Groundwater: Towards an Aquifer Management Framework

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This article outlines an "aquifer management" approach towards utilisation of groundwater resources, which are rapidly being depleted across the country. The question of groundwater governance in India is twofold. First, we need to substantially support and empower the community-based systems of decision-making. Second, the existing legal framework and groundwater management institutions have to be fundamentally re-engineered to play a role facilitating and enabling community action.

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The Report of the Expert Group on Groundwater Management and Ownership (Planning Commission 2007) – EG report, hereafter – has provoked a healthy debate in the EPW through T N Narasimhan's critique (Narasimhan 2008) and the rejoinder by Tushaar Shah (a member of the expert group) (Shah 2008).

The Debate

In this note, we take the current debate further and suggest a viable approach to sustainable and equitable management of groundwater in India. Groundwater overexploitation has been recognised as a serious problem in India since the late 1980s (Moench 1992; Dhawan 1990, 1995; and Macdonald et al 1995). The EG report states that the rate of extraction of groundwater far exceeds the rate of replenishment in many blocks, leading to a progressive lowering of the water table. The EG notes that in 2004, an alarming 28% of the blocks in the country were in the category of semi-critical, critical or overexploited, compared to 7% in 1995.

In six major states (Gujarat, Haryana, Maharashtra, Punjab, Rajasthan and Tamil Nadu), the proportion of blocks in these categories was as high as 54%. By all indications, the situation could not have improved since then. These figures assume significance when we consider that groundwater accounts for 60% of the irrigated area in the country and is the critical input for livelihoods of millions of people. Indeed, nearly 85% of the additional irrigated area since 1970 is accounted for by groundwater. Moreover, tube wells (numbering around 8 million) have become the main mode of irrigation, covering nearly 37% of the irrigated area in the country. The depletion of groundwater is closely associated with worsening water quality, as indicated by the rising levels of fluoride, arsenic and iron. Given this context, the EG report does a commendable service of taking "groundwater" out of the black box of "water resources" and putting it in the forefront of the planning process.

The EG report also breaks new ground by refusing to get enticed by supply-side solutions to the looming groundwater crisis, such as enhanced artificial recharge.[1] The EG report states that while recharge of groundwater is urgently required, "even if the entire potential of recharge is utilised, shortage will still persist, underscoring the need for limiting extraction" (Planning Commission 2007). As long as groundwater remains an open access resource, there is very little room for regulating its overuse. Hence, "cooperative management by users to facilitate groundwater use in an equitable manner seems inescapable". However, the clarity with which the EG report presents the problem is not matched by the decisiveness of its recommendations on how to move forward.

In his critique of the EG report, T N Narasimhan says that the equitable management of groundwater must be "based on the best available, evolving scientific knowledge" (Narasimhan 2008: 25). There can be no argument about this. We also agree with his emphasis on integrating groundwater management with watershed development, land use, ecosystem management and public health protection. Where he goes wrong is in suggesting that models based on other contexts, such as that of California, as solutions to India's groundwater challenge. In his response, Shah (2008) rightly emphasises the inappropriateness of such models to the Indian context. His argument is that with a multiplicity of users (mostly small and marginal farmers desperately struggling for survival), each with established decentralised access to groundwater resources, the transaction costs of any legislative action are likely to be huge. Shah endorses the EG report's approach of "indirect" management (as opposed to California's "direct" approach), which tries "to manage groundwater demand by influencing the broader incentive structure and other exogenous determinants such as electricity supply and pricing regime" (Shah 2008: 117). We fully agree that groundwater management cannot be done by legislative action alone. A community-based system of management based on a cooperation of primary users is clearly the way forward.

However, we need understand the crucial steps which facilitate emergence of a community-based alternative in groundwater management.

Search for the Right Unit

To understand the essential characteristics of groundwater in any region, we need to know the physical framework within which groundwater occurs, ie, aquifers. An aquifer is the rock strata, which can store and transmit water to wells and springs. The amount of water it can store and transmit depends on the physical properties of the strata (such as void space, size and inter-connectedness of the voids), its thickness, spatial spread, extent of weathering, structural features (such as fractures, folds and faults), etc. Hence, to study the accumulation and movement of groundwater in an aquifer and its sustainable use over time, we need to move to an Aquifer Management (AM) framework.

