Can Rainwater Harvesting Promise Water Security[1]

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Abstract

Adoption of a holistic rainwater management calls for appreciation of the water problem in the first place. Appreciation involves awareness and understanding of the scientific and social dimensions of the problem and a will to implement a set of perceived solutions. Management includes capture, treatment, storage and recovery. And, importantly, the demand side management. Thus, a holistic approach on the above lines is essential. And it is here the role of the NGOs becomes important and that of the State as a facilitator by providing appropriate policy environment.

The paper examines the scope and potential of rainwater harvesting in meeting the ever increasing water demands of the human population. Questions include, what opportunities do the arid and semi arid regions, characterized by constraints of rainfall occurrence, uncertainties and variabilities, offer for addressing water scarcity conditions? What are the "missed" opportunities that could help restore the efficiency and scale of the natural recharge processes that provided water security to populations over centuries? Can rainwater harvesting help provide drinking and irrigation water security?

The paper examines the above aspects from a hydrogeological point of view too since understanding geology is imperative to proper recharge, storage and retrieval. This approach becomes extremely important from the "missed opportunities" point of view; also because the so called development has had been taking place at the cost of disturbing the natural processes such as the drainage lines affecting seriously the recharge potential. In conclusion, the paper stresses on the need for revitalizing the natural drainage lines, preserving from further damage in future, and enhancing the recharge efficiency of the water harvesting structures.

Water Resources of Gujarat and Variability

Gujarat is located in Western India and is characterized by high variations in rainfall conditions. The average annual rainfall varies from around 250 mm in western most part to 2200mm in the south Gujarat. Since early nineties, the per capita availability of fresh water is 1,137 cu m per annum, which is well below the 1700 cu m norm, indicating local water shortages as per Falkenmark criteria. Corresponding to the rainfall variation, there is high regional variation in the per capita availability of water which is 427 cum in north Gujarat, 650 cum in Saurashtra and 900 cum in Kachchh- all indicating water scarcity; only south and central Gujarat have 1932 cum per annum (UNICEF 2000).

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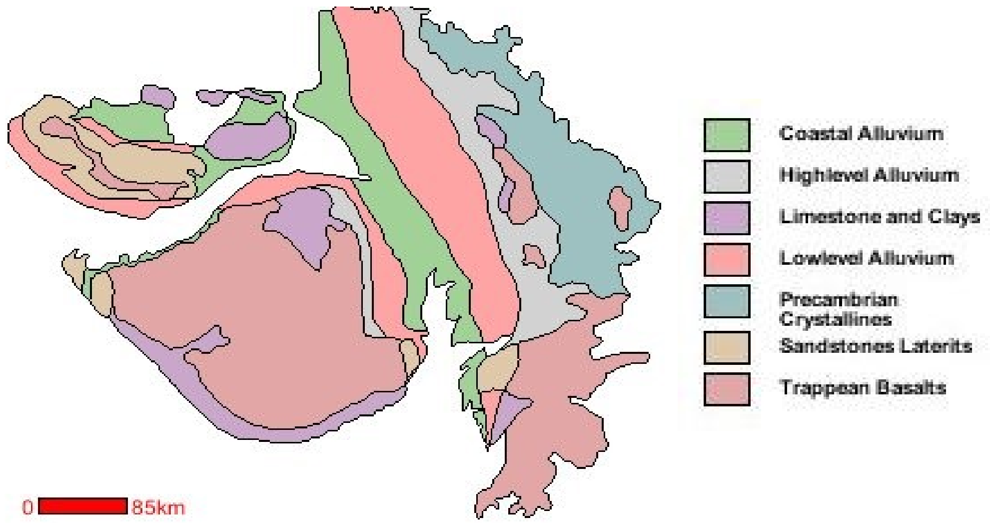
Therefore, not only rainwater management assumes great importance but planning of rainwater harvesting activity with a proper understanding of the rainfall characteristics as well as the agro climatic conditions is imperative. Hydrogeology is very important as the geological formations control recharge, storage, movement and yield. Needless to say, there are traditional practices too that the communities have evolved in the process of adapting to the water conditions, in the storage and retrieval of rain water both for drinking purposes or for irrigation purposes.

