COMPETITION AND CONFLICT AROUND GROUNDWATER RESOURCES IN INDIA

Himanshu Kulkarni And Siddharth Patil
Advanced Center For Water Resources Development And Management (ACWADAM), Pune

Forum for Policy Dialogue on Water Conflicts in India

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Children scraping the bottom of a spring box for drinking water in Tuensang district of Nagaland.
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16, Kale Park, Someshwarwadi Road, Pashan, Pune 411 008, Maharashtra, India
Tel: +91-20-20251168 / 2588 6542
Fax: +91-020-2588 6542
Email: waterconflictforum@gmail.com
URL: waterconflictforum.org; conflicts.indiawaterportal.org

Copies are available at the above address and at:
Advanced Center for Water Resources Development and Management (ACWADAM)
'Suvidya', 27 Kshipra society, Lane 3, Karvenagar, Pune-411052, Maharashtra, India.
Phone: +91-9172246959
Email: acwadam@gmail.com; acwadam@vsnl.net
Website: www.acwadam.org

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Abstract

India's growing groundwater dependency is exerting severe pressures on groundwater resources across the country's diverse aquifer settings. Stressed groundwater resources are not just about depleting and contaminated aquifers but also about a common pool resource coming under competition, leading to conflict between users. Competition for groundwater is observed not only within agriculture, domestic, industrial and ecosystem users but also between the users within each of these sectors. While surface water conflict often results from over-allocation of a known quantity of water and its misappropriation by individuals, groups or certain sectors, groundwater competition (leading to conflict) is a result of a race between the supply and demand wherein the stocks (availability and quality) are seldom gauged. A prolonged phase of groundwater competition usually precedes the phase of direct groundwater conflict.

The wide diversity of aquifer conditions present in India further complicates the arena of groundwater competition and conflicts. Even a broad typology of aquifer conditions reveals a range of drivers and impacts from competition and conflict across this wide-ranging typology of aquifers. Understanding the nature of the aquifer, along with the social, economic and ecological conditions under which groundwater resources are used from the aquifer, is important for understanding how competition unfolds as water conflicts emerge and how such conflict affects aspects of water equity and justice.

Similar water management responses to water scarcity across a wide-ranging aquifer typology lead to differentiated manifestations of competition having serious social, economic and ecologic ramifications. An increasingly larger number of users today have access to technology and resources that enable digging wells, installing pumps, digging deeper into springs and tapping a depleted source. The ability to access such instruments of developing groundwater resources can quickly turn into instruments of competition over groundwater, thereby resulting in inequality of access. As groundwater storages dry up because of aquifer-level depletion, users with multiple and / or deeper sources are better able to access the limited remaining stocks, leading to a condition of inequitable access and injustice, usually in case of the resource-poor.

The tension between the hydrogeological boundaries (aquifers) and the political-administrative boundaries (e.g. of villages, taluka or blocks, districts, states) is evident across the entire aquifer typology although manifestations are quite different. Such tensions shape the nature of competition between users and uses and how such competition unfolds in different ways over spatial and temporal scales. The characteristics of groundwater competition and conflict are not sufficiently researched, discussed and debated as part of the larger groundwater management and governance effort in India. This paper could serve as a beginning to address this gap so that discussions on groundwater management and governance will include aspects of social fairness and justice along with the typical buzzwords of efficiency, equity and sustainability of groundwater resources.

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Introduction

Groundwater is used widely across India for drinking water supplies, agricultural needs and industrial uses. Pictured here is a dug well created exclusively for ensuring drinking water for tigers in the Nagzira Forest Area, Maharashtra.

The continent of Asia uses 52% of the world's annual groundwater pumping in agriculture every year, while India alone uses 25% of the annual global groundwater pumping for all its uses (Margat and van der Gun, 2013). Various sources point to the high dependency on groundwater resources in India, with nearly 90% of rural drinking water pumped from India's shallow and deep aquifers, as well as 70% of water used in agriculture and 50% of the water supplied to cities (DDWS, 2009; Ministry of Agriculture, 2013; Narain, 2012). In a more practical context, the following statistics translate into interesting figures that have no parallel in human history:

1. Nearly 1 billion Indians use groundwater every day.
2. Some 700 million Indians use groundwater every day in rural India.
3. At least 420 million Indians use groundwater in agriculture during at least one season of the year

The Twelfth Five-Year Plan (2012–17) recognises that India faces daunting challenges in the water sector, with conflicts between competing uses and users of water growing by the day.

The early 1980s witnessed India's annual groundwater abstraction overtaking that of the United States (Shah, 2005; 2009). Even as far back as the late 1980s, Rushton (1990) reported competitive drilling and deepening from regions of Gujarat where emerging evidence showed the nexus between groundwater development, over-pumping and a race to access deeper sources of groundwater. Similarly, the long-term study of a single Deccan basalt aquifer in Maharashtra revealed that irrigation wells and drinking water wells tapping this aquifer in a single village were in competition, leading to public drinking water wells drying up (Macdonald et al., 1995). Based on several statistics on groundwater usage, about 60% of villages in India have potential competition around groundwater between domestic and agricultural usage. With increasing usage of groundwater in urban areas and in the industrial sector, this resource is not only stressed, but additionally, the degree of competition over its usage by different types of users has increased, leading to flash points of conflict.

The growing competition and conflict around groundwater resources in India is evident in many locations. For instance, the conflict between farming communities and the city of Chennai over filling up tankers for the city from wells used for agriculture is one such case (Janakarajan, 2008). The other well-known case involving Plachimada Gram Panchayat (village-level local-government institution formed through a constitutional process) and the Coca Cola Company is a case in point. Conflict around Coca-Cola's use of water from the groundwater system supplying Plachimada Gram Panchayat area led to a protracted legal battle over rights to groundwater (ELRS, 2012).

Increasing trends in accessing groundwater have resulted in the construction of millions of wells. While wells have been constructed by individuals with their own funds including farmers, collateral public investments in the form of subsidised drilling, pump systems and electricity have only increased the race to dig and drill for groundwater. It is evident that given the high dependency on groundwater for drinking and agriculture, there is an inherent competition for the resource between these two types of uses even within a single village. Drinking water security has been severely affected in parts of Punjab, Haryana, Andhra Pradesh, Telangana, Gujarat, Rajasthan and other regions that have undergone over-exploitation of groundwater due to uncontrolled pumping, primarily for irrigation. Growing urban pressures on already dwindling groundwater resources are bringing in another dimension of competitive extraction between urban and rural water users, especially in peri-urban spaces and during rural to urban transformations (Narain, 2012; NIUA, 2005; Shah and Kulkarni, 2015).

Environmental flows are also in a state of competition with the anthropogenic demand for groundwater. Such competition has essentially centred around the effects of pumping on base flows that otherwise provide perennial flows to many such rivers on the one hand and for the release of untreated effluents on the other. The health of a riverine ecosystem is thus severely affected by the overexploitation and contamination of aquifers, among many other factors.

This paper presents a broad-based narrative on groundwater competition and conflict, providing a largely qualitative account of the canvass of groundwater conflict, its scale and diversity, key drivers and impacts, with an end-piece on competition, equity and justice.

1 Canvass of Groundwater Conflict

Groundwater conflicts in India are not entirely visible. The nature of the resource, its invisibility and the complexity around sources, access and distribution of groundwater implies that open conflicts around groundwater are scarce. Wherever open conflict is evident, it is intense and complicated. However, what is commonly perceived is the intense and diverse competition surrounding groundwater resources. The next few sections describe the rather wide-ranging canvass of groundwater conflict, framed mainly around certain hypotheses and analyses pertaining to groundwater competition.

Surface water is visible and can be quantified through direct measurements, while the invisible nature of groundwater makes it difficult to understand and quantify. Photograph shows local resource persons measuring water levels in a well near a stream in Bhadar river basin in Chhatarpur district of Madhya Pradesh.

Groundwater invisibility : Precedence of Competition Over Conflict

Groundwater in an aquifer is sourced in a dispersed manner, and boundaries, quantities and interdependencies are less visible or measurable as compared to surface water resources, resulting in groundwater resources being subjected to intense and intricate competition between users and uses before conflicts become open (Kulkarni and Vijay Shankar, 2014). Moreover, individual access and complex distribution systems from multiple sources lead to complicated forms of competition over groundwater. Access and distribution take different forms and depend upon various social and economic factors. Often, understanding of resources is neglected in creating improved access and efficient distribution, leading to a contrast where the number of sources increases at the expense of creating a competitive arena that goes unnoticed for long periods before open conflict emerges.

Surface water is easily visible and therefore easier to measure volumetrically when compared to groundwater. Surface water is usually sourced through 'public' systems that have planned storages such as dams. Flows are regulated through means of distributing the water through flow in canals, channels, and pipelines. Measurement and monitoring of surface water are easier processes and can be planned, questioned and contested leading to the conflict itself (Kulkarni and Vijay Shankar, 2014). Social, political and even legal battles ensue because of the domain of allocations made possible through quantitative estimation of stock and flow of surface water. However, the allocation process itself is argumentative when questions of rights and priorities emerge despite legal and constitutional provisions. This leads to conflict and contestation spilling over into various forms ranging from protests to protracted legal battles. Administrative (land) boundaries often complicate matters leading to transboundary disputes between countries, states and other smaller administrative units.

The invisible nature of groundwater imposes severe limitations on easy understanding of the resource, and therefore, on its management and governance. Therefore, in the absence of quantification at the scales of the resource, i.e. aquifers, groundwater competition unfolds in myriad forms. In fact, many Indian states have formulated legislation that is currently in the form of either Bills that await constitutional procedures or Acts. However, the lack of a complete understanding of the resource has led to various forms and differing degrees of competition, even where overarching legislation exists. Moreover, data on groundwater is scarce and scattered, both from an analytical as well as a decision-making perspective (Vijay Shankar, Kulkarni and Krishnan, 2011; Shah, 2013). The Central Ground Water Board's (CGWB) national assessments are conducted at administrative units of 'talukas' or 'blocks'and in some States at watershed scales, while groundwater development, i.e. digging, drilling and pumping, is at scales of habitations, both urban and rural. In fact, both almost ignore the state of the aquifer in many ways. Hence, the mismatch between the scale of assessment and operations on the one hand and the lack of aquifer-level information and approaches on the other allow the proliferation of competition. As the study by Srinivasan et al. (2014) about the Noyyal River Basin in Tamil Nadu infers, "Groundwater use in India is largely unregulated and electricity is free, many farmers do not face absolute water scarcity, therefore, being able to 'postpone' scarcity by drilling deeper into the aquifer." Not only can this inference be extended to many parts of India's hard rock regions, but also such postponement of absolute scarcity is able to mask the growing competition and potential conflicts between different groundwater users for years, decades and even longer time frames.

Groundwater is sourced through millions of different sources such as different types of wells and springs. This picture shows three wells in close proximity to each other, in a small village in Ramgarh district of Jharkhand. The wells have been created under the MGNREGS programme. A source in every land parcel may improve access to water but may result in inherent competition over the resource (aquifer).

Distribution of water is usually about connecting to a source and supplying to an increasing demand. The photograph shows multiple pipeline connections installed in response to a growing demand for household connections in the town of Mokokchung in Nagaland. Each pipe is connected to the demand (household/hotel/institution etc.) downstream and to a common source, a spring, upstream. Each user is in competition with the others over the same source that taps a common resource (the aquifer, possibly feeding multiple springs).

Photograph showing people queuing up for accessing spring water brought down from mountain aquifers in the city of Kathmandu. The photograph is symbolic of the fact that access for the poor and marginalised (or generally, people who do not have household connections) is through common sources. Competition for groundwater,upstream, often affects the water security of an already marginalised population.

Groundwater competition : Paradox of Sources, Access and Distribution

Competition around groundwater is quite pervasive across India's diverse socio-ecological regions. Competition for groundwater occurs at all stages of groundwater resources development, i.e. during sourcing, access and distribution. Different users and uses share a common resource (an aquifer) through different types of sources. For instance, during ACWADAM's collaboration with Grampari — an organisation that works on rural development in the mountainous region of Sahyadris in Maharashtra — on spring water management in the source region of the Krishna River in the Western Ghats, new irrigation wells were found to be tapping the same basalt aquifer that supplies water to springs that meet the domestic needs of Akhegani village (ACWADAM, 2015i). Such competition often enables access to many users during the early stages of groundwater development, when the domestic demand of the community is secured through springs, the common source for many people. However, as sources such as wells and even springs are 'developed' and access is presumed to have improved with many individuals having their 'own' sources of water, groundwater resources from a common aquifer come under increasing pressure from both competing users and uses. Moreover, such competition deprives some sections of society from access to water, with further intensification leading to increased exclusion of the marginalised and poor (Kulkarni and Vijay Shankar, 2014).

