

A Brief Report on the Papers

Considering that Groundwater Governance issues deal with political, economic, administrative, social, institutional and scientific mechanisms, processes and relationships, the framework of technical deliberations of the Symposium has thus been designed to address these aspects under following five focal themes: (i) Groundwater management: emerging challenges, (ii) Groundwater governance: institutional and legal framework. (iii) Groundwater ownership and water rights—legal aspects, (iv) Sectoral allocation of groundwater and its pricing, and (v) Stakeholders participation in groundwater governance. Each theme contains a theme paper contributed by eminent expert of respective field followed by selected volunteered technical papers. A total of forty nine papers are included in the volume.

The theme **Groundwater Management—Emerging Challenges**, has been intended to cover scientific papers dealing with groundwater availability, emerging challenges in ground water, analysis and results of studies conducted by investigators, groundwater modelling and management, performance of advanced tools, pollution threats to groundwater, etc. The theme paper by *Saleem Romani*, Chairman, Central Ground Water Board, followed by seventeen technical papers encompasses the technical contents of the theme. In his paper, *Romani* has presented the scenario of groundwater availability in the country, and the different large-scale management strategies being followed in the form of structural and non-structural measures to meet increasing groundwater demand and to control any untoward threat due to the over-exploitations of aquifers. In structural measures, issues related to scientific planning and development of groundwater citing few successful case examples conducted under varied hydrology and hydro-geologic conditions have been mentioned. Under the non-structural measures, requirement of the need-based allocation and pricing of resources, effective management policy, involvement of all stakeholders, and capacity building of people have been stressed upon. For areas with scarcity of groundwater, rainwater harvesting and artificial recharge to ground water have been suggested to be an important management tool for augmentation and restoration of groundwater resources. The paper also gives an insight of emerging challenges in groundwater management, and describes the possible needs to combat those.

From the experiences on the World Bank funded projects with the states of Andhra Pradesh, Maharashtra, Rajasthan and Tamil Nadu, *Stephen Foster and Héctor Garduño* in their paper "*Groundwater Resources of India—Towards a framework for practical management and effective administration*", suggested that the main focus on the management of ground water should be in weathered hard-rock aquifers outside the command of major irrigation canal systems as they occupy very extensive areas in the drought-prone land-mass of India. The authors stated that groundwater resource depletion has already had serious impacts on dry-season cropping and village water-supplies, and consider that the major or only factors causing groundwater depletion are because of: (i) the

provision of free (or highly-subsidized) electrical power for pumping; and (ii) the failure to conserve watersheds and encourage groundwater recharge. Few key components on the Indian model Groundwater Development and Management Bill have been analyzed and discussed.

In their paper entitled "*Groundwater management in the state of Punjab*", M.P. Kaushal and A.K. Jain, based on the case study conducted in the Bist Doab tract of Punjab, have suggested that by changing the cropping pattern, i.e., paddy by cotton, maize and groundnut, the declining groundwater tables, very common in the state of Punjab, can reasonably be arrested. To simulate the seasonal groundwater behaviour, and to determine responses of the aquifer for different stresses, 'MODFLOW' has been used as the modelling tool.

P. Nandakumaran, in his paper entitled "*Challenges of groundwater management in hard rock terrain— A case study from Tamilnadu, India*" has indicated that because of exponential growth in number of open wells and bore wells in the state since years 1980-1981, groundwater levels in the aquifer have been depleted considerably, which have put about 16,000 wells out of use. These have resulted in a decline of irrigated area from 2.1 ha during year 1980-81 to about 1.37 ha during year 1999-2000. In hard rock areas, large-scale heterogeneity in the properties of aquifer materials limits the yield of aquifers, and thus poses severe constraints for augmentation of resources in depleted aquifers by artificial recharge techniques. Considering these aspects, a two-pronged strategy involving regulation of groundwater abstraction on a regional scale coupled with cost-effective recharge augmentation at the local level has been suggested.

In their paper titled "*Optimal groundwater pumping from Palla well fields to augment drinking water supply to Delhi*", S.V.N. Rao et al., presented results of a real-life problem involving pumping of ground water from a series of ninety existing wells along river Yamuna floodplain, which has the threat of saline water interference. Embedding the calibrated groundwater model within a simulation-optimization framework, a non-linear, non-convex problem has been solved. Optimization has been accomplished by using simulated annealing (SA). Problem formulation and solving techniques have been discussed in details in the paper. The paper also suggests the management strategy to be followed for groundwater development in the study area with least interference of saline water.

