Groundwater management
Typology of challenges, Opportunities and approaches

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GROUNDWATER MANAGEMENT

Typology of challenges, opportunities and approaches

A compilation of papers from the groundwater conference held in Pune in May 2009

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Background

The report of the Expert Group on Groundwater Management and Ownership *(Planning Commission, 2007)* notes that in 2004, an alarming 28% of the blocks in the country were in the category of critical, semi-critical or overexploited as compared to 7% in 1995. In some states, including Maharashtra, the percentage was as high as 54%. The situation has certainly not improved since. In fact, with continued exploitation, it is expected that by 2020 more than 50% blocks in the country will be critical. Add to this the magnitude of groundwater quality deterioration, and one can foresee one of the biggest challenges India will face during its so-called march towards becoming a developed nation - that of managing its groundwater resources.

The potential challenge, therefore is on two fronts; firstly, in the nitty gritty of actual groundwater use, and secondly, on issues of resource literacy and governance. In more specific terms, groundwater management in India needs to proceed on multiple fronts - understanding the complex nature of aquifers including their variability through space and time (hydrogeology), developing robust systems of groundwater use (considering the social, economic and political milieux) and attempts to respond appropriately and at the right scale, possibly through a set of multiple response tools. One ought to also remember other cross-cutting issues like energy-groundwater and ecology-groundwater inter-linkages that will continue to play a critical role not just in the way groundwater is used but also in how policy and practice respond to groundwater related problems. Groundwater management is not only about scientific and engineering solutions, although hydrogeology provides the basis for understanding the physico-chemical characteristics of the resource. It is as much about hydrogeology as it is about economics and ecology and about breaking challenging social barriers in the quest for improved and sustained management.

Advanced Center for Water resources Development and Management (ACWADAM) is a non-profit, voluntary organization possessing an expertise base in various branches of Earth and Water Sciences. It is active in research and education on groundwater, hydrogeology being its core strength. ACWADAM's work on groundwater management has attempted to combine its hydrogeological experience and the socio-ecomonic capacities of various partner organisations in attempts to manage groundwater resources, mainly through participative community-based approaches. This compilation of papers is a consequence of a workshop on 'groundwater' jointly conducted by ACWADAM and Arghyam Trust. This two-day workshop covered diverse topics like: importance of scale in groundwater resource planning and management, importance of aquifer typologies, participatory processes of groundwater management, groundwater regulation and groundwater linkages - watershed development, markets and policy matters.

This publication includes ten papers, covering a diverse range of topics. The lead paper by Dr. Tushaar Shah, an eminent groundwater scholar sets the scene for various topics and attempts to look at the groundwater management challenge through the livelihoods and environment windows. Dr. Himanshu Kulkarni and his group at Advanced Center for Water resources Development and Management (ACWADAM) explain the concept of groundwater typology, which, in turn, is useful in developing protocols and community-driven pilots on improved forms of groundwater use. Dr. Yogesh Jadeja of Arid Communities and Technologies (ACT) discusses an interesting initiative in the Katchchh region of Gujarat, wherein the synthesis of informal and formal science paves the way for community action on groundwater use. Dr. Sunderrajan Krishnan's paper reviews the groundwater quality challenge in India and further highlights the concept of typology in managing groundwater quality. Mr. Eklavya Prasad, who anchors the unique Megh Pyne Abhiyan in parts of North Bihar and Mr. Vijay Shankar of Samaj Pragati Sahayog, working with tribal communities in Dewas district from Madhya Pradesh bring in the 'practitioner' view to the concept of groundwater management. They discuss groundwater management issues, problems and solutions in highly contrasting contexts - *floods and droughts*. Mr. Ravi Kanth Ganti from Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) discusses the unique process of empowering farmers to collectively manage their groundwater resources through the APFAMGS initiative; he further discusses the potential scale of such an initiative. Mr. Avinash Krishnamurthy writes about experiences in rainwater harvesting and groundwater recharge from urban centres, mainly from Bengaluru. Dr. Philippe Cullet, whose pioneering work on water law in India, writes about the importance of reforms in the existing legislative framework on groundwater. An interesting contribution to this publication has been the paper from Groundwater Surveys and Development Agency (GSDA), perhaps the only autonomous State-level Agency dedicated to groundwater resources in India; the paper presents the working of the organisation in dealing with up-and-coming groundwater challenges in the State of Maharashtra.

ACWADAM through this publication, has attempted to highlight contemporary issues in the subject of groundwater management. It is perhaps the first step to look at groundwater resources through multiple lenses - *hydrogeology, sociology, economics, livelihoods, environment, disasters* and so on. We thank all the participants of the May-09 Groundwater Workshop held in Pune and the paper writers of this publication. The financial support and encouragement by Arghyam Trust, Bengaluru, is gratefully acknowledged.

India's groundwater irrigation economy:
The Challenge of Balancing Livelihoods and Environment

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Abstract: In 1948, independent India inherited some of the world's largest irrigation systems. In the following decades, we built many more. Yet, today groundwater irrigation is the backbone of Indian agriculture. Consequent upon the advent of Green Revolution in India, the use of groundwater has become very intensive. Despite negligible public investment in groundwater irrigation, this source of water contributes more to agricultural wealth and well being than any other source of irrigation. This has given rise to unsustainable pattern of groundwater use in many parts of the country, where extraction of groundwater has exceeded annual renewable recharge. Groundwater is a so-called "democratic resource" in the sense that individual farmers have direct access to it. Three problems dominate in groundwater scenario in India: depletion, salinization and pollution and these have far-reaching socio-economic and environmental consequences. This pathology of groundwater decline in region after region reflects a remarkably similar 4-stage pattern; from a stage where underutilized groundwater resource becomes instrumental in unleashing agrarian boom to one in which, unable to apply brakes in time, the region goes overboard in exploiting its groundwater resources. Dealing with these requires a comprehensive regime for groundwater governance. Indian discussion on governing the groundwater socio-ecology is recent. Moreover, we know much more about the supply-side of the groundwater economy than the demand side. This presentation will focus on exploring the demand-side of India's groundwater boom.

1 This is a revised and updated version of a paper the author has been developing since 2006. Several versions have been used. It was first written for Silver Jubilee Conference of Indian Council for Research on International Economic Relations, held on November 6-7, 2006. More recently, it was the basis of a presentation the author made in the workshop on 'Groundwater' organized by ACWADAM in Pune – the current paper draws heavily on the Pune Workshop Version. Key ideas are taken from the author's Taming the Anarchy: Groundwater Governance in South Asia published by Routledge, New Delhi.

1. Introduction

Stagnating agriculture has emerged, during recent years, as a speed breaker in India's otherwise splendid and enviable growth story. The failure of rapid economic growth to bring about poverty reduction in commensurate manner is also another major concern linked with stagnant agriculture. It has been widely thought that the slow down in public investment in agriculture, mainly irrigation development, is the main culprit behind the deceleration in agricultural growth.Government of India's Accelerated Irrigation Benefits Programme (AIBP) was conceived of as a response to the plea for increased public investment in irrigation. In recent budgets, the Union Finance Minister has been laying great stress on completing the "last mile irrigation projects" to step up the pace of irrigation development. Despite these initiatives, the area irrigated by public irrigation systems in India has stagnated, even declined (*Shah 2009*). In this paper, I want to argue that irrigation in India is in the throes of a major transition. The irrigation business model that India has followed since early decades of 19th century has rapidly changed in recent years, and public policies based on colonial model of irrigation development are no longer in sync with new developments in Indian agriculture, which has come to depend heavily on groundwater irrigation by boreholes and pumps. This transition has created a wholly new challenge of balancing food security and agrarian livelihoods on one hand and sustaining groundwater aquifers under stress. It brings into play a new socio-ecological dynamic that is best understood in the environmental economics framework.

Irrigation statistics compiled by the Government of India underestimate the scale of India's irrigation economy which is booming like never before. Official estimates of the net irrigated area in India based on land use surveys is 57 M ha and the gross irrigated area is around 90 M ha. Other sources, however, suggest that there is great deal more irrigation going on in India. The most striking have been new estimates of global irrigated area based on remote sensing data published recently by the International Water Management Institute (*IWMI*). Based on the analysis of high resolution satellite imagary backed by extensive ground-truthing work, IWMI's estimate suggests that in 2004, India had 99 M ha of net irrigated area and 132 M ha of gross irrigated area. Both these estimates are over 50 percent higher than the official estimates. In fact, IWMI's estimates of irrigated area of today are nearest to what the government of India would like to achieve by 2020. Incredible as these new estimates may sound, recent rounds of national sample survey also suggests that India's irrigation economy may be considerably larger than reflected in the official estimates[3].

2. The groundwater revolution

At the heart of the transformation that India's irrigation economy has been undergoing is the wresting, by millions of small farmers, of the initiative for irrigation development from

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2 *Also, http://www.sandrp.in/irrigation/100000_crores_spent_no_irrigation_benefits_SANDRP_PR_Oct2007.pdf visited on October 12, 2007.*

3 *see, e.g., http://www.econlib.org/LIBRARY/Enc/RationalExpectations.html, accessed 25 August 2006.*

the hands of the State. Under the model of irrigation development that India followed since the 1830's, the State has been the architect, entrepreneur, engineer and manager of irrigation systems. 'Command area' and 'duty' were the mantra of irrigation planning and management. The Government was the provider of irrigation and the farmer a passive recipient. In this model of unbalanced irrigation development, command areas were created near hydraulically opportune sites where reservoirs or weirs could be built and downstream areas could be 'commanded' by gravity flow. Farmers in the rest of the country were left to fend for themselves. Post-Independence, India followed much the same strategy for irrigation development that created pockets of prosperous command areas, leaving other parts to rainfed farming.

By 1970, the population pressure on farm lands in many parts of India had become so inexorable that farmers everywhere felt compelled to work their small farm holdings twice, or even thrice every year. Population pressure on farm lands then flagged off India's tube well revolution. India - especially, in western and north-western parts - had a centuries old tradition of irrigating with wells. Even in 1900, India had some 4 M ha under groundwater irrigation. At the time of independence, the areas irrigated by groundwater and surface water were evenly balanced. However, it was hardly expected by anybody that India would witness massive spread of tubewell irrigation in the surface-water-abundant Ganga-Brahmaputra basin or hard-rock peninsular India. Such a pattern of irrigation development appeared wholly inconsistent with the country's hydrogeology. Equally inconsistent seemed to be large-scale groundwater irrigation in peninsular India with hard-rock aquifers that have poor infiltration and low storage; tanks have been considered ideal for capturing and storing rainwater for irrigation in these areas that comprise 65 percent of India's land-mass.

This thinking was endorsed 70 years later by the second Irrigation Commission. However, come 1970's, and this age-old wisdom lay in tatters as a new era of *atomistic irrigation* unfolded and engulfed India - nay, all of South Asia - with small-pump irrigation spreading everywhere like wildfire - in canal commands and outside, in arid, semi-arid and humid areas, upstream and downstream of river basins, in excellent alluvial aquifers as well as in poor, hard rock peninsular aquifers with limited storage potential. If the era of 'constructive imperialism' began tinkering with the hydrology of river basins, the recent era of atomistic irrigation with small wells and tubewells went about reconfiguring it totally. In this new era of atomistic irrigation, the State as well as science became onlookers in a ballgame whose rules and logic they did not understand, much less dictate. In an incipient atomistic irrigation economy of the 1980's and later, neither the State nor the community was the entrepreneur, builder, or the manager of irrigation; it was the multitude of small-holders--Marx's 'millions of disconnected production units'- each with his tiny, captive irrigation system, ostensibly unconnected with the rest. Until now, crops had to wait for water to be released and flow through a network of canals before getting irrigated; now, water was scavenged on-demand and applied just-in-time when crops needed it most.

Between 1960 and 1985, India invested in irrigation projects many times more capital in real terms than the British had invested during the entire 110 year period between 1830 and 1940. Yet, even according to the government of India's figures, over 60 percent of irrigated areas are today served by groundwater. Other indicators suggest even this may be a serious underestimate. Remote sensing data as well as national sample survey suggest that as much as 75-80 percent of India's irrigated area today is served by groundwater wells. Until 1960, Indian farmers owned just a few tens of thousands of mechanical pumps using diesel or electricity to pump water; today India has over 20 million modern water extraction structures. Every fourth cultivator household has a tube well; and two of the remaining three use purchased irrigation service supplied by tubewell owners *(Shah 2009)*.

3. Socio-economic significance and impacts of the groundwater boom

The groundwater boom is a sub-continental phenomenon that has encompassed, besides India, arid regions of Pakistan, Punjab and Sind—which boast of the world's largest continuous surface irrigation system—and the humid Bangladesh and *terai* areas of Nepal. In these predominantly agrarian regions, the booming groundwater economies have assumed growing significance from viewpoints of livelihoods and food security; however, their significance as engines of rural and regional economic growth has remained under-studied. There are several ways to consider the scale of the groundwater economy; but one practical measure is the economic value of the groundwater production. In table 1 below, we attempt a rough estimation of the market value of groundwater use in the Indian sub-continent. India, Pakistan, Bangladesh have active markets in pump irrigation service in which tubewell owners sell groundwater irrigation to their neighbours at a price that exceeds their marginal cost of pumping. This price offers a market valuation of groundwater use in irrigation. For the Indian sub-continent, the corresponding estimate is around 10 billion US dollars. In many parts of water-scarce India, water buyers commonly

Table 1: **Proximate size of the Agricultural Groundwater Economy of South Asia (c. 2001-02)**

		India	Pakistan Punjab	Bangladesh	Nepal Terai
A	*# of wells (million)*	21	0.5	0.8	0.06
B	*Average output/well (m3/hr)*	25-27	100	30	30
C	*Average hours of operation/well/year*	360	1090	1300	205
D	*Price of pump irrigation (US $/hr)*	1-1.1	2	1.5	1.5
E	*Groundwater used (km3)*	189-204	54.5	31.2	0.37
F	*Value of groundwater used/year in billion US $*	7.6-8.3	1.1	1.6	0.02

enter into pump irrigation contracts offering as much as 1/3rd crop share to irrigation service provider; in water abundant areas, in contrast, purchased pump irrigation cost amounts generally to 15-18 percent of the gross value of output it supports. This can be used to draw the general inference that the agricultural output that groundwater irrigation supports is 4-5 times its market value.

Explosive growth in shallow tube wells and small pumps has democratized Indian irrigation much like personal computers have democratized computing globally. By the same token, large canal irrigation systems are heading towards the future that mainframe computers are facing. Boreholes and small pumps took irrigation away from command areas to the nook and corner of the country. Among several things, the booming pump irrigation economy has: [a] offered some irrigation access to an overwhelming majority, rather than concentrating all irrigation benefits on small privileged groups in command areas; [b] thereby, helped soften growing farmer unrest in the region's vast dry-land areas, which would have otherwise destabilized social and political structures; [c] has come to account for over 60 percent of irrigated areas, and 80 percent of irrigated farm output and resultant incomes; [d] drought-proofed the region's agriculture against at least one monsoon failure and made large-scale famines history; [e] improved farm wages and increased demand for farm labor year-round;[f] demonstrated a strong pro-poor, inclusive bias in irrigated agriculture; [g] supported a new drive towards intensive diversification to high value products such as milk, fruit and vegetables, especially in dry land areas in a scale-neutral format. These impacts have benefited—directly and indirectly, to lesser or greater extent--around half a billion rural people in South Asia. One cannot say that the South Asian peasant is much better off in 2000 compared to 1975; but one can confidently say that, other things being the same, he would have been immensely worse off but for the pump irrigation boom.

4. Sustaining the groundwater boom

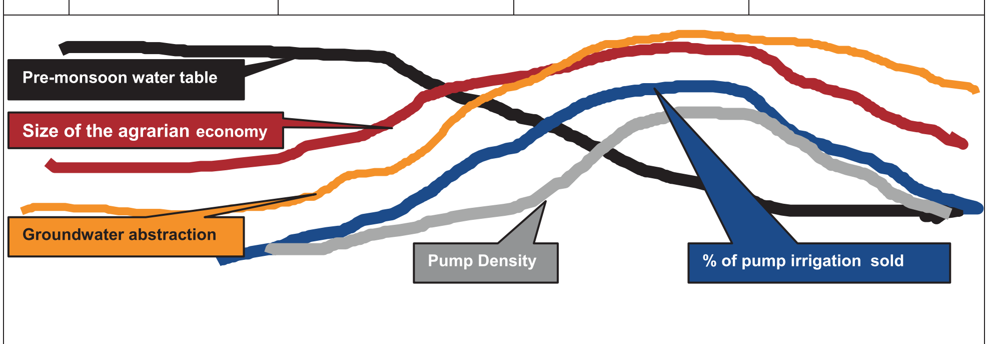
Nothing is an unmixed blessing; and this is true about South Asia's pump irrigation revolution since 1970's which has been a prominent target of doomsday prophecies about an impending socio-ecological disaster (*see, e.g., Seckler et al.1999; Postel 1999; Vaidyanathan 1996*). There is much truth in this concern; however, tubewell irrigation has generated substantial socio-ecological dividends as well. In flood prone eastern India, it has helped mitigate the rapacity of floods and water logging by reducing 'rejected recharge' by creating more storage in the aquifers. In the Indus basin too, tubewell irrigation has reduced water logging and salinization, a task which would have taken hundreds of million dollars of investments in drainage.

Groundwater horror stories of India are however becoming increasingly frightening in arid alluvial and hard-rock aquifers. In some coastal plains along with arid alluvial plains facing overdraft, the central resource governance challenge is coping with salinization and depletion which, in a chronic form already visible in some parts, may seal the fate of agriculture, and of human settlement itself. Then, in hard rock areas of peninsular India, where tubewell irrigation expansion is way out of proportion to the limited storage offered by aquifers, resource depletion is a serious issue in itself but has also aided growing concentration of fluoride and other salts in groundwater which is the main source of drinking water supply for rural as well as urban populations. Problems of geogenic contamination of groundwater - such as with arsenic in eastern Ganga basin and fluoride in much western and peninsular India - are large and serious. The causal role of pump irrigation in mobilizing fluoride and other salts in groundwater is clearer than in arsenic contamination whose chemistry is still tenuous and disputed.

