Peoples' Participation for Sustainable Groundwater Management

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Abstract India is the largest user of groundwater in the world. Over 85% of rural domestic water, around 48% of urban domestic water, and 60–70% of agriculture water are groundwater dependent. This has resulted in the overexploitation and acute depletion of the resource in many parts of the country. Despite the manifold short- and long-term consequences of such dependence on a fast depleting and critical resource, India has made little headway in its regulation or conservation. While groundwater exhibits the qualities of a classic common pool resource—those of subtractability and excludability, in reality, it has largely been treated as private property. Much of the problem lies in the juxtaposition between the public and common pool nature of groundwater and its rampant private, atomized, and unregulated extraction. As the volume diminishes and quality deteriorates, lack of regulation and appropriate management can lead to both inter- and intra-use conflicts with considerable political and socio-economic impacts. Therefore, in order to conserve this resource it is imperative to shift away from a paradigm of private groundwater development to a more sound system of groundwater management. This paper argues that despite the relative invisibility of groundwater and the complexities that surround its governance, decentralized management options offer better solutions for long-term sustainability of the resource and ensure social equity.

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Firstly, it argues for a hydrogeological foundation for groundwater management. Secondly, given the decentralized nature of aquifers, community participation is essential for the sustainability of this resource. Finally, it highlights the urgent need for policy initiatives that recognize the common pool nature of groundwater and facilitate bottom-up innovations that reflect the local geological and socio-economic specificities of the resource Sengupta 2015.

Keywords Groundwater · Participatory management · India · Hydrogeology Aquifer

1 Dependence on Groundwater in India

From historical perspective, water management in India can be broadly categorized under three distinct phases (Shah 2008). First, the pre-1800s or the Mughal period, which saw predominantly irrigation through wells and tanks. Although supported by state patronage, the governance of water was based on traditional knowledge systems and followed a decentralized system of governance. During the period between 1800 and 1970, the colonial and post-colonial periods, the model for groundwater management was through state-supported schemes, focused on enhancing the irrigation potential. It provided a major impetus to cash crop production and made the country food secure. Post-1970, with the proliferation of borewells and small pumps, irrigation became atomized and hugely groundwater dependent. The institutional mechanisms were retained under the state and policies followed a 'command and duty' regime.

Presently, the dependence on groundwater remains strong with irrigation for >85% of all groundwater extraction (MDWS 2016). It caters to 85% of the rural and nearly 48% of the urban drinking water needs. The overwhelming dependence on groundwater has put aquifers in several regions under a lot of stress (CGWB 2013).

2 Current Paradigm and Challenges

The atomized use of groundwater posits several challenges. The invisibility of groundwater does not lend itself to easy quantification and consequent management options. Its ownership is tied to land rights, which is in conflict with its nature as a common pool resource stored in aquifers and shared between a multitude of users. It also attracts competition and raises the potential for future conflicts. The problem analysis per se is neither new nor unknown, but needs to be understood from the perspective of bottlenecks to efficient groundwater management (Figs. 1, 2, and 3).

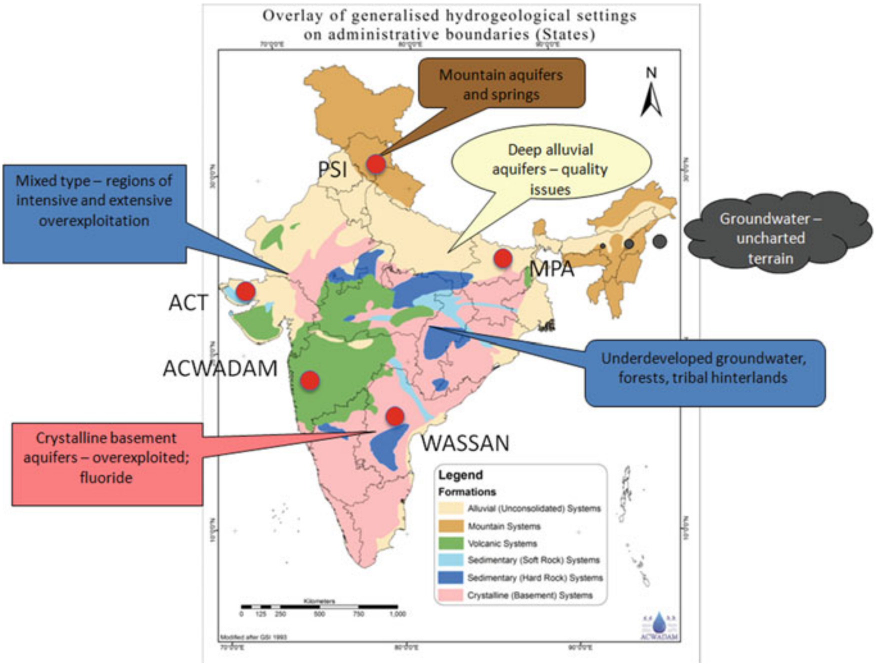


Fig. 1 Typology of hydrogeological settings in India (modified after COMMAN 2005; Kulkarni et al. 2009)