The proliferation of shallow hand-pumps, which provide water to people in their backyards, has led to community sources running to seed in many regions across Bihar. The work of Megh Pyne Abhiyan (Gopalkrishnan, Cortesi and Prasad, 2011) — an organisation that works on village-level drinking water security across the flood-prone districts — and its partners in five districts of northern Bihar clearly points to the increased vulnerability of people with such improved 'individual' access, to problems like iron and to a lesser degree, arsenic contamination (Gopalkrishnan et al., 2011; Patil, Prasad, Kulkarni and Kulkarni, 2015).

In India, the silent revolution by individual farmers who started creating their own sources such as wells led to community sources either remaining the only access for the marginalised, especially the poor, or steadily dying out. This fact is especially evident in the case of traditional springs in mountainous regions such as the Himalaya, the Western Ghats and the Eastern Ghats. Distribution of water, even in many of India's public water supply systems, has come to symbolise connecting to a source and supplying to meet an increasing demand, often ignoring the resource on which the source depends. Hence, many public water supply systems that are based on groundwater ignore the competition with and between tens, often hundreds and sometimes thousands of private sources, even while the distribution system from the public source may seem highly efficient with an elaborate system of 'water infrastructure' such as pipelines and taps.

Groundwater Conflicts : Few, far Between and Intense

Open conflicts around groundwater though visibly rare do exist. Inevitably, such conflicts are a result of early competition when the groundwater resource that has an established usage pattern (e.g. mainly for meeting rural domestic and agriculture needs) changes to cater to a different demand (e.g. an industry or a growing urban centre). The changed usage becomes a rallying point that spills over into the arena of open conflict. In such cases, there is usually a phase of competition, as both groups of users attempt to access as much water as possible from a common resource, the aquifer (Kulkarni and Vijay Shankar, 2014), before the two sets of users are up in arms, sometimes even in actuality. The well-known case involving Plachimada Gram Panchayat (village-level local government institution formed through a constitutional process) and the Coca Cola Company is a case in point, where the right to groundwater access and use was strongly contested by both parties (ELRS, 2012).

While legal battles over open conflicts in the case of groundwater may be few and far between, groundwater competition is increasingly becoming a norm. A prolonged phase of groundwater competition usually occurs before conflicts come out in the open, as in the case of Velliyur village versus Chennai Metrowater Board in Tamil Nadu state (Janakarajan, 2008). In another example, tourism, construction and industry in Goa are in competition with rural needs over groundwater through tacit markets, as inadequate municipal supply has led to a reckless rise in groundwater exploitation (Dongre and Potekar, 2008).

There is a significant amount of groundwater usage in India's growing towns and cities (NIUA, 2005; Narain, 2012). As towns morph into cities and cities into metropolises, public water supplies fall short of the ever-growing demand. Under this scenario, groundwater not only remains the last resort for citizens who receive poor or no supply from the municipality, but its usage grows for various purposes (Narain, 2012; Shah and Kulkarni, 2015). Similarly, public water supply connections are provided to new constructions in many municipalities only after 'completion' of the construction activity, i.e. at the stage when the construction completion certificate is issued. Hence, most construction sites in cities like Pune opt either for boreholes (which are largely unregulated) or obtain water through tankers, the tankers themselves drawing water from wells located either in the neighbourhood or sourcing it from rural neighbourhoods. The level of drilling and pumping in such a situation fuels further competition around a heterogeneous aquifer system that also has limited groundwater storage.

Groundwater Competition and Conflict : Regional Peculiarities

India had some 30 million wells in 2009 (Shah, 2009), and given the projections of nearly 0.8 million wells added every year, today's conservative count would be close to 37 million. This clearly amounts to the largest density of wells in the world. Much of this density is evident in two main regions, where CGWB's latest national assessment of groundwater (CGWB, 2011) shows various hues of over-extraction. There are two clusters of groundwater exploitation in India. The first cluster of large-scale groundwater exploitation is evident in northwestern India, mainly across the region encompassing the states of Punjab, Haryana and Rajasthan along with parts of western Uttar Pradesh and Gujarat. In this area, large-scale groundwater exploitation has occurred in extensive and thick aquifer systems within unconsolidated sediments.

The second cluster of groundwater exploitation is in southeastern India, mainly within the states of Andhra Pradesh, Tamil Nadu and parts of Karnataka. This region is underlain by heterogeneous, relatively local, hard-rock aquifer systems. Both these regions have witnessed large-scale competition between well owners. However, the nature of the competition and potential conflicts are different in these two scenarios.

Even as far back as the 1980s, competitive drilling and deepening was reported from the alluvial aquifers of northern Gujarat by Rushton (1990), when many dug wells were converted to dug-cum-bore wells, and a large number of deep tube wells were also constructed as a consequence of assessments indicating a large supply of groundwater. The number of tube wells increased, and so did depths and costs. As shallower aquifers dried down or became saline, tube wells became deeper with strategic technologies to bypass the saline groundwater zones. Moreover, groundwater had to be pumped from deeper levels demanding pumps of higher rating. Wealthy farmers thus established de facto control over the resource and 'colluded' against the resource-poor, at the same time spearheading political mobilisation to defend access and control over groundwater resources (Dubash, 2002).

Since the size of an individual farmer's appropriation of groundwater appears too small in relation to the overall size of the aquifer, a common belief is that the scope for competition in such aquifers is quite limited. However, being in a low rainfall tract of western India, groundwater development in northern Gujarat led to rising costs of extraction and formation of what Shah (2009) called "collusive opportunism", wherein the economy forced farmers towards opportunistic co-operation to pool capital and spread risks.

Groundwater competitions in alluvial aquifer systems symbolise the transition from large-scale groundwater availability to that of expensive access. The vicious cycle of deepening tube wells reduces on account of groundwater overdraft and an ever-increasing expenditure to continue access to water, and creates newer arenas of competition, with an ever-increasing stake in groundwater extraction. In other words, it becomes crucial to access technology that can reach deep down and pump water from great depths which only well-to-do farmers can afford.

The groundwater economy around the alluvial aquifers of northern Gujarat is discussed by many researchers (Dubash, 2002; Kumar and Shah, 2004; Prakash, 2005), with Shah (2009) succinctly summing up the issue as follows: "Tube well companies enjoy a high degree of monopoly power; once a shareholder of a tube well company, a farmer can expect equitable access but non-shareholders end up as groundwater refugees who get excluded from the groundwater economy." Two clear-cut types of conflicts are evident in the Mehsana alluvial aquifer system, the first, between members of a well-organisation — like a groundwater users association developed around the well — where timelines of water allocation lead to conflict and the second, between members and non-members, with pricing being the major issue (McKay and Diwakara, 2008).

Punjab and Haryana present a somewhat different case when compared to the alluvial systems of Gujarat. Intensive water resources mobilisation, in the absence of systematic groundwater management and robust water governance, has led to extreme depletion of groundwater resources on the one hand and a rising water level, leading to water logging and soil salinity, on the other (Perveen et al., 2012). The paradox of extreme exploitation, with CGWB reporting a groundwater index of more than 110% (CGWB, 2011), coupled with severe waterlogging and soil salinization (Kulkarni and Shah, 2013) has led to various degrees and types of competition around groundwater. The competition is further compounded by ever-increasing, often competitive demands for agriculture, industry and growing urban centres.

Crystalline rocks, including igneous rocks formed millions of years ago by cooling of molten magma inside the earth or outpouring of lava on its surface, and metamorphic rocks that have been transformed significantly due to the effects of burial, temperature and pressure, constitute large parts of western and southern India. These rocks are commonly referred to as hard rocks. Many hard rock aquifer systems depend upon groundwater storage in their weathered zone and groundwater transmission through their fractures. These weathered-fractured hard rock aquifers offer a limited time frame for competition, but strong competition is evident nevertheless (Kulkarni and Vijay Shankar, 2014). These aquifers not only have limited storage of groundwater but are also quite heterogeneous, i.e. they have variable storage and transmission characteristics. This implies intense competition for a short period of time until the limited groundwater storage lasts.

In regions such as peninsular India, limited storage has not stopped processes of competitive deepening, as farmers find solace in drilling into deeper zones of rock fracture that work on the principle of quick transmission but poor storage. Such deeper aquifers often hold water from a compounded stock of multiple years of recharge and yield water for a few years. The process soon becomes uneconomical, wells tend to be abandoned, and users eventually shift to less water-intensive forms of livelihood (COMMAN, 2005), although farmers or users located in better yielding zones tend to have extended access while others fall short. Water scarcity and competition from industry are a problem in some pockets of agriculture in the Noyyal River Basin of Tamil Nadu leading to farmers abandoning agriculture, although other factors like labour scarcity for farm work and high returns from converting land to urban layouts also play a role (Srinivasan et al., 2014).

The competition for groundwater in hard-rock aquifers results in rising marginal costs for individual well owners and a declining share in the limited water available (Kulkarni and Vijay Shankar, 2014). Many rural public drinking water sources in the hard-rock regions of peninsular India, are located in regions of long-term groundwater exploitation. The competition between private irrigation wells and public drinking water wells in a single village often leads to a potential conflict between drinking water supplies and irrigation demand. The significant decline in water levels due to pumping from irrigation wells in a basalt aquifer has likely impacts on public water supply wells (Macdonald et. al., 1995).

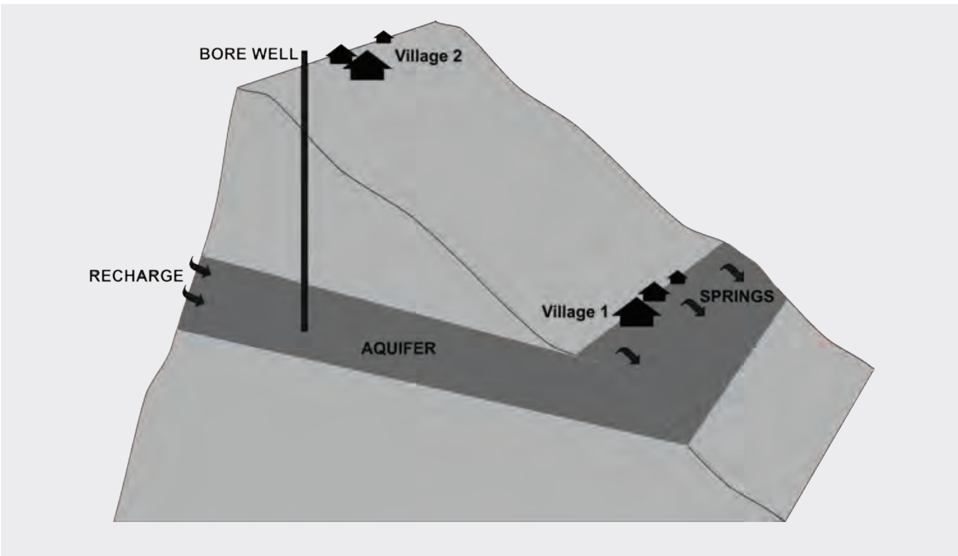
One of the wider fallouts of competition between wells in the hard-rock region of South India is the impact of such competition on stream and river flows. Drivers like groundwater pumping and land use change, rather than just climate change, are the most likely causes of the drying up of the Arkavathy River whose catchment overlaps with the western portion of the rapidly growing metropolis of Bengaluru (Srinivasan et al., 2015). Growing competition, especially in the dry, arid regions of India is driving users, especially farmers, not only to drill deeper but to extract water from river beds through temporary shallow dug wells called 'filter points' that are used to pump groundwater to farms located as far as 2–3 km away from the river. During a rapid hydrogeological reconnaissance of Barmer District in Rajasthan, a filter point density of 20 per km^2 was recorded (ACWADAM, 2015ii). These filter points 'skim' the fresh water that is temporarily perched atop saline water in the sand aquifer beneath the river bed just after the monsoon, implying that the status of competitive extraction has reached the limits of fresh water availability underneath the farmlands away from the river.

The population of the Indian Himalayan Region (IHR) according to Census (2011) is nearly 47 million, with a population decadal growth rate of just over 17%.[1] However, the tourist footprint in the region is large. According to provisional estimates, the IHR states showed tourist inflow of more than 50 million (Joshi, Kumar and Dhyani, 2016), clearly indicating the degree of increased stress on the water resources of the region. Mountain springs are the primary source of drinking water for a majority of rural households of the Indian Himalayan Region. In fact, many towns and cities also depend upon spring water as part of their public water supply. Spring discharge depletion is being widely reported across the Indian Himalayan Region for quite some time now. Rana and Gupta (2009) reported that half of the perennial springs in the region had either dried up or had become seasonal leading to an acute water shortage in nearly 8000 villages. The development of a 'springshed management' approach is being hailed today as a comprehensive methodology of spring revival and restoration (Tambe et al., 2011). However, what often goes unnoticed is the growing competition around spring water. This competition takes on various forms. For instance, in many villages and townships of Uttarakhand, Meghalaya and in the northern districts of West Bengal, our studies have picked up growing evidence of a competition between springs and bore wells that often tap into the same aquifer system conceptualised in Figure 1. Similarly, there is evidence of some springs in a village drying up, leading to a contestation with neighbouring villages about sharing of spring water, leading to even locking-up of some of the 'naulas' or spring-wells that were providing common access to multiple villages.