IWMI's past research to understand the dynamics of groundwater socio-ecologies indicates some recurring patterns. In much of South Asia, for example, the rise and fall of local groundwater economies follow a 4-stage progression outlined in Figure 1 below, which is self-explanatory. It underpins the typical progression of a socio-ecology from a stage where unutilized groundwater resource potential becomes the instrument of unleashing an agrarian boom to one in which, unable to apply brakes in time, it goes overboard in exploiting its groundwater.

The 4-stage framework outlined in *Figure 1* shows the transition that South Asian policymakers and managers need to make from a resource development mindset to a resource management mode. 40 years of Green Revolution and mechanized tubewell technology have nudged many regions of South Asia into stage 2-4. However, even today, there are pockets that exhibit characteristics of stage 1. But the areas of South Asia that are at stage 1 or 2 are shrinking by the day. Many parts of Western India were in this stage in 1950's or earlier, but have advanced into stage 3 or 4. An often cited case is North Gujarat

	Stage 1	Stage 2	Stage 3	Stage 4
Stages	The rise of Green Revolution and Tubewell Technologies	Groundwater-based Agrarian Boom	Early Symptoms Groundwater Over-draft/Degradation	Decline of the Groundwater Socio-ecology with immiserizing impacts.



Examples	North Bengal and North Bihar, Nepal Terai, Orissa	Eastern Uttar Pradesh Western Godavari Central and South Gujarat	Haryana, Punjab, Western Uttar Pradesh, Central Tamilnadu	North Gujarat, Coastal Tamilnadu, Coastal Saurashtra, Southern Rajasthan

Characteristics	Subsistence agriculture; Protective Irrigation Traditional crops; Concentrated rural poverty; Traditional water lifting devices using human and animal power	Skewed ownership of tubewells; access to pump irrigation prized; rise of primitive pump irrigation `exchange' institutions. Decline of traditional water lifting technologies; Rapid growth in agrarian income and employment	Crop diversification; permanent decline in water tables. The groundwater-based `bubble economy' continues booming; But tensions between economy and ecology surface as pumping costs soar and water market become oppressive; Private and social costs of ground-water use part ways.	The `bubble' bursts; agri. growth declines; pauperization of the poor is accompanied by depopulation of entire clusters of villages. Water quality problems assume serious proportions; the `smart' begin moving out long before the crisis deepens; the poor get hit the hardest.
Interventions	Targeted subsidy on pump capital; Public tubewell programmes; Electricity subsidies and flat tariff	Subsidies continue. Institutional credit for wells and pumps. Donors augment resources for pump capital; NGOs promote small farmer irrigation as a livelihood programme	Subsidies, credit, donor and NGO support continue apace; licensing, siting norms and zoning system are created but are weakly enforced. Groundwater irrigators emerge as a huge, powerful vote-bank that political leaders can not ignore.	Subsidies, credit and donor support reluctantly go; NGOs, donors assume conservationist posture zoning restrictions begin to get enforced with frequent pre-election relaxations; water imports begin for domestic needs; variety of public and NGO sponsored ameliorative action starts.

***Figure 1:* Rise and fall of groundwater socio-ecologies**

economy; here, the foresightful, well-off farmers - who foresaw the impending doom - forged a generational response and made a planned transition to a non-farm, urban livelihood. The resource poor have been left behind to pick up the pieces of what was a booming economy barely a decade ago. This drama is being re-enacted in ecology after groundwater socio-ecology with frightful regularity (*Moench 1994; Shah 1993; Barry and Issoufaly 2002*).

In stage 1 and early times of stage 2, the prime concern is to promote profitable use of a valuable, renewable resource for generating wealth and economic surplus; however, in stage 2 itself, the thinking needs to change towards careful management of the resource. Yet, the policy regime ideal for stage 1 and 2 have tended to become 'sticky' and to persist long after a region moves into stage 3 or even 4. IWMI's recent work in North China plains suggests that the story is much the same there as well. The critical issue to address is: does stage 4 always have to play out the way it has in the past? Or, are there adaptive policy and management responses in stage 2 that can generate a steady-state equilibrium, which sustains the groundwater-induced agrarian boom without degrading the resource itself? In the remainder of this paper, we review the prospects and opportunities for forging such a steady-state equilibrium.

5. Environmental economics of aquifers and institutional response

Groundwater modeling is the playing field for hydrogeologists. These have developed a rather formidable repertoire of models that analyze the complex behavior of aquifers in response to development. However, in a region like South Asia where millions of smallholders directly interfere with the aquifer processes without let or hindrance, we have little understanding of how users respond to its development, and in due course, its depletion or deterioration. Developing such understanding is an important area of work for environmental economists.

Much hydrogeology is about the impact of human intervention on aquifer behavior. But environmental economics also needs to explore the impact of aquifer conditions on human behavior, especially, the behavioral response of people living off it. By institutional response, I mean the central behavioral tendencies of groundwater irrigators and the social dynamics that result from different aquifer conditions. In keeping with *Veblen* (*1934*), the original institutionalist, I treat institutions as 'settled habits of thought common to the generality of men'.

An average groundwater user in India has little or no formal knowledge of hydrogeology. But s/he certainly has ideas and even theories about how it all works underneath the earth's crust (*Rosin 1993; Shah 2000*). A lot of these popular theories will not withstand scientific scrutiny; yet, farmers' decisions and actions are guided by their theories more than by formal science. One way to think about how farmers form their theories is by referring to what economist John *Muth (1961)* called rational expectations which help people formulate their view of the future state of things. Rational expectations are to be distinguished from adaptive expectations, which see the future as little more than a mechanical reproduction of the past. The rational expectations model suggests that people take into account all the information available to them—including the expectations of others they regard highly--to arrive at an expectation which differs from the actual only by a random error (*Muth 1961; Sargent 2002*). When the behavior of most or all agents is shaped by such rational expectations, self-fulfilling prophecies abound. If majority customers expect a bank to fail, and begin a run on it, a small bank may actually fail. If most traders expect stock prices to rise, and start buying in that expectation, the market will actually skyrocket even when fundamentals suggest no reason for it to. Likewise, the expectations people living on or off an aquifer have about where it is headed in response to development or conservation shape their individual or collective behavior towards it and towards the 'aquifer community'.

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4 *Cited in Paarlberg (1993:823-827).*

5 *http://www.econlib.org/library/Enc/RationalExpectations.html*

An 'aquifer community' can be viewed as a collectivity of aquifer users in a locality who are aware of their interdependence in their use of a common aquifer or a portion thereof. The *COMMAN Project (2005)* puts it elegantly as a group of groundwater users who are 'mutually vulnerable and mutually dependent because of the centrality of resource use in supporting livelihoods'. The level of awareness of this inter-dependence is a measure of the strength or weakness of the aquifer community. In understanding the institutional dynamic in an aquifer, important are the rational expectations that a representative farmer has about the impact of another farmer's withdrawal on own water availability (s), and of the whole community's withdrawals on her groundwater availability (S); individual farmer's water conservation effort on her water availability (h) and the community's conservation effort on her water availability (H). Five situations outlined in table 2 represent the types of institutional dynamic that aquifer conditions generate in response to development in South Asia.

[**Situation 1**] atomistic individualism ($s=0; S=0; h=0; H=0$): occurs when each farmer is an insignificant user in an abundantly recharged water table aquifer; his abstraction has little impact on himself or other users; likewise, aquifer development has little discernible impact on the individual user; here, interdependence amongst users goes unnoticed; 'aquifer community' is non-existent, and rational expectations fail to generate institutional dynamic of the kind we observe in the remaining four situations;

[**Situation 2**]collusive opportunism ($s=0; S<0; h=0; H=0$): occurs when aquifer development sharply raises the cost of groundwater abstraction without greatly reducing

***Table 2 :* Patterns of institutional responses to aquifer development in India**

Institutional response situation	Aquifer characteristic	Impact of aquifer development on typical user	Pump irrigation markets	Example	Ease of political mobilization of farmers	Scope for Local aquifer governance
[1]Atomistic individualism	High storage; high recharge resources	Insignificant	Efficient, deep and broad; WEM ownership a major source of neither power nor profit.	Most of Indo-Gangetic basin; alluvial canal commands	Low	Nil
[2]Collusive Opportunism	High storage; no or limited recharge resources	Sharply rising marginal cost of groundwater	Highly monopolistic, fairly deep and broad; resource poor elbowed out of pump irrigation economy	North Gujarat; Western Rajasthan	High for energy subsidies and surface water imports	Low or nil

[3] **Rivalrous gaming**	Hard-rock aquifer with low aquifer storage; some recharge resources	Rising marginal cost and declining share in limited water	Highly monopolistic; thin and shallow; poor have limited access at adverse terms	Inland peninsular India; Baluchistan	High for energy subsidies and recharge resources;	Scope for functional aquifer community
[4] **Cooperative gaming**	Alluvial with a confining layer or humid hard-rock environment with low storage;	Sharply rising marginal cost and declining share in limited water	Monopolistic; moderate in depth and breadth; access to groundwater more equitable	Eastern Rajasthan; coastal Saurashtra;	High for energy subsidies and recharge resources;	High; functional aquifer community
[5] **Exit**	Fragile aquifers prone to rapid quality deterioration	Sharp deterioration of water quality	Absent or insignificant	Coastal aquifers in Saurashtra; fresh water lenses in Sind	Low	Nil

water supply or quality; here, wealthy farmers establish de facto control over the resource, and collude against the resource poor but spearhead political mobilization to defend their access to and control over the resource; irrigators display limited inter-dependence and are a weak aquifer community;

[Situation 3] rivalrous gaming (s<0; S<<0; h=0; H>0): occurs when aquifer development sharply raises the cost of water production and also limits available groundwater supply that users actively compete for; this condition promotes intense and destructive rivalry among competing users; irrigators display a strong sense of interdependence but are a dysfunctional aquifer community; sporadic evidence of beneficial effects of community conservation fail to metamorphose into organized collective action;

[Situation 4] co-operative gaming(s<0; S<<0; h>0; H>>0): under certain catalytic conditions, rivalrous game metamorphoses into a co-operative game that reduces the cost and risk of water production and augments water availability to the entire community; positive expectations that so result foster a strong sense of benign interdependence and a highly functional aquifer community; such aquifer communities are ripe for proactive local groundwater self-governance;

[Situation 5] exit (s<<0; S<<0; h=0; H=0): This state occurs when groundwater development results in rapid quality deterioration without affecting supply. Costs and risks of groundwater use become prohibitive; and users begin giving up irrigated farming or farming itself. Pervasive negative expectations inspire fatalism, hopelessness and despair that overwhelm the strong sense of interdependence; aquifer community takes a downward spin and eventually withers away.

The framework set out above is helpful in making sense out of how millions of farmers have responded to the ecological consequences of rapid groundwater development in different parts of India. In alluvial aquifers of arid western Rajasthan and North Gujarat, groundwater irrigators are running a race to the 'pump house'; competitive deepening of tubewells is the name of the game here. In these regions, we never hear about spontaneous efforts by farming communities to harvest rainwater and recharge aquifers on a large scale; the predominant institutional response takes the form of mobilizing to maximize and preserve energy subsidies. In humid alluvial plains of the Ganga-Brahmaputra-Meghana basin, groundwater irrigation here is a major poverty-alliviator and poses no environmental threat. Yet it is rapidly shrinking in the face of a stringent energy squeeze; and small farmers here are unable to organize and mobilize political power to save their livelihoods. Most large-scale mass-based groundwater recharge initiatives are concentrated in hard-rock areas; here, well owners compete fiercely to maximize their share in available groundwater resource but can be organized in a co-operative game to augment the resource and regulate the abstraction. In fragile coastal aquifers, the ecological fall-out of rapid and unregulated expansion in groundwater abstraction are swift and disastrous, leaving 'exit' from irrigated farming as the dominant option.

6. In search of sustainability

In thinking about forging a sustainable groundwater governance regime, the emerging global consensus is for achieving the right balance between supply and demand side measures. Governments can meet groundwater depletion in a locale by investing in recharge and/or water imports. However, without effective demand-side measures, increased supply will quickly invite increased abstraction, leaving the resource depleted. In creating demand management regimes, four sets of ideas have been tried worldwide: direct regulation, economic instruments, tradable property rights, community resource management. These are reviewed briefly; but the interesting upshot of this discussion is that throughout the world, groundwater governance (GwG) is still work in progress.

Direct regulation through administrative action:

State claiming eminent domain and using the administrative apparatus of the government to regulate groundwater abstraction dominates the GwG regime in many countries, notably the Sultanate of Oman, Iran, Saudi Arabia, Israel and of course the western United States. In South Asia too, groundwater departments in most Indian states as well as Bangladesh have norms for siting irrigation wells and the minimum spacing to be maintained to minimize well-interference externalities. India has a draft groundwater law tossing around now for over 30 years; several state governments have passed groundwater laws providing regulatory powers *(Planning Commission 2007)*. The regulatory effectiveness of these however has remained limited for a variety of reasons, the chief being the lack of popular support, political will and enforcement capacity commensurate with the enforcement challenge.

Table 3: **Structure of national groundwater economies of selected countries**

Country	Annual groundwater use (km3)	No of Agricultural Groundwater Structures (million)	Average extraction/ structure (m3/year)	% of population dependent directly or indirectly on groundwater irrigation	Average farming income per farm worker
India	210	19	7900	55-60	~350
Pakistan	55	0.5	90000	60-65	~400
China	105	3.5	21500	22-25	~458
Iran	29	0.5	58000	12-18	~2200
Mexico	29	0.07	414285	5-6	3758
USA	100	0.2	500,000	<1-2	67800

Direct regulation of groundwater users through law is by far the most talked-about intervention in India. A model groundwater bill was formulated during the early 1970's and revised versions have been tossed around since then. Since water is a state subject in India, the action lies with state governments; and few showed interest in formulating a groundwater law; and even fewer in enforcing it. The key problem is the transaction costs of enforcing such a law on millions of scattered borehole owners in the countryside. As the following table 3 shows, the organization of groundwater economy is a major determinant of what kind of regulatory action is appropriate. India withdraws twice as much groundwater as does the US but would have to enforce a groundwater law on 100 times more irrigators.

Economic instruments:

Economic instruments are attractive because they can influence the behavior of numerous economic agents without having to coerce or invoke eminent domain. Using a price or a Pigovian tax or cess is basic economic instrument to signal scarcity value. The problem in pricing groundwater is often the high transaction costs of metering, monitoring and charge collection; as a result, pricing is effectively used when it can be levied on bulk users or service providers who can transmit the 'price signals' onward to users.Direct scarcity pricing of groundwater use in irrigation in developing countries is, however, rare, not because the principle is in doubt but its actual practice has proved difficult.

Tradable property rights:

The conceptual foundation of the tradable property right discussion rests on the premise that under open access, groundwater resource would always be open to depletion and degradation. One road to sustainable resource management is of creating enforceable private property rights, preferably tradable. Tradable water rights modify the outlook of the users as well as third-parties about externalities, leading to more efficient allocation—though not necessarily conservation—of the resource. At the conceptual plane, there is little to gainsay the hypothesis that tradable property rights result in superior allocation of scarce water. The real problem in using this approach effectively in a country like India, however, is the transaction costs, which rise in geometric progression with the increase in the number of users. While the property rights protagonists have not paid much heed to transaction costs, these were central in the scheme of Ronald Coase, the original master, who warned that the assignment of property rights would be of little avail: [a] if the information available to contracting parties were less than perfect, [b] if transactions costs were high, and [c] if the number of contracting parties was too large to permit easy negotiations amongst them.

Even where transactions costs are manageable, results are not uniformly satisfactory. Also, where the resource is threatened, demand management by reducing irrigated areas or groundwater withdrawals through rights administration is more an exception than a rule. When groundwater pumping is restricted to meet a threat to the aquifers, it is often because new water supply is offered in lieu of pumping of groundwater or because soaring pumping cost makes groundwater irrigation economically unviable.

Community aquifer management:

In evolving their groundwater governance regimes, Mexico and Spain have adapted the US experience of tradable water rights and Groundwater Management Districts. A more practical consideration was to use groundwater associations as agents in monitoring and enforcement of government policies and laws. The idea of groundwater organizations has a wide appeal; it was studied in detail for India by a British Geological Survey study *(COMMAN, 2005*). And in south India, the FAO supported Andhra Pradesh Farmer Managed Groundwater Systems Project has organized groundwater users in 650 habitations in 66 hydrological units (*Knegt and Vincent. 2001*). Spain and Mexico have however embraced groundwater organizations as key element of their official national water governance strategy. Concessions, in a way, have created a new dynamic of opportunism. Recently, the CNA announced its intention to withdraw unused portions of groundwater quotas; this generated a perverse 'use-it-or-lose-it' feeling among farmers. Luis Marin, a Mexican researcher, reported,

"In Mexico, the government has tried to give the stakeholders the responsibility for managing aquifers by establishing COTAS. However, COTAS depend financially on subsidies from... governments... Under the new law, stakeholders who don't use all of the volume that they have a permit for, stand to lose the unused volume the following year. As a result, stake holders extract their full volumes, even if much of this water is wasted, only not to have their concessions reduced." (*Personal communication by e-mail of 7 July, 2005*).