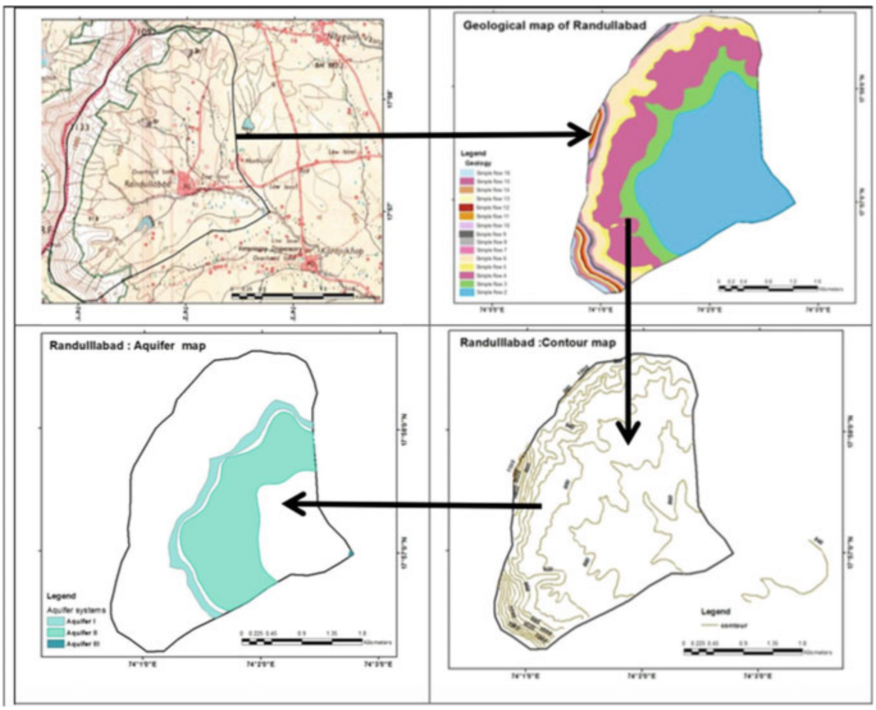


Fig. 2 Process of aquifer delineation in Randullabad (PGWM ACWADAM 2012)

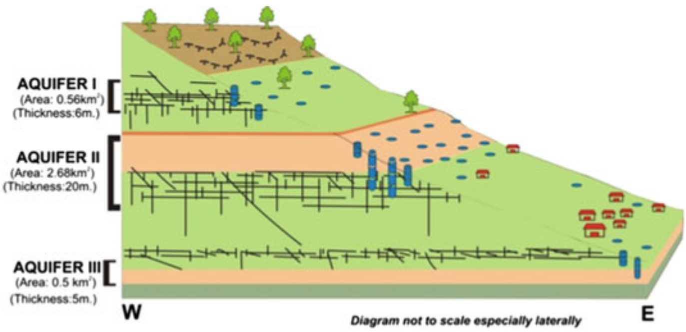


Fig. 3 Aquifer systems in Randullabad (PGWM ACWADAM 2012)

2.1 Development Versus Management

Till very recently the slant of looking at groundwater was more on development rather than on management. There is a continued emphasis on engineering solutions focused on source development rather than overall and sustainable management of the resource. The annual slip back of villages brought under safe drinking water supply is of around 40% (MDWS 2006) due to sources drying up or other issues like quality deterioration, points towards the inadequacy of this approach. Managing demand, especially in water-stressed areas, continues to be a political hot potato.

Beside large areas under overexploitation and unbridled, abstraction has sprouted the issue of quality deterioration, like flour decontamination in several states and arsenic contamination of large stretch of Indo-Gangetic plains and its sub-basins (CGWB 2013). Salinity ingress in coastal areas, nitrate, iron, and other heavy metal contaminations are also emerging as serious issues along with the potential bacteriological contamination of groundwater through increased toilet coverage. As per the data available, approximately 59% of the total districts in the country show groundwater vulnerability and have issues related to either water quality, quantity, or both (Figs. 4, 5, and 6).

2.2 Issues of Data and Institutions

There are multiple government departments that are engaged in different aspects of managing groundwater with very little coordination between them. The compartmentalization between the supply-side ministries and departments (Department of Land & Records, Department of Forest, CGWB, CWC, Department of Rural development, Department of Drinking Water Supply) and demand-side (Agriculture, Energy, Industry, Urban, etc.) renders has a common vision for water management very difficult. The Pollution Control Board, which plays an

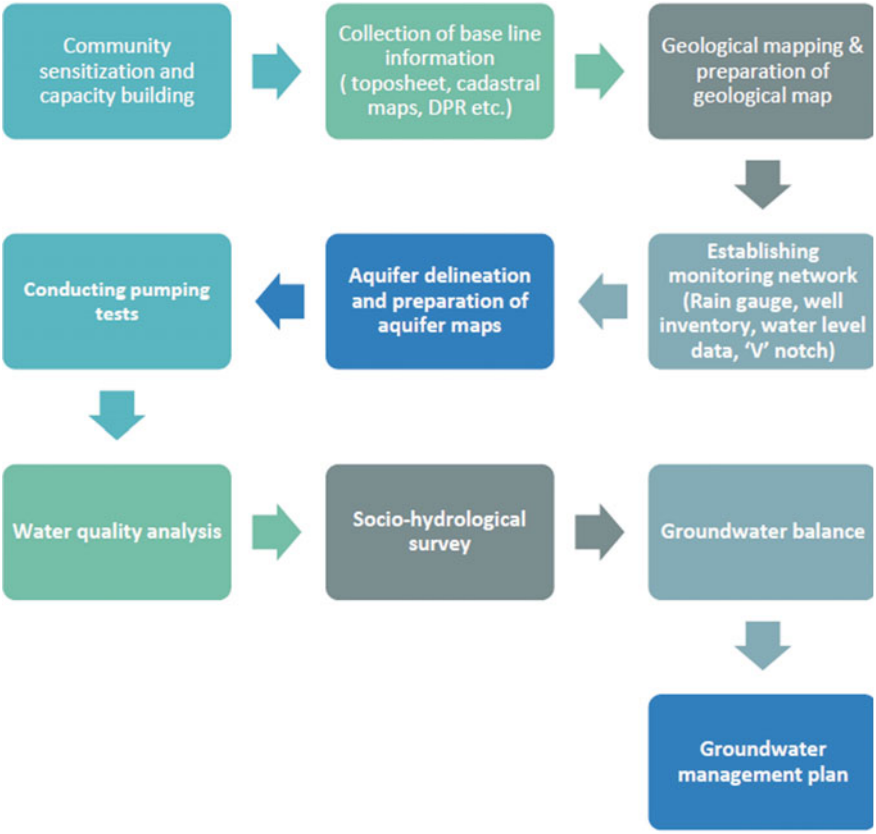


Fig. 4 Process of participatory groundwater management (PGWM ACWADAM 2014)

