Rapid urbanization, ecosystem disturbances and need for harvesting rain water in major urban sprawls of Uttar Pradesh

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ABSTRACT

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The indiscriminate and unplanned growth of urbanization in the state is posing serious threat to ecosystem and has greatly endangered the natural flora and fauna. The sprawling mango plantation of Kapoorthala area and guava orchards of Aliganj area in Lucknow city have totally vanished. Such haphazard urban expansion and growth of the cities has resulted into the ecological imbalance and the worst affected part is water precipitation and its impact on 'hydrological cycle'. Urban expansion, in total disregard to the ecology and environment, has led to the state of 'hydrological poverty'. Assured water supply is, thus, one of the core issues of urban planning. Ground water contributes to the major share of urban water supply. The development and sustainable management of potable/ safe water supplies warrant immediate attention to two major interdependent areas of concern, viz. ground water and pollution. There is an urgent need to provide ground water based sustainable water supplies in all urban sprawls through technical interventions. The most suitable and safe technique to augment our ground water reservoir in urban areas is roof top rain water harvesting and run off rain water conservation in hydrogeologically suitable urban locations. The technique is safe, eco-friendly and simple to adopt as well as cost effective. The prime objective of undertaking Rain Water Harvesting (RWH) and Ground Water Recharge (GWR) in urban areas is to enhance the sustained availability of the ground water resource, easily accessible for human needs and also for maintaining the ecological balance. It has been estimated that with the installation of 46670 Roof Top Rain Water Harvesting (RTRWH) structures in 11 Nagar Nigams, 138 Nagar Palika Parishads and 282 Nagar Panchayats, it is expected that assuming average recharge norm of approximately 180 m^3 per year per structure, about 8.4 million m^3 of additional recharge may possibly be generated which may be beneficial for the sustainability of the ground water resource availability and environment.

Key-words: Urbanization, ecosystem disturbances, rain water harvesting, Uttar Pradesh, India.

INTRODUCTION

Water is nectar of life. Every living cell is water dependent and water sustained. Anthropogenic activities are based on the availability of water. But rapid, unplanned and indiscriminate growth of urban settlements in total disregard to the ecology and environment in Uttar Pradesh State is posing serious threat to ecological system leading to the state of 'hydrological poverty', which has greatly endangered the biosphere. Humans and plants co-exist in a natural habitat, but the fast depleting green cover due to haphazard urbanization is creating ecological degradation, effecting human life adversely. The sprawling mango plantation, which once existed in Kapoorthala area, as well as the guava orchards of Aliganj area in Lucknow city have totally vanished. So much so that this menace of indiscriminate anthropogenic activity is spreading its tentacles even up to the rich mango belt and dense green cover around Lucknow city. Similarly, the once rich orchards and green cover existing in all the urban sprawls are

dwindling very rapidly. Such large scale devastation of urban flora amounts to the 'collapsing lungs' of our ecosystem, which in turn also affects the natural water cycle adversely. Low/ erratic rainfall, poor percolation/ recharge coupled with high and ever increasing pumpage/ withdrawal of ground water has led to continuous fall in water level. Here arises the necessity to harvest rain water to augment the ground water recharge and establish a balanced ecosystem.

State of Uttar Pradesh, occupying a large potential area of Indo-Gangetic alluvial plains, having multi-layered fluvial deposits of Quaternary age, has always been considered as largest repository of ground water resource, though replenishable, but it cannot be considered as unlimited. Since water is omnipresent, its existence is a fundamental assumption. Hence, it is considered to be a free commodity to be taken, (mis)used and wasted/ disposed without a thought that it is becoming precious every day.

Harvesting ground water is more common, about 85% of the drinking water supplies owe their origin to ground water. Hand-in-hand, technology development in drilling and pumping techniques has paved way for massive exploitation of ground water in irrigation, domestic and industrial sectors. It has increased manifold especially in urban areas where most of the households have installed their own borings/ tube wells for independent water supply. The commercial users of ground water, viz. recreation parks, resorts, hotels, shopping malls, workshops and building construction works are the greatest water guzzlers within the urban limits, adding woe to our over-stressed ground water regime and environment.