Enacting and enforcing a groundwater law, establishing clear tradable property rights on water, pricing groundwater as an economic good, installing and enforcing a licensing and permit system—all these have been discussed ad nauseum as desirable policy interventions to regulate groundwater overdraft (*see, e.g., Arriens et al 1996: 176-178; 239-245*). Nobody seems to disagree with the need for these; yet, no Asian country has been able to deploy any of these interventions effectively even as the groundwater situation has been turning rapidly from bad to worse. The scale of the groundwater threat is long recognized; but viable strategies for dealing with it are not forthcoming; indeed, governments are still busy promoting more groundwater development, as if they were in Stage 1.

Indirect levers

Because of our large number of small, scattered groundwater abstractors, India would need to devise its own groundwater governance strategy that fits with her context. There are potentially powerful indirect demand-management strategies that are not even part of the academic discussion on groundwater management in the developing world. These offer important trade-offs that need closer scrutiny. For example, it has been suggested that the Indian Punjab's groundwater depletion problems could be easier to resolve if its export of 'virtual' groundwater in the form of rice could be reduced or stopped; on the other hand, IWMI researchers have suggested that, in North Indian plains, using earthen canals for recharging with flood waters of monsoon rains can help counter groundwater depletion (*IWMI-Tata Water Policy Briefing 1*). Water- saving irrigation research—such as Alternate Wet and Dry Irrigation (AWADI) for rice in China or the System of Rice Intensification which has found enthusiastic following in scores of countries including India and Sri Lanka (*Satyanarayana, 2005 and Sinha and Talati 2007*)—can help reduce groundwater use; but it needs to be examined if these technologies would work as well in dry areas. In many developing countries, pricing and supply of electricity to tubewell owners can offer powerful levers for agricultural demand management for groundwater. Since levying a price on groundwater itself may entail high transaction costs of collection, energy price can serve as a useful 'surrogate' (*Shah et al 2004c; Scott and Shah 2004*).

Another key are to work upon in South Asia, especially India, are the perverse energy subsidies for tubewell irrigation. In the populous South Asian region, there seem no practical means for direct management of groundwater; laws are unlikely to check the chaotic race to extract groundwater because of the logistical problems of regulating a large number of small, dispersed users; water pricing and/or property right reforms too will not work for the same reasons. However, electricity supply and pricing policy offers a powerful toolkit for indirect management of both groundwater and energy use. Since electricity subsidies have long been used by governments in this region to stimulate groundwater irrigation, the fortunes of groundwater and energy economies are closely tied. India is a classic example. Today, India's farmers use subsidized energy worth some US $ 4.5-5 billion/year to pump some 150 km3 of water mostly for irrigation; the country's groundwater economy has boomed by bleeding the energy economy. With electricity industry getting close to bankruptcy, there are growing demands for eliminating power subsidies; but governments find it unable to do so because of stiff opposition from farmer lobby. Recent IWMI research (*Shah et al 2004*) has argued that sustaining a prosperous groundwater economy with viable power sector is feasible but it requires that the decision makers in the two sectors jointly explore superior options for energy-groundwater co-management.

IWMI studies recognize that switching to volumetric electricity pricing may not be politically feasible at present. However, they advocate flat tariff accompanied by sophisticated management of high quality but carefully rationed power supply to maintain at once the financial sustainability of energy use in agriculture and the environmental sustainability of groundwater irrigation; and has argued that such a strategy can curtail wasteful use of groundwater in irrigation to the extent of 15-18 km3/year.

7. Transition needed: from resource development to management mode

In the business-as-usual scenario, problems of groundwater over-exploitation in India will only become more acute, widespread, serious and visible in the years to come. The frontline challenge is not just supply-side innovations but to put in to operation a range of corrective mechanisms before the problem becomes either insolvable or not worth solving. This involves a transition from resource 'development' to resource 'management' mode *(Moench, 1994)*. Throughout Asia—where symptoms of over-exploitation are all too clear—groundwater administration still operates in the 'development' mode, treating water availability to be unlimited, and directing their energies on enhancing groundwater production. A major barrier that prevents transition from the groundwater development to management mode is lack of information. Many countries with severe groundwater depletion problems do not have any idea of how much groundwater occurs, and who withdraws how much groundwater and where. Moreover, compared to reservoirs and canal systems, the amount and quality of application of science and management to national groundwater sectors has been far less primarily because unlike the former, groundwater is in the private, 'informal' sector, with public agencies playing only an indirect role.

Gearing up for resource management entails at least five important steps:

[1] Recognizing that even as the bulk of the public policy and investments are directed at large government managed irrigation programs, in reality, South Asia's agriculture has come increasingly to depend upon small-holder irrigation based largely on groundwater; policy effort as well as resource investments need to adjust to this reality if these are to achieve integrated water and land resources management in the true sense;

[2] Information Systems and Resource Planning through establishing appropriate systems for groundwater monitoring on a regular basis and undertaking systematic and scientific research on the occurrence, use and ways of augmenting and managing the resource;

[3] Initiating some form of demand-side Management through [a] registration of users through a permit or license system; [b] creating appropriate laws and regulatory mechanisms; [c] a system of pricing that aligns the incentives for groundwater use with the goal of sustainability; [d] promoting conjunctive use of surface and groundwater by reinventing main system management processes to fit a situation of intensive tubewell irrigation in command areas; [e] promotion of 'precision' irrigation and water-saving crop production technologies and approaches;

[4]Initiating Supply-side Management through: [a] promoting mass-based rain-water harvesting and groundwater recharge programs and activities; [b] maximizing surface water use for recharge; [c] improving incentives for water conservation and artificial recharge; and finally,

[5]Undertaking Groundwater Management in the river basin context: Groundwater interventions often tend to be too 'local' in their approach. Past and up-coming work in IWMI and elsewhere suggests that like surface water, groundwater resource too needs to be planned and managed for maximum basin level efficiency. Equally instructive for the developing world will be the impact of the entry of big-time corporate players in the business of using aquifers as inter-year water storage systems for trading of water. As groundwater becomes scarce and costlier to use in relative terms, many ideas—such as trans-basin movement or surface water systems exclusively for recharge--, which in the yesteryears were discarded as infeasible or unattractive, will now offer new promise, provided, of course, that Asia learns intelligently from these ideas and adapts them appropriately to its unique situation.

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Groundwater management in India :
From typology to protocols and community-driven pilots

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Abstract: Even without statistics, it is obvious that irrigation development (dams, canals, surface water lift irrigation schemes), promoted through public investments, has proceeded rapidly in many parts of India. On the other hand, groundwater resources development continues to roll on the back of private, individual investments that have enabled millions of farmers the access to irrigation, even in the remotest niches of India's geographical outback. The scales on which groundwater resources in India are used are different from the picture presented through various irrigation documents. This dichotomous picture (explained in great detail by Shah, 2009) requires a different focus for efforts in groundwater management.

The approach of using types – typology – is useful in understanding the diversity of hydrogeological and socio-economic conditions that influence the patterns of groundwater utilization even in a small area. The approach can also be useful in understanding the underlying drivers of a particular groundwater problem. A typology, even in a small area, such as a watershed or a block, on which current status of groundwater exploitation is described, makes it possible to classify the physical and anthropogenic characteristics of groundwater resources, in order to develop improved responses in its management.

Such an attempt to typify groundwater domains has been attempted by ACWADAM in two areas in different geological settings. The first area lies in the heart of the Deccan Volcanic province, to the South of Pune District, while the other lies in South of Dewas district in the Narmada valley and is a region underlain by complex geology – multiplicity of rock types,

structure and hydrology. Whilst the former is has been ascribed an "overexploited" status, the later remains as a part of a "safe" block as per GEC estimates. This paper attempts to break down the status at both the locations, with a view to set forth the rationale for and the conceptual framework of understanding the typology of groundwater with a view to arrive at a set of protocols at the "aquifer" level. ACWADAM is attempting to pilot some of these protocols on the ground, with the aim of piloting "community based" groundwater management and drawing lessons for the policy space on groundwater management in India.

Background

Groundwater resources provide a reliable drought buffer in large regions of the world (*Calow et al, 1997*). The magnitude of impact of groundwater depletion on global food security is also a well known fact (*Postel, 1999; Brown, 2000*), although ensuring food security for a region involves other factors as well. Socio-economic dependency on groundwater cuts across classical divisions of 'arid, semi-arid and humid' regions (*Burke and Moench, 2000*), highlighting the need to tailor responses to situations under which groundwater problems emerge.

India's groundwater story is unique; scripted by millions of farmers in its agricultural hinterland, India is now the biggest user of groundwater in the world (*Shah, 2009*). With some 20 million odd wells, India is fast hurtling towards what Shah (2009) rightly terms 'groundwater anarchy'. And this despite the fact that India, along with China and United States has far outpaced the world in building large dams (*based on ICOLD, 1998, in World Commission on Dams, 2000*).

The flip side of the large-scale groundwater resources development – well numbers, densities and pumping from many abstraction foci – is reflected in the form of impacts on the status of groundwater resources. Groundwater scarcity and deteriorating quality of groundwater resources have gradually emerged as the major challenges in the water management arena and will continue to remain so for many years to come. The clamour for improved groundwater management, either through community based responses, legislation or simply through an improved framework of governance, continues (*COMMAN, 2005; MoWR, 2002; Planning Commission, 2007*). At the same time, the process of bringing such large scale responses to bear has not proceeded beyond the solution of augmenting recharge (*CGWB, 2006*). But, whether such solutions would be relevant and effective on the scale at which India's groundwater woes are impacting life and livelihoods, is a point worth pondering. We have, through the course of our work on the hydrogeology of aquifers in different parts of India, felt the need for a more focused understanding of groundwater resources, an understanding that will form a practical basis for implementing various programmes on the conservation, development and management of groundwater resources. Such focused understanding could be a more effective basis for a comprehensive programme on groundwater, a programme capable of integrating all the above into one package, at the national level (*Kulkarni and Vijay*

Shankar, 2009). This paper proposes a framework wherein groundwater management programmes can be made more meaningful and effective, with regard to India's unique groundwater syndrome.

Uniqueness of India's groundwater resources

Conventional approaches to groundwater management in India have involved a clear focus on the 'development' of groundwater resources from different geological settings, from the 1960s through the '70s and '80s until almost the mid-nineties. Groundwater overabstraction was recognized as a serious problem in the late 1980s (*Dhawan, 1990; Moench, 1992; Macdonald et al, 1995*). The mid-nineties saw almost a reluctant change in thinking – 'development giving way to management'. The new thinking, which strived to look at managing groundwater beyond sinking dug wells and drilling tube wells or bore wells, began to be backed by data from State and Central agencies, making it possible to track the national scenario on groundwater over a time-line (*Groundwater Estimation Committee Reports, 1994; 1997*). The report of the Expert Committee on Groundwater Management of the Government of India states that, in 2004, some 28% of India's blocks (nationally recognized administrative units) were semi-critical, critical or over-exploited as compared to 4% in 1995 (*Planning Commission, 2007*).

The physical status of groundwater resources in India's blocks can be tracked as a result of a methodology used by the Central Ground Water Board (*GEC, 1997*). The process of estimating the net change in (groundwater storage) as a consequence of recharge to and discharge from groundwater storages is used to decide the status of "a block". Blocks (and in some States, watersheds) are then classified as over-exploited, critical, semi-critical and safe, through a formula that estimates the total amount of groundwater used in proportion to the net availability, the latter based on recharge and discharge estimates for a certain block. The methodology of estimation follows two options; primarily, it uses the groundwater level fluctuation– specific yield relationship where sufficient data is available to track changes in an aquifer over a given period of time and secondly, it uses rainfall infiltration estimates for computations where water level and other such information is not readily available. The primary concern about the methodology, which the (GEC 1997) itself states, is the lack of an appropriately representative physical unit for estimation. The transition from 'blocks' to 'watersheds', as suggested in the report, has not happened as yet. However, the bigger question on whether the national status on groundwater is really representative of the micro-picture, remains unanswered even in the latest literature on groundwater resources in India.

There is clear evidence now regarding the increasing awareness about India's groundwater resources. Many now realize that groundwater conditions, trends of abstraction and emerging problems bear a strong correlation with the underlying geology. At the same time, there is little evidence on moving beyond conventional thinking around the so-called groundwater provinces of India (*Karanth, 1995*) or a slightly recast version of the same, called major aquifer systems of India (www.cgwb.nic.in).

While current approaches of using regional classes – geological or geomorphological – make some headway in the understanding of groundwater resources, they neglect the aspect of local diversity that is so common to the Indian groundwater context (*Kulkarni, 2005*). Capturing such diversity is important with regard to two basic requirements in groundwater understanding:

1. To identify the right unit for such understanding – aquifers, in the case of groundwater resources.
2. To create such an understanding at the appropriate "scale" because groundwater issues are felt most strongly at the farm-level.

This very rationale preempts the need to think differently about India's groundwater and boils down to understanding the *typology of groundwater resources at the right scale*. This paper attempts to explain the conceptual framework of understanding the typology of groundwater with a view to arrive at a set of protocols at the aquifer level.

From provinces to types – the framework for the Indian context

Conventional approaches to understanding groundwater resources involve "geological provinces". The groundwater provinces of India, or alternatively the aquifer map (*Karanth, 1997; Kulkarni, 2005; CGWB, 2006*) capture the gross physical characteristics of regional geological systems and the coverage of such systems. These provinces attempt to describe the physical settings in which groundwater accumulates and moves. However, this 'classical' approach, especially in the diverse context of India, not only simplifies the physical conditions that determine the storage, transmission and quality of groundwater, but remains only one-dimensional in failing to capture the anthropogenic dynamics that drive groundwater use. A long-term well hydrograph, for instance, indicates aquifer depletion and even the potential recharge required to bring such an aquifer back to normalcy (*Figure 1)*. The one-dimensional approach neglects the fact that groundwater is in transition and its status changes with the temporal changes within its nature of use. More importantly, it fails to capture the sociological, economic and ecological roles that groundwater plays and how these roles influence its behaviour in space and time. Understanding India's groundwater would be incomplete without a reference to the socio-ecological stages through which resources and people transit. These socio-ecological stages, developed for South Asia, involve changes in water levels, pumps, magnitude of abstraction, agriculture and groundwater markets (*Shah, 2009; also Shah, 2009 – part of this publication*)

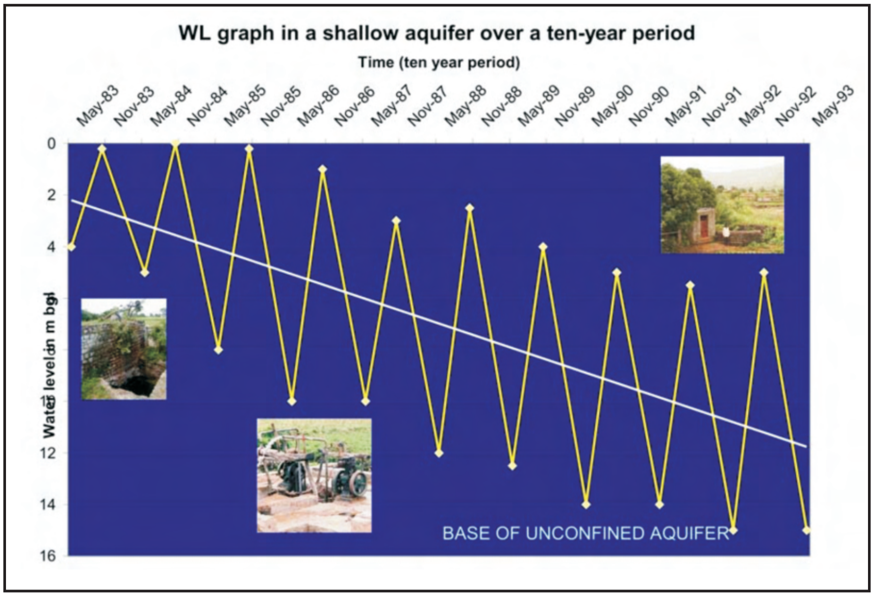
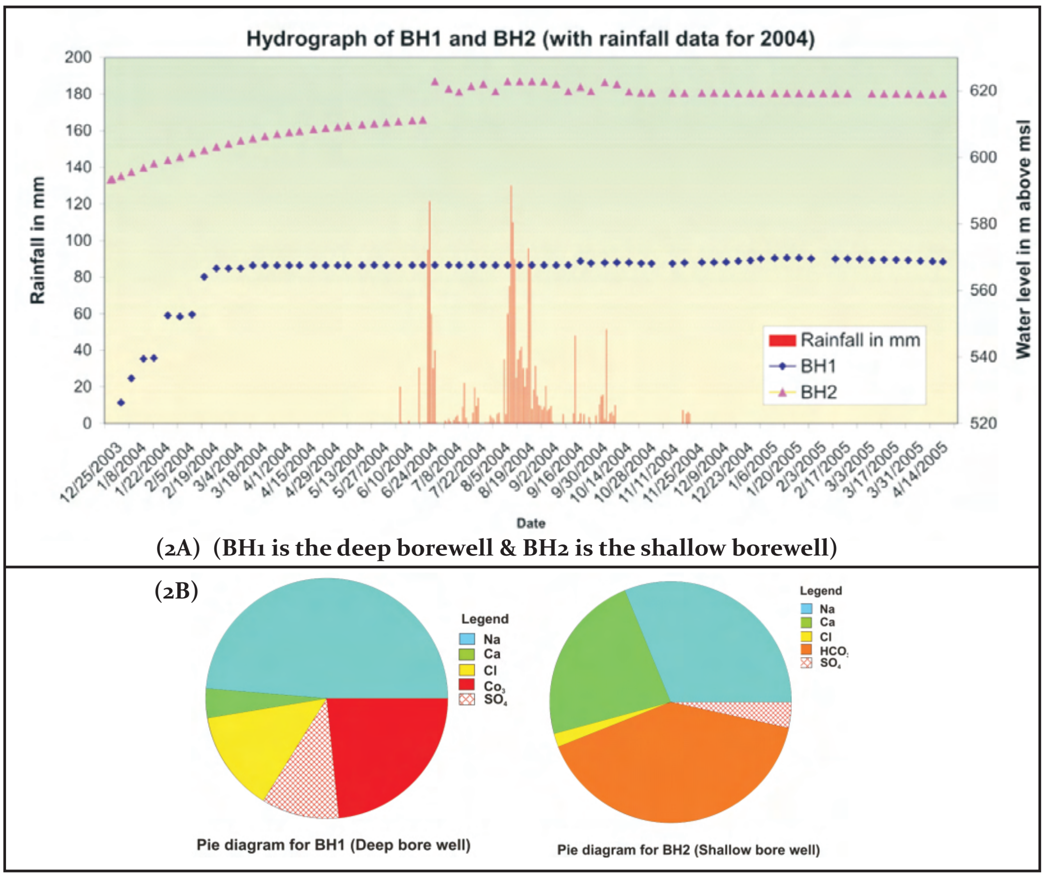


Figure 1: **Long term water level decline in an aquifer in hard rock area**

Even before getting into the hydrogeological details of an area, the ecology of a land unit, such as a microwatershed, can be described on the basis of a micro-level classification. The typology of eco-zones in the Neemkheda microwatershed from Dewas district is a case in point (*Shah et al, 1998*). Such an 'eco-zone' classification is indicative of a continuously evolving typology of a watershed in transition and ensures that ecological conservation is built into programmes like watershed development and catchment area treatment – programmes that also include a strong 'augmenting groundwater recharge' aspect. Also important, especially in context to the climate change scenario, is the ecological role of groundwater and how this role gets impacted through stages of groundwater development.