Isotope approach has emerged as one of the most advanced techniques for identification of the origin and recharge zones of ground water. In their paper titled "*Origin and recharge of groundwater in western Himalayan region, India: An isotopic approach*", S.P. Rai et al. have studied the origin and natural recharge zones of ground water using isotopic composition ($\delta^{18}\text{O}$ and δD) of groundwater in parts of upper Ganga catchment. The $\delta^{18}\text{O}$ - δD relationship for groundwater samples showed similarity to Local Meteoric Water Line of Bhagirathi river basin, which indicated that ground water in the area originates through precipitation only. The close resemblance in altitude effect of ground water and precipitation confirmed that the source of ground recharge is precipitation only. The paper also discusses analysis of results in depth.

Eighty per cent of the geographical area of the Chhattisgarh is hard rock, and its economy is mainly based on agriculture activity. Ground water is the major source for agricultural water supply. Arunangshu Mukherjee and Dinesh Tewari in their paper entitled "*Emerging challenges in groundwater resource management before a newly created State – with special reference to Chhattisgarh*" have reported that over last two decades, change in the groundwater abstraction pattern from dug well to bore well has exaggerated the threat of pathogenic contamination of geogenic origin to ground water.

V.V.S. Gurunadha Rao et al. in their paper "*Design of sustainable water supply for Hindalco-Muri works in Subarnarekha riverbed aquifer, Ranchi district Jharkhand*" have presented analysis and

results of study conducted for delineating the extent of aquifer and its potential to yield ground water of Muri works in Subarnarekha riverbed. Vertical Electrical Sounding (VES) technique has been used for exploration of groundwater.

Because of operational efficiency, large-scale replacement of centrifugal pumps by submersible pumps, particularly in the rice-wheat cropping areas, is very common in the state of Punjab and Haryana. *M.J. Kaledhonkar et al.* in their paper suggested that if farmers are not suitably trained on operational aspects of the submersible pumps, there are chances of depletion in groundwater level. The paper presents analysis of survey conducted in the trans Indo-Gangetic plains.

Using GIS and remote sensing as analysis tools, *Moumita Roy et al.* in their paper entitled "*Artificial groundwater recharge planning in northern Uttar Pradesh using GIS and remote sensing*" analyzed and suggested an artificial groundwater recharge plan for the construction of recharge structures in the Bijnore district of northern Uttar Pradesh, where the groundwater table has the trend of gradual depletion. The paper also presents analysis of different maps prepared using GIS and remote sensing.

R.K. Goyal, in his paper titled "*Groundwater scenario under changing climate: Rajasthan*", has analyzed the effect of climate change on groundwater resources of Rajasthan. Considering change in evapotranspiration is the consequential effect of climate change, and it is an indicator, additional water requirement for the cropped area has been assessed for rise in temperature over the normal. Changes in scenarios of groundwater status in terms of 'safe', 'critical' and 'over-exploited' for different rises in temperature have also been analyzed. The Penman-Monteith model was used to estimate evapotranspiration.

Hydrological and hydrogeological features of islands and their groundwater related problems are different than the normal aquifers in the main lands. *J. Sundaresan*, in his paper "*Groundwater perspectives of small islands – Lakshadweep islands, India*" presented an analysis of groundwater scenario, and impact of sea level rise on the aquifers of Kavarathi and Bengaram islands. The Ghyben-Herzberg equation was used for assessment of availability of freshwater resources, and the Brunn's rule was used for estimation of impact of sea level rise.

Excess iron concentration in ground water over the permissible limit is very common in aquifers of northeastern region of the country. Over-exploitation of such aquifers would not only exaggerate the problems of environmental hazards but would also affect the plant growth when iron-rich groundwater is used as irrigation water. *U.M. Hazarika and S.C. Patra*, in their paper entitled "*Use of iron-rich groundwater for irrigation in Sonitpur district of Assam*" have tried to focus these aspects from the case study conducted in the Sonitpur district of Assam. The main reason of increase in use of ground water by construction of shallow tube wells has been reported to be because of agriculture-based schemes being promoted by different financial institutions.