Potential and Scope of Recharge

As is commonly experienced, water levels in many parts of the state have gone quite deep, in particular, in the semi arid and arid regions such as north Gujarat and Kachchh. The depths to which borewells are drilled typically range 250-300 metres such as in Mehsana and Ahmedabad districts in Gujarat. The shallower aquifers usually go dry.

Further, many shallow to medium aquifers in hard rock areas go seasonally dry when the rainfall is normal or subnormal; however, during continuous years of low rainfall, water scarcity conditions set in. People extract whatever quantum of water that is available for survival of their livelihoods and drinking purposes, in the process, totally depleting these aquifers. For example, the shallow aquifers in Satlasana



Ground water Aquifers of Gujarat

taluka have gone almost dry during drought period of 1999-2002/3 with the result that the net sown area for the years 2000 to 2002 was nil (Mudrakartha 2005,). What needs to be recognized here is the "opportunity" in the form of huge storage space that these aquifers offer when they become dry.

Figure above shows the various ground water aquifers in Gujarat. The last three aquifer formations, namely, Precambrian crystallines, sandstone, laterites and basalts comprise the hard rock area while the rest is mostly alluvium. The occurrence and movement of ground water in these two broad types of aquifers is different.

Recharge may be natural or induced; for the latter, we need some structures to store and aid the recharge process. Again, in order to recharge aquifers located at different depths, different conditions of hydraulic connectivity, pressure and gradient should exist.

Ground Water Recharge Structures

In a typical rainwater harvesting activity, a structure is created that harvests rainwater; the structure may be a pond, tank or similar storage structure. Interestingly, small check dams, as against minor check dams are becoming important from water harvesting point of view, as the number and spread of these structures being promoted under various government and non government schemes is quite significant. The focused check dam construction schemes promoted under the name of SJSY scheme in Gujarat and as part of watershed programmes, are some examples. Khet talavadis (farm ponds) is another scheme that is being promoted in large numbers.

Therefore, there is a need to look beyond the so-called irrigation definition of the rainwater harvesting structures which were primarily structures for "centralizing" the rainwater. The above "small" structures such as the check dams, tanks and farm ponds have the following advantages compared to the centralized structures:

1. The run-off water in the streams is halted by the check dams for small periods of time, many times, during monsoon, thus not significantly affecting the flows. Structures spread out like this have higher probability of connecting with the lineaments and thus enhance ground water recharge, in particular, when the drainage pattern is seriously affected due to the so-called infrastructure construction such as townships, roads, and other civil structures.
2. Costing low, in Gujarat, in particular, the small check dams are constructed routinely by local masons belonging to the village. In other words, the government schemes have encouraged local talent to construct and own the schemes, paving way for better post construction maintenance. The entire process of construction of the check dams and their maintenance is generally noticed to be better wherever NGOs are involved. The fact that even the unprecedented rains of 2006 monsoon could not damage check dam structures constructed/supervised by NGOs is proof enough for good quality and high degree of people's involvement.
3. In areas where people are more aware and have strong community based institutions, the possibility of better ground water management exists (Mudrakartha et al 2004, COMMAN 2005) leading to efficient resource management.
4. The evaporation losses are reduced to a significant extent, especially when the storage is possible in the top zone with high porosity such as the alluvial veneer in Satlasana taluka as described in the following section. The tanks actually provide continuous supply to the wells and for a few months; in such conditions, positive impact on drinking water supply sources and the agriculture crops is observed.
5. These structures increase both access and spread and thus help reduce inequity in ground water access. This is in particular true in areas where groundwater regime is shallower such as the hard rock areas of the upper catchment of Aravalis in north Gujarat.

Efficiency Assessment Study of Recharge Structures

VIKSAT has partnered with British Geological Survey[3] and carried out a two and a half year research study on assessing the performance efficiency of check dams and tanks in Satlasana taluka which is a hard rock area with thick alluvial veneer.

