4th International Conference on Water Resources and Arid Environments (ICWRAE 4): 298-304
5-8 December 2010, Riyadh, Saudi Arabia

Management of Ground Water Resources in Context of the National Action Plan on Climate Change: A Case Study from Neelamangla in Karnataka

Anshuman

The Energy and Resources Institute, New Delhi, India

Abstract: Water resources faces multiple pressures with increasing complexities of peaking demand, unscrupulous use and additional likely risks due to climate change. With the multifarious stress on the resource, the pursuit for its conservation and efficient management is indispensable. This paper highlights an integrated approach of groundwater management that involved a preliminary diagnostic assessment of the groundwater resources for Neelamangala watershed (India) using GIS and modeling tools and subsequent identification and implementation of suitable intervention for conservation and efficient management of groundwater resources in the region. The project thus attempts for long-term availability of groundwater resources in the studied watershed through water conservation interventions such as artificial recharge of groundwater.

Key words: Climate change • Conservation • Modeling • Groundwater recharge • Watershed

INTRODUCTION

India gets an average of 1200 mm rainfall every year. This amounts to a total precipitation of 4000 billion m^3. Of this only 1123 billion m^3 is available as utilizable surface and ground water resource. Nearly 60 % of this utilizable water is available as surface water and the rest as ground water. Increasing water demand due to growing population and developmental activities has led to a tremendous decline in the per capita water availability in India. While per capita water availability was 5177 m^3 in 1951, it reduced to 1820 m^3 in 2001 and has further fallen to 1654 m^3 in 2007. River basin wide water availability situation is worse and many of the basins are water stressed with the high likelihood of being categorized as water scarce by the mid of this century [1]. The per capita storage capacity when compared with other countries is seemingly less at 213 m^3. Of the 7928 blocks/talukas/ watersheds, 673 are overexploited units and 425 are in the dark and critical categories [2].

The impacts of climate change may further worsen the situation. An increasing body of evidence gives a collective picture of a warming world and changes in the climate system. Some observations over the 20th century include [3].

- Increase in temperatures
- Decrease in snow and ice cover
- Rise in global average sea level rise (SLR)
- Rise in Sea Surface Temperatures (SSTs)
- Increase in frequency and intensity of extreme events

Besides increasing temperatures a number of other climatic parameters are likely to get influenced because of global warming. Climate change is known to lead to intensification of the global hydrological cycle with concerning repercussions across various regions and potential to affect ground and surface water supply used for irrigation, domestic, industrial supply, hydropower generation and navigation.

Climate models indicate increase in temperatures to the scale of 3 degree Celsius by 2050. Climate models also indicate changes in precipitation, its frequency and intensity. This is likely to have a direct effect on the runoff rates and influence the occurrence and intensity of floods and droughts.

Given the various issues discussed above, it is essential to increase the efficiency of water use, explore options to augment water supply in critical areas and ensure more effective management of the resource including promotion of integrated watershed management and artificial recharge of ground water, restoration of

Corresponding Author: Anshuman, Associate Fellow, The Energy and Resources Institute, New Delhi, India

traditional water harvesting structures supplemented by latest water harvesting methods, pollution abatement and water quality maintenance, review and revisit policies and legislation relating to free power for irrigation and ownership rights to reduce groundwater exploitation. New regulatory bodies looking into pricing and incentive structures to promote efficient usage of the resource and use of appropriate technologies will be required. This may require the development of a recharge plan for ground water, treatment of sewage both centralized and decentralized, waste water recycle.

The National Action Plan on Climate Change- Mission on Water: The National Action Plan on Climate Change (NAPCC), constituted by Government of India, in this context has outlined the need for a National Water Mission with a focus on the following elements [4].

- Management of surface water resources
- Management and regulation of ground water resources
- Upgrading, enhancing and developing capacities for water storage and waste water drainage
- Conservation of wetlands and
- Development of desalination technologies

Of the various elements of focus mentioned above key areas of intervention have been identified and proposed. The focus on ground water resources has been on managing and regulating its use. Groundwater accounts for nearly 40 % of the total available water resources in India and meets nearly 55 % of the irrigation requirements, 85 % of the rural requirements and 50 % of urban and industrial requirements [4]. Overexploitation of the resource has lowered water tables in many regions and might further worsen conditions under an enhanced climatic situation. Therefore the NAPCC outlines key policy and regulatory interventions that include;