The ground water reservoir has depleted significantly, our once very potential aquifers are under great stress, a condition which has emerged in vast expanse of urban as well as rural areas. Bore wells, that form the major source of urban water supply, are now beginning to run dry in the season of peak demand. The dig from them is getting deeper and costlier, entailing greater cost of pumping. The powerful diesel and electric pumps made it possible to extract ground water at rates that exceeded the natural recharge from rainfall and other sources. There is another problem inherent with such over-exploitation of underground aquifers, coupled with improper disposal of urban solid waste: toxic chemicals and level of Total Dissolved Solids (TDS) tend to rise beyond permissible limit. This may get manifested in the form of various crippling and incurable diseases. All this not withstanding, the drinking water supply departments/ individuals have concentrated their efforts on the indiscriminate exploitation of ground water from different depths.

WHAT IS RAIN WATER HARVESTING

Ground water is the high value natural resource, supporting public health, economic growth and eco-diversity. Though an important source of urban/ rural domestic water supplies, still it is insufficiently understood, widely under valued, irrationally exploited, misused, wasted and inadequately protected. Ground water level is falling, lean river flow is polluted and Jal Sansthan/ Jal Nigam can not meet the ever increasing demand of urban agglomerations. People pump ground water indiscriminately as if it rains underground. Adding to the misery is the phenomenon of 'water –proofing' of our open spaces, having concrete structures, pucca lawns, pathways, off sets and pavements, not allowing even a drop of rainwater to percolate down. Hardly 30% rainwater goes down through soil moisture profile and remaining 70% rain water falling on such manmade pucca catchment surfaces runs off to the drains and rivers. Although drinking water and domestic sector requires only about 5% of utilizable water resources, given first priority in 'National Water Policy-2002', even then we have burns of 'water crisis' during summers. Having average annual rainfall of about one meter, it appears there should not be any shortage of water, but for the lack of 'sensitivity' and 'mindset' of water consumers. If people in the state like Rajasthan with 200-250 mm rainfall can survive with the help of rain water harvesting, then why there should be a water shortage in Uttar Pradesh having four to five times more rainfall.

The community is the rightful custodian of water and without their active participation, local water resource development and management in urban sprawls is not possible. People's participation at a mass

scale can definitely help in saving at least about 20% of more rainfall run off in all the cities, which will go a long way to mitigate the present water crisis, besides the problem of choking drains and flooding in urban areas and help in restoration of balanced ecology. The problem of depleting water resources and ever growing demand leads to the imperative need for large scale rain water harvesting for sustainability of ground water development. Therefore, there is urgent need for mandated water harvesting and recharge zone in urban settlements.

Rain water harvesting is a simple, economical and eco-friendly technique of preserving every drop of rain water by guiding it to the bore-wells, pits, ponds and wells, which otherwise runs off through manmade impervious/ semi-pervious land surface or catchments. Catchments include roof-tops, compounds, pathways, pavements and roads in urban areas. The rain water collected through these pucca surfaces should be channelized through the process of filtration and allowed to percolate down to the ground water table. But in this process and effort of catching more and more water, the aspect of quality of recharge water is of utmost importance and it should not be ignored at any cost. The waste/ poor quality water in no case/ circumstances should be used and allowed to percolate down. The waste water, if allowed to go down, may contaminate the underground aquifers, rendering ground water unfit for human consumption. This may lead to a situation where they may be 'water-water everywhere but not a single drop to drink'.

The amount of water harvesting (collected and stored) depends on the frequency and intensity of rainfall, the catchment characteristics and how quickly and how much rain water infiltrates through the surface/ recharge pit to reach the aquifer.

Roof–water can be conserved through individual house connected by PVC down pipe to percolation tanks, pits, ditches, trenches, and through building complexes having pebble bed ponds and artificial recharge wells in a corner of the parks. This in turn recharges the ground water and arrests the water table decline.

Most of water, which infiltrates during rainy period, is entrapped in the top soil and is lost due to potential evapo-transpiration. Thus the rain water harvesting for ground water recharging for sustainable development of the resource should take in account the following important aspects: 1. Rainfall, its pattern, intensity and distribution; 2. Potential evaporation- in case of surface storage; 3. Soil type and infiltration rate; and 4. Hydrogeological frame work, i.e. succession of stratified fluvial sediments below the ground including depth to ground water level and its lateral extents.