1. For more details about the Himalaya and the IHR, please refer to gbpihedenvis.nic.in/indian_him_reg.htm.

Millions of springs form the only source of water in mountainous regions. Increasing pressure from tourism and urbanisation has increased the access to groundwater through borewells that tap the same aquifers as the springs, leading to depleted spring discharges. The poor and marginalised suffer due to this competition for a common pool resource. Photograph shows children filling up water by scratching the bottom of a spring-box in Tuensang district of Nagaland.

Figure 1: Local Aquifers, Different Types of Sources and Competing Habitations



The preceding sections, although only indicative, clearly reveal that groundwater competition and conflict prevail in various forms across the Indian landscape. Hence, the canvass of groundwater conflict is not only large but is multi-dimensional and is influenced by various factors, both natural and anthropological. It would be useful to examine some of these factors that are primarily a consequence of the nature of aquifer settings on the one hand and the layering of the social milieu on the other.

2 Scale and Diversity in Groundwater Conflicts

Groundwater is a fugitive (cannot be held "captive" underneath a defined piece of land) and invisible (as a subsoil resource, it is largely unseen) common pool resource (CPR) (Blomquist and Ostrom, 1985; Ostrom, 1990). This very nature of the resource has allowed the proliferation of groundwater extraction structures in large parts of India. The most dramatic change in the groundwater scenario in India is the increase in the share of tube wells in irrigated areas from a mere 1% in 1960–1961 to 40% in 2006–2007. Such explosive growth of groundwater extraction is now evident across a wide range of hydrogeological and agro-ecological typologies in India (Shah, 2009). The impacts of groundwater exploitation and coterminous contamination are also quite diverse, given the diversity within the socio-ecological typologies of India. Therefore, the scale and nature of groundwater competition and the resultant conflicts are also quite varied. This section attempts to synthesise how the scale and diversity of groundwater conditions in India define the arenas for groundwater competition and conflict.

Some researchers argue that there is no fundamental reason why the temporary over-exploitation of aquifer storage for a given economic benefit is an undesirable process as part of a logical water resources management strategy, as long as the groundwater system is well understood in order to evaluate impacts (Foster, 2000; Price, 2002). However, in practice, India's groundwater resources development has preceded the systematic understanding of its aquifers. For instance, the National Project on Aquifer Management (NAQUIM), the flagship aquifer-mapping programme in India, began only around the year 2012. However, nearly 26% of India's districts showed various levels of groundwater exploitation even in 2009 (CGWB, 2011). Moreover, groundwater exploitation or contamination or both have emerged in nearly 60% of India's districts and across a diverse range of agro-climatic and hydrogeological conditions (Kulkarni, Vijay Shankar and Patil, 2015).

Groundwater exploitation in agriculture and growing urban centres tends to exhibit a competition about "who pumps out more and how quickly", either through deeper wells or larger pumps. The situation of erratic and uncertain electric supply in rural India only adds to such competition. In the race to access and pump groundwater, its common property value is rapidly converted to private goods. In other words, groundwater use is not subjected to a planned and controllable exploitation, as is the case in large parts of India. Hence, as Foster and Chilton (2003) point out, groundwater resource degradation is "much more than a localised problem" and threatens the sustainability of the resource base on a "wide-spread geographical basis".

A groundwater typology can be defined by a region's hydrogeological settings, aquifer scales and socio-economic factors (Kulkarni et al., 2015). These three factors on their own are quite variable across the country, imposing a significant amount of diversity in India's groundwater typology. India's geological diversity determines the variations in hydrogeological conditions not only across the country, but even within a single village or watershed. These conditions are reflected in well yields and in the short and long-term responses of aquifers to natural and anthropogenic fluxes.

India's geological diversity makes the understanding of aquifers challenging but all the more important because local situations often govern the nature and extent of groundwater competition and conflict. For instance, with nearly 650,000 rural habitations and more than 5000 growing urban centres, local situations govern the magnitude to which basic drinking water security is endangered due to various kinds of groundwater competition, under given levels of dependency and exploitation of groundwater resources, often from a single aquifer. Some of these conditions are discussed in the following sections, based on the broad typology of aquifer settings in India. Figure 2 and Table 1 show the six broad hydrogeological settings or typologies into which the country can be divided (COMMAN, 2005; Kulkarni and Vijay Shankar, 2009; Vijay Shankar et. al., 2011) and their surface (outcrop) areas.

Figure 2: Hydrogeological formations in India

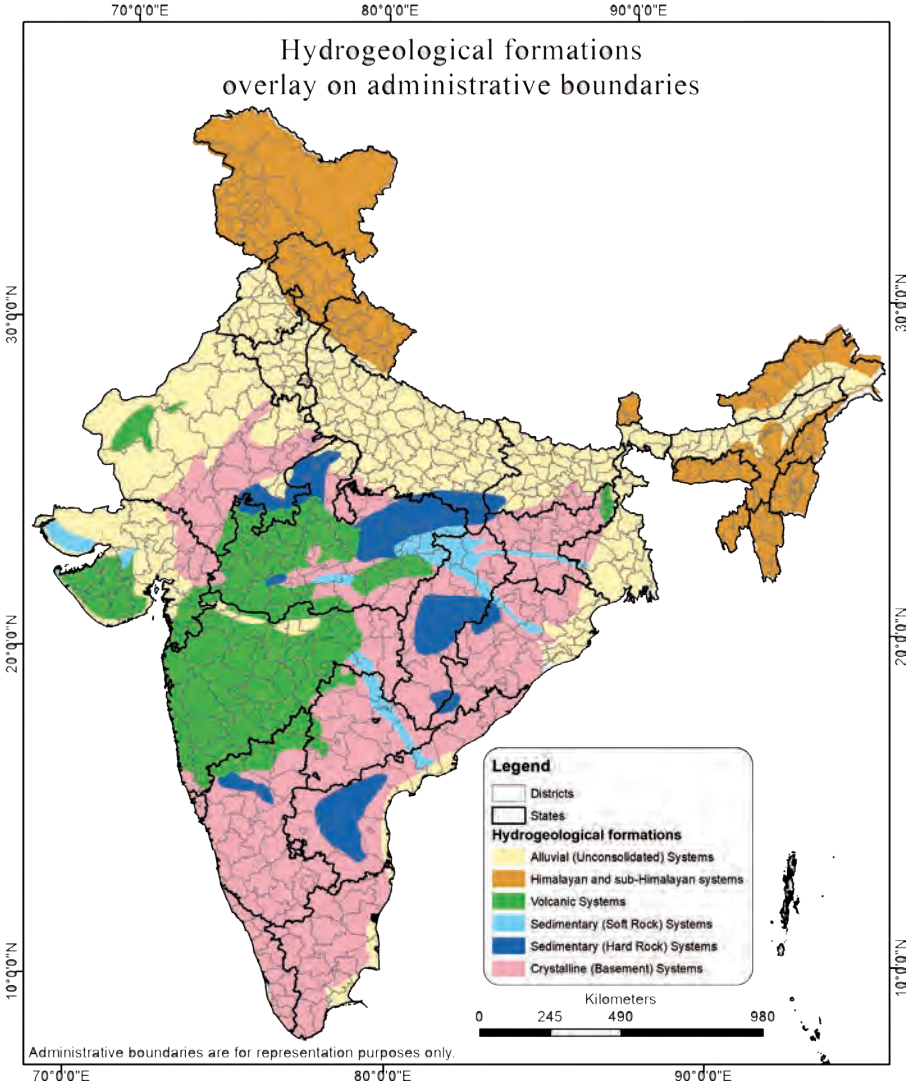


Table 1: Distribution of hydrogeological settings based on exposed surface area[2]

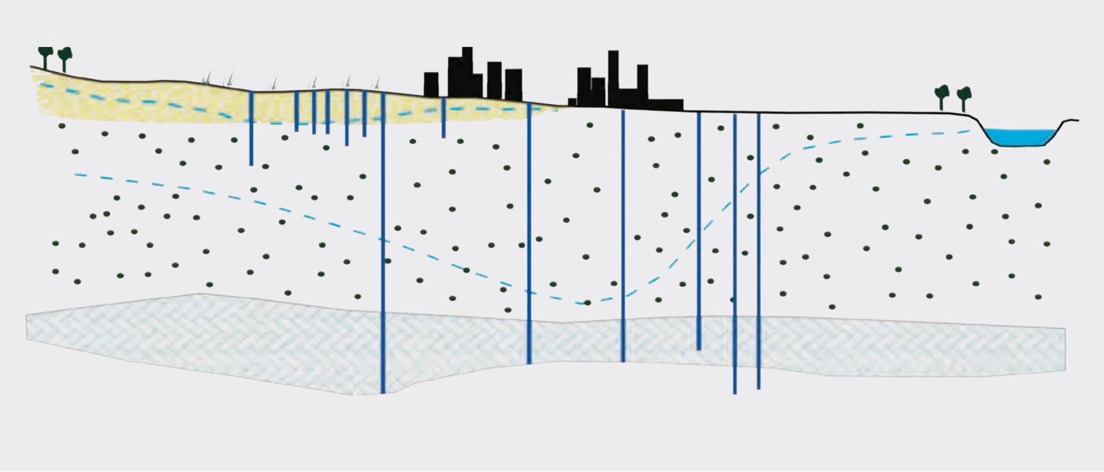
Hydrogeological setting	Area (km²)	Share in Total Area (%)
Alluvial (Unconsolidated) Systems	931,832	28
Himalayan and Sub-Himalayan Systems	525,067	16
Volcanic Systems	525,036	16
Sedimentary (Softer Rock) Systems	85,436	3
Sedimentary (Harder Rock) Systems	194,798	6
Crystalline (Basement) Systems	1,023,639	31
Total	3,285,808	100 (Total error 0.13%)

Brief descriptions of the characteristics of a typical aquifer setting from each of the six hydrogeological settings and the nature of competition and conflict are provided below. Representative cartoons of the conceptual section in each setting (based on Shah and Kulkarni, 2015) are also provided.

Alluvial (Unconsolidated) Systems

An alluvial aquifer setting is both extensive and thick. It is usually overlain by tens, even hundreds, of villages and towns/cities competing for a common resource that gives a sense of infinite abundance. Groundwater storage in an alluvial aquifer is not only large, but the layered sequence of alternating permeable and impermeable (clay) layers gives rise to multiple aquifers. Springs and seeps are also common, providing the base flow to small and large rivers flowing through the region. In multiple, overlying aquifers, with virtually infinite lateral boundaries, competition appears through a race to drill *deeper* and pump *more*.

Figure 3: Extensive alluvial aquifers: transboundary competition



2. The map and the table are based on generalisations drawn from various sources. They are used to provide a comparative synopsis of settings on the national scale. A more recent compilation of Aquifer Systems of India (CGWB, 2012) provides greater detail.

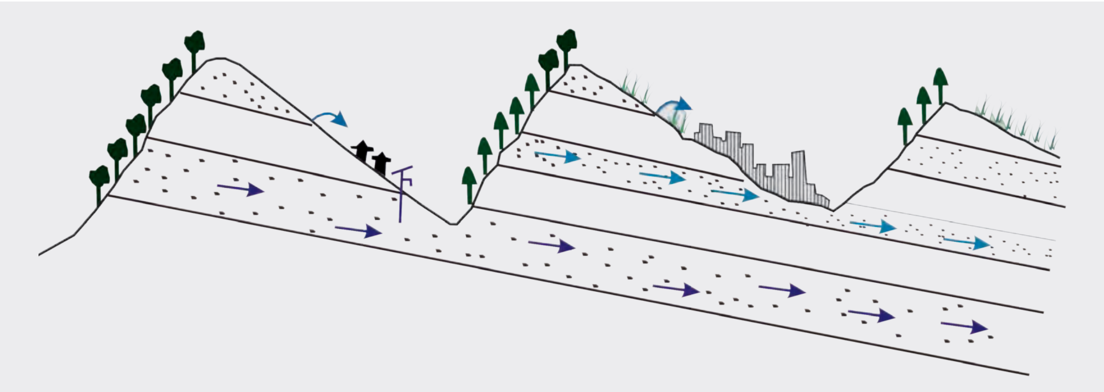
In some regions, such as Punjab, Haryana and particularly western Uttar Pradesh, one can notice that when the number of wells grows, some users with larger pump capacities can capture extra water, although the relative share of water available to each may progressively decline as water levels across the aquifer drop over the long term. However, the most significant and often hidden component in this aquifer setting is that of groundwater quality. Salinity, iron and arsenic are not spatially and temporarily consistent in groundwater, although there could be patterns of occurrence. In dense population pockets such as those in northern Bihar, the occurrence of these in groundwater leads to complex patterns of access to basic water such as that required for domestic usage, including drinking water. Often, community sources that are susceptible to biological contamination from poor sanitation are replaced with individual sources such as shallow tube wells wherein the presence of iron and sometimes arsenic goes unnoticed (Patil, et.al., 2011).