- Mandating water harvesting and artificial recharge in relevant urban areas
- Enhancing recharge of the sources and recharge zones of deeper water aquifers
- Promotion of efficient water utilization technologies
- Mandating water assessments and water audits
- Empowering panchayats to regulate water withdrawals
- Regulation of power tariffs for irrigation
- Ensuring proper waste disposal
- Providing incentive structures to promote growth of dry land crops

Each of the interventions discussed above requires an outlay of a clear cut implementation plan that can reap the resulting benefits. TERI [5] has been involved in many studies that cover the abovementioned interventions. This paper discusses an implementation study conducted by TERI [5] at Neelamangla district in the state of Karnataka (India) which corresponds to focus on one of the interventions outlined above viz. enhancing recharge of sources and recharge zones of deeper ground water aquifers.

Description of the Case Study: The study was launched with the aim to promote the concept of integrated watershed management with an overall objective to achieve socio economic development at the chosen site. The study was undertaken in two phases. The first phase aimed at the diagnostic assessment of water resources in the study area while the second phase focused on the implementation of the interventions identified in first phase including rejuvenation of traditional water systems through community participation.

Phase-I Study (Diagnostic Phase): This phase involved conducting (a) a scoping exercise for evaluating water resources and (b) Preparation of an area-wide management plan for identifying implementable interventions for water resource management.

Description of the Study Area: Neelamangala watershed, a semi arid watershed, is located in south of India close to the city of Bangalore. It lies between 13° 00′ 04″ to 13° 00′ 14″ N latitude and 77° 00′ 17″ to 77° 00′ 24″ E longitude and falls in the Arkavathy sub basin of Kaveri river. Tepeda Begur, the main study village in the micro-watershed, lies between 13° 00″ 08″to 13° 00″ 10″ N latitude and 77° 00′ 19″ to 77° 00′ 21″ E longitude. The elevation in the watershed ranges from 800 to 980 m above the mean sea level (msl) and consists of a number of interconnected tank systems as can be seen in the figure 1 below.

Based on the topographic information and GIS framework a digital elevation model (DEM) run was obtained to classify the entire watershed into 3 micro watersheds (Figure 2).

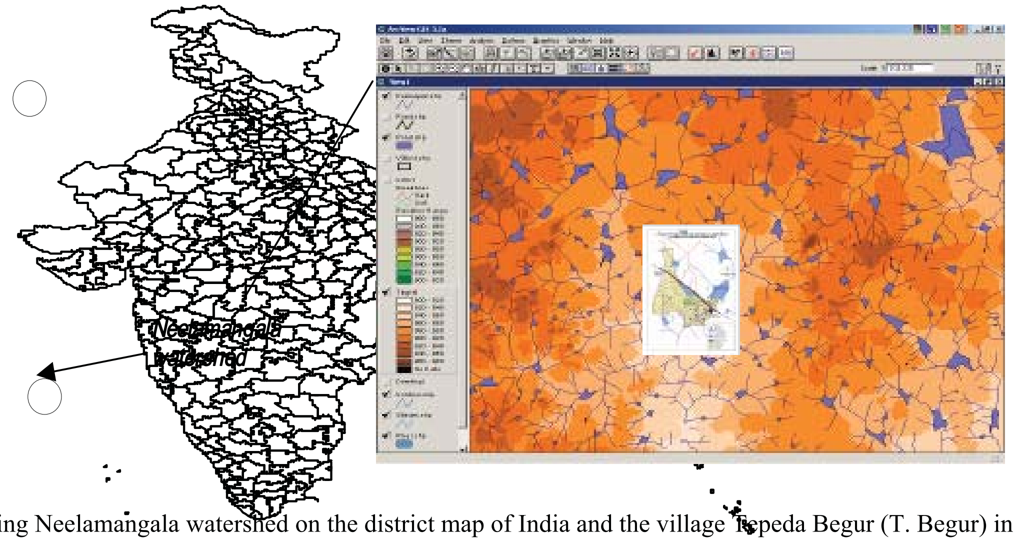


Fig. 1: Showing Neelamangala watershed on the district map of India and the village Tepeda Begur (T. Begur) in DEM (Digital Elevation Model)