BENEFITS OF RAIN WATER HARVESTING

The major benefits of rain water harvesting are: 1. Quality of ground water improves. 2. Raises the water levels in hand pumps, wells and bore wells that are drying up. 3. Helps in restoration of ecology and environment. 4. An ideal solution to water problem in areas having inadequate water resources. 5. Reduces the soil erosion as the surface runoff is reduced. 6. Choking of storm water drains and flooding of roads decreases. 7. Saves energy to lift ground water as one meter rise in water level saves about 0.40 kwh of electricity (assuming 10 hours of average pumping/ day, the energy saved in 1 year could be 1460 kwh).

ADMINISTRATIVE AND LEGAL ASPECTS

The accelerated degradation of ground water system through pollution of aquifers, lack of professional and public awareness about the sustainable use and economic importance of the resource and implications of not resolving ground water demand and supply highlight the importance of administrative and legal aspects of ground water recharging.

While managing especially non-monsoon water input for ground water recharge projects, ensuring quality of water used, cost to benefit and land problems are to be addressed adequately before taking any recharge project. The Water Act 1988 says "No person shall knowingly cause or permit polluting poisonous, noxious or any polluting matter to enter (directly or indirectly) into any stream, well, sewer or on land". Ground Water Department, (G.W.D.) Uttar Pradesh, the 'Nodal Agency', has issued detailed guidelines for

ground water recharge and provides technical help. 'Swajal' is taking a lead in planning rain water harvesting in Bundelkhand region, utilizing existing dug well for sustainability of their domestic water supply system perhaps @ ₹ 30,000 per household.

MASS AWARENESS

Instead of building proponents for rain water harvesting, the government agency in its zest-legislate, ban and then forget implementation. Just issuing a Government Order is not enough. It has to be supported with a massive campaign for public awareness and with hard policy actions, which provide 'incentives' and 'disincentives' for its effective implementation. In such cases the incentives will have to come in the form of fiscal measures, which support households to capture their rain, and disincentives in the form of pricing of water and supportive urban taxation.

Social awareness has to be created by constructing experimental artificial recharge schemes involving community participation. Artificial recharge and conservation of rain water is being practised since centuries in India, especially in rain deficit and water scarce areas. It is yet to be socially acceptable in other areas where at present ground water resources seem to be in plenty but are fast depleting and water levels are declining at an alarming rate. Ground water quality is also deteriorating due to excessive stress on first aquifer and pumping of saline water on surface of the soil. In such areas, 'Water Blindness' need to be removed by educating the masses. Masses once motivated and actively involved, will themselves feel the benefits of such housing schemes as 'seeing is believing'.

No technology is said to be developed if socially not accepted. Jal Sansthans/ Jal Nigams have to play their role as facilitator in providing the basic minimum services of safe drinking water through social mobilization and participation of people at all levels.

STRATEGIES

Rain water harvesting should be initiated in government buildings and group housing schemes of development authorities or builders as role model. Government building may take the lead.

Community participation and what should be the role of water and land user association? Do they need any legislative back-up?

Natural recharge through conservation and strengthening of water bodies, forestation or grass – covering of denuded land surface should form first priority to restore ecology.

In urban areas, where land availability is a constraint and costly, artificial recharge project should take care of adequate infiltration rate. All this can only be done if we make people aware of the value of the raindrop.

We need a policy for rehabilitation and maintenance of existing ponds/ tanks so that they may continue to augment ground water in future also.

Traditional wisdom/ structures for rain water harvesting need to be respected/ rehabilitated.

Ground water recharging movement may turn to be the people's projects for recharge augmentation. Action is the need of the hour.

We may adopt simple, cheaper and easily acceptable technique of rain water harvesting which are suitable to local condition. The existing local methods may need some modification.

GROUND WATER SCENARIO

(a) Water level fluctuation: The study of behavior of ground water storage for long period is essential for planning and management of ground water utilization. The ground water storage is depleting over considerable parts of the state resulting in decline of water level. The overall affect is an adverse impact on economy and environment of such areas.

(i) Water level decline in urban areas: In the urban areas, especially in Ghaziabad, Varanasi, Kanpur, Lucknow, etc. decline of ground water level has been observed from 22 to 73 cm/ year during the last decade. In major cities, average water level decline/ year is given in Table 1.

Table 1. Average water level decline/ year in major cities of Uttar Pradesh.