The study concludes that uniform solution in terms of promoting a particular structure is not an effective solution for addressing water scarcity. Effectiveness is a complex function of climate, rainfall, geology, aquifer conditions, scale, governance systems including community-based, and operational and maintenance aspects. Hence, the artificial recharge structures should be identified through adequate research and promoted with discrimination.

The in-depth study covered three check dams and two tanks with a catchment of about 9 square kilometres area. The study area comprises gneiss which is intruded by Ambaji granites of the Aravalli hill range belonging to the Delhi Super Group. The top zone comprises thick alluvial veneer.

The weathered granite underlying the alluvial zone is transected at many places by Ambaji granite with vertical to subvertical fractures, often filled with pegmatite veins, themselves fractured, favouring accumulation and movement of ground water to deeper levels. Located in Aravallis on the Gujarat side, and forming the catchment zone for the Sabarmati river, the study area is extremely important from water resources point of view.

Analysis of water level data collected from a network of piezometers (including existing well and borewell structures) on 70 well structures around 1 kilometre radial distance from the check dams has yielded interesting results. Being a semi arid region, the rate of evaporation in Satlasana is quite high: the mean minimum monthly evaporation was 264 mm and mean maximum monthly evaporation was 350mm. The average annual rainfall is 680 mm.

However, due to the alluvial veneer, the check dams and tanks retain water for a small time period-from a few hours to a couple of weeks depending upon the intensity and spread of the rainfall. The research indicated that the alluvial zone absorbed all the water and gradually contributed to the groundwater which was accessible through wells and borewells to the farmers over a distance ranging from 475 metres. Contrary to the common belief that evaporation losses render choice of tank for storage inefficient, the tanks played a very significant role in Satlasana type of geological conditions.

Livelihoods survey indicated that there was 64% increase in the cropping intensity, 11% increase in irrigated area and 70% increase in the income.

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[3] Other partners of the Augmentation of Ground Water Resources through Artificial Recharge (AGRAR) project supported by DFID-UK include Institute for Social and Environmental Transition (ISET), USA, Advanced Centre for Water Resources Development and Management (ACWADAM), Pune, Water Technology Centre, Tamil Nadu Agricultural University (TNAU).

In the case of landless, they could reduce migration for labour and concentrate on livestock; the overall increase in their income was 30% due to increased fodder availability.

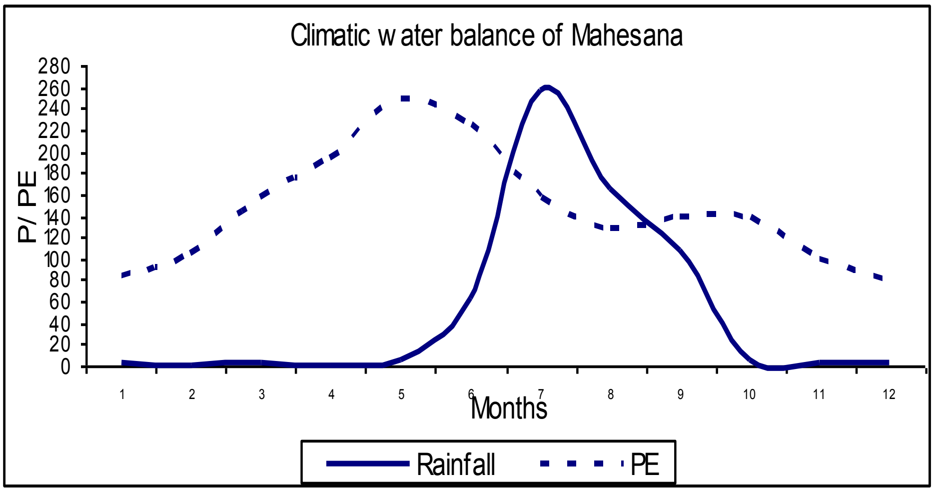
Another research study (COMMAN[4] supported by DFID-UK, www.viksat.org or www.bgs.ac.uk/hydrogeology/COMMAN) in the same area indicated that community efforts at groundwater management become meaningless when it is not supported by strong external water policies.

In conclusion, the research indicates that when artificial recharge schemes are being designed, the key factors that need to be considered include climate and rainfall conditions, hydrogeology, soil and aquifer conditions and governance systems.
(For full report, visit www.bgs.ac.uk or www.viksat.org).