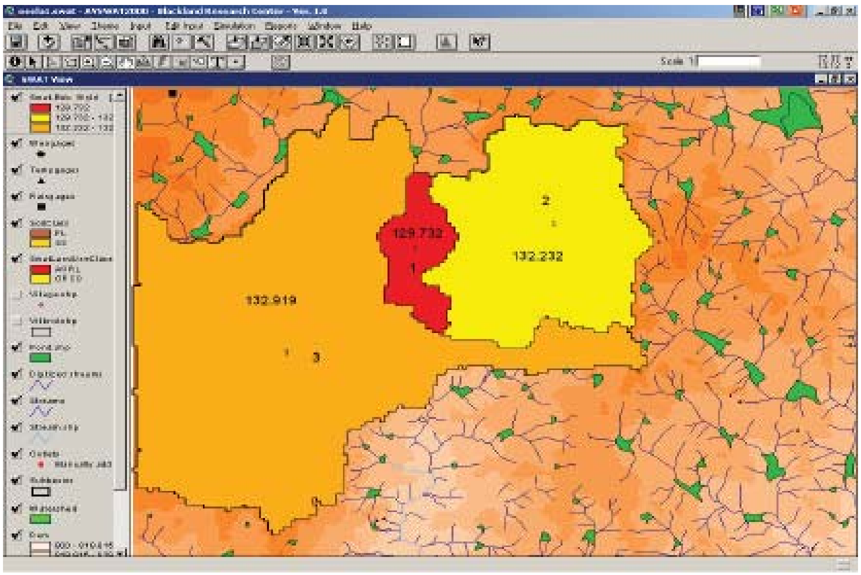


Fig. 2: Micro-watersheds 1, 2 and 3 delineated from the topography map using digital elevation model.

Of the 3 micro-watersheds, micro-watershed 1 (of which village T. Begur, the main study village, is a part) has a limited catchment due to its natural topography and valley formations. T. Begur (micro-watershed 1) faces huge constraint with respect to the natural availability of surface water. The area receives an average rainfall of about 892 mm / year and experiences frequent spells of drought. Groundwater exploitation has been in practice for irrigation purposes in the village.

Methodology for Diagnostic Phase: Groundwater investigations were carried out to establish the movement of groundwater. A geological barrier was found to be affecting the movement of groundwater in its basin. Hence, further investigations were carried out using geo-physical studies, water table monitoring and geological mapping of T. Begur and its neighboring watershed. Additionally, isotope studies were carried out to determine the age of groundwater, recharge rates were assessed and detailed water quality monitoring and analysis were conducted for different seasons.

Questionnaire survey based need assessment, asset inventory and mapping of water supply and drainage network of the watershed was carried out. Aspects like human waste disposal, solid waste management and wastewater management were studied which included building of awareness, demonstration of toilets etc. in the community. This included demand assessment from various sectors and land use studies. All the necessary map coverages and datasets created were transferred into the modeling framework followed by model calibrations. Further ground truthing of the outcomes was undertaken to validate the results.

Based on the thorough scientific investigation and results a development plan was proposed with a set of interventions/plan of action including groundwater recharging in the region.

RESULTS AND DISCUSSIONS

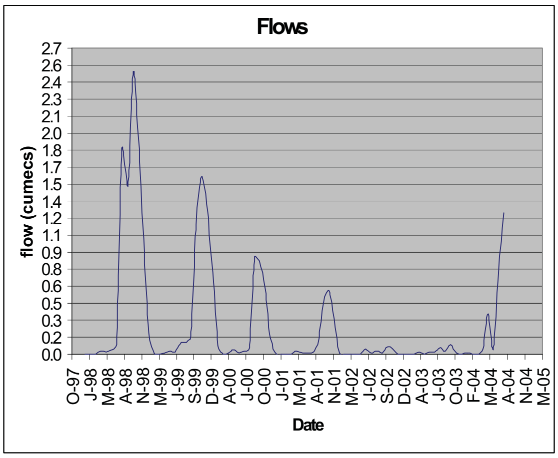
The hydrological modeling results indicated that the average daily surface runoff (water yield) is very low for the T. Begur micro watershed. Further the region had drought years during 2001 to 2003 which was characterized by low rainfall and high temperature due to which flows were dismal (figure 3a). Thus for the tanks in the watershed to get filled and sustain water, consecutive good rainfall years are must for the region. In absence of the consecutive good rainfall years, runoffs reaching the tanks in the monsoon period are feared to eventually get lost either as infiltration loss or as evaporation loss (a major loss).

The ground water model results showed that although surface runoff in micro watershed 1 and 2 were separated but due to natural topography groundwater flows were connected. The annual groundwater balance (as shown in figure 3b) revealed negative balance indicating depleting water table and high stress on the resource.