Name of city	Water level decline (cm/ year)
Lucknow	73
Kanpur	45
Agra	40
Aligarh	40
Mathura	36
Varanasi	23
Ghaziabad	22

(ii) Water level decline in Lucknow City: The mega-city of Lucknow, the greatest water guzzler in the state, is heading fast towards a major water crisis. The danger of acute water shortage, especially during the peak season, is looming large over the citizens of the state capital. The depth to ground water level (G.W.L.) monitored on 22 Piezometers, from year 2003 to 2007, indicates that ground water level ranges from 10.07 m in Sarojini Nagar to 29.60 m in Dilkusha Colony in Pre-monsoon of 2003, whereas 12.10 m in Sarojini Nagar to 31.30 m in Gulistan Colony in Pre-monsoon of 2006. The minimum lowering of 1.27 m has been observed in Arya Nagar, with 0.62 m rate of average annual decline in Cis-Gomti area, whereas maximum lowering of 6.08 m has been observed in Gomti Nagar, with 0.84 m rate of average annual decline in Trans-Gomti area in Pre-monsoon period as given in Table 2.

(b) Present status of ground water development: Ground water department has carried out block-wise estimation of available resource, based on ground water data as on 1st April, 2004, by adopting the recommendations of Ground Water Estimation Committee (GEC-97). Region-wise status of ground water recharge, annual draft, balance ground water available and stage of ground water development is as given in Table 3 (in million hectare metres).

Table 2. Ground water level data of urban Lucknow

Location of Piezometer	Depth to G.W.L. (in metres) (Pre-monsoon)		Total fall in G.W.L. (in metres)	Average annual G.W.L. decline (in metres)
	2003	2007		
Cis-Gomti Area				
Narhi	27.05	31.00	3.95	0.98
PQS Phase Cantonment	17.99	21.08	3.09	0.77
Rajajipuram	25.55	28.60	3.05	0.76
Mahila College, Aminabad	13.00	15.80	2.80	0.70
Gulistan Colony	28.82	31.30	2.48	0.62
River Bank Colony	19.63	22.12	2.49	0.62
Sarojini Nagar	10.07	12.10	2.03	0.50
Dilkusha Colony	29.60	30.90	1.30	0.32
Arya Nagar	20.13	21.40	1.27	0.31
Trans-Gomti Area				
Gomti Nagar	15.47	21.35	6.08	1.52
Indira Nagar	21.49	26.13	4.64	1.15
Vikas Nagar	22.06	25.73	3.67	0.91
Mahanagar	24.05	27.30	3.25	0.81
Nirala Nagar	26.30	29.55	3.25	0.81
New Hyderabad	19.21	21.90	2.69	0.67
Lucknow University	24.94	27.51	2.56	0.64
Bhujal Bhawan	16.06	18.42	2.36	0.59
Lucknow University (New Camups)	11.17	13.20	2.03	0.50

Source: Central Ground Water Board

Table 3. Region-wise ground water status in Uttar Pradesh

Region	Net GW availability	Annual GW draft for all uses	Balance GW available for future	Stage of GW development (%)
Eastern Region	2.54	1.68	0.86	66
Western Region	2.58	2.05	0.53	79
Central Region	1.45	0.96	0.49	66
Bundelkhand	0.44	0.19	0.25	43
Total for Uttar Pradesh	7.01	4.88	2.13	69

(c) Trend of ground water use during 20-25 years: In the coming years, the ground water utilization is likely to increase manifold for the expansion of irrigated agriculture and in the fields of industry and increasing domestic use. The recharge and draft (development / use) figures for different years for the state are given in Table 4 (in thousand hectare metres).

Table 4. Periodical changes in ground water status of Uttar Pradesh

Item	Year					
	1975	1986	1990	1995	2000	2004
Ground. Water recharge	7050	7693	6410	7160	8080	7018
Ground Water draft	2632	2622	2640	2689	4224	4878
Ground Water draft for industrial and domestic use	40	40	40	40	70	340

It is evident from the above table that the ground water use in agriculture, industrial and domestic (urban and municipal) sectors is increasing day by day. It has appreciably increased since 1995, leading to rapid depletion of ground water resources.