Some 46% of the large cities and 32% of small towns in India exist in the region underlain by alluvial aquifers (Shah and Kulkarni, 2015). Complex groundwater markets, both in the drier western regions and the eastern flood-prone region, are emerging as what Shah (2009) labelled 'collusive opportunism'. In a region that is riddled with the potential threat of several levels of contamination including that from growing industry and intensive use of chemicals in agriculture, competition and conflict over groundwater is looming large. With issues such as severe overexploitation on the one hand and water logging on the other, groundwater competition will only grow in the immediate periods across the alluvial aquifer setting.

Himalayan and Sub-Himalayan systems

Most of India's non-peninsular rivers originate in the Himalaya. Rivers like the Ganga and Yamuna originate as glaciers and bring down snow-melt and precipitation runoff in large quantities to India's flood plains. Some of the rivers, like Kosi, are transboundary rivers and flow across different socio-ecological environments. Springs are often the only source of reliable and sustained supply of freshwater for the inhabitants of this region. Mountain springs, locally known as 'dharas', supply water to 80% of households in Sikkim (Tambe et al., 2009). The CGWB's report regarding the groundwater scenario of the Himalayan Region (CGWB, 2014) also refers to the potential danger to the environment and overall sustainability of the Himalaya on account of the impact of unplanned exploitation and multifarious developmental activities on spring sources and groundwater.

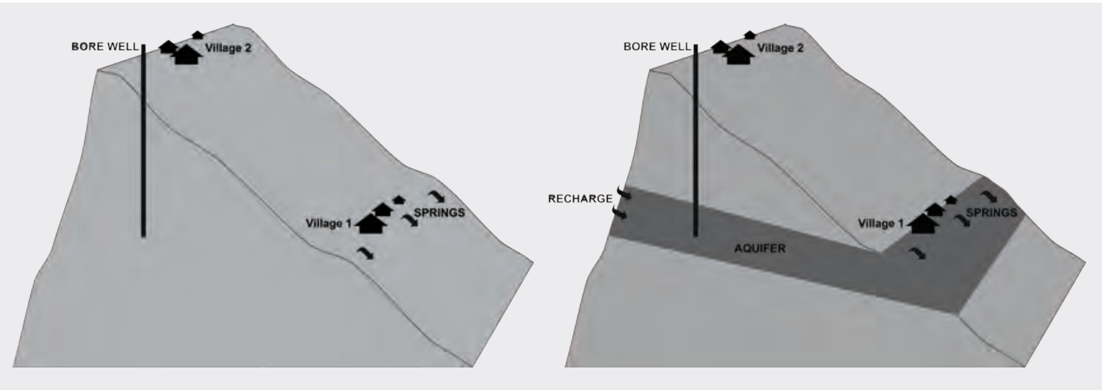
Figure 4: Himalayan systems: competition across watersheds



The reduction in the discharge of springs is attributed to deforestation, changing land use, intense grazing, and decline in rainfall (Valdiya and Bartarya, 1991; Rawat and Rawat, 1995). Changing climate, increasingly variable weather patterns and loss of forest cover alongside increasing demand for water resources due to a growing population, changing aspirations of people and an increasingly urban lifestyle have meant a growing competition around relatively low stocks of groundwater across the Himalayan countryside. Moreover, growth in tourism, spurt in construction and alteration of drainage patterns due to various forms of infrastructure development also affect the natural stocks and flows of groundwater, eventually impacting spring water discharge and quality.

The hydrogeological conditions prevailing across large parts of the region shows hydraulic continuity across watersheds. In simple terms, this translates to the fact that recharge of groundwater occurs in a watershed on one face of a mountain, finds its way through a fractured system of rocks, often dipping away from the slope, to emerge as springs on the other side (Figure 5). However, what this also implies is the unseen competition when bore wells are drilled down to the same layer (aquifer), and even pumped to create a competition with naturally discharging spring water. This competition could happen in one single village or across villages that share an aquifer underneath their lands or watersheds spilling over into conflict in the longer run, especially if the users that depend upon these two sources are mutually exclusive. Deforestation, open defecation or inappropriately designed sanitation systems in the natural recharge areas, of such a system, may further complicate the situation by affecting the quantities and quality of water available to both, the springs in village 1 and the bore wells in village 2.

Figure 5: Local aquifers, different types of sources and competing habitations



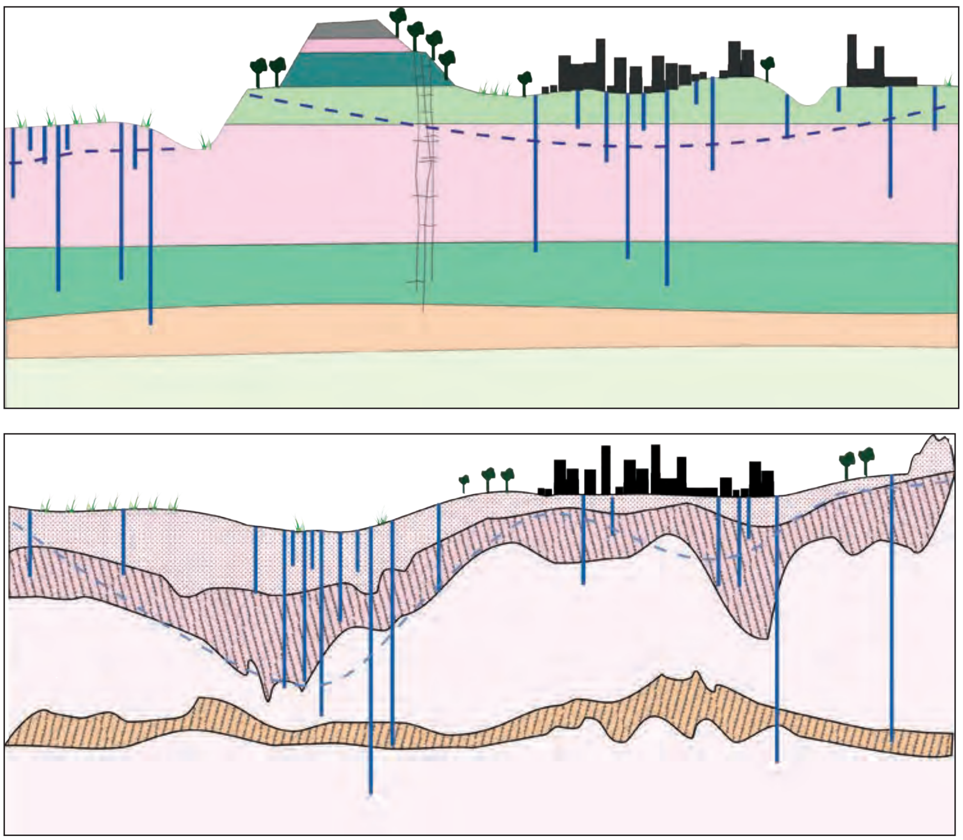
Extending the argument to a more regional scale is also important with regard to growing urbanisation and industrialisation affecting water sources and access to rural communities, especially down-slope (and down-dip). Contamination from both on-site sanitation and waste disposal clearly affect the quality of spring water used by villages surrounding such sites (personal communication, People's Science Institute, March 2017) because of the relatively rapid transmission of contaminants through the fractured aquifer system. This, in turn, creates competition in the affected villages to source clean water, but on a more serious note, it creates a potential arena for conflict across different types of water users — urban versus rural, or domestic versus industrial, or even urban versus industrial. Lastly, while agriculture has remained largely rainfed in the region, there are trends of shifting to irrigation, building another layer of competition around the fragile, low-storage aquifers in the region (Shah and Kulkarni, 2015).

Hard Rock Aquifer Systems: Volcanic and Crystalline Systems

Nearly half of India's geographical area, i.e. 46%, is underlain by hard rocks (volcanic and plutonic rocks along with metamorphic rocks) and is constituted of heterogeneous aquifers where conditions of groundwater accumulation and movement change significantly laterally and vertically. Crystalline rocks may subsequently outcrop on the surface due to erosion and tectonic movements. Groundwater occurs in these rocks in secondary openings due to the weathering of the rocks and/or fractures present in these rocks. Characteristics such as porosity and permeability of these rocks are limited resulting often in shallow aquifers or limited areal extent. Deeper aquifers in fractured zones also occur in some places.

Basalt aquifers are constituted through a horizontally stacked layered system of relatively high and low permeability units that show a range of properties even over short distances (Deolankar, 1980). Pumped heavily for irrigation in different pockets and increasingly being used for supplementing urban water supply as well as industrial requirements, competition unfolds over limited but layered stocks of groundwater, often within the same type of users.

Figure 6: Hard rock aquifers: searching for permeable horizons through competitive drilling



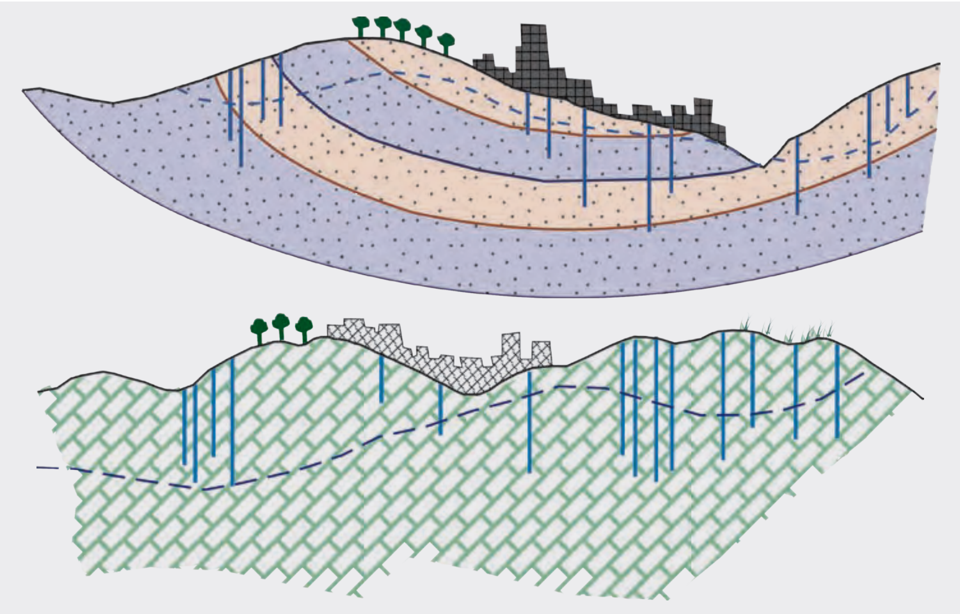
Older crystalline rocks such as granites, gneisses and other associated genres outcrop in large regions of peninsular India within the three main river basins of the region, i.e. Godavari, Krishna and Cauvery. In peninsular India, limited groundwater storage within the weathered and fractured crystalline rocks has not stopped processes of competitive drilling and deepening, as various types of users — from farmers to urban residents to industries — have drilled into deeper fractured zones as shallower zones deplete.

In both cases, aquifer depletion and mineralisation occurs rapidly during competitive development of groundwater resources. Rapid fall in water levels compels further deepening with higher energy requirements as groundwater has to be pumped from deeper levels. In Bengaluru, for instance, there have been various levels of well deepening, with some bore wells already touching 600 m depths. Hence, competition is essentially around who can drill deeper and strike water. This competition has further intensified in urban centres such as Bengaluru and Chennai with the introduction of technologies such as 'camera inspection' of bore wells, often followed by further development achieved by increasing fracture-flow through methods like 'hydraulic fracking' that take off from technologies in the oil industry. Easy and cheap access to such technologies also increases the degree of competition, particularly in urban centres.

Consolidated Sedimentary Rocks: Softer and Harder Sedimentary Systems

Rocks that have consolidated through millions of years after being deposited, deformed, weathered and fractured fall under this category. Sandstones, limestones and shales are the common examples. Sometimes these rocks undergo changes and become indurated due to certain processes like compaction and diagenesis (we have labelled these as harder sedimentary rocks). When such changes do not take place, the rocks remain softer (we have labelled these as softer sedimentary rocks). These rocks retain some intergranular porosity even as they go through processes of compaction, weathering and fracturing. Hence, they are more conducive to the accumulation and movement of groundwater than hard rocks.