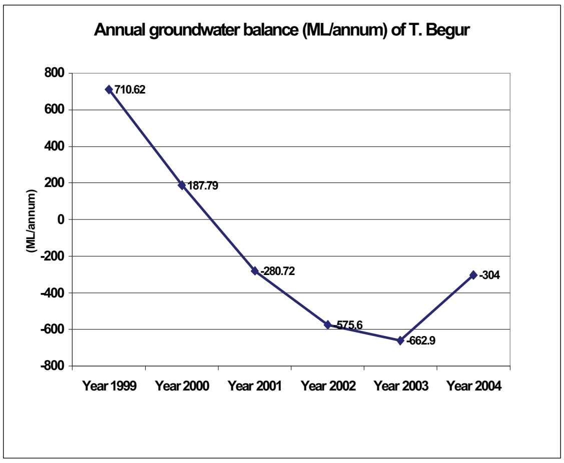
A complete average water balance of the micro watershed 1 and 2 for the period 1998-2004 had shown precipitation of 771 mm with a high actual evaporation loss (562 mm) which was about 72.89 % of the total rainfall. The runoff was low and accounted for about 19% of the total rainfall while natural recharge (74 mm) was moderate being about 9.50 % of the total rainfall.

Further, a comparative analysis was done in the (Soil and Water Assessment Tool) SWAT model using four major variables viz. precipitation, water yield that translates into runoff, groundwater recharge and actual evaporation loss.

Modeling outcomes and ground verifications corroborated that the actual evaporation loses were as high as 70 percent of the total precipitation in the watershed and surface runoffs in T. Begur watershed were negligible with 50 % flows being as low as 0.07 to 0.1 cubic m/s. Thus surface flows being almost non-existent, groundwater has been highly stressed with the major stakeholders (i.e., industry, agriculture and domestic sectors) being dependable on it. With the groundwater tables in the region showing a high declining rate of 1 m per annum, groundwater recharge emerged as the most important long term sustainable intervention.



(a)



(b)

Fig. 3a-b: a: Seasonal flows in T. Begur
b: Annual groundwater balance

Thus based on the above outcomes following two prime interventions were proposed to be the most suitable and effective for management of water resources for this particular watershed.

To Undertake Groundwater Recharging

To Minimize the Evaporation Loses of Water from the Surface: It was proposed to develop those tank systems or catchment areas which could contribute to the enhancement of groundwater recharge for the benefit of micro-watersheds.

Phase-II Study (Implementation phase)

Groundwater Recharging in T. Begur: In concurrence with the proposed interventions of phase I of the study, the phase-II aimed at implementation of interventions with special emphasis on integrated water resource management and ground water recharging of T.Begur watershed with an overall objective of

- Ensuring long-term availability of ground water resources.
- Improvement in the quality of life of the community.
- Institutional development and community empowerment.

The activities under the project were designed as planning phase, implementation phase and post implementation phase. The planning phase consisted of engaging community in the decision making process through community mobilization, formation of village development committee (VDC), youth groups etc. after which the implementation phase was started wherein number of entry point activities such as construction of individual household toilets, vermi-composting pits; harvesting structures, drip irrigation layouts and farm ponds were undertaken.

For the purpose of focus of the current paper on the groundwater management in context of NAPCC, only the intervention on groundwater recharge at T. Begur watershed is being discussed with elaboration.

Methodology for Implementation Phase: Initially investigative activities were carried out in this phase with methodology and approach as in phase I, wherein further detailed investigations and validations were carried out for the T. Begur watershed.

Thus a part of T. Begur watershed was selected for hydrological modeling to assess the quantum of water that can recharge groundwater. This micro-watershed, named as stream 12, has an area of 18 ha and elevation difference of 14m and is located at the southwestern boundary of T. Begur watershed. The model was used to estimate the contribution of water from micro-watershed of T. Begur watershed to the recharge bore wells chosen for the purpose. Modeling was done using SWAT in ARC VIEW GIS using 14 years of daily rainfall and temperature data for the watershed.

Geophysical studies, isotope studies and aquifer pump tests were carried out to determine local site specific properties and aquifer characteristics. Surveys were conducted to identify the location of recharge structure. Based on the information from these and keeping in view the presence of subsurface barrier (dykes) that restricts the flow of groundwater into the southern part of the village, location of recharge structures was identified farther to the south of dyke to accrue maximum benefit for the village community.

Figure 4 shows the location of the recharge structure in the watershed.

Conclusions and Outcomes of the Study: The selected recharge site has good stream length (415 m) and slope (1.93 degrees) with excellent flow that contributes to the recharge structure and is safe from encroachment due to developmental activities.