Rainwater Harvesting and Artificial Recharge

As discussed elsewhere, the ground water levels have generally gone very deep, down to few hundred metres. In such highly depleted areas with hampered surface drainage and reduced natural recharge, rainwater harvesting is increasingly seen as a viable option. However, the terms "rainwater harvesting" and "artificial recharge" are often used interchangeably; hence, it might be useful to distinguish between these two terms.

Rainwater harvesting is often used to denote impoundment of water in structures such as check dams, ponds and tanks, and in streams and rivers. In this case, there is an enhanced time span available for facilitating recharge, under conditions of natural infiltration. Evaporation losses are quite significant, in particular, in arid and semi-arid regions. The water balance in these regions is usually negative, except for the monsoon period. The figure below is a typical representation of the climatic water balance for Mahesana district.



In government parlance, the term 'rainwater harvesting' is applied to convey a generic meaning of capturing rainwater where it falls; in urban context or in rural context, the term 'rooftop rainwater harvesting' is used to describe specific efforts for collection

[4] Community Management of Ground Water Research Study (2003-05) supported by DFID-UK. Partners include ODI, ACWADAM, ISET-USA, WTC-TNAU, IDS-Jaipur and VIKSAT.

of water drinking purposes. In this paper, the generic meaning is preferred to maintain uniformity.

Artificial recharge implies using techniques for putting rainwater into the ground almost immediately thereby giving less scope for generating run off or evaporation through streams, rivers or tanks/ponds. This may mean “conveying’ water into the ground through a recharge borewell.

Artificial recharge implies “conveying” water from the surface into the aquifers where water is stored for later retrieval. Needless to emphasise, the water being conveyed should be free from all impurities and contaminants. Further discussion is beyond the scope of this paper.

Artificial Recharge experiment

VIKSAT constructed an artificial recharge system on a village (Sargasan) tank in Gujarat in 2001 with financial support from Gandhinagar Urban Development Authority (GUDA). The major objective of the experiment was to demonstrate augmentation of local supplies through the recharge route. The artificial recharge technique comprised developing an existing tank, drilling a recharge borewell and facilitating recharge through a filter bed constructed with the borewell as the centre. Analysis of water level data collected over 3 years from all the 32 existing borewells situated within a radius of 1.5 km from the recharge structure showed that in a normal rainfall year, the Sargasan tank was harvesting 33.2 million litres of rain water. The zone of influence was found to be 800-900 metres from the recharging borewell. The experiment was done in normal conditions where farmers continued with their agricultural operations. At the end of the year, there was almost a net 2.0 metre rise in the water level[5]. According to estimates of Central Groundwater Board, Gandhinagar has an annual ground water draft of 130.35 MCM from 2382 borewells and a natural recharge of 111.57 MCM leaving a gap of about 19 MCM which is 15%.

In other words, the study shows that recharge efforts, if properly planned, can over a few years effectively contribute to closing the existing demand-supply gap between extraction and natural recharge. It is essential to combine demand side management for holistic approach to water resources management.

Directed Recharge

This section describes the usefulness of directed recharge which helps in rejuvenating various aquifer layers at different depths as preferred by us.

Over the past two decades in particular, thousands of wells in most parts of the country have gone out of function due to declining water levels. The same situation exists in Gujarat too. These wells mostly belonging to poor, small and marginal farmers are abandoned and remain as Non-performing Assets (Mudrakartha 2004).

How can we bring these back to life? The answer lies in what is called Directed Recharge. If we consider a given area of say 100 square kilometers, one can plan to have recharge structures which convey water to aquifers located at different levels. Detailed geological survey and geophysical surveys should be conducted to map the

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[5] For full paper visit www.viksat.org.

subsurface lithology in order to arrive at a suitable design, keeping in consideration the topography, rainfall and other weather parameters. There may be leaky aquifers; however, broadly, we would be rejuvenating the different aquifer zones and providing access to farmers with shallow and deep well structures.