The existence of fresh water overlying saline water in groundwater system is widespread in many inland aquifers as well as in most coastal aquifers. When the fresh water is pumped from a well tapping a fresh-saline aquifer the underlying saline water rises towards the well to maintain the hydraulic equilibrium. In such a scenario, scavenger wells are used for pumping the fresh water. A scavenger well system consists of two pumping wells located side by side, one of which taps the freshwater zone while the other taps the saline water zone. In their paper entitled "*Modelling of a scavenger well system*", *K. Saravanan et al.* adopting a finite-difference model on both advective and dispersive components of saltwater transport, the upconing below a scavenger well system has been studied. The paper presents formulation details of the numerical schemes, and its solution technique with suitable numerical experiments.

Hilly terrain, because of topographic variability and varied geological possessions, has limitation to groundwater availability. However, when the demands of groundwater in various development activities are far more than the availability, like the plain lands augmentation of groundwater resources in hilly-terrain is not a straightforward approach. *E. Kikon and Katiwaba Ao*, in their paper “*Groundwater development in hilly terrain: Case study in and around Kohima town, Nagaland*”, have discussed the scenario of ground water in Kohima town, and suggested some measures to overcome emerging problems related to demand.

R.K. Nema et al. in their paper entitled “*Affectivity and extent of Haveli areas – A system of water prosperity*” presented the results of study carried out in Jabalpur and Narshingpur districts on affectivity of the *haveli* system of cultivation—a traditional method followed in Madhya Pradesh. In *haveli* system, cultivated fields surrounded by huge bunds are kept fallow during kharif season. Rain water is collected in the fields and is retained for about three months and then drained in the month of October. The authors stated that adaptability of modern recharge structures on individual level is very poor due to requirement of high initial investment, and the response of community basis adaptation is not favourable. The paper also presents detailed analysis and performance evaluation of the *haveli* system of cultivation.

In their paper entitled “*Groundwater management options – A case study of western Yamuna canal command, Haryana*”, *K.J. Anandhakumar et al.*, have presented an analysis of reconnaissance survey of the Western Yamuna augmentation canal including its performance evaluation in terms of impact on groundwater level and financial viability.

The Tsunami caused by the earthquake on 26.12.2004 on Indian continent had a devastating effect on groundwater resources in the Andaman and Nicobar islands. However, the extent of damage on the groundwater resources in the islands is still to be assessed. In their paper entitled “*Hurdles in framing groundwater management strategies in A&N Islands in the aftermath of Tsunami*”, *Amlanjyoti Kar and C.P.Gawri*, have tried to focus the problems being faced in obtaining the reasonable assessment of fresh groundwater resources and in developing sustainable groundwater management scheme in the aftermath of Tsunami. The authors have portrayed a scenario of variation in groundwater levels by comparing the situation before and after the Tsunami. The extensive data support provided in the paper may help readers to look into the insight of the problems to derive possible development schemes.

The theme **Groundwater Governance: Institutional and Legal Framework** has been designed to envelop scientific papers dealing with governance and management issues, institutional and legal framework, challenges in the groundwater governance, issues of the groundwater regulation, control and legislation act adopted by different state governments, etc. A total of thirteen papers have been included in the volume under this theme. Out of thirteen papers, eight papers contributed by the State Groundwater Departments, namely; the state of Tamil Nadu, Kerala, West Bengal, Gujarat, Haryana, Punjab, Madhya Pradesh, and Rajasthan deal with an overview of the groundwater resources in the respective state, and the provision, scope and challenges emerging from the enactment of the groundwater regulation, legislation and control acts adopted by different state governments. Remaining five papers are volunteered based on analyses, thoughts and research studies.

The paper by *K. Nagarajan* of Tamilnadu Groundwater Division, gives an overview of groundwater development in the Tamil Nadu State, and focuses the salient features of the acts enacted by the state on control and regulation of groundwater resources. It was suggested that the ownership of the groundwater should be vested with the state government making suitable amendment in the

Constitutional provision delinking the groundwater ownership from the land ownership, by repealing the relevant clause 7 of "The Indian Easement Act".