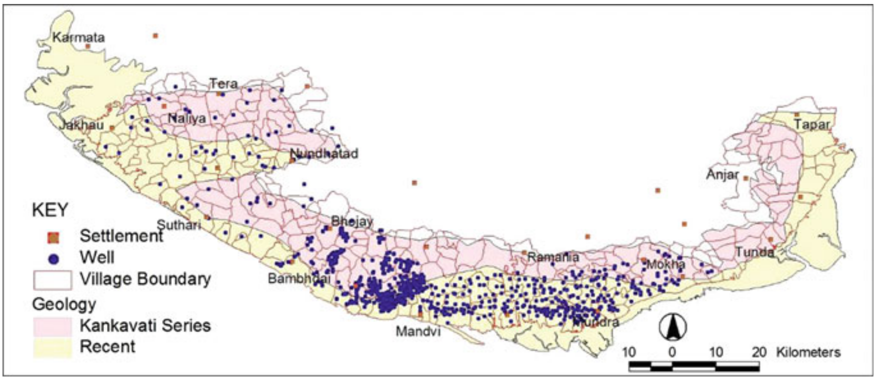


Fig. 5 Villages based on Kankavati Sandstone (PGWM ACT 2014)

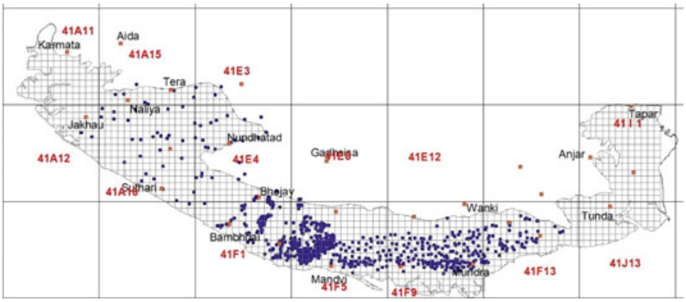


Fig. 6 Existing well on monitoring network grid (PGWM ACT 2014)

important role in monitoring and regulation of effluent discharge into ground and surface water, is at the periphery of groundwater management.

While each agency has its own mechanisms and repositories of data, the use and users of such data are not predefined. For example, CGWB's groundwater assessment reports are possibly the only data sets available on various uses of groundwater and are very useful. However, it suffers from both a lack of granularity and a time lag in publishing the reports that make decision-making based on the data relatively inaccurate. From a user point of view, say a farmer or even the collector of a district, it may not be very easy to find data related to groundwater, surface water, irrigation, and weather at a village or block level, making it difficult to develop decision support systems for allocation of water for various users. The water quality data on bacteriological and chemical contaminations are collected by different departments and are not integrated in a common platform. The fragmented institutions and processes raise some questions related to the use of data for the management of groundwater as a resource, like the mapping of aquifers through National Aquifer Management Programme (NAQUIM) taken up by CGWB that eventually should lead to participatory groundwater management.

Two questions arise out of this. One, can the water data be crowd sourced from citizens, which will enhance the density of the data to be collected? Second, can the citizens or managers be enabled to engage with the data that help them in understanding the resource better and therefore partake in the management of the resource? The use of technology in collecting these data can make compilation and analysis in real time and useful for management compared to what is currently the practice (Figs. 7, 8, and 9).

2.3 Groundwater Ecosystem Connection

Our knowledge is improving on the interplay between forests, wetlands, springs, and wells as a part of the same ecosystem. The changes in one element of the ecosystem have profound impact on the others. Upstream–downstream issues in the

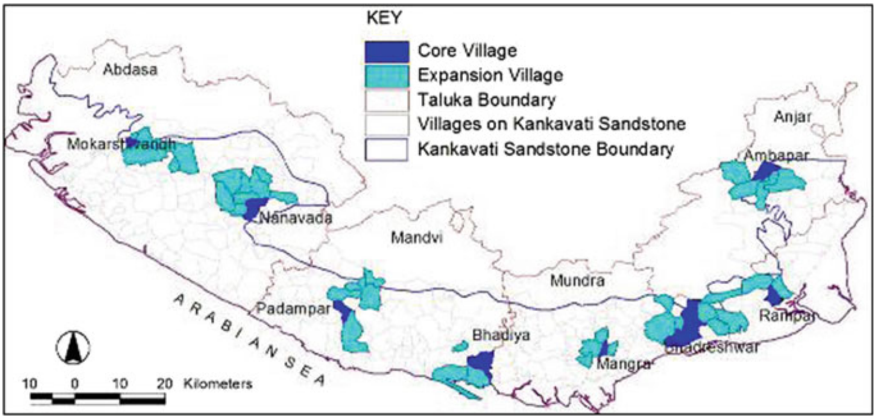


Fig. 7 PGWM demonstration clusters (PGWM 2014)