The foremost reason for moving to an AM framework is simply that the aquifer is the natural unit within which groundwater occurs. Sustainable groundwater use requires that the "average annual withdrawals from an aquifer do not exceed annual recharge" (EG report: 8). The primary concern here is the *protection* of the resource, which becomes possible with an identification of a "sustainable yield management goal" for an aquifer. A more fundamental reason is that by its very nature, groundwater is a common pool resource.[2] As we have argued elsewhere, rights over the water contained in an aquifer extend to all users. Wells and tube wells are only the mechanisms of appropriating this water by an individual user (Kulkarni et al 2004). Therefore, the AM approach necessarily implies the need for a collective and equitable management of groundwater. Groundwater is an invisible, non-stationary, "fugitive" resource, which does not respect boundaries set by landholdings. Clearly, the water below "my" land is not "mine". The spillover consequences of my actions on my neighbour are determined by the connectivity of the aquifers. The more the connectivity of the aquifer, the more is my "zone of influence" and the more the likely negative impact of my actions on my neighbours and vice versa.

Recognition of aquifer complexity is missing in the *current methodology of assessment of groundwater potential*. The methodology of assessment of groundwater in India follows either the rainfall infiltration method or the groundwater level fluctuation and specific yield method as recommended by the Groundwater Resource Estimation Committee (GREC 1997). In both methods, aquifer characteristics, such as storage, transmissivity and diffusivity (the relationship between storage and transmissivity) are secondary or missing from the method of assessment. This, in turn means that degradation of the resource often escapes the eyes of those who are supposed to monitor it. The pervasive disconnect between the picture of plenty as portrayed by the groundwater surveys and the reality of water scarcity has much to do with the defects in the methodology. Surprisingly, the notion of groundwater as common property eludes even some of the carefully designed resource conservation programmes like watershed development. Watershed planners appear to forget that just as there is a surface water catchment, there also exists a groundwater catchment. Though the boundaries of the two catchments do not necessarily coincide, we always define a watershed with reference to the surface water catchment alone (GOI 2006). To our mind, this is symptomatic of the deficiency of understanding of the very basic idea of AM in India.

Is Aquifer-Based Management Practical?

The obvious question is whether we are ready for an AM approach. Indeed, we must acknowledge that there are some crucial difficulties. One key difficulty is hinted in the EG report itself – that groundwater aquifers do not map neatly to units of social organisation such as villages, blocks or districts. Conversely, one aquifer may be spread over two or more villages or may even cut across blocks and districts (in alluvial terrains). It is true that the GREC recommends, "A watershed with well-defined hydrogeological boundaries is an appropriate hydrological unit for groundwater resource estimation" (GREC 1997: 41), especially in the hard rock regions. Even with this awareness, the watershed units used in estimation often remain too regional to provide any clarity on the aquifers in each watershed.[3] However, we must remember that a similar difficulty exists in the case of surface water basins as well.

A common dilemma in watershed development projects is the mismatch between watershed and village boundaries. This does not mean that we should give up either the river basin or watershed approach. While studying the basin as the technical unit, our attempt must be to try to overlap its boundaries with those of administrative units to whatever extent possible. In situations where many administrative units are involved, systems of coordination across basins should be developed. The key point is that while most discussions on sharing and equity in water resources are centred on management of surface water basins, no comparable effort seems to be going into thinking on groundwater in India. We need to correct this critical imbalance.[4] A related difficulty is the paucity of data at the aquifer level to enable management. Available data is seldom organised at the required scale. A lot more micro-level work is required to generate information at an aquifer level. More importantly, we need to have management organisations with the required institutional capacities to generate such data.

Clearly, the primary task of the AM approach is to carefully define the aquifers in a region, including mapping out their boundaries. Mapping the aquifers is also needed to identify groundwater recharge and discharge zones and developing appropriate strategies of intervention. While mapping aquifers, it may be useful to delineate *different typologies* of groundwater, based on variations in hydrogeological and socio-economic contexts. The variability in aquifers is particularly high in the crystalline and "hard rock" formations, which underlie about 60-70% of the geographical area of India (COMMAN 2005). Due to their inherently heterogeneous character, hard rock aquifers are limited in their thickness and extent and consequently hold relatively limited groundwater storage. Moreover, the rock strata here often contain layers with widely varying physical properties. Overlapping of different strata with variable physical properties within a limited physical space renders the study of the occurrence and movement of groundwater highly complex. The management system needs to take these complexities into cognisance.