State level information on geology is available in the form of 'district resource maps' published by the Geological Survey of India. These are useful starting points for any hydrogeological study. They provide a fairly accurate regional picture of 'what to expect'. However, one must be careful while turning good geological information into effective hydrogeological understanding for an area. The mismatch between units of geological mapping (regional) and aquifers (local) is often the first hurdle; seldom are existing maps indicative of aquifer related information, which in certain cases is desirable in order to understand groundwater resources to their fullest. It is important to recognize that groundwater systems, especially in regions underlain by hard rock systems (ancient crystalline rocks of igneous and metamorphic origin and volcanic rocks formed by extrusion of lava onto the surface of the earth), operate at the micro-scale; aquifers are local, so solutions ought to be developed at the scale of such aquifers with talukas, blocks or districts in the background.

One of the first attempts in the process of identifying 'hydrogeological typology' was the classification of the Deccan basalt aquifers into two basic types – groundwater systems A and B – wherein the geometry of openings and a basic lithological (rock type) character was used to classify groundwater occurrences in the Deccan basalt *(Kulkarni, 2000)*. Similarly, a simple yet clear-cut classification between unconfined (also called phreatic) and confined (usually deeper) aquifers is often desirable. Observation bore holes drilled in such shallow and deep basalt aquifers in the Walki river basin near Pune city enabled understanding the characteristics of the groundwater system, based on a typology established through groundwater level information and groundwater quality for these two types of aquifers (Figures 2A & 2B). A detailed understanding of natural and artificial recharge to these systems was possible on the basis of such a classification. (*Kulkarni et al. 2005; Gale et al., 2006*).



(2A) (BH1 is the deep borewell & BH2 is the shallow borewell)

Figure 2: **(A) Hydrograph for deep & shallow bore well in Deccan basalt; (B) Variation in the water quality in the two bore wells**

Typology – a closer look from the ground

A closer look at hydrogeological settings from across different parts of India has revealed that aquifers (the geological units which store and transmit groundwater) behave in various ways, especially in context to how much groundwater they store and the manner in which they transmit it. The water quality profiles of different aquifers differ. Aquifer responses to various fluxes – natural and anthropogenic – are also quite diverse. Hydrogeology provides the first step in understanding "typologies" of groundwater resources. A typology-based understanding makes it easy to develop strategies of groundwater management, relevant to the hydrogeological conditions, the status of groundwater use, the anthropogenic characteristics of the area and other such factors that have a significant bearing on groundwater use.

ACWADAM, with the help of its partner organizations (mostly Non-Government Organisations - NGOs), is attempting to develop processes of groundwater management, based on the typology concept in at least 5-6 locations across India. ACWADAM's work supported by Arghyam Trust, Bengaluru to facilitate Gram Gaurav Pratishthan (and the Pani Panchayats) in Purandar taluka of Pune district is an important initiative. The other important initiative goes back to a collaborative project between ACWADAM and Samaj Pragati Sahayog, for nearly 10 years on the trot. Located within a tribal enclave of about 100 villages forming a part of the West-Neemad region within Dewas district of Madhya Pradesh, strategies for groundwater management are emerging as a consequence of a well-structured programme through a grant from Sir Dorabjee Tata Trust, since 2006.

The processes followed in both the cases were similar. They involved detailed geological mapping, hydrogeological investigations, weather-monitoring and socio-economic surveys. Emphasis, during the studies, was on mapping of aquifers and delineating at least rough-cut boundaries of aquifers, mainly on the basis of geological factors and on the distribution of 'heads' (water table elevations) across the area (*Figure 3*).

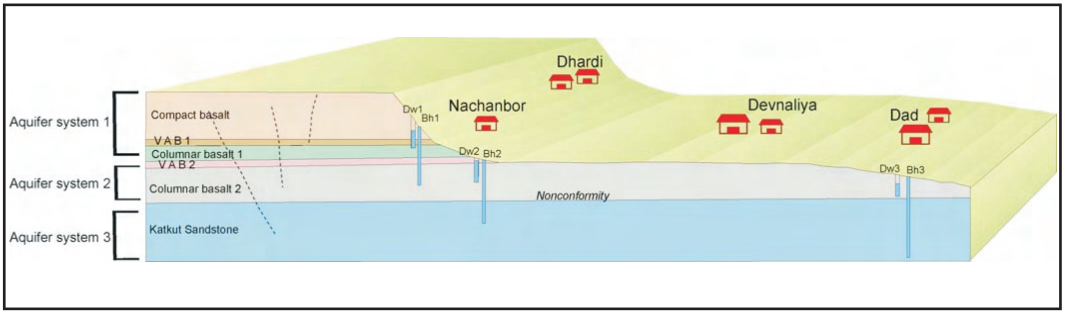
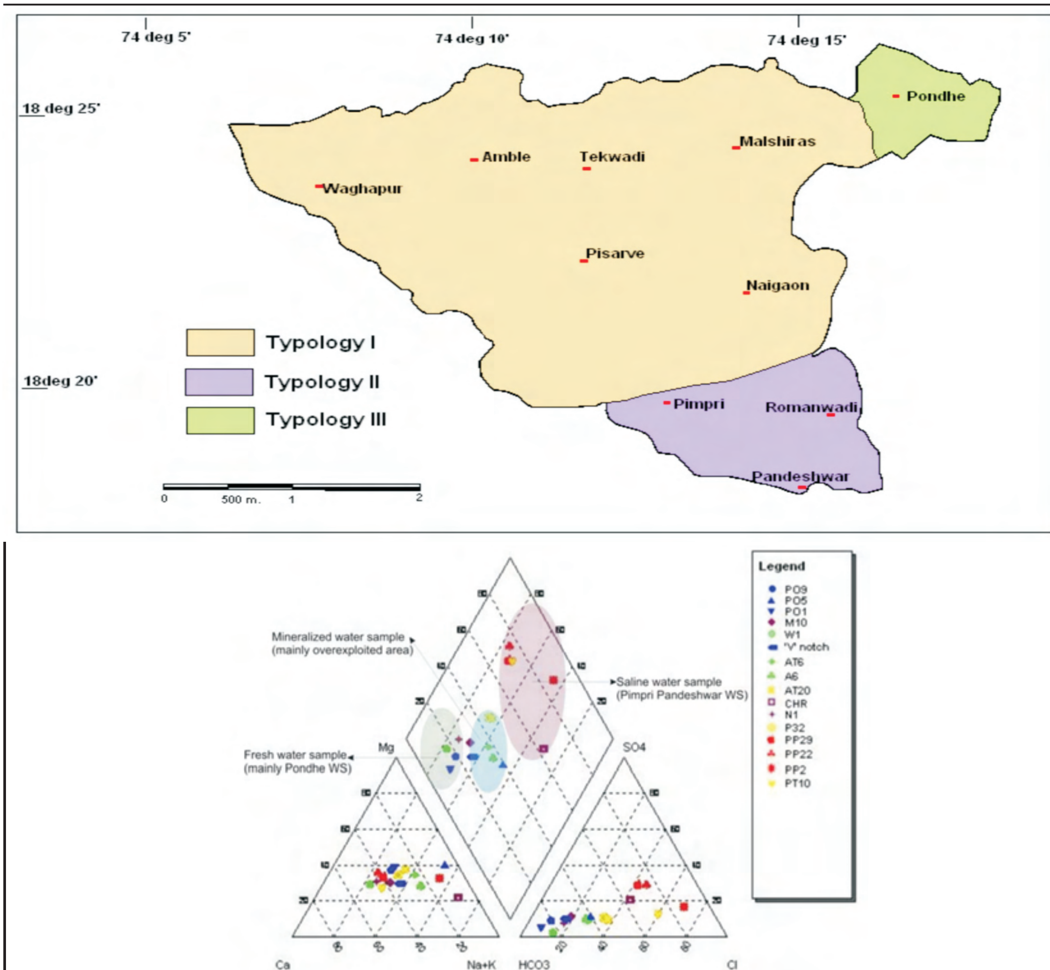


***Figure 3:* Aquifer schematic for Typology 1 in the study area of Dewas district of Madhya Pradesh**

The processes, per se, are not new and are commonly used as a methodology to study groundwater. The key lies in how results from these processes are used to typologise conditions that control groundwater and the situations that result from patterns of their use. This, in turn, enables a correct prognosis of the overall situation and the best possible response to the problem. Such an approach has the advantage of avoiding predisposed responses that are often too gross to be implemented or do not always consider the root cause of the problem itself.

The study in Purandar taluka of Pune district, located within a drought-prone regime underlain by Deccan basalt, enabled understanding groundwater resources in a conventionally 'overexploited block' of Pune district. This is also the area where Late Mr. Vilasrao Salunkhe's Gram Gaurav Pratishthan (GGP) developed the Pani Panchayat initiative. The typology of groundwater conditions in the area suggested three clear scenarios – overexploitation, groundwater salinity and limited groundwater resources development (*Figure 4*).



(B)

Figure 4 : **(A)Groundwater typologies in Purandar;**
(B) Piper plot for Purandar indicating different water types in the three typologies

The biggest lesson from this classification lay in the fact that conventional perspectives, based on grossly representative data from observation wells and piezometers set up by Central and State Agencies only perceive the problem as 'overexploitation' of groundwater. The typology approach enabled a more realistic classification of the three problems – each independent of the other, over a contiguous area. In the eastern part of Purandar taluka, where the main study was located, Typology 2 has a different geological framework that sets it apart from typologies 1 and 3. Typologies 1 and 3 have near-similar geology; the basalt rocks formed from the Deccan Volcanic activity that constitute the hydrogeological frameworks in these two areas are similar. Groundwater conditions in typology 3 depend upon thin, but consistent presence of river alluvium in juxtaposition with the surrounding basalt rocks. Rainfall regimes are different even across the three typologies and so are conditions of groundwater withdrawals and land-use. A detailed analysis of the three typologies is published as a separate technical report, highlighting the hydrogeological

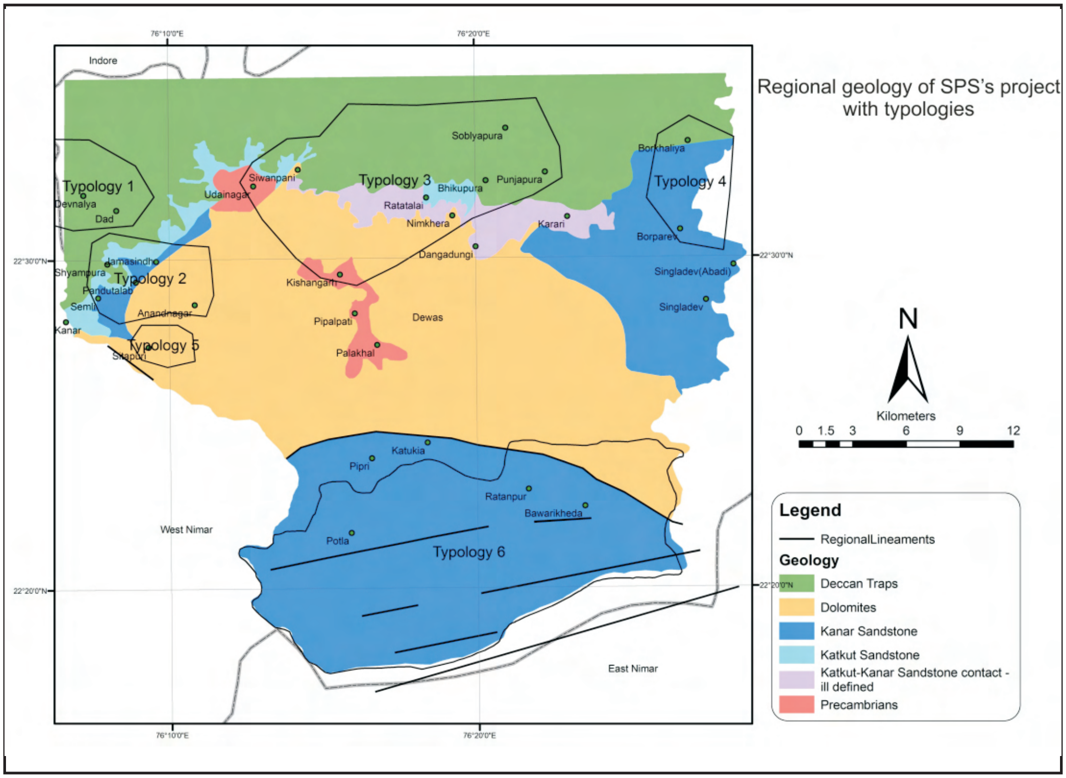


***Figure 5:* Geological map of the study area in MP along with the different typologies**

and socio-economic features that enable a typology-wise classification of such an area (*Badarayani et al, 2009*).The Dewas study is located in a region underlain by complex geology – multiplicity of rock types, structure and hydrology (*Figure 5*).

The study benefited immensely from early work by one of ACWADAM's founders on deciphering the complex geology of the region (*Kale, 1985; Kale, 1989*). More interestingly, the area forms a part of an evolving paradigm of watershed development by Samaj Pragati Sahayog (SPS), an organization working with the tribal communities in the region. What began as a small technical input and developed into an idea of implementing 'demand management' protocol (*Kulkarni et al, 2004*), was taken up to the scale of 'typologies' of situations within which SPS was working. These typologies were based on hydrogeological conditions, social and economic factors and the land-cover features of the region of interest. The conceptual framework of going from a watershed-based approach to an aquifer-based approach was a significant feature of this study and was attempted in all the typologies studied. (*Figure 6)*

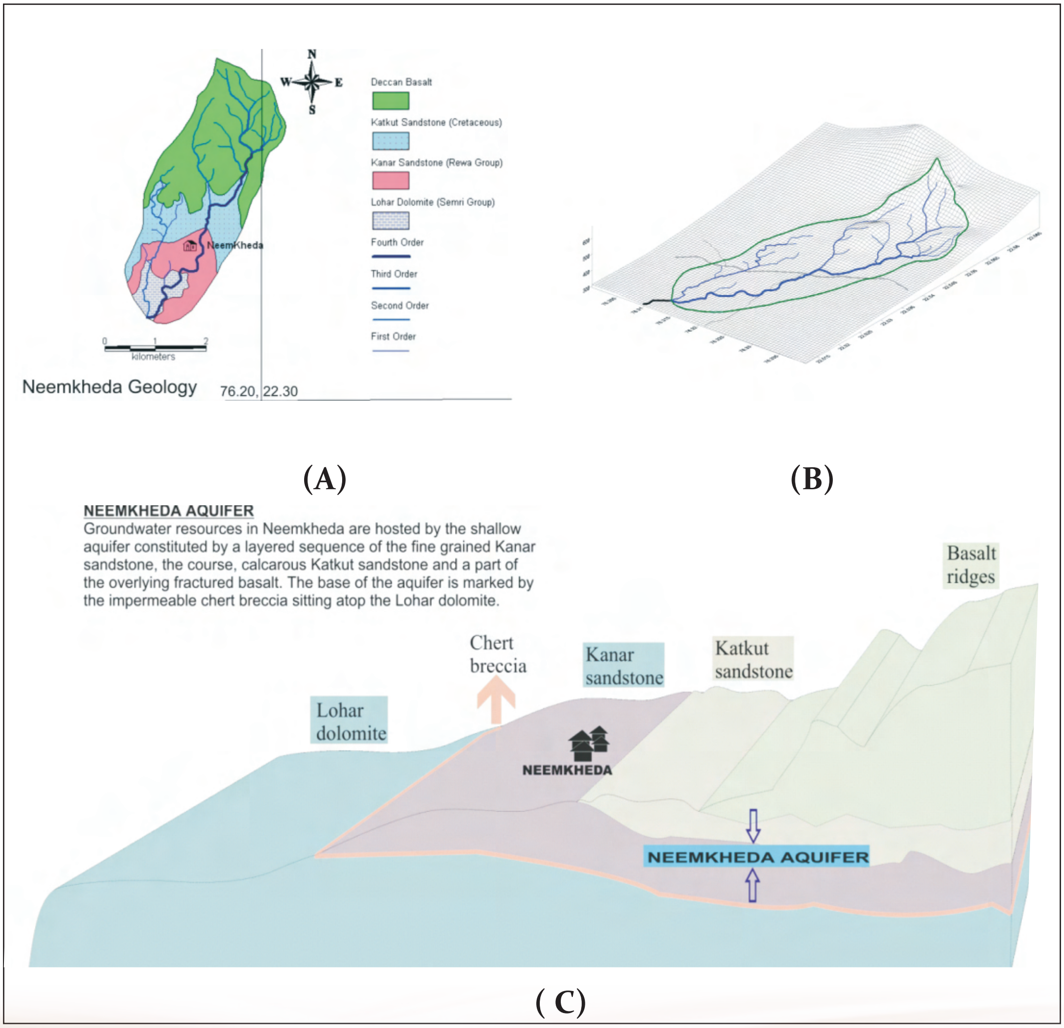


Figure 6 **: (A) Neemkheda geology; (B) Neemkheda watershed and (C) Neemkheda aquifer from Devas district of Madhya Pradesh**

Similarly, even aquifer-wise comparison across any two typologies shows how, in some areas, aquifers occur in isolation of other conditions and are a simple reflection of the sequence of rocks (Figure 7); The map also illustrates the main groundwater *recharge* and *discharge* zones. In other typologies, aquifer systems are complex and interconnected due to a certain disposition of rock-types, structural features in the rock and patterns of groundwater use downstream.