The paper of the Kerala State Groundwater Department by *J.P. Kukillaya and A. Rajan* highlights various aspects of Groundwater Act, 2002 adopted by the state government for the purpose of regulation and control of groundwater extraction and use. The paper also discusses about ownership and pricing aspects of groundwater. For successful implementation of the Act, necessity of awareness at all levels on groundwater management has been suggested. The need for groundwater pricing leading to more efficient use of the resource has also been stressed upon.

The paper of the West Bengal State Water Investigation Directorate by *P.K. Ray Chowdhury* mainly presents the various aspects of the groundwater Bill, named as, "The West Bengal Groundwater Resources (Management, Control and Regulation) Act, 2005", enacted by the state government. This Act envisages (i) protection of the resource with due consideration to conservation and management, (ii) protection of resource against quality degradation and (iii) ensuring social equity. The author, however, pointed out that successful implementation of the provision made in the Bill essentially depends on the involvement of the common people.

The paper by *V.M. Yagnik et al.*, titled as "*Groundwater Governance in over-exploited/dark and saline areas of Gujarat State*" besides giving an overview of the groundwater resources in the state, brings out reasons of groundwater over-exploitation, and focuses few issues relating to groundwater governance.

R.K. Khullar in his paper entitled "*Groundwater management in Haryana and emerging issues*" presented an overview of the state groundwater resource and its development and exploitation taking place in different forms. The major policy decision taken by the state government to conserve and restore back the depleted groundwater table has been discussed. It was suggested that participatory approach in the form of working with existing grass-root institutions and capacity building of these institutions could bring sustainability in management of groundwater resources. The paper also discusses different groundwater management strategies adopted by the government.

In his paper, entitled "*Groundwater governance issues and perspectives regarding model Bill application in Punjab State*", *Kuldip Singh Takshi* has given an overview of water resources development including groundwater resources linking historical development of irrigation and agriculture in the state of Punjab. The paper also discusses several aspects related to groundwater governance and its legislative proposition. A critical analysis on the Model Groundwater Bill with its advantages and disadvantages including a view of Punjab state has been presented in the paper. The legal position of groundwater ownership as enacted in the Indian Easements Act, 1882 has been discussed. From the point of view that legislation has no merits to acceptability or not even successful, the author has suggested for corrective and suitable measures in the bill to control the demand, conservation and augmentation of groundwater resources for its effective management.

The paper by *N.R. Khare*, entitled "*Groundwater resource assessment and management strategies with special reference to Madhya Pradesh*" presents an overview of groundwater resources and its development and exploitation taken place in the state. Corrective measures adopted to restore back the exploited groundwater resource have been highlighted in the paper. The need for an integrated approach involving rainwater harvesting, water conservation measures, rejuvenation of traditional water harvesting structures combined with people participation and suitable water act has been suggested for sustainable groundwater development and management in the over-exploited/critical areas.

The paper of the Rajasthan state, entitled "*Groundwater resource management in the state of Rajasthan*" by *V.N. Mathur* gives an overview of groundwater resource development, and the management practices being followed to balance the demand with the available supply. The concept of Information, Education and Communication (IEC) approach adopted by the state for conservation of groundwater is one of the key points mentioned in the paper.

Kavaratty, a small tropical island of Lakshadweep, which constitutes high population density and deep rooted vegetation, shallow groundwater condition, large groundwater draft, improper sewage disposal, has the groundwater condition of shallow freshwater zone floated over the seawater in the form of lens susceptible to interference by saline water. *K. Md. Najeeb and N. Vinayachandran*, in their paper entitled "*Groundwater governance in Kavaratty Island of Lakshadweep, India*" have described status of groundwater in the Kavaratty islands both in terms of quantity and quality. Deterioration of groundwater quality due to presence of high concentration nitrate ($\text{NO}_3 > 50 \text{ mg/l}$) has been reported to be one of the major concerns for reduction in fresh groundwater availability.

K.D. Sharma, in his paper titled "*Groundwater Governance: The Indian Scenario*", stressed the need for developing long-term policy to protect groundwater overuse. The author has suggested some means to impart sustainability to ground water; those include: switching over from development to management, supply-side to demand-side management, enacting and forcing groundwater laws, establishing clear tradable property rights, pricing of groundwater, installing licensing and permitting systems, strengthening institutions/processes to enable management, creating incentives, etc. The paper also presents a critical analysis of the different concepts.