A National Groundwater Management Programme

It is a sobering thought that in as many as six states, the number of blocks in the semi-critical, critical or overexploited category has crossed the half-way mark (EG report: 7). It is clear that the groundwater resources in the country cannot be managed the way they have been in the last 30 years. The way forward is to initiate a national programme on groundwater management, based on an AM approach. Only such a nationwide programme could render the ideal of cooperative management mentioned in the EG report workable. How can this be done? The key steps in implementing such a national programme:

(1) Aquifer Mapping of the Entire Country at an Appropriate Scale: Ideally, aquifer mapping should take place at the scale of watersheds of the order of 1,000 to 2,000 hectares. These maps can be then aggregated at a more regional scale. The objective of such mapping is to develop understanding of groundwater at the right scale so that the local governance mechanism can make informed choices about the resource use. Sufficient time must be allocated to build the necessary capacity in the local community of users in resource mapping. In other words, the exercise of resource mapping must empower the community to understand the resource and develop effective strategies of its protection.

(2) Data Generation at the Right Scale: Once aquifers are mapped at the right scale, more information needs to be generated on their actual condition. Such data are generated through study of water levels in observation wells. The required density of wells would vary depending on the hydrogeological setting. Our studies of hard rock aquifers on scales ranging from 200 hectares to 10,000 hectares indicate that on an average, the density of monitoring wells should be one well for every 25 hectares. This implies that steps should be taken to raise the density of observation wells to match the requirement. Some states in India have already undertaken hydrology projects and possess some framework for collection, retrieval and even sale of data. These systems could easily be modified to bring in data at the right scale.

(3) Characterisation of Aquifers: After this, we need to characterise water contained in the aquifers in terms of its *quantity, quality and inter-connections*. This characterisation brings out the *problems-typology* of a specific region with respect to groundwater. First, aquifer transmissivity and storativity tell us how long wells can sustain pumping and how these vary between seasons. Second, transmissivity is also an important factor in gauging the movement of pollutants through an aquifer. The chemical signature of groundwater helps in developing a better characterisation of the pollution load in water accumulating and moving within the aquifer. Third, the relationship between aquifers, watersheds and river basins and the hydraulic connectivity between aquifers present within a watershed and across watersheds need to be characterised. Such information is useful to understand the closure of basins, especially in regions where base flows from groundwater contribute to stream flows.

(4) Evolving Strategies and Protocols for Sustainable Management of Available Groundwater: After we characterise the aquifer in this manner, an appropriate and strategic *matrix of responses* in response to the problems-typology in specific hydrogeological settings is developed. This response is formulated as protocols of sustainable groundwater use, covering the range of supply-side (recharge-oriented) as well as demand-side solutions. These are not fixed solutions frozen at a point in time, but rather an evolving set of rules emerging from a continuous and active dialogue within the community of users. These rules are facilitated and supported by an enabling legal and institutional framework.

(5) Running Groundwater Management Pilots: Such management models incorporating the principles of community management need to be evaluated by piloting them under different conditions. A few dark and overexploited blocks facing acute groundwater crisis could be identified to run such pilots. A good deal of experience in groundwater management is already available through several scattered government and NGO-led interventions for increased recharge and demand regulation. Innovative approaches and best practices from such experiences should be documented along with that from the fresh pilots and again experimented over different typologies at a larger scale.

(6) Development of an Appropriate Legal Framework: As summarised in the EG report, the existing legal framework for managing groundwater follows a command and control approach. What is proposed in these legislations is a regulatory regime that includes everything from establishing authorities to issuing licences to imposing bans and penalties. However, in the Indian context, without a direct involvement of the millions of farmers and households, scattered over the entire landscape of the country, no meaningful management of groundwater could be visualised. Law has to be the facilitator and supporter of community action rather than a mere regulator.

(7) Scaling up the Institutional Framework: The current nature of institutional framework governing groundwater resources is mainly a "state-based" one, which does little to integrate community efforts at managing groundwater resources. Some states have a separate agency handling groundwater-related issues, while most have the groundwater agencies nested inside other departments like water resources, PHED, etc. It would be premature to even suggest an institutional framework before outlining a process for management. Nevertheless, considering the primary challenge of institutional restructuring for developing groundwater literacy at all levels, we propose a skeletal framework as follows:

- New institutions need to be visualised at the *aquifer level* and at the watershed level, with a clear "aquifer" focus. The membership of these institutions will be drawn from the user community, the panchayat raj institutions, civil society and district level representatives of state groundwater agency. These institutions will manage aquifers and will function as registered bodies duly recognised by the block and district level administration.
- At the *block level*, a facilitation centre will operate collecting and organising information generated by study of aquifers within the block. This centre will ensure that the plans for intervention at the aquifer level are coherent with the overall priorities in water resources within the block. It will also facilitate information flow between the aquifer level and the district and state levels.
- At the district level, a District Groundwater Management Agency (DGMA) should be set up, which in itself will include an advisory panel of experts from academia and civil society. The DGMA will establish a monitoring network to generate aquifer-level information, run trainings, process data and disbursing expert advice on management processes. The DGMA will work in close coordination with other agencies engaged in water resource management like the District Watershed Management Agency (DWMA). Approval of the DGMA will be mandatory for all watershed plans presented to the DWMA.
- At the state level, the Groundwater Regulatory Authority (GWRA) will monitor all groundwater within the state. The authority will take necessary steps to ensure that exploitation of groundwater resources does not exceed the natural replenishment to the aquifers and advise the state government on remedial measures whenever such mismatch occurs. The Central Groundwater Board (CGWB) will support the GWRA and play an advisory role in the governance structure. The CGWB will put in place its own monitoring processes, with the objective of generating and disseminating information in the public domain.