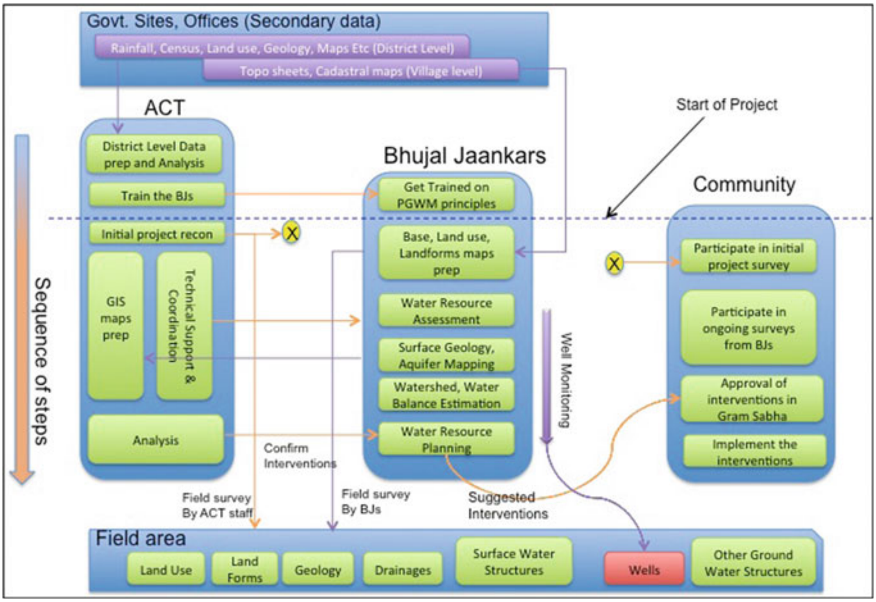


Fig. 8 PGWM process adopted in Kachchh area: activities, participants, and interactions (PGWM ACT 2016)

case of springs and rivers, effect of overabstraction by borewells on base flows, ground and surface water interplay in the flood plains, the possible connection between forest fires and groundwater recharge, ownership of the sources of groundwater, etc., are some of the issues that need to inform the local management and governance. It is challenging for any centrally driven approach to respond to the diversity of our ecosystems. On the other hand, traditionally every subculture

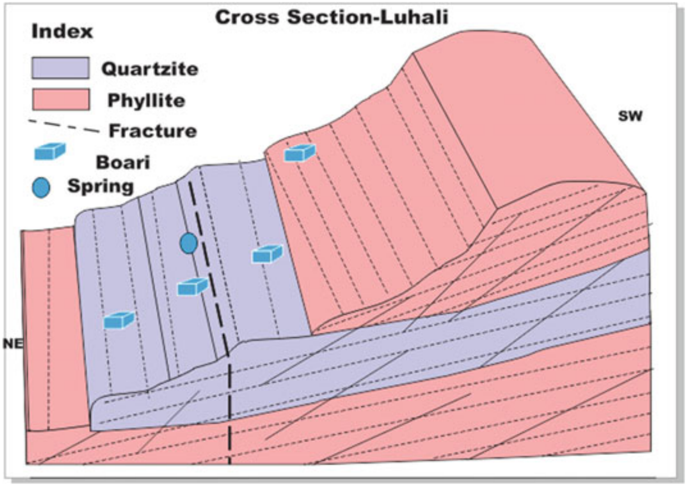


Fig. 9 Cross section of Luhali village (PGWM PSI 2012)

across regions had a good understanding of its ecology. As we would see in the cases below, traditional knowledge when meshed with modern science and technology helps in developing contextually appropriate systems and practices of groundwater management.

2.4 Human Resource: Issues and Challenges

For a state-driven approach, there seems to be an acute mismatch of manpower at all levels, both, in terms of quality and quantity. Perspective building for resource management at the top to skills required for mapping and managing aquifers seems to be woefully inadequate. These in turn have implications on efficient management of the resource. Inadequacy of physical infrastructure like good-quality water testing laboratory hampers timely detection and mitigation of water quality problems. With many institutions presiding over the management of groundwater and the poor coordination between them has led to an overall lack of accountability within the system (Figs. 10 and 11).

While most of the policies and programmes have been espousing peoples' participation for managing groundwater, the statist approach has created a patronage system that undermines the agency of the citizens in urban as well as rural areas in playing a critical role in management of the resource. The work on ground informs about the dire need of shifting from a services-centric to a more resource-centric approach. The emergence of citizens' groups both in urban and rural areas has demonstrated a qualitative improvement in resource management outcomes, including the critical aspects of equity and sustainability. However,

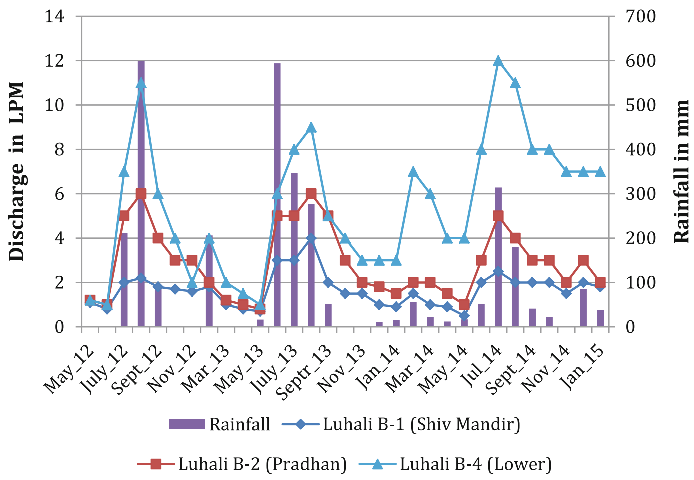


Fig. 10 Luhali spring hydrograph (PGWM PSI 2015)

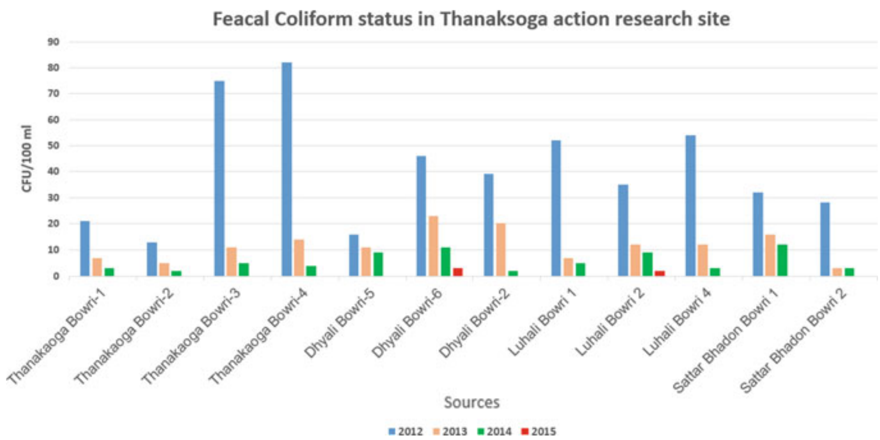


Fig. 11 Springs water quality improvement hydrograph (PGWM PSI 2015)

citizens' actions are more often triggered through natural causes such as scarcity or some health hazards due to poor water quality. Besides, it is not very easy to incentivize peoples' participation through public policy instruments.