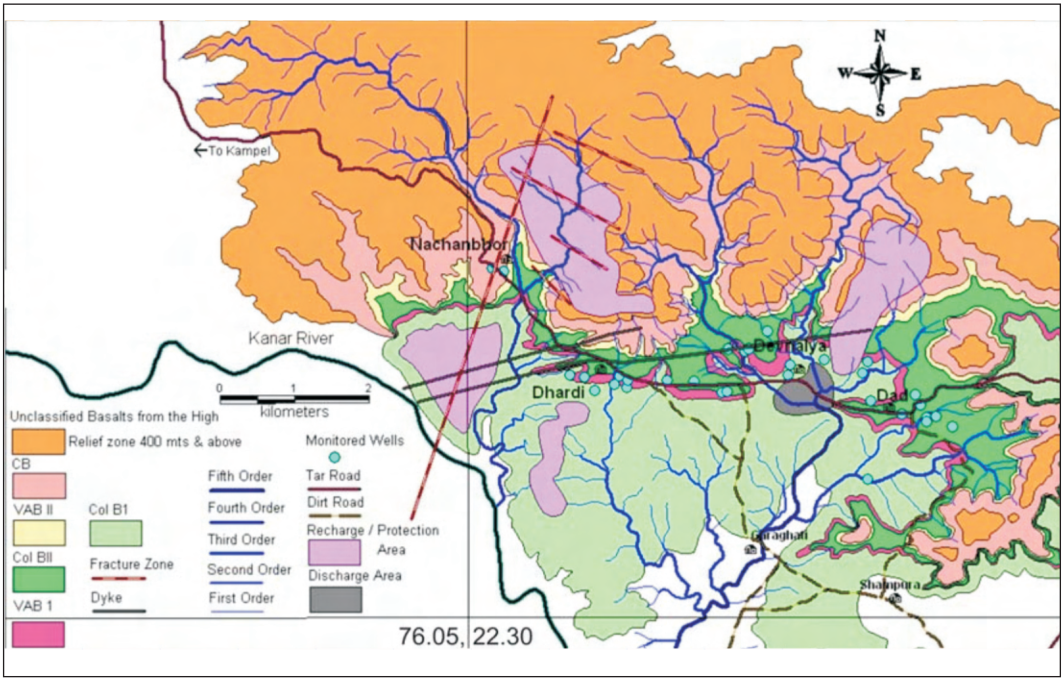


Figure 7: **Geology and aquifer map of typology 1**

Tailoring responses: protocols and pilots

Clearly, responses to scenarios that emerge through a typological approach will be different from how current response-models approach the groundwater problem. On the one hand, the site-specific nature of problems require *customized* responses rather than popular, *one-fits-all* type solutions. While the latter holds immense possibilities in *going to a scale*, the former is desirable in making a comprehensive difference on the ground. A typology approach leads to protocols of groundwater management. Tables 1 and 2 summarise the protocols of groundwater management developed for the Purandar and Dewas initiatives and are a consequence of detailed investigations, intensive data-gathering and an equally intensive analytical process, aided by simple groundwater modeling, the detailed description of which is outside the scope of this paper.

Table 1: Matrix of protocols and feasibility of their implementation as part of the Groundwater Management Strategy in Purandar

Protocols	Typology 1 (Overexploited area)	Typology 2 (Pimpri-Pandeshwar)	Typology 3 (Community based groundwater management)
Geohydrological science in Watershed Programme (Special reference to recharge area demarcation)	* ?	* ✓	
Recharge area protection (Forest cover & community lands)	* ?		* ✓
Efficient use of individual wells		* ?	* ✓
Pump capacity regulation	* ?		
Regulation of distance between wells (Drinking well protection)	* ?	* ?	
Construction of recharge structures for water quality improvement		* ✓	
Regulation of agricultural water requirement (crop water requirement)	* ?	* ?	* ✓
Groundwater sharing through community participation	* ?		* ✓
Community sensitization and awareness generation for groundwater use		* ?	* ✓
Government regulations to controloverexploitation	* ?	* ✓	

(* = Necessary ; ? = Uncertainty in implementation ; ✓ =Possible to implement)

Table 2: Matrix of protocols and feasibility of their implementation as part of the Groundwater Management Strategy in Madhya Pradesh

Protocols	Typology 1	Typology 2	Typology 3	Typology 4	Typology 5	Typology 6
Geohydrology in WSD	* √	*	* √	* √	*	* √
Protection of recharge areas	* √	* √	* **Land-use protection** ?	* √		*
Efficient well use	*		* ?	*	* ?	
Pump capacity regulation	*	*	*		* ?	*
Distance (w.r.t drinking water well) regulation	* √	*	* √	* √	* √	* ?
Depth regulation (w.r.t drinking well)	* √	* ?	* √			* ?
Regulation of agricultural water use	* √	*	* √	* √	* ?	
Groundwater management through sharing	* **User groups** √ **Nachanbor**	*	* √ **Patpadi**	* **User groups** √ **Borkhalya**	*	*

(* = Necessary ; ? = Uncertainty in implementation ; √=Possible to implement)

The two tables above are just *first-cut* strategies of converting protocols (set of good practices) into actions on the ground, through a participatory process (potential action). These tables have already gone through a round of discussions with various stakeholders – mostly the partner organization and with some community members.

In Purandar, for instance, piloting in typology 3 is currently on, with a village-level, participatory managed system of well-user groups (*Kulkarni et al, 2005; Kulkarni, 2009*). Implementing protocols under typology 1 and 2 would require support and initiatives at a much higher level, perhaps even including a back-up through a formal legislative framework. The magnitude of desirable interventions in these two typologies would mean larger investments in terms of human resources, institutions and time-frames.

On the other hand, in the Dewas initiative, ACWADAM has been able to make certain inroads into using such an approach on the ground. The goal of this project is strategizing improved groundwater management initiatives, through a community-based approach. The decision support matrix of actions, across six typologies of groundwater conditions (*Table 2)*, has evolved on the basis of hydrogeology, ecology and socio-economic factors. Responding to groundwater issues in these six typologies has involved a continuous dialogue with the partner organization (SPS) and the community, leading to developing a set of protocols and identifying niches in which these protocols may be implemented. Piloting some of these protocols has begun and will continue through a period of the next two years or so. One of the most significant developments in this regard is the process of using geohydrology in all the microwatershed programmes of SPS, particularly with regard to recharge augmentation through structures like percolation tanks and discussions around special protection of 'recharge zones' in forest areas. Similarly, a dialogue with communities in typology 1 has resulted in the Gram Sabha of Nachanbor village passing a resolution of community-based management of their aquifers. In other typologies, work is in progress, in attempts to convert protocols into action, as per the summary illustrated in *Table 2*.

In conclusion

The major challenges in implementing solutions to address the complex groundwater resources syndrome in India include the following:

1. Scale: current planning is on regional scales, whereas the dynamics of resource use plays out locally. There is little effort on understanding groundwater characteristics and groundwater use at the appropriate scale.
2. Mapping: Even the best of geological maps, which provide the first input to a complete understanding on groundwater resources, are available only for a region – a district, for instance. The information on such maps is too coarse to lead to a sound understanding of groundwater at the scale of aquifers, the basic units required in the planning, development and management of groundwater resources.
3. Information: The source of information, type of information and the scale on which it is collected determines the feasibility of turning such information into an effective

decision support tool. Hydrogeological information on aquifers is currently not available in most parts of India.

Regional classification of groundwater resources in India is available from various sources. However, the inability to look beyond groundwater provinces is only a result of a complete neglect of field hydrogeology. The obvious 'types' of groundwater conditions based on the physical characteristics and the socio-economic setting under which groundwater resources are used, remains largely neglected. Identifying typical features of an aquifer or a groundwater system in an area is crucial to the design and implementation of groundwater management responses.

It is important to note that the concept of typology is not new. However, understanding types at the right scale is. This paper sets forth a conceptual framework for improved understanding of groundwater resources by recognizing the typology of groundwater in an area. The typology is defined by the hydrogeology, patterns of use, magnitude of groundwater resource development and appropriate response mechanisms to address existing and potential problems surrounding the resource. The approach presented here leads to improved responses that make decisions on where-to-do-what-and-when feasible. It would also be interesting to test out the typology process in understanding groundwater under the following situations, wherein groundwater-related inputs are greatly desired:

- Management of spring water in the Himalayan region and in other uplands of the country.
- Regional and local aquifer settings from the crystalline basement rocks of peninsular India.
- Characterising geogenic groundwater contamination, especially in Fluoride and Arsenic prone regions of the country.
- Understanding the site-specificity of salinity ingress along the coastal belts of the country.
- Based on these and other studies, it would be interesting to even construct a national 'typology' of groundwater, with the basis being hydrogeological settings, although aquifers as the basic units for such a typology would be more desirable.

Acknowledgement

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Hydrogeology in watershed planning:
A practitioners view

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Abstract: By its very nature, groundwater is a common pool resource (subtractible but difficult to exclude). Perhaps the most critical weakness of watershed programmes in India is that it is not informed with this understanding of groundwater. Watershed planners forget that just as there is a surface water catchment, there also exists a groundwater catchment and the boundaries of these two catchments may not coincide. As groundwater occurs in aquifers, careful mapping of the properties of aquifers is important in watershed planning. Composite rock strata with varying aquifer properties gives rise to specific groundwater typologies. These typologies are not just physical entities but go with a historically governed pattern of access to and use of groundwater by communities. While the physical structure broadly sets out the range of options available, the choice is by no means determined by the physical structure alone. Hence, a groundwater typology is a socio-physical category. The true watershed community is the one that shares an aquifer. The vexing issue at the level of implementation is the scale at which interventions at the typology level need to be co-ordinated. The science of hydrogeology has to play a crucial role in generating the database to arrive at an appropriate scale of intervention.

From this perspective, watershed development involves strategies to ensure the protection and the sustainable and equitable use of groundwater by the community. SPS has been trying to work out (with the help of ACWADAM's technical advice) strategies for sustainable and equitable use of groundwater in each of the 6 groundwater typologies of its area of operation. This is not just a technical planning exercise. It is a process of social decision-making backed by a scientific understanding of the resource. People's institutions play a key role in this process – Gram Panchayats and SHG federations are two such institutions which could play an important role in our context.

Introduction

Groundwater irrigation has been one of the prime movers of agricultural growth in India in recent years. Of the addition to irrigated area of 25.7 million hectares (mha) between 1970 and 2003, groundwater accounted for over 85%. At present, about 62% of the irrigation in the country is from groundwater. The area under canal irrigation has ceased to expand significantly since the mid-seventies while the area irrigated by tanks has actually declined. The most dramatic change in the groundwater scenario in India is that the share of tubewells in irrigated area rose from a mere 1% in 1960-61 to 39% in 2002-03. By now, tubewells are the largest source of water for irrigation in India (*Table 1*).

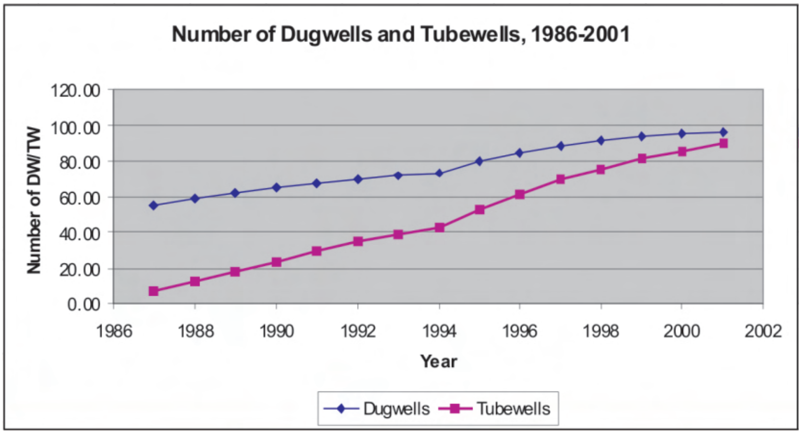
Table 1: **Share of Various Sources (5 Year Averages) in Net Irrigated Area in India, 1950-2007 (%)**

Years	Canal	Tank	Tubewell	Other Well	Others	NIA (Mha)
1950-51 to 1954-55	41%	17%	0%	30%	11%	21.4
1955-56 to 1959-60	42%	20%	0%	29%	10%	23.2
1960-61 to 1964-65	42%	18%	3%	27%	10%	25.5
1965-66 to 1969-70	41%	15%	9%	26%	8%	27.9
1970-71 to 1974-75	41%	12%	17%	24%	7%	32.1
1975-56 to 1979-80	39%	10%	22%	22%	7%	36.6
1980-81 to 1984-85	39%	8%	26%	21%	6%	40.8
1985-86 to 1989-90	38%	6%	30%	20%	6%	44.0
1990-91 to 1994-95	35%	6%	31%	21%	7%	50.5
1995-96 to 1999-00	31%	5%	36%	22%	6%	55.7
2000-01 to 2006-07	26%	4%	41%	20%	9%	57.4

Source: Indian Agricultural Statistics,2008; NIA in Million Hectares

The growing importance of tubewells is also indicated by the data from the All India Minor Irrigation Census (*MoWR, 2001*). There has been a dramatic rise in the number of tubewells in India between 1986 and 2001 (*Figure 1*). There is no reason to believe that the growth of tubewell irrigated area has abated since then.

The MI Census data shows that 60% of the tubewells are concentrated in four states, UP, Punjab, Haryana and Rajasthan. Dugwells, by comparison, are concentrated more in the hard rock and dryland regions of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh and Tamil Nadu.



Source: Minor Irrigation Census, 2001

Figure 1: **Number of dugwells and tubewells(in thousand), 1986-2001**

Groundwater is also important as a source of drinking water. According to the figures of the Department of Drinking Water Supply, GoI (*DDWS, 2009*), nearly 90% of the rural water supply is sourced from groundwater. NSS surveys confirm this. According to the latest available data, 56% of the rural households get drinking water from handpumps or tubewells, 14% from open wells and 25% from piped water systems based on groundwater (*NSSO, 2005*). Though the share of drinking water in total water use is about 7% whereas irrigation accounts for over 80%, rapid expansion of groundwater irrigation can threaten drinking water security in the long run. Indeed, there is mounting evidence that this could be happening in many parts of rural India, as shown by the statistics of several habitations "slipping back" from full coverage to partial coverage (*DDWS, 2009*).

Problem of groundwater overuse

The annual extraction of groundwater in India (210 billion cubic metres) is by far the highest in the world (*Shah, 2009*). It is now generally recognized that with such high levels of extraction, the crisis of groundwater is indeed growing in magnitude (*Moench, 1992; Dhawan, 1995; Macdonald et al, 1995; Kulkarni and Shankar, 2009)*. The recently published Report of the Expert Group on Groundwater Management and Ownership (*Planning Commission, 2007*) gives further evidence that the situation has only worsened, if anything. The report accepts that the rate of extraction far exceeds the rate of replenishment in many blocks, leading to a progressive lowering of the water table. In 2004, an alarming twenty-eight per cent of the blocks in the country were in the category of semi-critical, critical or overexploited, compared to 7% in 1995. In six states (Gujarat, Haryana, Maharashtra, Punjab, Rajasthan and Tamil Nadu) the proportion of blocks in these categories was as high as 54%. By all indications, the situation could not have become any better since then. Moreover, tubewells (numbering 21 million) have become the main mode of irrigation in the country, covering nearly 37% of the irrigated area in the country.

The depletion of groundwater is closely associated with worsening water quality, as indicated by the rising levels of fluoride, arsenic and iron.

A comparison of the CGWB's assessment of annual replenishable groundwater resources in 1995 and 2004 highlights the fact that groundwater crisis is spreading into a much larger area now and is affecting a significantly higher number of people (*Kulkarni et al, 2009*). In a short time of less than 10 years, the proportion of districts in the semi-critical, critical and over-exploited categories (districts which could be said to be in an “unsafe” category) has grown from 9% to 31%, area from 5% to 33% and population affected from 5% to 35%. This shows that the time for complacency with regard to the groundwater situation is over and we need to now urgently address the task of sustainable management of our precious groundwater resources. The Planning Commission report emphasizes the need for “adopting for all groundwater management units a sustainable-yield management goal, which means that average withdrawals should not exceed long-term recharge” (*Planning Commission, 2007, p.47*).