Figure 7: Consolidated sedimentary aquifers: searching for permeable horizons through competitive drilling



Consolidated sedimentary rocks constitute only a small proportion (10%) of outcrops in India. These rocks are found in pockets spread over different regions of India. Incidentally, many of the regions underlain by these aquifers often correspond to forests, tribal communities and potential mineral resource hot-spots. They have a relatively smaller footprint of groundwater exploitation (Kulkarni et al., 2015), and possibly therefore, a significant amount of springs, wetlands and perennial rivers are found in regions underlain by consolidated sedimentary aquifer systems. Consolidated sedimentary rock aquifers have wide ranging spatial scales and therefore the time scales to exploitation (and contamination) vary over significant temporal scales (Moench, Kulkarni and Burke, 2012). These aquifers are quite regional, particularly in some limestone formations that have 'karst features' with high permeability and regional hydraulic continuity. Hence, groundwater flow is not only large in volume but takes place at regional scales. Some of these rock formations may hold groundwater that has been recharged over longer time frames of several years, maybe even hundreds of years.

Groundwater pumping in such aquifers, by and large, does not lead to competition and conflict at local scales, although some evidences are emerging from pockets in Central India where aquifers (harder sedimentary rocks) are local in nature (Kulkarni, Vijay Shankar, Deolankar and Shah, 2004). Increasing private access alongside public water supply for growing townships is evident from some such areas, especially urbanising centres in mining foci such as the coal belts of eastern and central India.

Mining for coal near Korba town in Chhattisgarh. The impacts of mining on groundwater can include dewatering and contamination of aquifers. At the same time, urban centres such as Korba that are growing rapidly owing to industrialisation show an increased access to groundwater through private sources that now tend to compete over dewatered and contaminated aquifers.

However, these aquifers, are facing competition between mining, tourism and industrialisation leading to distress amongst local (often tribal) populations, particularly in eastern India. Hence, the competition and conflict between extractive and ecosystem services of groundwater is most seriously felt in areas underlain by such formations where base flows to rivers is affected both in terms of quantities (due to removal of potential aquifer storage during mining, for instance) and quality (pollution from industrial and mining-related effluents). Many mines in the areas adjoining townships like Dhanbad and Hazaribagh in Jharkhand, Korba in Chhattisgarh and Chandrapur in Maharashtra are likely to have dewatered significant aquifer stocks during the process of mining, inadvertently affecting the groundwater component of the existing or potential water supply of such townships alongside release of contaminants like iron, fluoride and arsenic into groundwater (Kulkarni et al., 2015). However, more work is required on these aquifers as they remain the least researched, given their smaller percentage and their unique locations in the country.

The wide diversity of aquifer conditions present in India further complicates the arena of groundwater competition and conflicts. The scale of an aquifer is clearly one of the reasons for the nature of competition and resultant conflict. The congruence of aquifer systems with the overlying hydrological (from land parcels through watersheds to river basins) and administrative boundaries (from a single habitation of a small village to multiple habitations encompassing villages, towns and metropolises) also determines this competition. Even a broad typology of aquifer conditions that accounts for scales of aquifers from each of the hydrogeological settings described in the foregoing section, reveals a range of drivers and impacts from competition and conflict across this wide-ranging typology, summarised in Table 2 below.

Table 2: Groundwater settings and their relevance to competition and conflict

Regional groundwater settings	Aquifer scale and natural conditions prompting competition	Significance, with regard to groundwater competition
Mountain aquifers	Highly localised aquifers — non-coherent village, watershed and aquifer boundaries; springs being major sources of water supply but no reference to aquifers as resources	Major changes in land-use and the advent and proliferation of drilling for extraction is imposing competition between various types of uses — industry versus drinking water or agriculture versus drinking water or communities versus individuals; springs are drying up in some villages, as a consequence, even leading to depletion in base flows of small and large rivers
Unconsolidated sediment (mainly alluvial) aquifers	Regional groundwater systems (extensive and deep) — multiple aquifers with even a single aquifer overlain by many villages; each village can vertically tap multiple aquifers; potential competition between habitations rather than individual well-owners; wide ranging conditions from water logging on one hand to extreme exploitation of aquifers on the other; high vulnerability to groundwater contamination that often precedes quantitative depletion	Extremely variable investments required for access to groundwater; as depletion sets in large investments create marginalisation; competition is not restricted to 'quantities alone' but to the access of better quality water. Water intensive industries could 'capture' a large share of water from such aquifers without obvious impacts to neighbouring industries or to villages (agriculture and domestic water) until a point of conflict is reached

Regional groundwater settings	Aquifer scale and natural conditions prompting competition	Significance, with regard to groundwater competition
Consolidated sedimentary aquifers	Scales highly variable, from local to regional aquifers, hence scales of competition vary from neighbouring farmers to that between villages; many areas fall under the 'mining' sector, creating a competition between water used (pumped) from mines and the direct users	Impacts of groundwater quality tend to be more pronounced than impacts on the quantitative side, especially where there is large scale mining activity, creating competition for better quality groundwater and conflicts around high-quality groundwater
Volcanic rock aquifers	Highly heterogeneous aquifers that are stacked in the form of a vertical pile; watershed and aquifer boundaries are often coherent; a single village may be underlain by many aquifers but groundwater storages are limited leading to a large number of sources within both, a single type of use and multiple uses	Rampant competition is usually through digging and drilling deeper to access successive layers; many sources are created that compete for limited stocks; capacities to store groundwater are limited but large-scale surface water harvesting gives an impression of 'unlimited' recharge, often implying an intensification of competition after such measures are undertaken; springs in the upper reaches are also coming into increasing competition with sources like deep bore wells, leading to conflict between villages and private parties
Crystalline rock aquifers	Regional and local aquifer systems due to the complex relationships between shallow and deep aquifers; this results in variable scales of villages and aquifers; similar in some ways to consolidated sedimentary aquifers, but with tighter limits of storage and recharge cycles	Depletion of aquifer storage concurrently affects quantities and quality, making drinking water sources highly vulnerable; intense competition involving deepening of wells, widening of wells and progressive drilling of bore wells at well-bottoms eventually through independent deep bore wells; capacities to store groundwater are variable; large-scale surface water harvesting gives an impression of 'unlimited' recharge, often implying an intensification of competition like that in volcanic rock aquifers

Adapted from Kulkarni and Vijay Shankar, 2014

3 Groundwater Conflict: Drivers and Impact

This picture from a village in Neemrana in Alwar district of Rajasthan shows how groundwater usage is entirely governed by demand, with availability being seldom gauged. The photograph shows a well gone dry (right hand side). Subsequently, a handpump was drilled to access deeper water, which also ran dry owing to the competition from agricultural and industrial pumping in the neighbourhood. An energised borewell was then drilled to access deeper aquifers for supplying drinking water. The entire process is reflective of the story of groundwater development in India – chasing falling water levels with ever-evolving technology.

India is the largest user of groundwater in the world today (Margat and van der Gun, 2013). With increasing pressures on domestic, agricultural and industrial fronts, the already overstressed system of groundwater resources is coming under severe fatigue. However, stressed groundwater resources are not just about depleting and contaminated aquifers but also about a common pool resource coming under competition, becoming increasingly fragmented, usually resulting in gainers and losers, eventually leading to conflict between its multitude of users.

Competition for groundwater is observed not only within agriculture, domestic, industrial and ecosystem users but also between the users within each of these sectors. One of the most distinguishing features between surface water conflicts and groundwater conflicts is the ignorance of both, the quantity and nature of 'resource-stocks' that constitute groundwater. This ignorance makes groundwater a blind spot amongst many of its users, leading to a wide-ranging arena of competition described in the preceding two sections of this paper. While surface water conflict often results from over-allocation of a known quantity of water and its misappropriation by individuals, groups or certain sectors, groundwater competition (leading to conflict) is often a result of a race between the supply and demand wherein the stocks (availability and quality) are seldom gauged. As a consequence, one level of competition leads to another and so on, usually as a response of harnessing the 'flow' component of the resource.

The foregoing section clearly highlighted how similarities and differences in aquifer conditions create a range of conflicts surrounding groundwater resources. At the same time, the proliferation of technologies for easier and increased access to groundwater through different sources drives the competition over groundwater. What is even more important is that social drivers such as economics, caste and gender play a role in fuelling and intensifying competition around groundwater resources. Hence, we list three main drivers for groundwater competition in India. These are:

1. Aquifer settings
2. Technology
3. Social aspects

Aquifer settings

The layered nature of aquifers in an unconsolidated alluvial hydrogeological setting creates a notion of infiniteness of the resource. Groundwater storage per unit volume of aquifer material is large in these aquifers as compared to any other aquifer system. Unconsolidated alluvial aquifers are also homogeneous in nature. In multiple, layered alluvial aquifers, since aquifers have virtually infinite lateral boundaries, competition appears through a race to not only drill deeper but to extract water over longer periods of time, often at high rates. On the other hand, hard-rock aquifers have limited extent and thickness in addition to being heterogeneous, even in case they are layered. In such aquifers, digging wells and drilling vertical and horizontal bore holes are mechanisms that define competition in accessing a limited resource with uncertainties in well-yields. In mountain systems, regional flow (often of limited quantities) may result, connecting local aquifers and even surface water bodies, leading to competition between different types of sources that often goes unnoticed. Mineral deposits in sedimentary rocks tend to be far more valued than groundwater. This leads to competing demands between higher and lower valued uses across various scales in such aquifer systems. Clearly, hydrogeology and aquifer character form the first, natural drivers of competition.

The costs for drilling in India are extremely low, fuelled by the massive demand for accessing groundwater coupled with local ingenuity in manufacturing and operating drilling rigs. The dug well, which is at least a couple of thousand years old, has been far outstripped in numbers by borewells and tube wells, within a few decades. Easy and cheap access to technology – drilling in this case – has enabled people to access groundwater in their backyards, as and when they wish.

Technology

There is nothing new about accessing groundwater through different sources, whether globally or in India. With a few exceptions, groundwater abstraction around the world remained at relatively shallow depths until the end of the 19th century, although society's systematic exploitation of groundwater might have begun 9000 to 11000 BP, during the transition from foraging to sedentary farming (Moench et al., 2012). In India, the oldest known (step) well is dated between the 3rd and 2nd millennia BC at Dholavira in Kutch district, Gujarat[3], i.e. some 5000 years ago.[4]

Access to technology and energy will continue to dominate and entrench 'self-supply' of groundwater under liberal conditions that prevail in most countries (Jones, 2012; Moench et al., 2012). However, technology for deeper abstraction is relatively recent to India. Shah, Singh and Mukherji (2006) provide three interesting inferences from their analysis of South Asia's irrigation groundwater economy. To quote from their paper:

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3. See 'Excavations – Dholavira', at asi.nic.in.
4. Ankur Tewari | TNN | Oct 8, 2014, 01.20 AM IST, timesofindia.indiatimes.com.

1. South Asia's (including India's) agriculture experienced a major boom in tube well irrigation after 1970.
2. On the sub-continental scale, however, no single factor has played as dominant a role in creating new irrigation as the diesel pump.
3. Electricity subsidies result in a higher use of energy and water per hectare of land.

Competition around groundwater has and will continue to be driven by technology. However, the transformation that each layer of technology brings in improving access through different types of sources and water lifting devices also comes with its share of competition and conflict. To demonstrate this impact, we take the example of a single aquifer that has witnessed changing technology over a 15 to 20-year period. This is illustrated in the following table (Table 3) based on a simple model developed from average values of various parameters during studies on the typically heterogeneous, basaltic Pabal aquifer in Maharashtra during the period 1983 to 1996 (Kulkarni, 1987; Macdonald et al., 1995). The table shows how two technologies, sinking of wells and drilling of bore wells, and water extraction mechanisms drive the nature and degree of competition around a finite resource in a typical basalt aquifer.