3 The Contours of Groundwater Management

Arghyam has been supporting work around water and sanitation over the last decade across India. The learning has informed its work on groundwater management. Some empirical principles have evolved from the experience of our partners' work on the ground. With the only input for any water being rainfall, the question becomes that of capturing this water for deferred use. Rainwater stored in reservoirs, dams, or ponds are more common to be seen but cost more as compared to storing the same in natural underground aquifers, where there is less evaporation and reach through natural recharge. However, understanding the boundaries and characteristics of aquifers is not very easy and neither is the quantification of groundwater, both of which requires quite an understanding of hydrogeology.

Much of our collective learning stems from the understanding of nature of groundwater as a resource and our communities' historical understanding accrued through the interaction with this resource. The aquifer boundaries within the rock layers make groundwater a renewable but finite resource. Given that the resource supports several uses and users, it exhibits the twin characteristics of subtractability and excludability for any Common Pool Resource (CPR). And as for any CPR, exceeding its carrying capacity leads to problems of scarcity or even quality problem.

Having a unit of management, in this case the aquifer assists in defining the problem statement for that unit and helps in monitoring if the objectives of management are being achieved. The problem statements could be related to scarcity, quality, access or a combination of all three. This approach also helps in looking beyond the source to understanding the resource. This helps in bringing supply augmentation and demand management as integral parts of the management plan.

The work has demonstrated that communities come up with their own management protocols once their connection with the resource improves. Resource understanding requires the science of hydrogeology to be broken down for the communities to assimilate better, which in turn is meshed with their own traditional knowledge. The practice has shown that the communities can use their own agency to develop water security plans that are a combination of supply-side earth construction and demand-side interventions through a set of decisions defining the usage of water for multiple uses and users. The principle of subsidiary applies for decision-making. Decisions or protocols once agreed upon are formalized in the Gram Sabha. Over time, the panchayats or water user groups have been able to mobilize resources from existing government schemes for implementing the interventions.

The participatory groundwater management (PGWM) programme has helped in building a cadre of para-professionals who are now adept in collecting data, developing maps, and facilitating water balance exercises with the communities that helps in water budgeting. The data collected are either used for developing decision support systems or for evidence building. In most cases, it requires the support of an intermediary NGO to analyse the data, which is shared among the community members for decision-making.

It is important to engage with the community leadership, particularly women. The interventions are planned keeping in mind the issues of equity and sustainability. The protocols developed work more on the basis of social sanctions and do not necessarily have a legal anchorage. The endeavour has been to institutionalize these management protocols in institutions of local governance.

Given the complexities of institutional structures at the state level, the panchayat becomes the focal point of convergence for various programmes, schemes, and interdepartmental coordination as well as implementation. The state needs to create a conducive environment where negotiations on allocations, incentives, and regulations can take place. It can help formalize the management protocols developed by communities themselves. More importantly, it should be able to resource the water security plans developed by the communities.

Ensuring that the decision-making is decentralized to the level of the panchayat and enabling the communities to manage their resource has turned out to be efficient and effective than the purely statist approach. The lack of manpower, especially at the last mile itself acts as a deterrent. It has been observed through our work that thorny issues such as prohibiting new borewells to be sunk, moving away from cash crops, and sharing of borewells become relatively easy through community engagement and for the resource management. Conflicts related to water sharing, if any, can be settled at the lowest levels of governance. This process derives strength from the provisions in the 73rd and 74th amendments and helps in deepening the democratic processes in this respect.

However, externalities weigh heavy on this work and it is still not clear about the long-term sustainability of such efforts. For example, any change in the catchment areas of springs due to deforestation or forest fires can reduce the discharge of springs; price or energy incentives for cash crops in a water-stressed region may lead to the disregard of social protocols; additional complexities arise for peoples' participation, when the same aquifer is shared between multiple villages, pushing the management boundaries beyond the confines of administrative units. In Himalayan region, where the recharge and discharge areas can follow a valley-to-valley approach, rather than a ridge-to-valley approach can also make peoples' participation for management of the resource a bit more complex.

Despite its limitations, the impact of the PGWM programme has been significant. Some are illustrated in the following partner case studies, representing critical hydrogeological typologies of India.

4 Case Studies

4.1 Hard Rock Areas—Western India

Droughts, drinking water scarcity, depletion of groundwater levels, and water quality are the main water-related issues of Maharashtra. In the state, the rainfall ranges from 400 to 4000 mm; however, over the last three years there has been a deficit rainfall resulting in consecutive cycle of droughts. This has led to severe shortage of ground and surface water in the region. Groundwater is considered as the lender's last resort, and hence, there is high dependence on this common pool resource, which is under threat due to increased exploitation of the aquifers.

However, a few villages in the state have managed to tide over this vicious cycle of crisis. In these villages, local communities used scientific principles along with their traditional knowledge to manage groundwater in a democratic, equitable, and sustainable manner.

In the drought-prone villages of Muthalane in Pune District and Randullabad in Satara District of Maharashtra, a three-year-long watershed development project undertaken with PGWM principles brought the village back from the brink of drinking water scarcity to becoming a water-sufficient village. The project involved geological mapping, recharge of regional aquifers, testing of water quality, and establishing usage protocols for drinking and irrigation. Drilling of borewells was banned, and 90% of wells in the village were used on a sharing basis as farmers took turns to irrigate their lands. Groundwater recharge and discharge areas were demarcated.