The looming danger of the increasing water crisis has been an area of national concern, The World Bank, in one of its recent report "India's Water Economy: Bracing for a Turbulent future", has warned of serious water crisis in India in the next two decades due to inadequate water supplies and poor management of ground water resources. The report further says "unless water management practice are changed and changed soon, India will face a severe water crisis within the next two decades and will have neither, the cash to build new infrastructure not the adequate water needed by its growing economy".

(d) Environmental and health impacts of ground water over-development: There is no doubt that overuse of ground water can have devastating effects on communities and environment as the ground water level starts going down. Over-exploitation of ground water without taking adequate steps to recharge has resulted in continuous decline of water level in urban sprawls of the state. Declining of ground water levels cause huge environmental and economic costs because of following main factors: 1. Salinisation of aquifer which affects drinking water quality. 2. The pollution of aquifers, e.g. fluoride, arsenic and chromium, which effects drinking water and has serious health consequences. 3. Increased cost of pumping. 4. The abandonment of wells (from which water can no longer be lifted). 5. Wilting of plants and trees as their roots go dry. 6. At few places, viz. in Allahabad, Kanpur Dehat, Fatehpur and Furrukhabad districts incidences of land subsidence in the fields have been observed due to over-development of ground water through closely spaced battery of cavity type tube wells, but it is not a common phenomenon in the state.

POLICY INITIATIVES/ DECISIONS

Rain water harvesting has been made mandatory for all new housing schemes plots/ buildings, group housing schemes with separate network of pipes for combined RWH/ Recharging system. In all developed schemes, Roof top rain water harvesting system made compulsory for plots of 100 m^2 and above but for the plots below 200 m^2, network of combined recharge system be provided and utilized. For the plots of 200 m^2 area and above, if combined system of recharge is not available landlord has to install the recharge system individually. In government buildings (both new as well as old), installation or Rain Water Harvesting structure is made compulsory. It has been made mandatory for housing schemes of 20 acres or more to develop pond/ water bodies in 5% of the total proposed area. Lawns, pathways, parks and road pavements should remain kuchcha to allow maximum infiltration of rain water to the underground aquifers.

Ground Water Department has been declared as "Nodal Agency" for monitoring, ground water research,

investigation, management and co-ordination, planning of rain water harvesting/ recharging programmes in the state and providing technical guidance. A decision has been taken to observe 10th June every year as "Ground Water Day" throughout the state with a view to create mass awareness and ensure people's participation in respect of rain water harvesting, ground water recharge, management and its balanced development. Private/ institutional consultants are being trained by the Ground Water Department in Rain Water Harvesting technique so that people at large get proper guidance regarding right techniques of rain water harvesting and ground water recharge. Rain water harvesting has been introduced as a chapter in the syllabus of 6th to 8th class in the state.

For the protection of ground water resource from pollution hazards, rain water from open area (paved/ unpaved) is not be used for recharging of aquifers (Government orders issued).

Ground Water Department has issued detailed guide lines for implementation/ execution of RWH and GWR schemes.

GROWTH OF URBAN SPRAWLS

The poor rural economy and growth prospects are responsible for migration of population to urban areas. Consequently, there is a continuous increase in size of urban population/ sprawls at a fast pace, leading to the greater stress on natural resources. The point of concern is that in order to meet such rising demand, ground water resource is being extracted to unsustainable levels. All such conditions culminate into degraded environment. Trend in growth of urban population from 1971 to 2001 is given in Table 5.

PRIORITY URBAN AREAS

In Uttar Pradesh State, there are 628 major and small towns, which are broadly classified into three categories, i.e. Nagar Nigam, Nagar Palika Parishad and Nagar Panchayat depending upon the population. However, continuous rise in population and subsequent expansion of urban settlements has raised the demand of drinking water tremendously over the past 10-15 years. Since surface water sources are inadequate to meet the rising demand of drinking water, therefore, in majority of these towns, ground water is gradually becoming the main contributor of drinking water supply. As such, the ever-increasing water supply demand has simultaneously put high pressure on ground water resources of the urban sprawls, which led to its indiscriminate extraction, resulting into depletion of aquifers and significant decline of water levels as evident from the data of various cities.

Table 5. Trend of urban population growth in Uttar Pradesh from 1971 to 2001.