Need for a new framework

In order to determine this “sustainable-yield management goal” for groundwater, we need to understand the physical framework within which groundwater occurs, i.e., aquifers. The amount of water an aquifer can store and transfer depends on the physical properties of the rock strata like void space, size and inter-connectedness of the voids etc. Accumulation and movement of groundwater in an aquifer depends on its physical properties, thickness, spread, extent of weathering, structural features (such as fractures, folds and faults) etc. The variability in aquifers is particularly high in the crystalline and volcanic rocks (often referred to as “hard rock” formations) on account of their low primary porosity (*Kulkarni, 2005; COMMAN, 2005*). Such rocks underlie about 65% of the geographical area of India. Groundwater resource in hard rocks is characterised by limited productivity of individual wells, unpredictable variations in productivity of wells over relatively short distances and poor water quality in some areas. The initial thrust of irrigation by tubewells following the Green Revolution was restricted to India's 30% alluvial areas, which are generally characterized by relatively more pervious geological strata. But from the late 1980s, tubewell drilling was extended to hard rock regions where the groundwater flow regimes are extremely complex. Deeper aquifers often have good initial yields, but a tubewell drilled here may be tapping groundwater accumulated over several hundreds of years. Once groundwater has been extracted from a deeper aquifer, its replenishment depends upon the inflow from the shallow system or from the surface several hundred metres above it. The path this water has to traverse is characterized by relatively unfavorable media, which greatly slows down the rate of groundwater recharge (*Shah et al, 1998*). This poses a severe limit to expansion of tubewell technology in areas

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1 *An aquifer is described as a rock or rock material that has the capacity of storing and transmitting water such that it becomes available in sufficient quantities through mechanisms like wells and springs.*

underlain by these strata. Similarly in the mountain systems, which comprise 17% of India's land area, effects of groundwater overuse do not take very long to appear (*Kulkarni et al, 2009*).

An understanding of this complexity escapes even more carefully planned natural resource management initiatives like the watershed programme. The central weakness of watershed programmes in India has been that they operate almost as if there is essentially no difference between surface water and groundwater. As its augmentation is one of the main objectives of watershed development, groundwater enters the programme only as something to be recharged and replenished. It appears to hold no other significance at all in watershed planning. Watershed planners appear to forget that just as there are surface water catchments, there are also *groundwater catchments* and the boundaries of the two catchments do not necessarily coincide. But we continue to define a watershed with reference to surface water flows alone (*GoI, 2006*). There could be one aquifer cutting across several watersheds; on the other hand, there could be different aquifers within the same watershed. The transmission and storage properties of the aquifers are highly variable. Hence, one needs a *micro-level mapping* of geological strata and of aquifers in order to visualize integration of interventions at an aquifer level. From this point of view, the true watershed community is the one that shares an aquifer. Hence, getting this community together, to rally around their community groundwater resource is the required social engineering focus. Hence, understanding the properties of groundwater catchments becomes an integral component of watershed planning.

From mapping to typologies

The complex issue at this stage is the relevant scale at which mapping and interventions need to be co-ordinated. This appropriate scale is determined by the degree of interconnections between aquifers and the extent to which actions done in one part of the aquifer affects other parts (*zones of interference between wells*). Here, the science of hydrogeology plays a crucial role in generating the necessary knowledgebase.

Augmentation of groundwater by various methods has become an integral part of the watershed programme. Most programmes seldom consider the importance of the geological formations in recharge processes. Moreover, groundwater quality is also an aspect that ought to be considered alongside depletion and appropriate recharge responses. *Alluvial systems*, in general, have recharge cycles at a regional scale, with groundwater occurring in multiple aquifers (an aquifer is overlain by many villages, also each village can vertically tap parts of multiple aquifers). Quality issues here could escalate exponentially along with depletion. In such situations, aquifer systems need to be mapped at the scale of small river basins (size 500-1000 km^2) and appropriate strategies worked out for conservation and recharge at this scale. *Crystalline formations ("basement rocks"*) can have recharge systems that are local in nature and depletion here tends to be more on the quantitative side. Interventions need to be co-ordinated at the scale of milli-watersheds (100 km^2), with emphasis on tuning strategies of conservation and recharge to the local dynamics of water availability and quality. At the other extreme, we can have the *mountain systems* with extremely localized recharge, where the appropriate scale of mapping and intervention is that of a micro-watershed (1-10 km^2). Aquifer mapping at this scale would emphasise strategies of conservation and recharge to be oriented mainly towards local recharge-discharge balances (*Kulkarni et al, 2009*).

Aquifers seldom exist in pristine isolation. The complex layering of rock strata with varying aquifer properties gives rise to specific *groundwater typologies*. We must remember that while the physical structure is often useful in identification of properties of rock strata, the typologies are not just entities in physical space. They go with a historically governed pattern of access to groundwater and the social processes that regulate its use. Identification of typologies becomes more complex when we introduce considerations of water quality into the discussion. While the physical structure broadly sets out the range of options available, the trajectory of development of groundwater resources is governed by specific historical context and the choices made therein. Hence groundwater typologies need to be seen as a socio-physical category.

The basic idea emerging from the above is that groundwater in an aquifer is a common property to be managed as a community resource, even when access to it is private. Groundwater is an invisible, non-stationary, "fugitive" resource, which does not respect boundaries set by landholdings. Clearly, the water below “my” land is not “mine”. This follows from the connectivity of the aquifer cutting across field boundaries and administrative divisions. *By lowering the depth of his tubewell, my neighbour can squeeze all water out of my well. And by increasing the horsepower of my pump and running it for more number of hours, I can draw more water to irrigate my sugarcane field. The spillover of the consequences of my actions to my neighbours is determined by the connectivity of the aquifers.* From this perspective, watershed development involves strategies to ensure the protection and the sustainable and equitable use of groundwater by the entire user community. The primary concern here is that of protection of the resource, with a clear idea of the annual inflows to and outflows from the groundwater system. The notion of the groundwater community goes beyond the “village” and embraces all those who draw water from the aquifer in question.

Two key ideas are helpful in guiding our thinking on this issue. The first is the fundamental, revolutionary idea of the Pani Panchayat movement in Maharashtra (started by Vilasrao Salunkhe), which is the separation of right to water from the right to land. By convention in India, water rights go alongside with land rights, bringing with it a whole plethora of challenges in community-managed groundwater systems. However, the Pani Panchayat movement proposed, for the first time in India, to separate the two and entitle even the landless to right over water. This “water reform' in many ways goes much beyond the traditional left agenda of “land reform”. The second idea is the key distinction emphasized by KR Datye, the visionary thinker, between “basic service” and “economic service” of water (*Datye et al., 1997*). Basic service is the minimum quantity of water to be assured to all households irrespective of their land size to meet their basic requirements at affordable cost. This follows from the principle of "specific egalitarianism" put forward by James Tobin. In any society, there are certain goods, which should be distributed less unequally than people's ability to pay for them. These are mostly public goods, such as water, access to which is critical for a healthy living. Hence, we must make special arrangements so that their distribution is less unequal than the configuration that warranted by an unequal distribution of income (*Tobin, 1970*). Economic service of water is the part over and above basic service, which is devoted to entrepreneurial or profit-making activity. While basic service costs will be provided at an affordable price to all, pricing of economic service could gradually move towards a full cost recovery (*Paranjape et al., 2009*). Both these ideas underline the importance of managing groundwater as common property.

From typologies to strategies

Clearly, the primary task of sustainable management of groundwater is to carefully delineate typologies of aquifers incorporating variations in hydrogeological and socio-economic contexts. Once the assessment of the water availability in a region or a watershed is made, we need to fix priorities of its use and attempt to shape the existing use pattern to suit these priorities. This involves development of location-specific protocols and agreements within the user community on the sustainable use of water. The most significant aspect of the protocols is that they emphasise drinking water security as the primary goal. Two principles which could be adopted here are: a) reserve a certain quantity of available water for drinking purposes; and b) fix a certain amount which will be left out of the system, which will meet the ecological services and the basic needs of the downstream regions (*Datye et.al, 1997*). A region or watershed could then develop a plan to meet the drinking water needs of the community. In case where the available "internal" water is not adequate, provision of "external" water should be considered.

Identification of strategies is not a technical planning exercise. It is a process of social decision-making backed by a scientific understanding of the characteristics of the resource. The location-specific protocols offer a menu of options relevant to a specific typology. This menu of options outlines the contours of a comprehensive strategy of groundwater management relevant to the particular set of conditions controlling the occurrence, movement and utilization patterns of groundwater resources within the aquifer(s) in an area (*Kulkarni et al, 2009*). Protection of drinking water security involves norms related to controlling the depth and spacing of wells, increasing efficiency of existing wells, controlling capacity of pumps used and a regulation of the overall groundwater use to move towards community managed systems.

Closely related is the issue of pricing of water. Much of the recent initiatives in privatisation of water have centred on pricing reform. There is no question that the percentage of cost recovery in the water sector in India has been abysmally low (*Vaidyanathan, 2006*). From an ecological economics perspective, it is undeniable that

2 *Tobin defines this as "non-market egalitarian distributions of commodities essential to life and citizenship that are in inelastic supply" (Tobin, 1970).*

resources like water must be priced (*GoI, 2006*). However, this perspective is not the same as that of "getting prices right" or full cost recovery. The use of price mechanism should be to regulate wasteful uses of water and to direct it to ecologically appropriate channels. The underlying principle, as mentioned earlier, is a separation of the basic service and economic service of water. The attempt is to ensure domestic and livelihood water for basic needs to all households at affordable cost. Any use of water over and above this level should be subject to a user charges at differential rates reflecting concerns of equity.

In the next section, we illustrate the process of identification of typologies and location-specific protocols, with examples from the area of operation of Samaj Pragati Sahayog, which among various initiatives, has implemented watershed development projects in a tribal enclave of about 100 villages in Dewas district of Madhya Pradesh.

Some examples

Samaj Pragati Sahayog (SPS) and the Advanced Center for Water Resources Development and Management (ACWADAM), Pune, have been engaged in this exercise of delineation of typologies of hydrogeological situations and developing appropriate management responses in Dewas district of Madhya Pradesh. SPS has been engaged in watershed and other natural resource conservation programmes in this drought-prone, semi-arid part of Narmada valley for the last fifteen years. This area receives an annual rainfall of about 800-900 mm. The major rock types of the area are igneous (*Deccan Trap basalts*) and sedimentary (Vindhyan sandstones, shales and dolomitic limestones) rocks. The broad geological map of the area is given below (*Figure 2*).

Within this area, the SPS-ACWADAM team identified 6 typologies covering roughly 1000 km2 and 90 villages. The field study involved collection and analysis of rock samples, seasonal monitoring of water levels, measurement of stream flows and water levels in locally constructed tanks and other water bodies, observation boreholes to monitor water levels in deep-seated aquifers and pump tests to determine aquifer properties. A team of two persons has been placed at the SPS location fully devoted to performing these tasks, with the support from SPS watershed teams and occasional visits of ACWADAM personnel. After nearly two years of hydrogeological and socio-ecologic surveys, the SPS-ACWADAM team has identified the following broad protocols to be implemented and the priority to be given to each protocol in a given typology (*Table 2)*.

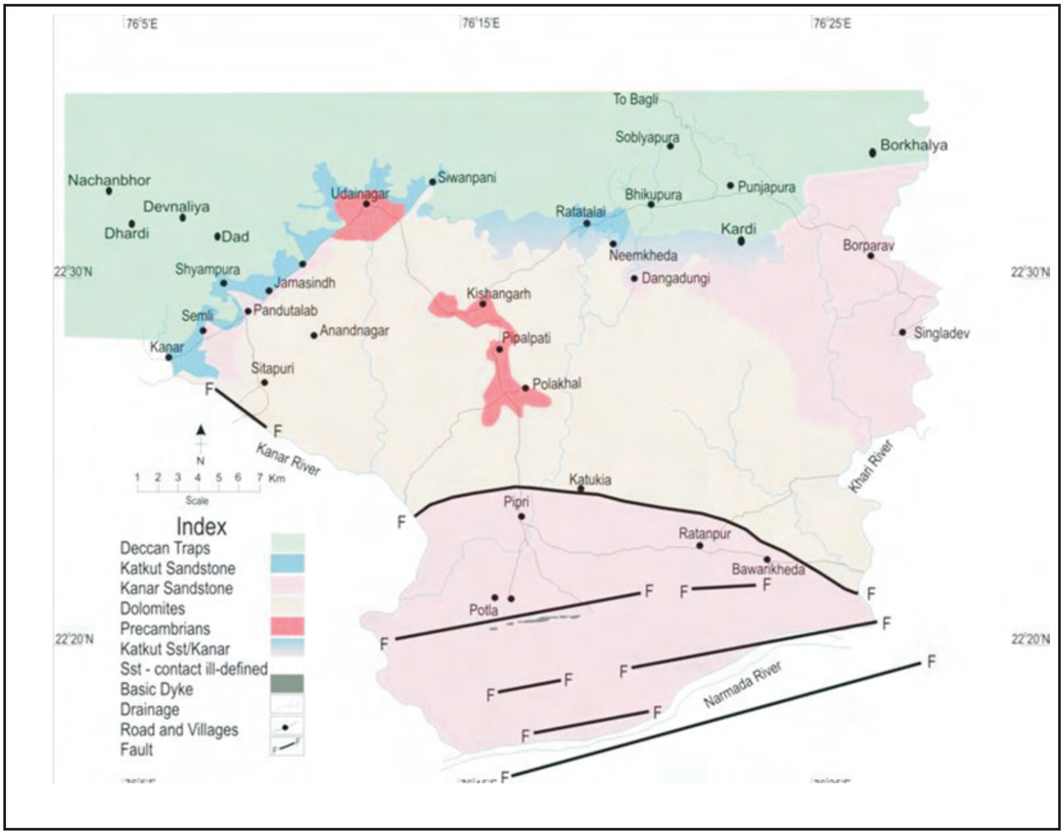

Figure 2: **Geological setting of the project area**

Table 2:**Protocols Identified and Prioritised in each Typology of SPS Project Area**

PROTOCOLS	TYP 1	TYP 2	TYP 3	TYP 4	TYP 5	TYP 6
Recharge Area Protection	**	**	**	**		**
Efficient Use of Individual Wells			**	**		**
Pump Capacity Regulation		**	**		**	
Regulation of Depth and Distance of Wells	**	**	**	**	**	**
Optimisation of Water Use in Agriculture	**	**	**	**	**	**
Community Sharing of Wells	**	**	**		**	

Some village-specific aspects of these protocols is discussed with reference to some of the typologies mentioned:

Typology 1: Nachanbor is a village located in Typology 1, which is underlain by Deccan Trap formations of igneous origin. Basalt is the major rock type here. The village has very few irrigation wells on account of its hard rock geology. The major stream in the village, which carries seasonal runoff, is the only source of irrigation. In this stream, SPS has constructed a series of stopdams enhancing storage of water in the stream and recharge of basalt aquifers in the village. Meanwhile, the District Panchayat sanctioned several individual wells to be constructed with NREGS funds in Nachanbor. However, the calculations by the ACWADAM team showed that the actual available recharge is not sufficient to support so many wells. Moreover, excavating more wells could harm the drinking water sources of the village and worsen the already dire water situation. The SPS-ACWADAM team put forward the idea to the village community that instead of wasting money on a large number of (probably shallow,) individual wells with uncertain yield, it is better that the farmers come together, form groups and construct proper community wells that are in line with the hydrogeologic situation in the village. A plan for constructing 7 wells along at appropriate locations, in close proximity to the newly constructed stopdams has been drawn up. Each well will cater to 6-7 households, who will come together as a group owning a well. Water from the well will be shared in a way ensuring all households an equitable share in water. Along with construction of group wells, a plan to protect the recharge area (a specific forest patch) as well as the drinking water sources has also been drawn up. The Gram Sabha meeting held on 14th April, 2009 ratified the agreement at the village level, stating all these components. This agreement ratified by the Gram Sabha also states that the village community will not construct any new wells within a specified radius of 100 metres from the drinking water sources and under no circumstances shall the depth of any new well in the village exceed the depth of wells used for drinking water.

Typology 2: Pandutalab is a medium sized village located in Typology 2. This village has coarse-grained calcareous sandstones as the main aquifer. Irrigation in the village is largely from a set of open dugwells constructed on these Vindhyan sandstone aquifers. In addition, the village also has a few deep tubewells that pick up water from the dolomitic limestone aquifer lying below the sandstones. The village had only limited irrigation till recently on account of poor availability of electricity. However, with the improvement in the quantity and quality of power supply, the village has started exploiting its groundwater resources aggressively. The most urgent intervention required in the village is a regulation of the pump capacity and hours of pumping together with control over spacing of the wells and tubewells. These need to be supported by a regulation of cropping pattern to minimize dependence on water-intensive crops and a shift to crops and varieties that economise the use of water. Since the sandstone aquifers of the village hold good potential for groundwater recharge, recharge area protection also becomes one of the major priorities in this village.

Typology 3: Neemkheda is the first watershed developed by SPS. It is located in Typology 3. Like Pandutalab, the extent of groundwater use in Neemkheda has gone up over the years, also as a result of the watershed interventions undertaken by SPS. There has been a more than three-time increase in the area under irrigation; the depth of irrigation (number of irrigations per unit of cropped area) has nearly doubled. Through long-period observation, however, SPS-ACWADAM team has identified that the major aquifer of the village (Vindhyan sandstones underlying most of the productive shallow wells in the village) has a thickness of about 20 metres and extends over nearly 500 hectares. With this information, SPS had drawn up a plan for sharing individual wells through sequencing in his village (*Table 3*).