Table 3: Simplified model of an aquifer under increasing wells and changing pumping technology

	Before 1984	**1984 - 1988**	**1988 - 1992**	**1992 onwards**
Number of wells	150	200	270	350
Technology of water extraction	Bullock driven leather sacks ("Mhots") – *similar to Persian Wheels or 'Rahets'*	Diesel powered centrifugal pumps	Electric pumps (mostly centrifugal)	Electric pumps (mostly submersibles)
Rate of extraction (litres per minute)	50	350	500	700
Average daily pumping hours	8	2	3	5
Average number of pumping days per year	100	100	100	100
Potential annual groundwater abstraction per well in m^3	2,400	4,200	9,000	21,000
Potential annual groundwater abstraction from the aquifer in m^3	360,000	840,000	2,430,000	7,350,000
Aquifer storage at optimum saturation in m^3	1,500,000			
Surplus or deficit when compared to annual available groundwater storage in m^3	1,140,000	660,000	-930,000	-5,850,000

	Before 1984	1984 - 1988	1988 - 1992	1992 onwards
Number of wells	150	200	270	350
Adjustments to cope with deficit between technology-driven demand and actual availability	None, but early deepening of existing wells as well as digging of new (deeper) wells with the realisation that most existing wells do not fully penetrate the thickness of the aquifer	Diesel pumps have their own limitations. This phase usually witnesses the seeds of competition with demands for rural electrification with subsidies alongside deepening of wells	Deepening of wells to tap into reserves that often do not exist (as most wells have reached full penetration of the aquifer thickness) with users drilling horizontal bore holes in different sections of the existing wells to overcome deficits	The larger deficit implies drilling vertically to greater depths; the deficit implies that wells in a typical basalt sequence must tap into at least three additional basalt aquifers to obtain yields to meet this demand; even when some farmers obtain such yields, they do not remain sustainable, needing another round of drilling

Modified after: Kulkarni, 1987; Macdonald et al, 1995; COMMAN, 2005

Social aspects

Conflicts over water distribution, water-derived benefits, and risks often play out along axes of social differentiation like caste, wealth, and gender (Joy, Kulkarni, Roth and Zwaverteen, 2014). Social drivers such as economics, caste and gender are clearly interlinked to both hydrogeology and technology aspects. However, even on a stand-alone basis, they can give rise to friction and conflict around groundwater resources. Dominant communities exchanged water amongst themselves on strictly controlled terms, and supplied water to subordinate groups in highly exploitative ways, involving sharecropping arrangements (Hardiman, 1998) in the region underlain by alluvial aquifers in northern Gujarat. Moreover, Dubash (2000, 2002) clearly shows how competitive extraction and falling water levels led to a shutting out of the lower castes, typically marginal farmers and the landless, from well ownership altogether, in the water-scarce environment of northern Gujarat.

Similarly, in hard-rock regions of Tamil Nadu, differential impacts of irrigation across social groups are clearly evident (Janakarajan and Moench, 2006). Competition in pumping, accessing groundwater under falling water tables and competing for uncontaminated water all tend to deepen social divides along both economic (rich versus poor farmers) and caste (upper versus lower castes) lines. The rich and dominant castes are able to own and control groundwater through ownership of productive wells while the poorer castes despite owning wells are trapped in a regime of constantly recurring investments without assurance of substantial returns (Kulkarni and Vijay Shankar, 2015).

The classic case of contamination of groundwater illustrates how the dimension of gender is interwoven into the drivers and impact of groundwater competition and conflict. The identification of contaminated wells may lead to greater conflict over uncontaminated water, especially in the form of greater hardship for women procuring water for daily domestic usage (Crow and Sultana, 2002).

The other aspect is how even in a village sectoral division of water is along the gender axis. For instance, in Gujarat, Maheshwari et al. (2014) found that although women are found to be significantly involved in irrigated agriculture in two watersheds, the revenue generated from agriculture is entirely controlled by men. This study further mentions how this division clearly separated intra-household activities according to gender, impeding women's access and control over this scarce resource.

The impacts from groundwater competition are quite varied depending upon the context of the competition. The most significant impact of ever-increasing groundwater extraction has been the widening gap between those who have and can retain access to groundwater and those who cannot. This gap is a consequence of both the socio-economic capacity to access deeper and/or safer quality groundwater, and the hydrogeological regime under conditions of groundwater over-extraction and/or contamination, with impacts being varied, even over limited parcels of land in a heterogeneous aquifer (Kulkarni and Vijay Shankar, 2014). The broader impact across various hydrogeological settings implies that agricultural productivity may increase on account of improvements in the sourcing and access of groundwater, but often leads to increasing competition which then poses questions with regard to the sustainability of the sources as the resource (aquifer) undergoes depletion and contamination. Moreover, as the resource depletes or deteriorates, solutions to overcome the problem are usually in the form of technologies that often fuel further competition, even resulting in conflict between parties.

One of the large impacts of competitive extraction of groundwater is the unregulated use of energy to gain quick and more access to limited stocks of groundwater, widening the gap between the haves and have-nots. In more recent times, it has become obvious how the extractive services of groundwater have overtaken the ecosystem services in different regions of India, creating four domains along the two axes of groundwater services representing extractive and ecosystem dimensions (CGIAR Research Program on Water, Land and Ecosystems (WLE), 2015). When the extractive service from groundwater begins to exceed its ecosystem services with increasing share of groundwater usage to surface water, natural sources of groundwater such as springs come into competition with sources such as wells to the extent that springs are often converted to wells, thereby altering the nature and degree of competition between these two types of sources. Access domains also change and community sources can quickly change to private sources.

4 Groundwater Conflict: Competition, Equity and Justice

A photograph of Leh town in Ladakh district of Jammu and Kashmir. Increasing urbanisation fuelled by tourism has led to a spurt in drilling of borewells. There has been a direct impact on the springs due to such drilling. Such springs, called 'chumiks' locally, not only provided drinking water to the local dwellers, but also provided the required soil moisture for agriculture in close proximity to the springs. Groundwater use by the tourism industry is competing with groundwater use for agriculture, drinking water as well as ecological services even though sources tapping a common aquifer system are seemingly different.

Water conflicts are becoming endemic at all levels in India (Briscoe and Malik, 2006) with various social, economic and ecological dimensions to these conflicts (Joy, Gujja, Paranjape, Goud and Vispute, 2008). The invisible and fugitive nature of groundwater makes it difficult to perceive, understand and mitigate groundwater competition that precedes potential conflict. The growing gap between an increasing demand and dwindling supply is a consequence of both the socio-economic capacity to access deeper and/or safer quality groundwater, and the hydrogeological regime under conditions of groundwater over-extraction and/or contamination. While groundwater usage in India has helped in improving food production, it raises crucial issues regarding water, such as access, rights and justice in view of growing competition, environmental degradation, and calls for regulation and enforcement of such usage (Kulkarni and Vijay Shankar, 2014). At a broader scale, an important reason for a specific ‘water justice’ focus lies in the existence of a wide variety of time-, place-, and context-specific conceptions, definitions and perceptions of water rights (and rights to water), as well as related notions of legitimacy, equity, and justice (Roth, Zwaverteen, Joy and Kulkarni, 2014). At the same time, various dimensions of groundwater rights and justice have been succinctly elaborated in various papers under the special issue on “Water rights, conflicts, and justice in South Asia”, Roth et al. (eds.), 2014. We use some of the salient contributions from the issue to highlight the spectrum of contexts and the complex nature of the interrelationships between competition for groundwater, equity and justice in this section.

The extensive use of groundwater in India, cutting across users and benefiting some while marginalising or excluding others leading to competition and potential conflict, raises many challenges on the subject of water justice. These challenges are evident at different scales: among farmers, between farmers and the village as a community, drinking water versus irrigation and irrigation versus industry. The largest contribution of groundwater, volumetrically, has been in agriculture. Nearly 70% of water in agriculture is groundwater (Ministry of Agriculture, 2013). Conflicts and competition, therefore, are bound to be significant in the sector. It is beyond the scope of this paper to cover the spectrum of groundwater conflicts across the range of hydrogeological, social and agroclimatic zones of the country. However, we provide two examples to illustrate the dimensions of equity and justice in the competition for groundwater in agriculture.

Firstly, we provide an example (Badarayani, Upasani, Dhawan and Kulkarni, 2009) from an area in Pune district underlain by mixed geology. A single village (Pandeshwar, Purandar taluka, Pune district) taps two different aquifer systems. The first is a fractured basalt aquifer, with limited permeability and groundwater storage, occupying the highland portions of the village. Being an inert rock (chemically) and with small but quick groundwater flow, the groundwater quality in this aquifer is very good, without any significant contamination. The other aquifer is a deposit of sand and gravel that overlies the basalt in the low-lying portions of the village. The sand-gravel aquifer has good groundwater storage accumulated perhaps over many years of recharge. Groundwater in this aquifer has relatively higher dissolved solids than the basalt aquifer. Most rainfed and subsistence farmers were tapping the basalt aquifer until some of them moved to cash cropping, resulting in an increased groundwater extraction from the basalt aquifer and leading to progressive drying up of wells.

On the other hand, most of the groundwater extraction from the sand-gravel aquifer is for sugarcane cropping. The wells in this aquifer retain water in the summer as well despite the extraction. While the disparate situation of the two sets of farmers is clearly apparent and can be attributed to their location, clearly ascribing a case of iniquitous demand and supply from the two aquifers, drinking water is a common problem to both sets of people and to the village at large. The freshwater availability from the basalt aquifer has been impacted by increased extraction, while the water available in the sand-gravel aquifer is not potable due to the high degree of salinity in wells that have water during the summer. The result is a regular supply of tankers to meet the summer drinking water demand in the village.

So, does the above example point us to the fact that better organisation of a community into water user associations or mechanisms of participation ensure improved equity and justice? The answer lies in the example from northern Gujarat. Here, conflicts between members and non-members of well-user organisations are deeply entrenched in a race for groundwater exploitation that is connected to profits associated with water sales by ground-owned wells (McKay and Diwakara, 2008).

India's groundwater crisis is discussed in great detail in many recent works with the overarching need for improved water governance (Shah, 2009; Shah, 2013; Kulkarni et al., 2015). However, Joy et al. (2014) argue that water expertise and policies tend to assess and justify such water re-allocations on grounds of efficiency, effectiveness, or productivity, rather than on the basis of (anticipated) implications for social equity or justice. They go on to state that Indian examples of re-allocations and the intensification of conflicts suggest that access to and control of water become increasingly concentrated in the hands of a few privileged actors — often those with the capacity to invest in technological means to access it, to the detriment of many others. Envisaging the argument with regard to surface water is easy but the complex socio-ecological dimensions of groundwater make things more complicated. For instance, at another scale altogether, groundwater gets reallocated from aquifers due to both a change in the access from a single or multiple aquifers and the change in demand even when the overall stakeholder base remains constant — say the farmers in a village. This clearly brings to light not only how the equity equations change in the area, but how they change in time as well.

Moreover, users tend to accept solutions surrounding efficiency of groundwater usage, but improving equity remains the largest challenge when working even in a small, remote village in India, primarily because of two factors. The first is a reluctance to acknowledge heterogeneity in nature that ascribes the first level of inequity to the groundwater resource, particularly in the hard-rock regions of India. And the second, there is a tendency to compete so that there are fewer haves than have-nots in the competitive game of sourcing and access to groundwater.

This confusing mosaic of definitions and interpretations around 'right to water' and 'water rights', which are clearly distinct, is highly conducive for the ongoing privatisation and appropriation of dwindling water resources, contributing to water injustice of a serious order (Krishnan and George, 2014). In the case of groundwater, moreover, the basic question of rights is often linked to land-rights. Delinking of land-rights and access to water, although difficult is desired (Kulkarni et al., 2015). Further, in the case of groundwater, for instance, rights are also framed around the question of sourcing water. Sourcing water is viewed in many domains as a fundamental right of a landowner to dig or drill a well in his plot of land. Seldom is there any acknowledgement of the fact that water in her or his well may well have moved through the aquifer underneath the lands of not only several neighbouring farmers but also may have travelled from underneath lands covered by forests and by the village itself.

Urban expansion leaves a strong ecological footprint on peri-urban locations by appropriating land and water to augment urban water supply, while discharging urban wastewater, which is widely used in agriculture but with adverse health consequences (Narain, 2014). As towns and cities grow, one witnesses both lateral and vertical growth in which groundwater is an integral component. Privately driven, individualistic pumping of groundwater in large parts of urban India has provided benefits by filling gaps in public water supply (Shah and Kulkarni, 2015). However, the marginalised and poor often get left out of such access either because they do not have resources to access supplementary groundwater on their own or because they are located in areas where such access is limited due to social (lack of space to create a source), economic (lack of resources to develop common sources) and hydrological (lack of resource character — no aquifers or contaminated aquifers or exploited aquifers) reasons. Aspects of equity and justice are far more complicated in the case of urban aquifers because of the huge gaps in knowledge not only about urban aquifers but the place of groundwater within the larger arena of urban groundwater competition and conflict.