The directed recharge may seem simpler and easier in alluvial formations. Identification of lithological sequence and the favourable strata for recharge are important. The Sargasan artificial recharge experiment proves that significant quantity of water can be stored in the alluvial formations. Further, certain number of Sargasan type of recharge systems can be constructed and activated in periods of excess rainfall (Mudrakartha S and S Chopde 2002).

In contrast, artificial recharge in hard rocks is much more complex. Identification of lineaments that help recharge the aquifers is imperative in particular for aquifers located below the weathered zone. Often, such lineaments are connected at unknown distances and places. Further, recharge in hard rock areas requires hydraulic pressure to "inject" water into the hard rock aquifers (partially/fully fractured/jointed). Structures such as tanks and check dams come handy if the link between the lineaments and the location of such structures could be made through appropriate surveys.

There is another great opportunity offered by hard rocks. Often, there is a thick weathered zone running into several tens of metres. Even if we consider say a 20-metre thick weathered zone, assuming a specific yield of 1.5%, we have a storage capacity of 300000 cu m of ground water for every square kilometer of the area under those geological conditions. For the same one square kilometer area, rainfall of 700 mm yields 7000000 cu m. The weathered zone therefore can store approximately 4-5% of the incident rain water. This quantity becomes significant in semi arid and arid conditions. Effectively, it will store more than that because there is movement of ground water as well as losses due to specific retention, in addition to extraction even during the rainy season.

Drinking water security

Groundwater forms a major source of drinking water in Gujarat in rural and urban areas. The same source is tapped for agriculture and other purposes too. In short, we have a situation where there is one source and multiple uses. Surface sources are limited in number and significant quantity of surface flows is stored in dams and reservoirs. Village tanks contain water generally during the duration of the monsoon period, and most of these have reduced storage capacity due to poor maintenance.

The drinking water supply sourced from Narmada is planned to supply a maximum of two and half hours per day. However, this supply often suffers from irregularity and inadequacy due to leakages including illegal tapping.

In this context, it is essential to consider whether rainwater harvesting can provide drinking water security to households. Particularly because centralised schemes suffer from attenuation of performance efficiency with time. In addition, the cost of service too keeps going up from time to time due to increasing cost of O & M, in addition to high infrastructure cost.

Rainwater harvesting can also provide drinking water security at household level, and when considered for a city or urban township, this still holds good (Mudrakartha 2004). The paper shows that as against the annual drinking water demand of 767 crore litres at the rate of 5 litres per person per day, a huge quantum of 2400 crore litres of water, that is at least 3 times, is available from the rooftops. Broadly speaking, out of the 6300 crore litres of total rain water availability, at least 4000 crore litres (which is other than the roof water) is available for recharge into the ground.

While this might sound exciting, is this achievable in practice, and if so what are the limitations and constraints? What are the problems that we might encounter in achieving this?

The first and foremost is the pattern of distribution of rainfall itself. In India, we have either a unimodal or bimodal rainfall pattern. The rainfall is variable and rainy days are few: 50% of the rain is incident in about 15 days and less than 100 hours, out of a total 8,760 hours in a year. The total number of rainy days is as low as five days in a year in the arid regions of Gujarat and Rajasthan to 150 days in the Northeast, although there could be high-intensity rainy events on some days. Therefore, it is very important to capture this rainwater, which just comes and goes in a few hours.

In other words, storage is a big issue in view of the highly variant and intense rainfall, and especially in the highly crowded city environs. Reservoirs and tanks created historically have either silted up or have disappeared due to demand on land in urban areas. For instance, the number of lakes in Ahmedabad has reduced by half in the past 25 years.

However, if the rain water can be stored in a decentralised fashion, by individual households, public institutions, corporate, entertainment units and educational institutions, then this becomes feasible. To realise this, we need both policy as well as commitment from the people who are the users.

It is well demonstrated that all the drinking water needs can be stored at individual household both in rural and urban areas. Surely, there will be problems related with covering each and every individual household. In slums or in very backward villages, for instance, there may not be adequate, proper roof available. In multi-storeyed buildings too, and in low rainfall areas, it may not be possible to have significant rainfall collected. Yet other areas related to industrial areas where the environmental pollution might cause contamination of rainfall leading to harmful effects such as the acid rains. Barring these and similar areas, the rainwater harvesting can be a major, significant option.