Table 3: **Model for Optimal Use of Groundwater in Wells across the Season**

Well Characteristic		STORATIVITY (S)	
		Low	High
TRANSMISSIVITY (T)	Low	Drinking Water (1)	Last Use (4)
	High	Early Use (2)	Interim Use (3)

Here, wells tapping an aquifer or part of the aquifer with low storage and low transmissivity (1) would be preserved exclusively for drinking water. Wells with a low storage of water and high rates of transmission out of it (2), could be used in the first part of the season, as water is not going to last for long in these wells. Where storage is high but so are the expected losses due to transmission (3), water could be used in the middle part of the season. The best wells, which have high storage of water and lose it also slowly (low T) (4), could be used only at the fag end of the season, with a part of the water from such wells apportioned for drinking water during the summer (*Kulkarni et.al., 2004*). While technical feasibility and detailed protocols for such sharing can be worked out, the problem is that the social processes in the village are not strong enough to support such a community initiative. Therefore, at present the attempt is limited to rationalizing water use through propagation of less water-using varieties and crops through the agricultural programme as well as more intensive work in the recharge area of the village.

Typology 5: Sitapuri in this typology was an extremely poor village, underlain by dolomitic limestones with high vertical permeability. This village has only one or two productive shallow wells. Most of the cropped area in the village had no irrigation cover. When SPS began its watershed work in Sitapuri, the village had no access to electricity as well. SPS introduced two lift irrigation systems in the village, both of which drew water from surface well constructed on the banks of the main stream of the village. Irrigation water and electricity first came to the village through these schemes. Later, in 2003, a new electricity line was laid in the village with the funds provided by the local MLA. A few farmers tried to install borewells tapping the deeper, limestone aquifers underlying the village. The initial efforts at this were hugely successful in drawing out substantial quantities of water. Encouraged by the initial successes, many more farmers followed suit and soon there arose a situation akin to a run on groundwater in the village. In some three years, 18-20 borewells were drilled in the village, all of which drew water from the limestone aquifer. The geographical location of Sitapuri, at the tail-end of a groundwater catchment stretching over 2000 km2, further favoured uncontrolled extraction of groundwater. In other words, Sitapuri at present is acting like a free-rider benefiting from the recharge efforts implemented by SPS in the upstream villages (and typologies). A drastic change in the situation is called for to control the untrammeled exploitation of groundwater in Sitapuri. The effort could focus on controlling excessive withdrawal and over-irrigation by tubewells, through regulation of cropping pattern, rate and depth of pumping, a complete ban on new borewells being constructed etc. However, it is doubtful whether community action alone would suffice in such extreme situations, especially when the village is interfering with the recharge-discharge cycles of villages located at a distance on the upstream side. We may need to use a mix of direct and indirect instruments, such as licensing of borewells, metering and pricing of electricity at volumetric rates etc., implemented simultaneously with community action for effectiveness in the long term.

What does this mean for policy?

What are the implications of all these for public policy? First, until now, groundwater has not been given its due place in water resource planning in India. In watershed programmes, for instance, it is usually seen as something to be passively recharged or actively utilised. The notion of groundwater balance has not been accorded its right place, since we cannot talk about this balance without going into the properties of the aquifers. This situation needs to be radically altered with initiation of programmes specially focused on groundwater. The time has come to launch a National Groundwater Action Plan focused on aquifer-based management of groundwater. This programme will help open up the black box of water resources and place groundwater at the center stage of interventions.

Second, supply augmentation is not enough to tackle the problem of groundwater overuse. The solutions lie on the demand side. The Expert Group report (*Planning Commission, 2007*) is perhaps the first statement on the part of the government acknowledging the importance of demand regulation. However, the steps involved here will need a great deal more of detailing.

Third, in a country like India with millions of individual users with decentralised access to groundwater, all of whom are trying desperately for their own survival, state regulation and a command and control approach is not going to work. The challenge of groundwater governance in India is two-fold – a) we need to substantially support and empower the community-based systems of decision making; and b) the existing legal framework and groundwater management institutions have to be fundamentally re-engineered to play a role facilitating and enabling community action. The thrust of the framework of aquifer mapping, identification of typologies and location-specific protocols is precisely in this direction.

Fourth, as part of the National Groundwater Action Plan, we need to run groundwater management pilots in different regions of the country to arrive at a set of appropriate practices for each hydrogeological setting. National level programmes like watershed programme and the NREGA could be converged with this programme synergistically.

Fifth, the scientific input into the planning process has to be strengthened. Since India's groundwater challenge is unique in many ways, taking recourse to "traditional wisdom" of the communities will work only to a limited extent. We need to develop a new understanding of the emerging challenges on the basis of the science of hydrogeology. With these scientific inputs, capacities should be created within the communities to understand and intelligently approach the issues facing them. In other words, the interventions should merge the scientific understanding of groundwater with an active role being played by the communities and people's institutions in equitable management of the resource.

Sixth, the current methodology of estimation of groundwater balance needs to be thoroughly revamped. The current methodology (*GEC, 1997)* has very little reference to aquifers and aquifer properties. The scale issue is inadequately handled in this methodology, as the unit of estimation is a district or a block. A more careful, disaggregated approach to measurement and assessment of the potential, needs to be put in place. Without this, the problem of resource depletion will continue to escape the eye of the agencies in command of protecting the resource.

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Groundwater quality in India:
Distribution, Social burden and Mitigation Experiences

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Abstract: A variety of quality issues affect groundwater in India. The reasons for these quality problems are rooted to groundwater exploitation, external contamination from point/non-point sources and natural geogenic processes. Biological and chemical contamination of water account for a massive disease burden on society, leading to child mortality, labour loss due to recurring disease, chronic ailments, etc. The impact of some of these problems is exacerbated due to the current status of hygiene, malnutrition and poverty of the people.

Background

The key groundwater quality problems in India, can be pointed out as – Biological contamination, Fluoride, Salinity, Nitrate and Iron problems; and Industrial contamination. Apart from these other quality problems such as Strontium, Heavy elements etc. also exist and interact with the above wider-spread problems. One of the main challenges in tackling groundwater quality issues is the lack of good geological understanding of the distribution of these contaminants. Since the current network of quality measurements is highly insufficient, numerous civil society initiatives have emerged attempting to involve community in monitoring around groundwater quality. Some understanding has emerged out of this, but the quality of these measurements and kits are sometimes questionnable.

The social burden of some of these quality problems have been documented by research studies. Problems such as Fluorosis impose a massive social cost which can be a significant part of the income. On an already malnutritioned population, Fluorosis and Arsenicosis add to health complication leading to severity, which otherwise would not be observed in healthy individuals. The loss to agricultural productivity from water quality problems arises especially in salinity affected areas. In Iron affected areas, pipes and wells can be affected. Kidney stones, a root cause of which is poor hydration, is also a major health burden.

Mitigation measures are possible for each of these quality problems. In many cases, however, there is an interaction between quality problems such as those with Iron-Arsenic-Fluoride (Assam), Salinity-Fluoride (Saurashtra, Gujarat) and say, Biological-Arsenic (WB). Therefore, there is a need for a region-specific typological approach that considers the particular characteristic problem of the area. There are good successful cases for several of these mitigation issues – watershed based measures along the coast, for Salinity in Saurashtra, RO plants in affluent areas across the country, rain water harvesting for assuring safe drinking water, referral hospitals for particular problems such as Fluorosis, low cost filters for Fluoride and Arsenic etc. Even for the problem of what is popularly called groundwater salinity a national typology of the problem exists (*Figure 1*).

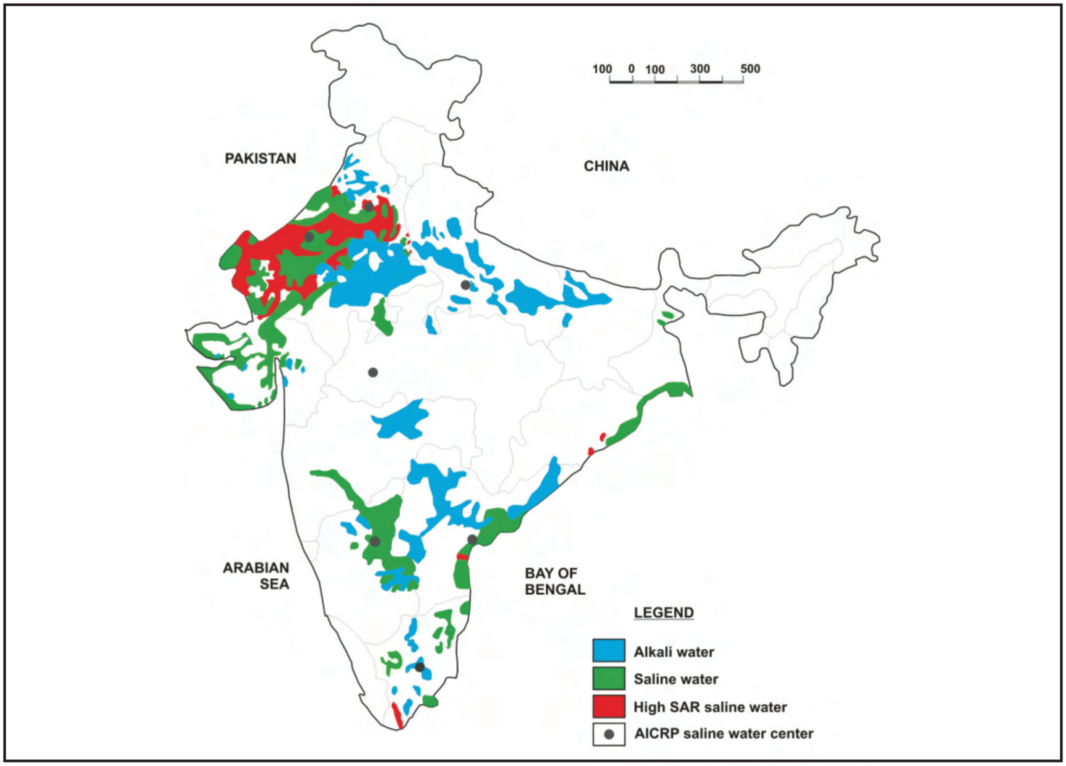

Figure 1: **Distribution of areas with water quality problems in India *(after ICAR AICRP)***

As a good response to all these problems, what is needed is the integration of efforts – across different disciplines such as Geology, Health, Technology and Management; across different departments such as Public Health, Water Supply, Education, Rural Development; across tiers of the Government and Panchayati Raj Institutions (PRIs); across Public and Private institutions. Water quality management needs to enter into every aspect of governance in order to achieve an overall impact.

Distribution and social burden

Contamination of groundwater occurs due to naturally existing geogenic sources as well as substances that infiltrate aquifers. The existence of contaminants and also transport of substances are highly site-dependant. Still, there are some regional variations that are broadly known, but few good syntheses are available (*Kumar and Shah, 2003*)

a) Vast tracts of Rajasthan, Gujarat and Andhra Pradesh are affected by groundwater with Fluoride concentrations of greater than 1 mg/l. Fluorosis can lead to varying degree of afflictions: from dental problems to severe musculo-skeletal deformity. The contaminant is found naturally in the rocks and sediments of aquifers and the depths of its occurrence vary with the formation. For example, in Mehsana district of Gujarat, high Fluoride concentrations are found in aquifer layers deeper than 100m, whereas in Vishakhapatnam, high Fluoride is found in shallow groundwater at depth less than 15m (*Rao et al, 1998*). Smaller areas of several other states like Punjab, UP, Karnataka, Maharashtra and MP also exhibit high Fluoride concentrations in groundwater.

b) High Arsenic content (*greater than 0.05 mg/l*) is found primarily in sediments of the Alluvial Indo-Gangetic-Brahmaputra basins (*Chowdhury et al, 1999*). Initially observed in high concentration only in Bangladesh and West Bengal, now the contaminant is reported from Assam and Nepal to parts of Pakistan. Newer areas are being discovered every year. Symptoms of Arsenic poisoning range from Diffuse Melanosis (darkening of skin) to Spotted Melanosis (pigmentation) and finally to Keratosis. In the final stage, the affliction can reach up to the stage of Skin Carcinoma.

c) Coastal and inland salinity are found in large tracts of the country. Saurashtra and Kutch in Gujarat and parts of Andhra Pradesh, Orissa and West Bengal show intrusion of sea water into coastal aquifers. Inland salinity is present in the states of Punjab, Haryana, Rajasthan, Gujarat, MP, Maharashtra, UP and some pockets of other states. Apart from being harmful to the productivity of crops and soil quality, high salinity can cause ailments such as Kidney Stone (*Indu and Rawal, 2007*).

d) High Iron concentration in groundwater is found in Eastern parts of the country, especially in Assam, Bihar, Uttar Pradesh and West Bengal. Prolonged intake of high Iron content water can cause Homochromatosis.

e) Increasing use of Nitrogenous fertilizers in India has led to Nitrate contamination of aquifers at levels greater than 40mg/l in many parts of the country (*Agrawal et al, 1999*). The states of Punjab and Haryana are in high risk from Nitrate contamination. Other states with areas showing high Nitrate levels are Gujarat, Tamil Nadu, West Bengal and Uttar Pradesh. Consumption of water containing high levels of Nitrate can be a cause for some types of Cancer. It can also cause the blue baby syndrome, which affects new born babies.

f) Pesticide contamination of groundwater has raised alarm in recent times. High pesticide content in groundwater has been reported in the agricultural intensive regions such as Punjab and Haryana.

g) Many regions of the country have been marked as having aquifers polluted by industrial chemicals. These include areas in and around the towns in rural areas where industrial units are often located. Ankleshwar (South Gujarat), Chembur (Mumbai), Patencheru (Hyderabad), Tiruppur (Tamil Nadu), Behala (West Bengal) are some examples. These aquifers show high concentrations of substance such as Chromium, Mercury, Lead etc., the effects of which can range from minor skin diseases to being carcinogenic, hence directly life-threatening at times. Apart from these, there are numerous instances where effluents from small industries are released in unlined channels or dumped directly into borewells, as reported recently in South Gujarat and also in cities like Kanpur and Kolkata.

h) Groundwater acts as a conduit for various viral and bacterial diseases especially in shallow aquifers through mixing of sewage and infiltration from latrine pits. Since shallow groundwater is used for drinking in much of the Eastern Gangetic plains, this is a common problem in this region. The gastroenteritic epidemics generally peak during the time of the monsoon. Some other regions such as South Gujarat figure high on this list. Diseases include minor afflictions such as Diarrhoeal, Viral and Ameobal infections to more severe diseases such as Cholera.

Salinity

One of the major health crises from poor water quality is that of high Salinity in drinking water mostly in coastal areas, but in many inland areas also, especially in western India (*Indu and Rawal, 2007*). The lack of fluid intake and reduction in volume of urine are the key factors that lead to renal stone and overcoming these primarily forms part of its prevention as explained by R. Siener and A Hesse in their paper (*Siener and Hesse, 2003*). *Brikowski et al (2008)* attribute the mean annual temperature and consequently high rate of perspiration, lower urine volume, to be the primary control on patterns of Kidney stones. The south-eastern US, which is also considered a kidney-stone belt is cited as an example to support this observation. High Fluoride in water is also considered to be one possible contributor to formation of stones (*Singh et al, 2001*). Evidences are given to show presence of Fluoride in stones, but how strong a role Fluoride plays in stone formation is currently being studied.

It has been shown that high Salinity along with high Calcium in drinking water can result in increasing incidences of kidney stone problems. A census of affected villages of Junagadh district in Gujarat revealed that 7.9 percent of the population in fully saline villages and 3.2 percent in non-saline villages had at least one of the five symptoms for Kidney Stone. The combination of two key symptoms (signifying a definite presence of Kidney stones) was found among 4.4 percent population of the saline villages and 2.0 percent in the non-saline villages. The average amount of TDS and Calcium found in saline villages was 2,462 mg/litre and 296 mg/litre respectively, far beyond the maximum permissible limits prescribed by ISI (500 mg/litre for TDS and 75 mg/litre for Calcium). The corresponding figures in non-saline villages were 345 mg/litre and 52 mg/litre respectively. In the saline villages, the average treatment expense incurred by an affected person was Rs 5,790 and average wage loss was Rs 3,520. Urologists say that about 80 percent of kidney stone cases have a chance of recurrence, raising the expenses incurred on treatment even further.

Fluoride

Water induced Fluorosis is expected to have around 60 million patients exposed to risk in India. The main symptoms are those of Dental and Skeletal Fluorosis, and then allied diseases. On a secondary level, different other Fluoride related disorders include Kidney stones, risk to pregnancy etc. Generally, the WHO standard of 1.5 mg/l is an exposure limit, but lower degree of symptoms are present in even more patients in areas with lesser Fluoride than 1.5 mg/l. Apart from water, people residing in Fluoride affected areas are exposed to risk also from food-crops that are irrigated with Fluoride rich groundwater. There is also consumption of Fluoride from some common food items such as tea, rock salt etc., but Fluorosis resulting from such a route is not that widespread. Almost every state in India has some Fluoride affected villages, but the main affected states are Rajasthan, Andhra Pradesh, Maharashtra, Karnataka, Gujarat, Tamil Nadu and MP. States like UP and WB are also revealing more areas with high Fluoride. (*Figure 2*) As groundwater use for drinking develops and newer sources of groundwater tapped, the prevalence is just increasing constantly. Some places are just few steps into the disease with only very young children affected, eg. Jhabua in western MP, but other places like Anantapur in southern AP have several generations of affected patients. In such places, the problem has become part of folklore, a gradual fact of life.