Rural India virtually depends upon groundwater to meet its domestic requirements. With groundwater exploitation acknowledged in some 25–30% of India's blocks (CGWB, 2011), it is clear that domestic and agricultural demands from a common aquifer system have come under intense competition, even within a single village. However, such competition has serious equity-related ramifications. For instance, summer water scarcity in a groundwater dependent village in Surendranagar, Gujarat, not only brings out caste dynamics, but also affects the landless and lower caste women the most due to harassment by upper castes who are able to shift their summer residences closer to farmland wells with water (Prakash and Sama, 2008). This glaring case of iniquitous access brings us to the question of privatised, structured markets that are often part of the groundwater economy like the alluvial aquifer system of northern Gujarat. Tube well companies in Mehsana, for instance, enjoy a high degree of monopoly power; once a shareholder of a tube well company, a farmer can expect equitable access, but non-shareholders end up as groundwater refugees who get excluded from the groundwater economy (Shah, 2009). Hence, groundwater markets may create a certain degree of equity in access to and distribution of groundwater, but are not always inclusive of all stakeholders, particularly in the advanced stages of water level decline and competition in aquifers (Kulkarni and Vijay Shankar, 2014).

Finally, while the clamour for stricter groundwater regulation grows in certain circles, with Maharashtra having recently passed its comprehensive Maharashtra Groundwater (Development and Management) Act, 2009, many states have lined up Bills and Acts as part of their approach to groundwater regulation. The recent effort at reforms by the Ministry of Water Resources included the redrafting of the Groundwater Model Bill. However, while there may be allusion to competition and conflict in some of these Bills and Acts (including the recent Groundwater Model Bill), most regulation deals with access to groundwater, the impacts of pumping, and groundwater contamination, but scant attention is paid to understanding groundwater in its natural state. Many of these Acts, Bills and Laws link landownership to legitimate access to groundwater, resulting in the exclusion of the landless from access to a resource that is, in a normative sense, increasingly regarded as "common" or "public" (Kulkarni and Vijay Shankar, 2014). Moreover, the lack of a clear articulation of rights and duties in the legislative framework for groundwater, including the policies that deal with it, raise questions about equity especially in such a competitive environment wherein uses and users of groundwater are located. Finally, the limited visibility and data on groundwater resources often create a conflict in the domains of legislation and jurisprudence. In the Plachimada case in Kerala, the Division Bench of the High Court of Kerala, asserted the primacy of landowners' control over groundwater in the absence of a specific law prohibiting extraction, while prior to this, the single judge of the High Court had used the principle of public trust and its link to the right to life and stated that a system leaving groundwater exploitation to the discretion of landowners can result in negative environmental consequences (ELRS, 2012).

Conclusion

While the typology of aquifer conditions described above provides a platform to differentiate between the nature of competition across it, there are also similarities in responses to water scarcity across the typology, leading to differentiated manifestations of competition through a set of similar actions by users — actions that have serious social, economic and ecologic ramifications. Users, for instance, respond to scarcity — either due to rainfall failures (temporary) or due to aquifer depletion because of over-extraction — by increasing the number of their sources or by installing higher capacity pumps to gain quicker and greater access, and by expanding their scope of access laterally and/or vertically through available technologies. An increasingly larger number of users today have access to resources that enable digging wells, installing pumps, digging deeper into springs and tapping a depleted source. The ability to access such instruments of developing groundwater resources can quickly turn into instruments of competition for groundwater, thereby resulting in inequality of access. While the overall long-term impact may be groundwater overuse to which a large section of users are party, fundamental access to water in groundwater dependent situations in such instances leads to increased inequity amongst users. As groundwater storages dry up because of aquifer-level depletion, users with multiple and / or deeper sources are better able to access the limited remaining stocks, leading to inequitable access and injustice, usually in case of the resource-poor.

A prolonged phase of groundwater competition usually precedes the phase of direct groundwater conflict. Understanding the nature of the aquifer, along with the social, economic and ecological conditions under which groundwater resources are used from the aquifer, is important to explain how competition unfolds as water conflicts emerge and how such conflicts affect aspects of water equity and justice. Groundwater management and governance, especially in India, must consider the dimension of groundwater competition and conflict. Thus, the primary requirement in devising governance and management responses in different situations of groundwater competition is to clearly understand the aquifer, the nature and characteristics of the sources that are used to access the aquifer, aquifer characteristics and the demands and dependencies of communities on the aquifer.

The tension between the hydrogeological boundaries (aquifers) and the political-administrative boundaries (e.g. of villages, talukas or blocks, districts, states) is evident across the entire aquifer typology, although manifestations are quite different. A common observation is that competition turns into conflict when an aquifer that is being used to supply water for a certain purpose suddenly begins to also cater to demands for a different purpose. For instance, the competitive arena for the use of groundwater for irrigation may suddenly turn into a conflict when competitors (irrigation) rally against a new user (industry), even after a phase when both groups of users attempt to access as much water as possible in a common resource, the aquifer. These conditions shape the nature of competition between users and uses and how such competition unfolds in different ways over spatial and temporal scales.

This paper is a broad, sweeping narrative around certain arguments related to groundwater competition and conflict. However, it surely raises the fundamental question around how many of the groundwater conflicts — from competition to contestation — get reported and synthesised. It therefore suggests a systematic approach at first compiling stories and narratives from different parts of India across a variety of scales. This compilation of case studies could cover a wide-range of narratives, analyses and syntheses of groundwater competition and conflict from different parts of India. These case studies could be based on work on the ground by civil society organisations, activists and government departments working on water in general and groundwater in particular. It is quite likely that during such work they have come across competition and conflict around groundwater resources. At the same time, these case studies would become equally important because in most cases, there could have been an attempt to address competition and conflict as part of a larger groundwater management agenda either through direct community-led action or through some process of policy engagement. Surely, there are many more cases that justify documentation. Such documentation could be a beginning for bringing out more such cases with the hope that appropriate responses can only be designed when the characteristics of groundwater competition and conflict are sufficiently researched, discussed and debated as part of the larger groundwater management and governance effort in India, that ought to increasingly include the aspects of social fairness and justice along with the typical buzzwords of efficiency, equity and sustainability of groundwater resources.

References

ACWADAM (2015i). *Hydrogeology of spring systems in Western Ghats – with special reference to select springwater systems of Pachgani – Mahabaleshwar Region, Satara district, Maharashtra*. Advanced Centre for Water Resources Development and Management (ACWADAM). ACWA/Hydro/2016/H45.

ACWADAM (2005ii). *A hydrogeological reconnaissance of parts of Barmer district – based on a rapid field appraisal.* ACWADAM Technical Report.

Badarayani, U., Upasani, D., Dhawan, H. and Kulkarni, H. (2009). *Hydrogeological studies for improved groundwater management strategies in the dryland areas underlain by Deccan basalts: An initiative in Purandar taluka*. ACWADAM Technical Report ACWA Report, H-09-1.

Blomquist, W. and Ostrom, E. (1985). Institutional capacity and the resolution of a commons dilemma. *Review of Policy Research*, *5*(2), 383–393.

Briscoe, J. and Malik, R.P.S. (2006). *India's water economy: Bracing for a turbulent future*. Oxford University Press, New Delhi,World Bank, 79 p.

Census of India (2011). *Primary census abstract – Data highlights*. Census of India, Office of Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India.

CGIAR Research Program on Water, Land and Ecosystems (WLE) (2015). *Groundwater and ecosystem services: a framework for managing smallholder groundwater- dependent agrarian socio-ecologies - applying an ecosystem services and resilience approach*. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 25 p. doi: 10.5337/2015.208.

CGWB (Central Ground Water Board) (2011). *Dynamic ground water resources of India* (as on March, 2009). CGWB, Ministry of Water Resources.

CGWB (Central Ground Water Board) (2014): *Dynamic ground water resources of India (*as on March, 2011). CGWB, Ministry of Water Resources.

COMMAN (2005). *Community management of groundwater resources in rural India*: Research report. British Geological Survey Commissioned Report CR/05/36N.

Crow, B. and Sultana, F. (2002). Gender, class and access to water: three cases in a poor and crowded delta. *Society and Natural Resources*, *15*, 709–724. Taylor & Francis. doi: 10.1080/0894192029006930 8.

Deolankar, S.B. (1980). The Deccan basalts of Maharashtra, India – their potential as aquifers. *Ground Water*, 18 (5), 434–437.

DDWS (Department of Drinking Water and Sanitation) (2009). *Mid-term appraisal of 11th plan – rural water supply*. New Delhi: Department of Drinking Water Supply, Ministry of Water Resources, Government of India.

Dongre, S.M. and Potekar, G.S. (2008). Rural needs or tourism: the use of groundwater in Goa. In Joy, K.J., Biksham, G., Paranjape, S., Goud, V. and Vispute, S. (Eds.) *Water conflicts in India: A million revolts in the making*. New Delhi: Routledge. Taylor & Francis.

Dubash, N.K. (2000). Ecologically and socially embedded exchange: "Gujarat Model" of water markets. *Economic and Political Weekly*, April 15, 2000.

Dubash, N.K., (2002). *Tubewell capitalism: Groundwater development and agrarian change in Gujarat*. New Delhi: Oxford University Press.

ELRS (Environment Law Research Society) (2012). *Governing water in India: Review of law and policy developments*. New Delhi: ELRS.

Foster, S. (2000). Assessing and controlling the impacts of agriculture on groundwater from barley barons to beef bans. *Quarterly Journal of Engineering Geology and Hydrogeology*, *33*, 263–280.

Foster, S.S.D and Chilton, P.J. (2003). Groundwater: the processes and global significance of aquifer degradation. *Philosophical Transactions of the Royal Society*, *358*, 1957-1972. doi: 10.1098/rstb.2003.1380.

Gopalakrishnan, C., Cortesi, L. and Prasad, E. (2011). *Towards self-reliance and access to safe drinking water and secure sanitation in north Bihar*. New Delhi: Megh Pyne Abhiyan, 58p.

Hardiman, D. (1998). Well irrigation in Gujarat: Systems of use, hierarchies of control. *Economic and Political Weekly*, *33*(25), July 1998.

Janakarajan, S. (2008). Unequal power, unequal contracts and unexplained resistance: The case of the peri-urban areas of Chennai. In Joy, K.J., Gujja, B., Paranjape, S., Goud, V. and Vispute, S. (Eds.), *Water conflicts in India: A million revolts in the making*. New Delhi: Routledge

Janakarajan S. and Moench, M. (2006). Are wells a potential threat to farmers' well-being? Case of deteriorating groundwater irrigation in Tamil Nadu. *Economic and Political Weekly, 41*(37), September 16, 2006.

Jones, M. J. (2012). *Social adoption of groundwater pumping technology and the development of groundwater cultures: Governance at the point of abstraction*. Thematic paper 7, Groundwater Governance: A Global Framework for Country Action, GEF ID 3726. Retrieved from, http://www.groundwatergovernance.org.

Joshi, R., Kumar, K. and Dhyani, P.P. (2016). *Policy brief on sustainability of tourism in IHR under climate change: analyses of policy options*. G. B. Pant Institute of Himalayan Environment and Development. Kosi-Katarmal, Almora, Uttarakhand, 16 p.

Joy, K.J., Gujja, B., Paranjape, S., Goud, V. and Vispute, S. (2008). *Water conflicts in India: A million revolts in the making.* Routledge, New Delhi, Tayor & Francis

Joy, K.J., Kulkarni, S., Roth, D. and Zwarteveen, M. (2014). Re-politicising water governance: exploring water re-allocations in terms of justice. *Local Environment: The International Journal of Justice and Sustainability, 19*(9), 954–973 doi: 10.1080/13549839.2013.870542.

Krishnan J. and George, A. (2014). Tribal communities, the forests, the fisher folk and the river: whither water justice? *Local Environment: The International Journal of Justice and Sustainability, 19*(9), 1012–1023. doi: 10.1080/13549839.2013.870143.

Kulkarni, H.C. (1987). *A study of the Deccan basaltic unconfined ground water system in the Pabal area of Shirur taluka, Pune district, Maharashtra State*. Unpublished Ph.D. thesis, University of Poona (now SPPU, Pune), 285 p.

Kulkarni, H., Vijay Shankar, P.S., Deolankar, S.B. and Shah M. (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),12*(2), 184–196.

Kulkarni, H. and Vijay Shankar, P.S. (2009). Groundwater: Towards an aquifer management framework. Commentary. *Economic and Political Weekly*, February 7, 2009.

Kulkarni, H. and Shah, M. (2013). Punjab water syndrome: Diagnostics and prescriptions. Review of Rural Affairs. *Economic and Political Weekly*, *XLVIII* (52), 64–73, December 28, 2013

Kulkarni, H. and Vijay Shankar, P.S. (2014). Groundwater resources in India: An arena for diverse competition. *Local Environment: The International Journal of Justice and Sustainability, 19*(9), 990–1011. http://dx.doi.org/10.1080/13549839.2014.964192.

Kulkarni, H., Vijay Shankar, P.S. and Patil, S. (2015). *The relevance of groundwater typology in India's rural development*. Chapter 2, IDFC Rural Development Network 2014. India Rural Development Report 2013/14. New Delhi: Orient BlackSwan.

