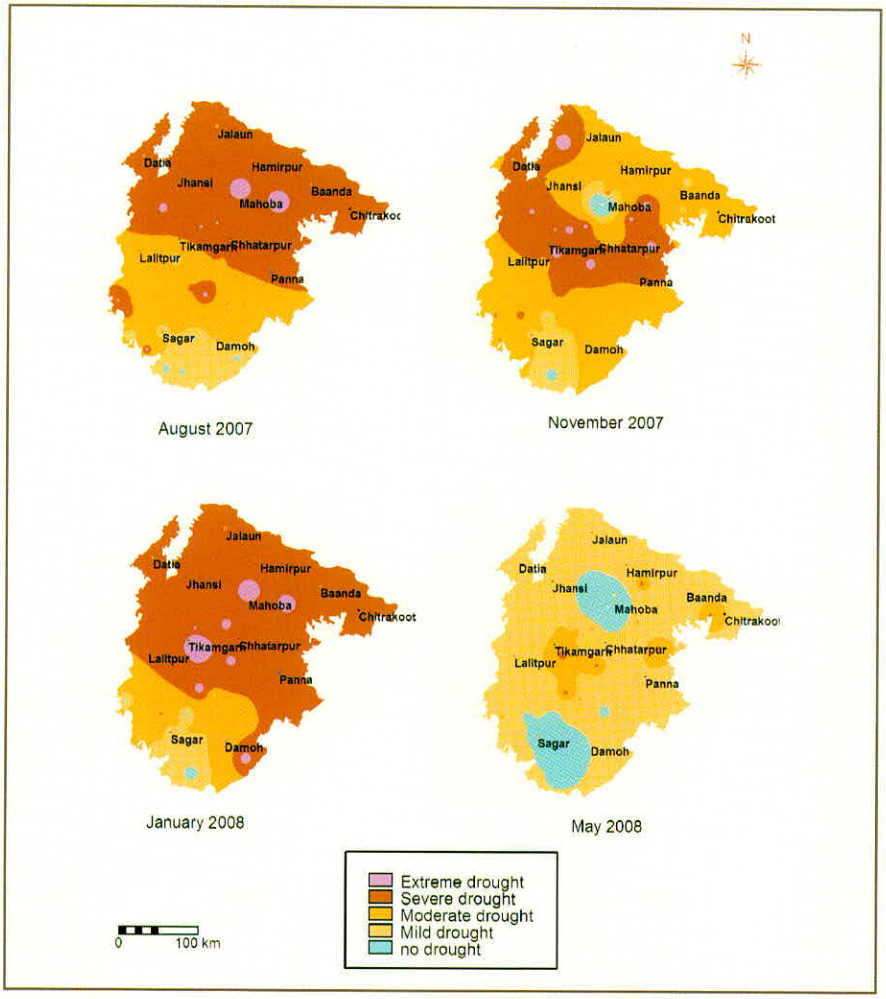
## *Water resources management study for drought affected Bundelkhand region*

The Bundelkhand region covers a wide geographical region encompassing seven districts in Uttar Pradesh and six districts in Madhya Pradesh. The drought analysis has been carried out for each block falling in the various districts in Bundelkhand. For the Bundelkhand region falling in M.P., drought prone blocks were identified in different districts as Sagar (6), Chhatarpur (3), Tikamgarh (6), Panna (3), Damoh (2) and Datia (2) whereas for the region in U. P., drought prone blocks are Lalitpur (2), Mahoba (3), Jhansi (7), Chitrakoot (2), Hamirpur (5), Jalaun (4) and Banda (6). The frequency of drought years varies between 1 in 3 years to 1 in 6 years.

To ascertain any change in climatic pattern being in the region, trend analysis was carried for rainfall anomalies based on the quarterly, seasonal and annual rainfall.



Generally a decrease in the rainfall have been observed but significant falling trends at 95% significance level has been observed only at few blocks namely, Naraini in Tikamgarh district, Moth in Jhansi district, Mahrouni in Lalitpur district, Charkhari and Mahoba in Mahoba district. Significant falling trends in the number of rainy days were observed at Karbi and Mau in Chitrakoot, Lalitpur and Mahrauni in Lalitpur district, Charkhari in Mahoba district, Panna in Panna district and Niwadi and Jatara in Tikamgarh district, whereas the other blocks too depicted a fall in the number of annual rainy days. Dry spell analysis indicates that the first critical dry spell (CDS) of 16 days generally occurs during July third week whereas the second CDS of 17 days occurs during the last week of August; the probability of occurrence of the first CDS being very high. A rising trend in the duration of maximum dry spell length, but not significant at 95% significance level have been observed in most of the blocks in the Bundelkhand region but significant rising trends is observed only at Orcha in Tikamgarh district and Orai in Jalaun district. The rainfed agriculture in



Bundelkhand can be protected from the stresses during the critical dry spells which is a regular feature in the region, by provision of supplemental irrigation which has been estimated for both CDS based on major crops grown.

Drought prone area maps have been prepared for the various districts in Bundelkhand region. The Standardised Precipitation Index (SPI), which allows for monitoring the intensity and spatial extension of drought, has been computed at various time scales of 1, 3, 6, 12 and 24 months. The maps showing the spatial variation of drought including its progression and recline during the various drought years have been prepared and compared. The hydrological drought analysis and the low flow analysis were carried out and the seasonal deficit in stream flow volumes and duration of low flows during the drought years were computed, for varying truncation levels. The Stream flow Drought Index (SDI) has been estimated for the major rivers traversing Bundelkhand. A precipitation and potential evapotranspiration based drought index namely, Reconnaissance Drought Index (RDI), which is one of the most recent developments for assessment of drought severity, has been computed for all the drought prone blocks in Bundelkhand region to identify various drought states.

printed in anubhav printers, rke, ph: 9710004321