This article in no way tries to prescribe a final solution to the groundwater problem in India. Rather, it attempts to outline the broad contours of a long-term management strategy. A lot more needs to be done to put this strategy in operation. The question of groundwater governance in India is twofold. First, we need to substantially support and empower the community-based systems of decision-making. Second, the existing legal framework and groundwater management institutions have to be fundamentally re-engineered to play a role facilitating and enabling community action. The attempt in this article is not as much to suggest a governance structure for groundwater management as to identify critical processes required for such a structure to emerge.

NOTES

1 For instance, the "Master Plan for Artificial Recharge of Groundwater in India" prepared by the Central Groundwater Board (http://cgwb.gov.in/documents/MASTER%20PLAN%20Final-2002.pdf), takes a strongly supply-side view, listing the 2,25,000 large structures and 3.7 million small structures for an artificial recharge of an estimated 36.5 billion cubic metres of groundwater per annum, at an outlay of Rs 25,000 crore.

2 A common pool resource shares with public goods the characteristic of difficulty of exclusion but is subtractable like a private good, i e, consumption by one person reduces the quantity available to others.

3 For instance, Maharashtra is divided into 1,500 odd watersheds spread over an area in excess of some 3,00,000 km², implying that the average area of each watershed is 200 km² (20,000 hectares). Such a unit, in case of hard rocks, would mean numerous aquifers.

4 The complete absence of reference to groundwater in river-sharing agreements, such as that of Narmada, is striking (Ranade 2005).

REFERENCES

Central Groundwater Board (2002): "Master Plan for Artificial Recharge in India" in *Report of the Expert Group on Groundwater Management and Ownership*, Planning Commission, Government of India, p 61.

COMMAN (2005): "Community Management of Groundwater Resources in Rural India", R Calow and D Macdonald (ed.), *Research Report: British Geological Survey Commissioned Report CR/05/36N.*

Dhawan, B D (1990): *Studies in Minor Irrigation with Special Reference to Ground Water* (New Delhi: Commonwealth Publishers).

– (1995): *Groundwater Depletion, Land Degradation and Irrigated Agriculture in India* (New Delhi: Commonwealth Publishers).

GoI (2006): "From Hariyali to Neeranchal – Report of the Technical Committee on Watershed Programmes in India", Department of Land Resources, MoRD, p 222.

Groundwater Resource Estimation Committee (1997): "Groundwater Resource Estimation Methodology – 1997", Report of the Groundwater Estimation Committee, Ministry of Water Resources, Government of India.

Kulkarni, H, P S Vijay Shankar, S B Deolankar and Mihir Shah (2004): "Groundwater Demand Management at Local Scale in Rural Areas of India: A Strategy to Ensure Water Well Sustainability Based On Aquifer Diffusivity and Community Participation", *Hydrogeology Journal (Springer)*, v 12(2), pp 184-96.

Macdonald, D M J, H Kulkarni, A R Lawrence, S B Deolankar, J A Barker and A B Lalwani (1995): "Sustainable Groundwater Development of Hard-Rock Aquifers: The Possible Conflict between Irrigation and Drinking Water Supplies from the Deccan Basalts of India", *British Geological Survey NERC Technical Report* WC/95/52, p 54.

Moench, M (1992): "Drawing Down the Buffer", *Economic & Political Weekly*, XXVII: A-7-A-14.

Narasimhan, T N (2008): "Groundwater Management and Ownership", *Economic & Political Weekly*, 43 (7), 22 February.

Planning Commission, Government of India (2007): *Groundwater Management and Ownership: Report of the Expert Group* (New Delhi: Planning Commission).

Ranade, Rahul (2005): "Out-of-Sight, Out-of-Mind: Absence of Groundwater in Water Allocation of Narmada Basin", *Economic & Political Weekly*, Vol XL, No 21.

Shah, T (2008): "Groundwater Management and Ownership: A Rejoinder", *Economic & Political Weekly*, 43 (17), 2 May.