As a result of these interventions, groundwater levels have improved and local water structures have been revived. The impact of the programme is seen in improved kharif productivities, improvement in irrigation and water use efficiency, improved equitability particularly for farmers, and improved drinking water security.

The chief reason this programme succeeded was because of the involvement of the community. Over a period of three years from 2011, there was a significant increase in groundwater recharge despite rainfall being below normal. This was because of the watershed development undertaken by the village water and sanitation committee that facilitated construction of check dams in natural recharge areas. A sense of ownership among the farmers helped them take decisions together, such as diversifying crops based on the availability of water, using low-powered pumps, and adopting micro-irrigation techniques for effective use of water and reduce abstraction considerably.

4.2 Mixed Sedimentary Systems—Kachchh

Groundwater is the only reliable and critical source for drinking water in arid and semi-arid regions both for rural and urban areas. Surface water, particularly in such regions, becomes a supplementary source, given its scarcity and seasonality. Groundwater, apart from drinking water security, also supports other natural resource-based livelihoods such as agriculture, animal husbandry, pastoralism. It has enabled industrial development in regions that would otherwise have seemed impossible due to the scant availability of surface water seasonal sources. Groundwater is increasingly getting stressed that adversely affects the quality, quantity, and sustainability of the resource.

The sites are located in Kachchh area which is underlain by the Tertiary and Jurassic sedimentary formations—mainly sandstones—in the Kankavati river basin and in Kamaguna-Vatacchad watershed. It is a mixed-type region with intensive and extensive overexploitation, contamination (geogenic and bacteriological), and salinity ingress into the freshwater aquifer systems in the coastal parts, which has directly impacted the traditional drinking water sources.

The participatory groundwater management at 18 locations in this hydrogeological typology setting has been studied and monitored for last 5 hydrogeological cycles. On the basis of which groundwater management plans were made and implemented in these villages, which helped in achieving water security particularly drinking water.

The programme has now expanded to four areas, spread across Kankavati Sandstone in Bhuj and Nakhatrana Taluka (sedimentary: multi aquifer system); Wagad Sandstone in Mandvi, Mundra, and Anjar Taluka (sedimentary: single aquifer system); and north Gujarat Alluvium in Kheralu Taluka (unconsolidated sediments: multi aquifer system), that includes aquifer mapping and their characterization, and a participatory groundwater management plan. The programme has also scaled up the efforts towards achieving water security for drinking water needs and developed participatory decision support tools that will guide the interventions and protect groundwater resource from exploitation in the sedimentary and alluvial systems, which also include a shared aquifer system. A groundwater monitoring network through community participation has been established in this region to facilitate understanding of the resource, plan interventions, and develop groundwater management protocols based on decision support tools.

The programme has demonstrated how the communities or group of stakeholders relying on an aquifer can reduce water stress and conflicts by adopting PGWM principles. Through various interventions, these stakeholders have understood and demonstrated an equitable and sustainable sharing mechanism based on the area's hydrogeology. It has incorporated aquifer management into mainstream watershed and drinking water projects.

ACT's work across Kachchh District and several locations across India showcase PGWM-based water security can be achieved. It also demonstrates cadre building at various levels (para-hydrogeologists or Bhujal Jankars), key stakeholders resource understanding, community-based groundwater management and its governance supported by scientific evidences.

4.3 Mountain Typology—Himalayan Aquifers and Springs

Springs, which occur where groundwater table intersects the surface and provide safe, perennial drinking water, feed rivers, and anchor entire ecosystems. Springs are a source of common pool resource, i.e. groundwater. But this vital resource is under threat due to environmental degradation, increasing water demand, and climate change. Spring discharge and quality is declining due to rampant drilling in the catchment, unregulated abstraction changing land use patterns, ecological degradation, poor sanitation, population pressure, and climate variations.

Studies carried out in the Himalayan region in the Sirmour District, Himachal Pradesh. The area lies in the Proterozoic rock formations of the Lesser Himalayan region. In the Himalayan mountain systems, local aquifers are found over a large region that feed springs and streams. The aquifers are often fed by recharge from distant locations. Dependency for drinking water is high on springs and spring-fed streams than on wells in this region.

Springs require a different approach of management. The conventional ridge-to-valley approach does not necessarily work in these regions. The springshed approach looks at valley-to-valley interventions and has demonstrated positive results. The major interventions would need to focus on springs rejuvenation and understanding the mountainous aquifer systems. Based on the implementation of interventions, springshed recharges area protection, social fencing, developing community for springs/groundwater management through the various institutions like van panchayats, and mitigating quality issues based on the hydrogeological interventions.

A pilot action research initiated in five villages, viz. Thanakasoga, Luhali, Dhyali, Dandor, and Sattarbhadon of Thanakasoga Panchayat in Sirmour District, has developed an understanding of mountain aquifers, its augmentation, and management using physical, vegetative, and social measures through community participation. These interventions have protected and regenerated springs, which have led to an improvement in the availability of water for the communities especially during the lean months of the year. Social fencing of the recharge area and its protection from open defecation, cattle grazing, deforestation, and land use change is one of the major outcomes of this programme which has resulted in significant water quality improvement for all the springs in the pilot locations.

PSI has demonstrated that recharge treatment area for springs is on an average 2 ha, as compared to more than 10 ha used by traditional watershed management approaches. Thus, the springshed approach has potentially reduced overall costs by 80%. Interventions indicate that springshed management requires an investment around Rs. 30,000 per ha. This investment includes the cost of essential infrastructure, human resource development, and knowledge sharing costs.