The modeling results showed that in this watershed, total groundwater recharge by one recharge structure would be around 10-12 ML (million liters) per annum. It was thus assessed that through the recharge structures the percentage of groundwater recharge shall increase from about 39 % to about 65 % of total precipitation helping in the recharge of the local aquifer.

Mean values for different hydrological components such as precipitation, potential evapo-transpiration (ET) and surface runoff as depicted in Figure 5 shows that PET (Potential Evapo-transpiration) exceeds precipitation for most of the years.

Thus for efficient water management in the area that ensures minimum evaporative losses, groundwater recharge structures were preferred over the surface water storage structures. Also since surface runoff and precipitation curve follows a similar trend, surface runoff is directly proportional to precipitation and hence to the recharge in recharge structure.

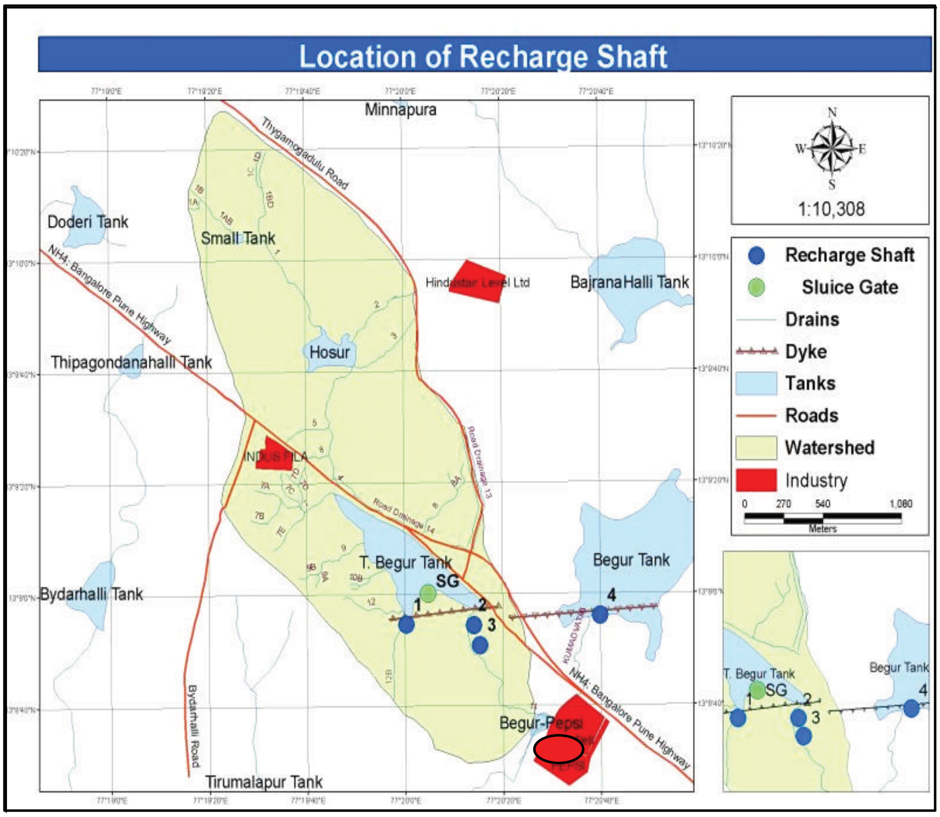


Fig. 4: Map showing groundwater recharge sites

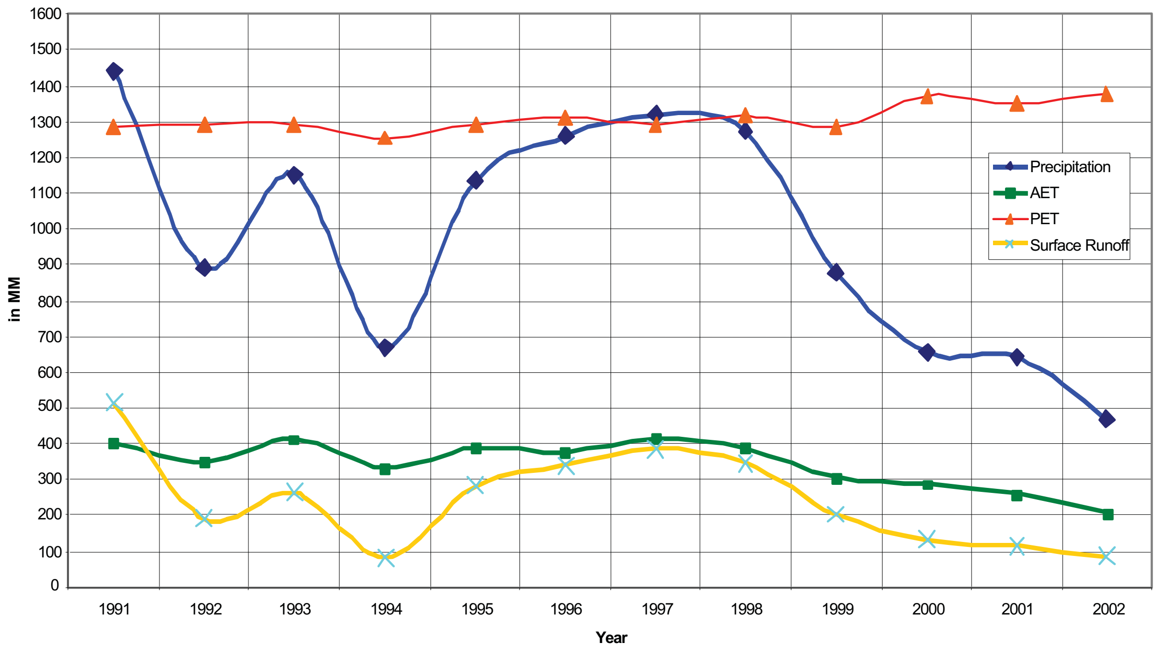


Fig. 5: Deciding frameworks for estimating recharge potential from stream no. 12.

Construction of Recharge Structures: Following the scientific analysis and evaluation, estimation and construction work of the groundwater recharge structures were initiated wherein recharge shafts were placed at the selected recharge site. Recharge shaft technique were chosen over other technique for being one of the most efficient and cost effective structures for direct aquifer recharge. Six recharge structures have been constructed under the study in the study region.

Potential Benefits: The potential benefit from one recharge structure has been assessed to be about 10-12 ML/year. However, the direct benefits predicted from all the six recharge structures to the local aquifer would be much larger.

Scaling up similar interventions for other part of watershed could further conserve water or feed the local aquifer significantly and would cover up the negative draft in the region. Also, it was estimated that a sum of all the interventions implemented under the study would help in the increase in water tables.

Monitoring, Operation and Maintenance Plan: Further to assess the impact of the recharge structures monitoring exercise were designed which include the following activities