Census Year	Population (In millions)		Urbanization (%)
	Total	Urban	
1971	88.34	12.38	14.02
1981	110.86	19.90	17.95
1991	139.10	27.60	19.84
2001	166.05	34.50	20.77

Based on the above background of ground water situations in urban areas, 431 Urban Local Bodies including major as well as small cities/ towns, situated in 45 districts of the state have been identified for Ground Water Recharge (GWR) activity through Roof Top Rain Water Harvesting (RTRWH).

Table 6. Selected priority urban areas proposed for RWH/ GWR activity (Roof Top Rain Water Harvesting)

District	Nagar Nigam	Nagar Palika Parishad	Nagar Panchayat
40 (Excluding Gorakhpur)	11	138	282

The urban areas, as subjected to heavy withdrawal of ground water resource and further having less possibilities of natural recharging of rain water due to concrete structures and pucca land surfaces, need specific attention for carrying out effective ground water conservation activities, so that the depleting ground water aquifers could be saved in order to ensure sustainable domestic water supplies and restoration of ecosystem.

NORMS FOR RECHARGE STRUCTURES

Roof Top Rain Water Harvesting (RTRWH) structures are proposed to be constructed in government/ semi-government as well as private/ commercial buildings in the selected urban areas.

Hence, for carrying out this activity, following norms/ parameters are assumed to quantify recharge structures for different categories of urban areas (Table 7).

Table 7. Proposed recharge structures in urban areas

Name of Urban Area	Number of Recharge structures to be installed in a grid of 1 km^2 (Each for Roof Top Area of 200-250 m^2, assuming 300 m^2 as average)	Average Unit Cost (₹ million)
Kanpur, Agra, Lucknow and Ghaziabad	33	0.15
Moradabad, Aligarh and Meerut	30	0.15
Bareilly, Jhansi, Varanasi and Allahabad	16	0.15
Nagar Palika Parishad	4	0.15
Nagar Panchayat	4	0.15

ESTIMATION OF EXPECTED RECHARGE

Artificial recharge structures, viz. ponds, check dam, gully plugs, roof top rain water harvesting system are having different recharge potential under different hydrogeological conditions and, therefore, sub-surface/ downward vertical percolation of rainwater also varies depending upon the direct/ indirect flow into the strata.

At present, no prescribed norms or mechanism/ system is available for the exact estimation of recharge potential generated through on-going Rain Water Harvesting and Ground Water Recharge activates. However, different departments, viz. Central Ground Water Board, Minor Irrigation, Jal Nigam, Agriculture, Avas-Vikas, Development Authorities presently engaged with various water harvesting/ recharge programmes, are assuming some norms for evaluating expected/ probable 'Recharge Potential' of different recharge structures.

As such, the various norms assumed to find out the expected recharge potential are being adopted in order to arrive at some realistic assumptions of deriving possible quantum of recharge likely to be generated through various RWH/ GWR activities in the urban areas.

Expected unit recharge potential for Roof Top Rain Water Harvesting (RTRWH) structure, assuming 300 m^2 as average roof top area for each unit/ structure and taking 750 mm as average annual rainfall for the state, is likely to be 180 m^3 per year. Considering this norm, district wise expected recharge potential has been estimated. The gross recharge from RTRWH in 431 urban local bodies, after installation of 46670 structures, is expected to be 8400600 m^3.

CONCLUSION

Roof top rain water harvesting (RTRWH) in urban areas offers a good source of fresh water to augment the recharge of ground water resource. This will help in arresting the lowering trend of water level and over a period of time the depleted water level will recoup to the optimum depth of around 8 m below ground level. This in turn will ensure the sustained water supply for domestic needs at a lower cost of pumping, in addition to restoration of balance in ecology and environment. The techniques involved are simple, easy to adopt and replicate, eco-friendly and cost effective. Community participation coupled with modified building by laws will go a long way to mitigate the water crisis and help in enhancement of ground water potential, reduced due to rapid urbanization. This is our basic social responsibility to give back to nature what we take from it and also to ensure restoration of a balanced/ healthy ecosystem.

The urban growth is likely to continue in mega cities but it is likely to be relatively high in small cities and townships. This is an important aspect of implementation of RTRWH techniques. Hence, the local population of such small urban settlements should also be sensitized and motivated to resort to RWH in due earnest, much before the actual water crisis develops. The hydrogeological set up should, however, be the guiding criteria for implementation of RWH schemes, so that the investments do not become infructuous and fetch good dividends in the form of enhanced resources to meet the increasing human and ecological needs.