4.4 Crystalline Basement—Peninsular India

In the absence of knowledge of local aquifers that support local governance/management practices at community level, both government and individuals seem to be working at cross-purposes and result in a water crisis especially that of drinking and agriculture water.

The area under groundwater-based irrigation systems is increasing even those parts where traditionally surface water-based irrigation systems used to be popular. This is observed in Andhra Pradesh, Telangana, and other parts of Peninsular India too. Similarly, as groundwater abstraction has increased, the quality of drinking water in several sources has deteriorated. There is also an increase and acceleration of water markets and quick-fix solutions (through reverse osmosis plants) in several parts of peninsular India.

Studies have been taken up in Mahbubnagar and Ranga Reddy District in Telangana and Anantapur District of Andhra Pradesh (Fig. 12). These hard rock aquifers are heterogeneous and overexploited with a water quality problem of excess fluoride. There is high dependency on groundwater for both drinking water and agricultural purposes on the homogeneous aquifer systems. The various degrees of groundwater extraction have lead to intense competition around depth of wells and borewells.

The work carried out in this location under PGWM aimed to demystify the processes/protocols to enhance the application of knowledge in aquifer-based groundwater governance systems within mainstream public investment projects for enhancing water security at local level (with a clear focus on drinking water security and irrigation purposes).

In the villages identified in these districts for study, many farmers—both with and without access to groundwater, were facing an increasingly precarious livelihood situation. The farmers were brought together through a system of voluntary compliance. It meant rather than individuals digging new borewells, existing borewells were linked through a network of distribution pipes to provide access to water for all parties involved. The scope was to create a sustainable model for resource sharing and groundwater management.

The villages were to pool the groundwater from farmers who had borewells and share it with other farmers, who do not have access to water, thus providing critical

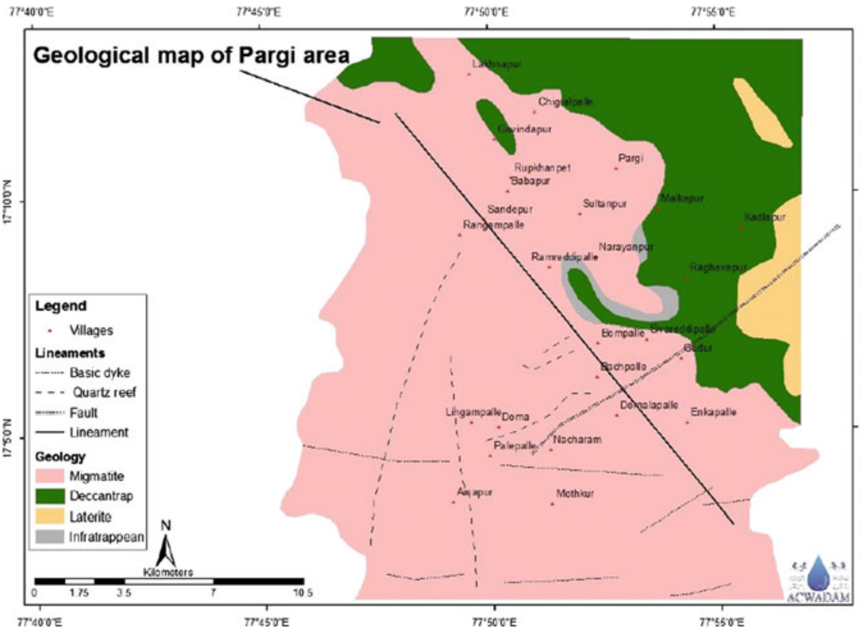


Fig. 12 Geological map of area around Pargi, Ranga Reddy District, Andhra Pradesh (after Geological Survey of India 1995)

irrigation to the rainfed crops and achieving water security with specific focus on drinking water. It has successfully demonstrated this groundwater sharing through borewells pooling in more than 100 villages and introduced the PGWM concept with significant change in agricultural cropping pattern based on participatory water budgeting exercises (Fig. 13).

Trainings and capacity building exercises for NGOs and government officials also organized to spread the knowledge and skills related to aquifer management and participatory groundwater management. It has demonstrated that large-scale replication of good practices is feasible through cadre building/training inputs to partners (village level to facilitators) on PGWM-related issues.

This study demonstrates social regulations evolving from within community with technological innovation like borewell pooling led to sustainable groundwater management and drinking water security.