In his paper entitled "*Institutional Framework of Managing Ground Water in a Water Stressed Region*", citing example of a case study, *Dipankar Bose* has suggested the need of strengthening institutional framework to address multidimensional requirement of groundwater management. The author has proposed a conceptual model of institutional framework of groundwater management involving participation of decision makers, planners, implementing bodies and direct beneficiaries.

N.C. Ghosh and Anupma Sharma, in their paper entitled "*Groundwater Governance: Few pertinent issues relating to availability and possible threat*", presented an analysis of availability of replenishable groundwater resources both in terms of depth per unit area and the change in per capita availability over the next two decades. The analysis has also been presented both river basin-wise and state-wise. The analysis presented could aid in development of suitable groundwater management plan to address governance issues related to ground water. The scope for augmentation of groundwater resources to meet the additional requirement and the probable threat to aquifers due to pollution hazards has also been discussed. The concept of donor and donee in pollution-threatened aquifers has also been suggested.

In their paper entitled "*Over-exploitation of aquifers: Need for proper planning, management tactics, awareness and legislation (examples from West Bengal and Orissa)*", *Amlanjyoti Kar et al.*, have discussed the hydrogeological setups, groundwater availability and development taking place with regard to ground in the state of West Bengal and Orissa. A critical analysis explaining reasons of over-exploitation has been presented in the paper.

The theme on **Groundwater Ownership and Water Rights - Legal Aspects** includes five papers pertaining to water rights and related legal aspects, importance of recent techniques like remote sensing in evolving appropriate laws, and problems encountered in groundwater regulation. The theme paper by *M.S. Rathore*, Professor, Institute of Development Studies, Jaipur, discusses in detail two alternative approaches to deal with groundwater problems in India viz., (i) water rights based approach

covering legal and regulatory provisions, and (ii) community management of groundwater resources. The paper recommends formulation of water rights in such a way that usage rights are held by the community rather than the individual, and adoption of river basin approach as the basis of planning for sustainable management of all natural resources including water.

In the paper entitled "*Contribution of remote sensing and geographical information system to groundwater ownership laws*", O. P. Dubey et al., have discussed the five rules generally followed by states in evolving groundwater laws. Usage of conventional techniques for collection, storage, analysis and dissemination of data is difficult and costly, which impedes decision-making essential for enforcement of these laws. The paper suggests that remote sensing data sets can be utilized for extracting and generating basic data for decision-making.

R.C. Purohit and Virendra Kumar in the paper entitled "*Ownership of groundwater and its pricing: Rajasthan perspective*" have discussed the status of ground water in terms of quality and quantity for the state of Rajasthan. The paper summarizes various water laws enacted at international and national level and proposes pricing structure of groundwater extraction for domestic, agriculture and industrial use.

In the paper "*Control and regulation of groundwater through pricing of water in the Kerala scenario*", P.N. Ajith Kumar and A.S. Sudheer discuss various schemes introduced in Kerala for utilization of groundwater for irrigation and drinking purposes. The global and Indian scenario regarding the pricing of water with special reference to Kerala has also been studied.

N.C. Nayak et al., in the paper entitled "*Emerging problems in groundwater regulation and governance, and the need for a groundwater database—A case study from Orissa State*", have cautioned about the adverse impact on ground water of the various ongoing and upcoming projects in Orissa in the rapidly growing mineral and metal sector. The paper stresses on the urgent need for creation of a groundwater database for such projects, so that impact on groundwater before, during and after the implementation of the project can be ascertained and timely corrective measures can be taken to safeguard the precious groundwater resource.

In the paper "*Groundwater ownership and legal aspects*", J. A. Tambe has analyzed the provisions, acts and enactments of laws, policies, regulating methods etc. and related complexities in implementation and operation of these laws. Based on realistic priorities, policies and objectives, suggestions have been made for effective groundwater management.