Monitoring of Groundwater Level: Surface water and ground water levels data were collected during the study. Networks of observation wells have been identified to study the ground water flow pattern and temporal changes in potentiometer head in the aquifer.

Water Quality Monitoring: Keeping in view the importance of the water quality of the artificial recharge schemes, seasonal water quality monitoring has been carried out. The data on the physio-chemical quality of native water during the artificial recharge schemes were collected by regular sampling from observation well net work and assessed.

Operation and Maintenance Plan: A sub-committee under the village development committee (VDC) trained by the project team, will be responsible for operation and maintenance of these structures which will include regular removal of silt from silt chamber, any repair of recharge structures, regular cleaning and maintenance of streams. Further monitoring of the impact of these interventions is planned to be taken up by a sub-committee trained specifically for the purpose which shall be supported by the VDC for infrastructural needs.

Way Forward: Implementation of various options including the option discussed above thereby has a strong potential to enhance recharge and conserve resources. A strong scientific study providing the basis for exploration of the various interventions proves useful as also leads cost optimization to work towards a long term strategy for water resource protection and conservation. Thus based on macro data analysis, highly stressed areas across India should be identified and scientific investigations for each of these regions conducted, to promote groundwater recharge and resource conservation.

ACKNOWLEDGEMENT

Author acknowledges guidance from Dr. Leena Srivastava, Mr. Ashok Jaitly and contributions from Dr. K. Narula, Mr. K.Murari, Mr. H.Mahadev, team and sponsors.

REFERENCES

1. TERI, 1997. Green India, The Energy and Resources Institute, New Delhi, India.
2. Planning Commission, 2008. National Portal Government of India as on 20/08/2008, Department of Information Technology.
3. IPCC, 2007. Intergovernmental Panel on Climate Change, WG II report on Impacts, Adaptation and Vulnerability Assessment. Cambridge University Press. Cambridge.
4. GoI., 2008. National Action Plan on Climate Change, Government of India.
5. TERI, 2005. Project Report No. 2004WM22. Project on ‘conducting a diagnostic study for assessing water resources and implementation of suitable solutions to address community concerns using a watershed approach’.