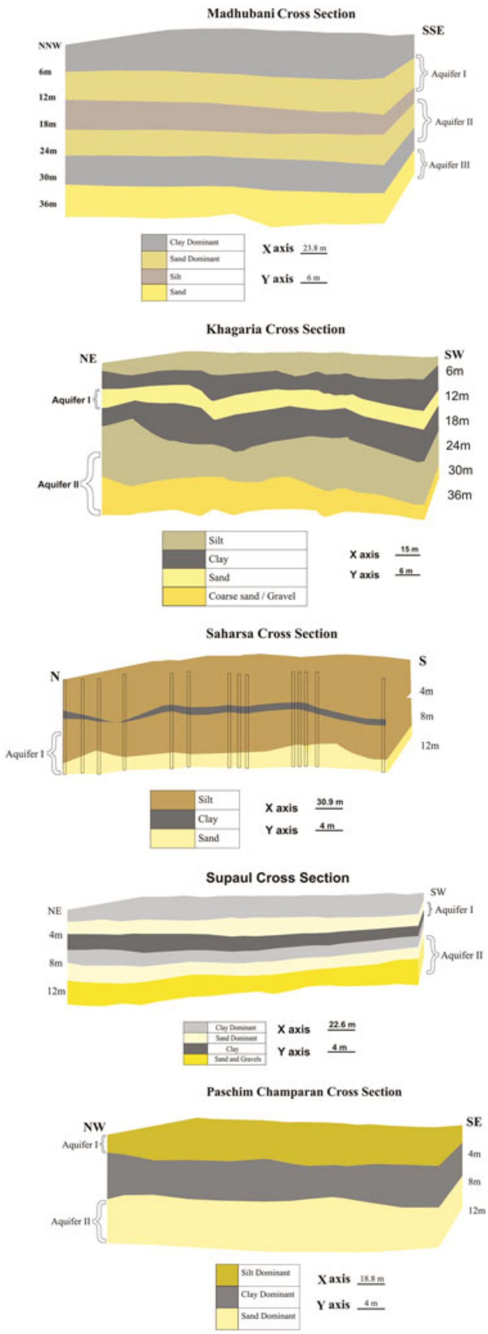
4.5 Alluvial Typology—Flood Plains

Floods in north Bihar are a recurring disaster and one of the most serious problems faced during floods is the inability to access safe drinking water. Groundwater is the only source of drinking water, for scattered habitations that dot the flat landscapes of flood-prone areas of north Bihar. While considering the region as water abundant, groundwater quality remains a serious issue to be addressed. Iron, arsenic, and biological contamination is widespread. Clearly, in such areas, the quantity of groundwater is of secondary importance as compared to accessing good-quality water.

Study taken up in these areas focused to enable the communities to shift from the contaminated hand pumps to community-owned dug wells as sources of drinking water. To add to the longevity and safety of the dug well, these communities engaged with design of the structure, hygiene, sanitation, and solid and liquid waste management at the individual household levels. The acceptance of phaydemandshauchalay (ecological sanitation), phaydemandsokta (banana circle), and phaydemand compost (compost) was encouraging and also went a long way in understanding and barricading the groundwater and sanitation nexus.

PGWM in alluvial flood plains of north Bihar aims to understand and address the high dependency on groundwater with the same principles and protocols for its management. Several communities in north Bihar are using geogenic—chemically (iron and arsenic) and biologically contaminated—water from hand pumps. Under PGWM guidelines, training, and capacity building, action research work commenced to help these communities develops an aquifer-based understanding of groundwater and evolves different options of long-term engagements with this common pool resource. Training and capacity building on key groundwater modules specifically designed for alluvial flood plains helped the communities, government officials, students, NGOs, and INGOs to understand various aspects of groundwater quality and quantity in these regions.

Fig. 13 Alluvial flood plain typologies in North Bihar (PGWM MPA and its partners 2016)



Alluvial flood plains of north Bihar area have unique typology of groundwater setting. It is a part of the great Indo-Gangetic plains, made up of sequences of loose unconsolidated sediments up to hundreds of metres in thickness, spread across regional expanses of land. Alluvial settings provide a very complex set of characteristics for groundwater studies. The storage capacities of such settings are exponentially higher than that of hard rock regions. High storage and high precipitation in north Bihar (approximately 1300 mm) and in the catchments of the Himalayan rivers in Nepal ensure that this region is persistently flood prone, with perennial surface water flow and shallow groundwater table. In addition, iron and arsenic contamination is widespread, but the distribution is poorly understood, and biological contamination is omnipresent.

The application of PGWM in the flood plains of Bihar has helped in understanding of groundwater hydrogeology of the aquifers including its sub-typologies. It also has evolved a nuanced understanding of floods in north Bihar and also its characterization while associating with water quality issues and possible solutions. It has facilitated in understanding the diversity within groundwater systems (availability, access, and contamination) in the alluvial flood plains and provided flood analysis and classified them under the following five sub-themes (sub-typologies): inside embankments, outside embankments, flash floods, general floods, and trans-boundary aquifers.

5 Conclusions

The PGWM principles, premised on groundwater as common pool resource, have now been demonstrated to be working across several regions and hydrogeological typologies. The approach invariably empowers the local communities, as managers of the local groundwater resource to make informed choices for achieving overall water security. The development and implementation of the water security plans is also a demonstration of bottom-up planning that fosters the agency of the communities with better outcomes for equity and sustainability. Peoples' participation encourages more collaboration with the government, yet less dependence on them for management. From passive recipients of water and sanitation services, communities have become active managers of the resource, in all the above cases. The community–government interaction also becomes much more informed and meaningful through this approach.

The outcomes of this approach go beyond mere drinking water security to resilience building of communities against climate variances such as rainfall, drought, and floods. The limitations of state's interventions for regulating groundwater use through punitive measures can be circumvented to a large extent by enabling communities to make informed choices—as has been demonstrated above through the instances of banning and regulating the depth of new borewells, shifts in cropping pattern, sharing of borewells, etc.

Peoples' participation is not new, and through this approach, the effort is to rediscover its contemporary relevance, meshed with a scientific temper. However, there are larger questions related to how peoples' participation would work with heterogeneous communities, in shared aquifer systems and its ability to deal with externalities such as urbanization, energy incentives, and other land use changes. The current phase of PGWM programme looks at collaborations with the state at various levels for scaling up the practice by using public investments and human resources of the state. Various technological options for data collection, collation, and analysis for decision support systems are being explored that could assist in accelerating the scaling up of the programme.

The draft model groundwater bill 2016 reflects several of the foundational principles of PGWM. The already expanding practice of PGWM across many states could pave the way for those state governments to change laws and frame policies informed by the draft model groundwater bill 2016, the draft national water framework bill 2016 as well as the proposed institutional reforms. Apart from the conjunctive use of surface as well as groundwater, the policies may provide the much needed legal backing for the community-based protocols and help in adjudication for conflict resolution and allocations for water sharing between various users of the common pool resource.

The programme's platform has also brought on board researchers and think tanks that are examining various legislations such as the Easement Act, 1882, relevant judgments of the supreme court forest policies and environmental acts, some of which support and some of which contradict the principles and practice of the PGWM programme. The need for responsive decentralized resource sensitive water governance is clearly being felt. A growing number of a community, NGOs, funders, academia, and governments at different levels are becoming a part of this collaborative effort that seeks to understand and manage the groundwater resources more sustainably and equitably.

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