VIKSAT has also proved that at least year round drinking water security can be achieved in a public institution of over 100 employees. Harvesting just 0.35 mn (that is, 3.5 lakh) litres out of the potential of 2.4 mn (or 24 lakh) litres against drinking water demand of 50,000 litres, the system is easily expandable to supply to many other users (VIKSAT 2003). Many agencies have worked for promoting household level rainwater harvesting systems which have ensured drinking water security for at least two years.

A question could be raised whether it is sensible to stop the entire rainwater incident in an urban situation. It may be noted that given the pattern of rainfall, there are always 3-4 events of high intensity rainfall events where water does overflow any domestic rainwater harvesting system. Secondly, generally the entire rainwater incident in an urban environment just flows down the gutters into the sewage system; such a sewage often causing damage to the groundwater quality.

Several studies have shown that the centralised systems of water supply suffer from reservoir sedimentation problems of at least 30 percent making its economics unviable (Naidu, Chandrababu and H.P. Singh. 2004).

In the case of individualised systems, the maintenance efficiency is expected to be high due to personal stakes. Hence most of the systems established by VIKSAT in both rural and urban areas are completely taken care of and are functioning very well years after installation (VIKSAT Annual Report 2003-04).

Concluding Remarks

There is no gainsaying the fact that unless concerted, aggregated efforts are made, rainwater harvesting and artificial recharge efforts will not make significant difference. While we have already stressed the need for a holistic approach that considers demand side management too, yet another imperative would be to develop a "drainage line treatment system" for tanks. Townships and other infrastructure have "disconnected" the surface flow from one tank to the other resulting in not only the disuse of the tanks but also leading to secondary floods as witnessed during 2004 and 2006 in many cities and towns of Gujarat, and in several other states. There is a need to revive this drainage line and the tanks along the stream flow complete with artificial recharge systems.

Resource management of the scale and complexity under discussion requires participation by the primary stakeholders. Unless some direct stake is seen, people would not accept any policy or policy instrument. Therefore, incentives, not subsidies, are essential to enhance acceptability and adaptation, in addition to providing suitable technical support for rainwater harvesting and artificial recharge activities.

There is also a dire need for consolidate research experience available in terms of rainwater harvesting including artificial recharge, identify structures appropriate for different hydrogeological settings, standardize technology options and then have policy made. For implementation, technical support should be provided along with awareness campaigns. Further, technical and applied research are needed on aspects such as the directed recharge to quantify the gains. Thus, a holistic approach to rainwater management in addition to the existing schemes such as Narmada is imperative if we aim for sustainable development.

References

Gujarat Ecology Commission 2000. State Environmental Action Programme (SEAP). Report-Phase I. March.

Mudrakartha 2005. Problems, Prospects & Attitudes in Ensuring Water Security in Arid and Semi Arid Zones. Proceedings of the Roundtable Conference on Water Security in Arid and Semi-Arid Zones in Asia, organized by UNESCO, Teheran. January.

Mudrakartha S and MP Madhusoodhanan 2005. Declining Water Levels and Deteriorating Livelihoods: Some Insights from ComMan Study Areas. Research Report on Community Management of Ground water Resources in Rural India. Commissioned Report, **DFID**.

COMMAN 2005. Managing Groundwater Resources in Rural India: The Community and Beyond. NERC, British Geological Survey Commissioned Report CR/05/35N. 2005. **DFID**.

Moench & Dixit (eds) 2004. Adaptive Capacity and Livelihood Resilience: *Adaptive Strategies for responding to Floods and Droughts in south Asia.* Published by ISET-USA and Nepal. June.

Mudrakartha S and Shashikant Chopde 2002. Closing the Demand-Supply Gap through Rainwater Harvesting *A Case Study of Sargasan, Gujarat, India*. Paper Presented at Pre-ISAR 4 UNESCO IHP-IAH Seminar on Evaluation of Recharge Enhancement Projects in Arid & Semi Arid Areas

VIKSAT Annual Report 2003-04.

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