The theme **Sectoral allocation of ground water and its pricing**, has been conceived to cover scientific papers dealing with groundwater governance issues including sectoral allocation, groundwater rights and pricing policy for management of groundwater resources. The session covers a theme paper followed by five technical papers related to the relevant technical issues. In the theme paper entitled "*Groundwater governance issues in irrigation development – A perspective*", John Kurien and A.K. Sinha have suggested certain experimental changes in the rules (technical and economic) and institutions governing the groundwater use in the country. Comprehensive institutional mechanism and regulations along with market-oriented approaches have been proposed to put in place both by the central and the state governments for governance of groundwater use to ensure equitable and sustainable water availability for future domestic, agricultural and industrial uses.

V.V. Damle, in his paper entitled "*Sectoral allocation and pricing of ground water: A stakeholder view*", discusses policy for entitlements, allocations, access and pricing structures and suggests alternate water markets with respect to types of sources – surface water or ground water. The paper also suggests an alternate basis for cost-benefit analysis where reduction in state expenditures on mitigation,

employment and poverty alleviation is considered as a sustainable benefit due to provision of water to stress areas.

In his paper entitled "*Sectoral allocation of groundwater and its pricing*", A. K. Lakhina has indicated that adhoc government policy has encouraged increase of pumpsets in agricultural sector mainly to protect the crop from the vagaries of the monsoon. He has given a state-wise picture of energized electrical pumpsets in use for withdrawal of ground water. The author has also put a view on the roles to be played by the State and Central Government on effective management of groundwater resources. Issues such as ownership of water, water allocation and water pricing have also been discussed in the paper.

A.K. Rastogi, in his paper entitled "*Groundwater rights and water pricing structure*", addresses the necessity of formulating administrative and legislative measures to protect the interests and groundwater rights of small farmers. The paper also focuses on the pricing structure of water, which is intimately linked with ground water.

In the paper entitled "*Allocation and pricing policy for groundwater resources*", B.K. Sahu discusses conflicting issues in groundwater management and pricing policy for groundwater supply.

K. Rajarajan and K. Md. Najeeb, in their paper entitled "*Groundwater pricing in over-exploited Torehalla watershed (4B4B2), Hassan district, Karnataka – A scientific approach*", have attempted to balance the groundwater availability and draft for all uses in the Torehalla watershed in Karnataka. Drainage morphometric characteristics of the watershed have been analyzed using GIS, and suitable zones for artificial recharge structures have been identified.

The paper "*Pricing policy and its role in groundwater management – a Karnataka experience*" by K. Md. Najeeb, K.R. Sooryanarayana and Afaque Manzar, deals with the role and necessity of groundwater pricing in management and attempts to compute the groundwater price in terms of investment towards watershed treatment to recharge groundwater aquifer so as to avoid the adverse impact of overdraft. A case study of Basavapura watershed has been discussed for computation of price.

The theme on **Stakeholders participation in groundwater governance**, includes five papers besides the theme paper by Srinivas Mudrakartha, Director, VIKSAT, Ahmedabad. In his theme paper, Mudrakartha has emphasized the need of multi-stakeholder participation in management of water resources. The author contends that in a real multi-stakeholder participation, all the stakeholders come together, discuss and debate the problems as well as solutions to bring openness and transparency in participation.

Rajendra Singh, a well-known water conservationist, in his paper on "*Water conservation*" has highlighted the impact of water conservation in a watershed in district Alwar, Rajasthan. In this paper, the author has shown that due to construction of a series of *johads*, the groundwater recharge has increased and the Arvari river has been rejuvenated.

In his paper on "*Management aspects of groundwater resources—community participation, augmentation and restoration*", M. Thangarajan has emphasized that with effective management of groundwater, it may be possible to alleviate the rural poverty. The author has also suggested that deeper aquifers should not be exploited indiscriminately, but should be reserved for emergency drinking water supplies.

P.K. Naik et al., in the paper "*Watershed development approach in groundwater augmentation in Nawapada district of Orissa*" have demonstrated that integrated watershed development programme

through construction of different water conservation structures like contour bunding, minor pit, check dams could be effective in improving groundwater level, decrease in soil erosion and improvement of vegetation growth.

In the paper, "*Stakeholders participation in groundwater governance in Kerala*", *E. Shaji and G. Sreenath* have put forward a view that water policy should recognize stakeholder participation or participatory approach towards water resources management. Further, the authors are of the opinion that social concerns, such as the water rights, should clearly be defined taking into account the local people's interests.