Kulkarni, H., Shah, M. and Vijay Shankar, P.S. (2015). Shaping the contours of groundwater governance in India. *Journal of Hydrology: Regional Studies, 4*(A), 172–192, September 2015, http://dx.doi.org/10.1016/j.ejrh.2014.11.004.

Kumar, D. and Shah, T. (2004): *Groundwater pollution and contamination in India: The emerging challenge*. Hindu Survey of Environment 2004, 7–12.

Macdonald, D.M.J., Kulkarni, H.C., Lawrence, A.R., Deolankar, S.B., Barker, J.A. and Lalwani, A.B. (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, 54 p.

Maheshwari, B., Varua, M., Ward, J., Packham, R., Chinnasamy, P., Dashora, Y., Dave, S., Soni, P., Dillon, P., Purohit, R., Hakimuddin, Shah, T., Oza, S., Singh, P., Prathapar, S., Patel, A., Jadeja, Y., Thaker, B., Kookana, R., Grewal, H., Yadav, K., Mittal, H., Chew, M. and Rao, P. (2014). The role of transdisciplinary approach and community participation in village scale groundwater management: Insights from Gujarat and Rajasthan, India. *Water 6*, 3386-3408. doi: 10.3390/w6113386.

Margat, J. and van der Gun, J. (2013). *Groundwater around the world: a geographic synopsis*. CRC Press / Balkema, Taylor & Francis. 348 p.

McKay, J. and Diwakara, H. (2008). Groundwater irrigation in North Gujarat: digging deep for answers. In, Joy, K.J., Biksham, G., Paranjape, S., Goud, V. and Vispute, S. (Eds.), *Water conflicts in India: A million revolts in the making.* New Delhi: Routledge. New Delhi: Taylor & Francis.

Ministry of Agriculture, (2013). *State of Indian agriculture: 2012-13*. Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi. 221 p.

Moench, M., Kulkarni, H. and Burke, J. (2012). *Trends in local groundwater management institutions*. Thematic paper 7, Groundwater Governance: A Global Framework for Country Action, GEF ID 3726. Retrieved from, www.groundwatergovernance.org.

Narain, S. (2012). *Excreta Matters*, Vol 1, Center for Science and Environment, New Delhi.

Narain, V. (2014). Whose land? Whose water? Water rights, equity and justice in a peri-urban context. *Local Environment: The International Journal of Justice and Sustainability, 19*(9), 974-989, doi: 10.1080/13549839.2014.907248.

NIUA (National Institute of Urban Affairs) (2005). *Status of water supply, Sanitation and solid waste management in urban areas*, New Delhi.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. New York: Cambridge University Press.

Patil, S., Prasad, E., Kaushal, N., Upasani, D., Poddar, P. (2011). *From Uncommon back to the Commons: An Experience from North Bihar.* Sustaining Commons: Sustaining Our Future, the Thirteenth Biennial Conference of the International Association for the Study of the Commons. Hyderabad, 2011.

Patil, S., Prasad, E., Kulkarni, H. and Kulkarni, S. (2015). *Participatory groundwater management in the flood plains of north Bihar: Preliminary results of arsenic distribution*. Challenges to groundwater management: Vision 2050. Kolkata: Centre for Ground Water Studies, 2015.

Perveen, S., Krishnamurthy, C.K., Sidhu, R.S., Vatta, K., Kaur, B., Modi, V., Fishman, R. Polycarpou, L. and Lall, U. (2012). *Restoring groundwater in Punjab, India's breadbasket: Finding agricultural solutions for water sustainability*. Columbia Water Center White Paper: Agriculture, India, 2012. Columbia Water Center, Earth Institute, Columbia University.

Prakash, A. (2005). *The dark zone: Groundwater irrigation, politics and social power in North Gujarat*. Hyderabad: Orient Longman

Prakash, A. and Sama, R.K. (2008). Social undercurrents in a Gujarat Village: irrigation for the rich versus drinking water for the poor. In, Joy, K.J., Biksham, G., Paranjape, S., Goud, V. and Vispute, S. (Eds.), *Water conflicts in India: A million revolts in the making*. New Delhi: Routledge, Taylor & Francis.

Price, M. (2002). *Introducing groundwater*. Second ed. Taylor & Francis, UK.

Rana, S. and Gupta, V. (2009)**.** *Watershed management in the Indian Himalayan region: Issues and challenges*. World Environmental and Water Resources Congress 2009, Kansas City, Missouri, USA. ASCE Publication. doi: http://dx.doi.org/10.1061/41036(342)527. April 26, 2012.

Rawat, J.S. and Rawat, M.S. (1994). Accelerated erosion and denudation in the Nana Koshi watershed, Central Himalaya, India, Part I: Sediment load. *Mountain Research and Development, 14*(1): 25–38.

Roth, D., Zwarteveen, M., Joy, K.J. and Kulkarni, S. (2014). Water rights, conflicts, and justice in South Asia. *Local Environment: The International Journal of Justice and Sustainability, 19*(9), 947-953, doi: 10.1080/13549839.2012.752232.

Rushton, K. (1990). Recharge in Mehsana alluvial aquifer, India. In, Lerner, D.N., Issar, A.S. and Simmers, I. (Eds.), *Groundwater Recharge: A guide to understanding and estimating natural recharge.* Hannover: IAH-Verlag Heinz Heise, 297–312.

Shah, M. (2013). Water: Towards a paradigm shift in the twelfth plan. *Economic & Political Weekly, 48*(3): 41.

Shah, M. and Kulkarni, H. (2015). Urban water systems in India: typologies and hypotheses. Special Article, *Economic and Political Weekly, L* (30), 57–69, July 25, 2015

Shah, T., Singh, O. P. and Mukherji, A. (2006). Some aspects of South Asia's groundwater irrigation economy: Analysis from a survey in India, Pakistan, Nepal Terai and Bangladesh. *Hydrogeology Journal, 14*, 286–309.

Shah, T. (2005). Groundwater and human development: Challenges and opportunities in livelihoods and environment. *Water, Science and Technology, 51*(8), 27–37.

Shah, T. (2009). *Taming the anarchy: Groundwater governance in South Asia*. Washington, DC: Resources for the Future and International Water Management Institute.

Srinivasan, V., Suresh Kumar, D., Chinnasamy, P, Sulagna, S., Sakthivel, D., Paramasivam, B and Lele. S. (2014). *Water management in the Noyyal River basin: A situation analysis*. Environment and Development Discussion Paper No. 2. Bengaluru: Ashoka Trust for Research in Ecology and the Environment.

Srinivasan, V., Thompson, S., Madhyastha, K., Penny, G., Jeremiah, K. and Lele, S. (2015). Why is the Arkavathy river drying? A multiple-hypothesis approach in a data-scarce region. *Hydrology and Earth System Sciences, 19*, 1905–1917. doi:10.5194/hess-19-1905-2015.

Tambe, S., Kharel, G., Arrawatia, M.L., Kulkarni, H., Mahamuni, K. and Ganeriwala, A.K. (2012). Reviving dying springs: Climate change adaptation experiments from the Sikkim Himalaya. *Mountain Research and Development (International Mountain Society Publication), 32*(1), 67–72.

Vijay Shankar, P.S., Kulkarni, H. and Krishnan, S. (2011). India's groundwater challenge and the way forward. Special Article, *Economic and Political Weekly, XLVI* (2), 37–45, January 8, 2011

Valdiya, K.S. and Bartarya, S.K. (1991). Hydrological studies of springs in the catchment of the Gaula river, Kumaun Lesser Himalaya, India. *Mountain Research and Development 11*(3): 239–258.

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- Water Conflicts in India: A Million Revolts in the Making (Routledge)
- Life, Livelihoods, Ecosystems, Culture, Entitlements and Allocations of Water for Competing Uses
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- Linking Lives-Reviving Flows: Towards Resolving Upstream Downstream Conflicts in Chalakudy River Basin.
- Water Conflicts in Odisha: A Compendium of Case Studies
- Floods, Fields and Factories: Towards Resolving Conflicts around Hirakud Dam
- Agony of Floods: Floods Induced water Conflicts in India
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- Resolving Upstream-Downstream Conflicts in River Basins
- Right to Sanitation: Position Paper of Right to Sanitation Campaign in India
- City Makers and WASH: Towards a Caring city
- Sanitation Rights and Needs of Persons with Disabilities
- Adivasis and Right to Sanitation
- Right to Sanitation: A Gender Perspective
- Dalits and Right to Sanitation

About ACWADAM

Academic research aspires to improve the understanding of a subject and provide deeper insights about the subject and its applications. However, highbrow research is of little importance to the society, which will appreciate research only if it helps resolve problems and address challenges on the ground. This is ACWADAM's point of departure from conventional approaches in water management.

Knowledge dissemination and action research form the core of ACWADAM's activities, without entering hands-on programme implementation. It has, through various partnerships, demonstrated the strength of collaboration, participation and demystification (of science) in its work. The work-so-far has also strengthened its resolve to develop a national strategy for groundwater management and governance alongside the mapping of aquifers. ACWADAM has also come to believe that the efficiency of programmes such as watershed development, drinking water and sanitation security and revitalising rain-fed agriculture can be significantly improved by integrating the science of groundwater during the planning and execution phases of these programmes.

ACWADAM has partnered a wide range of organisations. Most of these have been part of India's vibrant civil society. It has also partnered both Central and State Governments through their line departments on certain aspects of groundwater management across the country. ACWADAM's work is now evident across India's geodiverse landscape through field work, research and training.

ACWADAM's Vision

Education and research programmes on groundwater should be strategically designed to enable community-level decisions on managing resources like groundwater. Managing common pool resources – particularly groundwater – requires demystification of science. The need to lay emphasis on a participatory approach, in applying the science of hydrogeology to understand aquifers, thereby facilitating community decisions and action on groundwater management and governance was perceived to be equally important. This vision became the foundation of our work and continues to drive all our efforts even today.

ACWADAM's Mission

India has emerged as a hotspot of groundwater extraction, contamination and complex derivatives of the combination of demand, supply and availability of groundwater resources. ACWADAM's mission has been considerably aligned to the uniqueness of India's groundwater dependency. Our work has been driven by the purpose of generating knowledge in a participatory mode and developing capacities on using such (hydrogeological) knowledge in practice and policy.

Embedding groundwater management within the larger context of rural livelihoods and natural resources management forms the cornerstone of ACWADAM's work. This approach has defined a 'typology' of groundwater conditions and situations – at various levels from national to local – with large-scale capacity building, hand- holding of organisations in the field and science-based advocacy with communities as well as policy makers.

CONTACT

Advanced Center for Water Resources Development and Management (ACWADAM)
'Suvidya', 27 Kshipra society, Lane 3, Karvenagar, Pune-411052, India.
Phone: +91-9172246959
Email: acwadam@gmail.com, acwadam@vsnl.net
Website: www.acwadam.org

The Forum and Its Work

The Forum (Forum for Policy Dialogue on Water Conflicts in India) is a dynamic initiative of individuals and institutions that has been in existence for the last ten years. Initiated by a handful of organisations that had come together to document conflicts and supported by World Wide Fund for Nature (WWF), it has now more than 250 individuals and organisations attached to it. The Forum has completed two phases of its work, the first centring on documentation, which also saw the publication of 'Water Conflicts in India: A Million Revolts in the Making', and a second phase where conflict documentation, conflict resolution and prevention were the core activities. Presently, the Forum is in its third phase where the emphasis is on backstopping conflict resolution. Apart from the core activities like documentation, capacity building, dissemination and outreach, the Forum would be intensively involved in right to water and sanitation, agriculture and industrial water use, environmental flows in the context of river basin management and groundwater as part of its thematic work. The Right to water and sanitation component is funded by WaterAid India. Arghyam Trust, Bengaluru, which also funded the second phase, continues its funding for the Forums work in its third phase.

The Forum's Vision

The Forum believes that it is important to safeguard ecology and environment in general and water resources in particular while ensuring that the poor and the disadvantaged population in our country is assured of the water it needs for its basic living and livelihood needs. The Forum is committed to the core values of equity, environmental sustainability, efficiency, livelihood assurance for the poor and democratisation.

The Forum's Mission

The Forum's mission is to influence policies and actions at all levels and work towards resolving, and preventing water conflicts in an environmentally and socially just manner, and creating awareness for achieving participatory, equitable, and sustainable water use. The Forum aims to carry out these through stakeholder interactions, knowledge creation, policy advocacy, training, networking and outreach.

Contact

Forum for Policy Dialogue on Water Conflicts in India
c/o SOPPECOM, 16 Kale Park, Someshwarwadi Road,
Pashan, Pune 411008, Maharashtra, India
Phone: 0091-20-2025 1168, 2588 6542
Fax: 0091-20-2588 6542
URL: www.waterconflictforum.org; www.conflicts.indiawaterportal.org