Study of the socioeconomic impact of Fluorosis was conducted in 25 villages of North Gujarat by surveying a total number of 28,425 respondents (*Shah and Indu, 2004*). Of these surveyed people, nearly 36% people were affected by Dental Fluorosis (DF) and 16% were suffering from at least one of the symptoms of Fluorosis. About 70 % of the severely afflicted people were from the monthly income group of Rs 500 to Rs. 3500 with an average cost (medicinal + wage loss) of Rs. 5,500 per person per year. The proportion of Fluoride debility cases declined with rising income. Better nourishment, using packaged drinking water and better medical care could explain this decline. This hints that, in general, higher income group people could escape the ill-effects of poor quality groundwater and that

A field research study conducted at 5 Fluoride affected areas of Rajasthan, Karnataka and Andhra Pradesh shows that affordability of safer drinking water is related with higher income level and that the severity of Fluorosis affliction is higher for lower income levels (*Indu et al, 2007*). The cost incurred from medicines and loss of wages is a significant proportion (5%-25%) of the family earnings and has a general debilitating impact on the affected families. The per capita annual medical cost due to Fluorosis ranges from Rs 800 to Rs. 2800 and the wage loss due to loss of labour days ranges from Rs. 4500 to Rs 12000 annually.

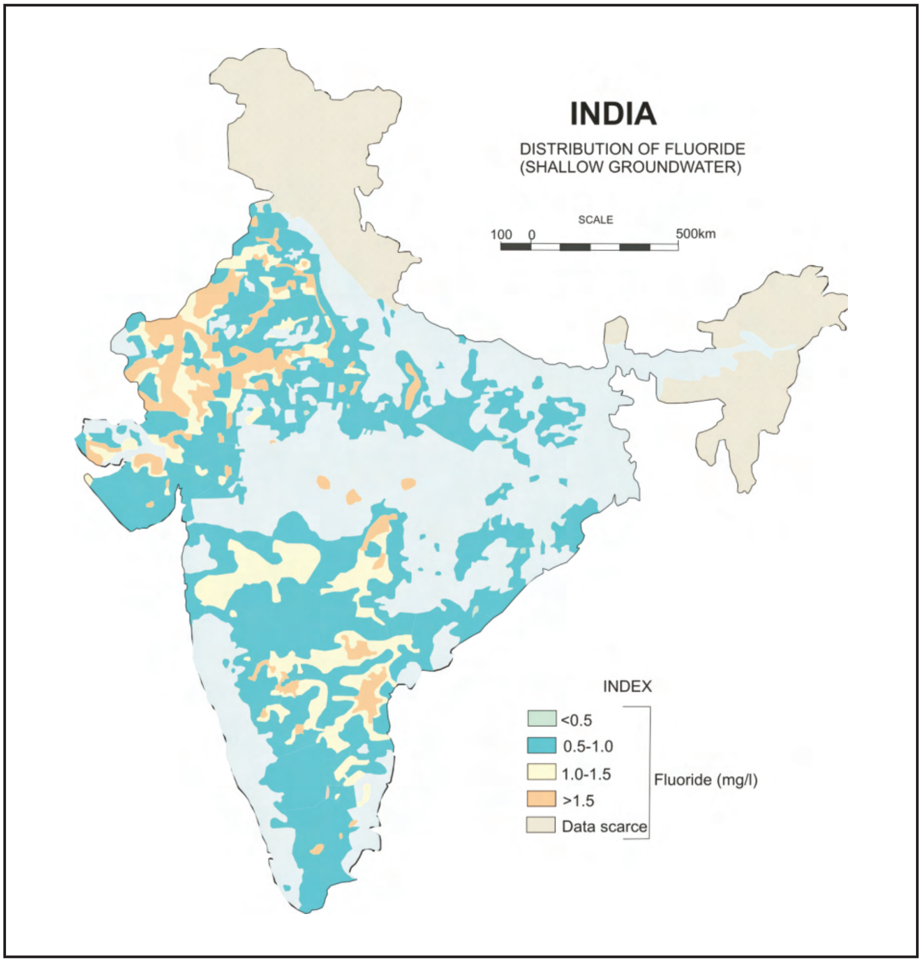

Figure 2: **Distribution of fluoride in India (*after CGWB*)**

Iron

Iron is recognized as an essential trace element for humans. Dietary sources of Iron can be through water, food (1.68 mg/ for fruits, vegetables; 4.8 mg/MJ for green vegetables, fish and tomatoes.)

The WHO does not recommend a health based guideline for Iron in drinking water. However, it follows a recommendation based on provisional maximum tolerable daily intake (PMTDI) of 0.8mg/kg of body weight (*WHO, 2003; JECFA, 1983*). The assumption they make is that 10% of Iron intake is through water and recommend the limit as 2 mg/l. One can complete this link in reasoning by assuming a human being of 50 kg weight and consumption of 2 litres/day. i.e.

Safe Iron concentration = PMTDI * Body weight * percentage from water/water consumption
= 0.8 mg/kg * 50 kg * 0.1 / 2 litres
= 2 mg/l

However, the Food and Nutrition Board of Institute of Medicine (of US) in recommending the Tolerable Upper Intake Levels Iron (UL) point out that Gastro-Intestinal (GI) problems are the primary proven health related risks from intake of Iron, especially when Iron intake is on an empty stomach, which is especially possible with water (*NAP, 2000*). Experiments performed using intake of Ferrous Sulphate has shown increasing levels of abdominal pain, diarrhea, constipation, bloating and nausea with increasing the dosage amongst subjects. The UL levels based upon only GI symptoms is placed at 45 mg/day for healthy adults.

Utilizing both these levels of 0.8 mg/kg of body weight and 45 mg/day, one can arrive at a standard for drinking water. The WHO assumes that 10% of Iron enters the body through water and utilizes the PMTDI value to arrive at 2 mg/l as the safe limit for Iron. It does not use the UL levels which were recommended later in 2001, whereas the WHO limits were imposed in 1983.

Safe Iron concentration = UL * percentage from water /water consumption
= 45 mg * 0.1 / 2 litres
= 2.5 mg/l
One can expect, according to this limit that gastro-intestinal problems can be caused by drinking water with Iron greater than 2.5 mg/l.

Apart from concerns on GI through, excess Iron is suspected to be related to the following conditions:

A. Iron overload

Iron overload is a condition when the body iron stores increases as a result of iron administration, repeated blood transfusions or disorders that increase the rate of iron absorption within the body. The known impacts of iron overload are mainly Cirrhosis (a liver disease which leads to a progressive loss of liver function), and some types of carcinoma, tuberculosis and other infections. Studies done on rural and urban populations show as high as 10% of population exposed to Iron overload conditions (*Gangaidzo et al, 1999*).

The other condition of Iron overload is linked to a genetic condition amongst northern Caucasian and Celtic populations who are supposed to be carrying a gene that transmits Hereditary Hemachromatosis. Excessive Iron storage in the tissues of such individuals leads to conditions similar to that of liver Cirrhosis and related disorders.

In Indian populations, there have not been any links established as yet to detect Iron overload (*Poddar, 2006*), but there is need for studies using results from the Human Genome Project and epidemiological studies to explore such links.

B. Cardio-vascular disease

The hypothesis that coronary heart disease (CHD) is more prevalent in post menopause women opposed to menstruating women, pushed research into looking at the connection between high iron stores and risk to CHD. There are studies to indicate positive relationship between higher serum ferritin concentrations and risk of greater CHD. However, no conclusive evidence has been yet shown to link high Iron stores and Iron intake to risk from CHD. The current understanding is that there is not enough evidence to either attribute or exclude Iron from risk to CHD (*NAP, 2000; JECFA, 1983*).

C. Iron-Zinc interactions

High Iron intake is linked with lowering on Zinc absorption in the body, especially when both are taken on an empty stomach. Zinc is essential for many enzymatic functions of the body and Zinc deficiency exhibits itself in problems with cell growth and repair. However, since there are no severe adverse impacts of Iron-Zinc interactions observed in clinical trials, this factor is not used to furnish a health based guideline for Iron *(NAP, 2000*).

Agrochemicals and Nitrates

Pesticides and other chemicals used in agriculture such as Nitrates seep into groundwater and can be the cause for public health concerns. Since even low pesticide levels can be harmful and currently available instrumentation in district laboratories are not equipped well enough, the impact of these problems lies un-addressed. However, Nitrate distribution is relatively better monitored, even though it is highly dynamic. High amount of Nitrates ingestion can lead to methaemoglobinemia, and could be triggers for cancer, increased infant mortality, abortions, birth defects, recurrent diarrhoea, changes in cardiac muscles, alveoli of lungs and adrenal glands (*Gupta et al, 2008*). When inhaled, Nitrates can cause unconsciousness, vomiting and nausea. Many of these effects lie undetected due to problems in causation and good epidemiological studies.

Arsenic

Arsenic in groundwater is emerging as a widespread problem in the floodplains of the Ganges and Brahmaputra. In India, many areas from West Bengal have been shown to be affected whereas Bihar is an emerging area with high Arsenic contamination (*Chakraborti et al, 2003*). Newer areas are suspected to be Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Nagaland, Uttar Pradesh and Tripura. Outside of India within the Ganges-

Meghna-Brahmaputra (GMB) basins, the southern parts of Bangladesh are long affected from Arsenic just as in West Bengal. Some reports of Arsenic in Nepal Terai are also accumulating (*Shreshtra et al, 2004*). Within this larger region, there are pockets of villages that show very high concentration of Arsenic, much above the WHO recommended safety limit of 10 micro g/l (micrograms/litre also some times called parts per billion, (ppb)). The Indian safety standard for Arsenic is 50 micro g/l which is adopted by several other countries partly due to the possible perceived magnitude of the problem otherwise. A matter of possible surprise is that density of Arsenic present in soil is not much above that present in other regions of the world. It is the specific geochemical conditions that aid in the release of As(III) into groundwater. Arsenic release from sediments in South Asia is attributed mainly to desorption or dissolution of Arsenic from iron oxides. This happens mainly due to reducing conditions in aquifers below the so-called redox zone or transition between oxidizing and reducing conditions a few metres below the water table.

Here, the higher oxidized As(V) reduces to As(III) which is released into groundwater. The reasons for onset of reducing conditions are several: rapid burial of organic matter, high microbial activity or recent anthropogenic carbon. Some or all of these contribute to the reduction process and mobilization of As(III) which is then released into the relatively deeper groundwater that has low flow rates due to the poor hydraulic gradients in the Bengal basin. Other factors contributing to the release of As(III) is the possible competition faced by As(III) from high level of phosphates present in groundwater towards adsorption on the surface of Iron oxide. Such adsorption would demobilize the released As(III), otherwise. An excellent summary of current knowledge on Arsenic geochemistry in South Asia is given in a World Bank summary report (*WB, 2005b*).

After several years of low level Arsenic exposure, various skin lesions appear. These are manifested by hyper-pigmentation (dark spots like rain drops), hypo-pigmentation (white spots) and keratosis (hardening of skin) of the palm of hands and soles of feet. After a dozen or so years, skin cancers are expected. Arsenic can be transmitted not just by drinking water, but also by direct exposure to skin and hair (*GoWB and UNICEF, 2004*). It also transmits through food grains and the possible transmit of Arsenic through summer (Boro) rice grown in the Bengal is an issue of debate (*Duxbury et al, 2003*).

Policy responses : An example of Fluorosis

A variety of factors add challenges to the problem of addressing solutions to water quality and health issues:

1. The nature of quality problems – Salinity, Fluoride, Biological, Arsenic, Iron – and their combinations require different technologies for water treatment. Also, we keep coming across newer problems such as increasing agrochemicals presence in drinking water of some areas.

2. The variable affordability of households to water treatment technology within any village means that not all households would be willing to shell out equally for a commonly owned treatment system, especially since the best techniques of treatment such as Reverse Osmosis (RO) also cost considerably as compared to saving levels of rural poor.
3. The variable quality of water of different sources at different times of the year means that one needs to employ the proper treatment depending upon source and particular time of the year
4. Adaptation of the technology to different needs – i) taking into account that many farmers drink water from bore-wells in the fields, ii) single common source of drinking water for several villages, iii) cultural beliefs eg. drinking water that is freshly supplied every day, iv) catering to old, disabled and remotely located inhabitants

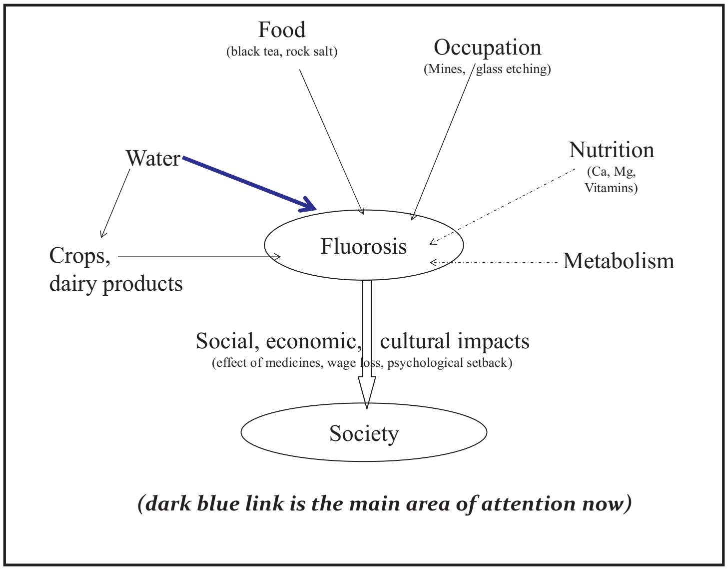

***Figure 3:* Linkages to Fluorosis**

An example of Fluorosis is considere here to understand the programs conducted in India for defluoridation. Defluoridation is not just entirely Fluorosis mitigation – which is a health concern. Apart from removal of Fluoride, focus must also be placed on nutrition and other preventive and palliative aspects.

Integrated plans : Special reference to Fluorosis

Many of our health problems in the past have seen recovery and pathway towards solutions. But these have seen massive communication programmes for awareness and training of health workers. Nothing like this has happened for Fluorosis, yet on a mass scale. Mass media has a role to play in this for sure.

Doctors are at the centre of this problem. Even for sale of Fluoride removal filters, there is a need for doctors to be involved. Perhaps an incentive model for doctors in promotion of such filters needs to be pursued just like for some medicines, as followed by some pharma companies. If water is seen as a major cause of Fluorosis and prevention is possible, then can health insurance schemes be utilized to address this problem? The National rural health insurance programme is now being implemented across the country. The annual expenses on Fluorosis due to medicines and loss of wage by patients comes to Rs. 5000-6000 per year (*Indu at al, 2008)*. If this is already being incurred by patients, then shouldn't the annual treatment cost of removal of Fluoride from water of Rs. 500-600 per year, be covered by such an insurance scheme? In that case, hospitals which are now part of this scheme would be more actively involved in Fluorosis mitigation. However, accepting this logic of applying health insurance to Fluorosis is a major step forward in thinking, in that one should look at safe water as preventive for Fluorosis and that preventive care needs to be covered by the health insurance scheme.

In all, an entire package of options needs to be available locally to Fluorosis patients, to be termed as Fluorosis Mitigation Support Services (FMSS). Today, even for patients who can afford it, there is no place they can visit for advice on the ailments and curative options. If one needs to buy a domestic filter for defluoridation, there is no such service available anywhere. What if all these are present together i.e. medical advice as well as curative options. Even for Fluoride removal filters, such a service needs to offer maintenance on filters eg., repair of parts, regeneration of Activated Alumina (for eg), replacement of AA material etc. Apart from this, FMSS should be responsible in training of doctors and educating them towards proper diagnosis of Fluorosis.

All these require investment. In the initial piloting stages, it could run as an entirely funded program, but over time, it would need to generate revenue. Probably an idea such as FMSS can generate revenue from the services it offers i.e. training, sale and maintenance of filters, advice on Fluorosis mitigation etc. But the question is that whether the patients would pay for these services. This is probably where the health insurance programme needs to come in. If the services offered by FMSS can be paid for by the health insurance programme, then such a programme has a chance at long term sustenance. However, these ideas need testing on pilot scales before they can be transported over to a national level. We need integration of different plans across levels (*Figure 3*).

Water quality assessment and monitoring

Firstly, we need much better databases of monitoring of drinking water (especially of wells), for water quality standards. When, there is such a huge social burden (as seen above) up to Rs. 4000-5000 every year per family, the cost of monitoring is justified. Each drinking water well needs to be monitored for which, allocation of funds is necessary. If databases developed after such monitoring are available at the Panchayat level, decisions would be rendered easier. Gram Panchayats could be responsible for such monitoring. Such databases could be maintained and integrated at regional levels to enable faciliation by experts.

Health agencies role in detection and mitigation

Apart from the geological input into monitoring water quality, the health agencies (along with PHEDs) need to be also involved in such health monitoring programs. The Health Department surely acts according to priorities. Life-saving priority and epidemics always come first. Such emergencies keep arising, say with natural calamities such as floods. There have been doctors we have visited, who are catering to 30,000 patients single-handedly! They have to cater to immediate emergencies such as accidents, pregnancies etc, and therefore longer term problems such as Fluorosis go unnoticed. Moreover, previously Fluorosis was not in the standard curriculum for medicine students. Now, it is present in the syllabus of preventive and social medicine. Therefore, most doctors are likely not to be trained in the diagnosis of Fluorosis, nor do they have facilities such as specific kits for urine and blood testing, or water quality testing for confirmation of Fluorosis. In most cases therefore, these cases get passed off as those of Muscolo-sketelatal disorder or disease / deformity (MSD). The expenses on medicine alone can go as high as up to Rs.2000/year for a family on average in Fluorosis affected areas (*Indu et al, 2008*).

But, why still an apathy from the Health Departments? Fluorosis is preventable and supply of safe drinking water is primarily the responsibility of the Public Health and Engineering Department (PHED). This is probably the reason why some of the Fluorosis mitigation programmes are hosted within the PHED department. Probably once the Health Department accepts Fluorosis officially, it somewhat absolves the PHED of its duty. Currently, patients hardly understand the root cause of their problems. It is the responsibility of doctors to make them realize that. They will play a critical role in creating demand for solutions.

Technologies

Lastly technologies are critical in this challenge and they need to cater to the requirement of the people they are serving. It is a trend now to install RO systems for solving water quality problems. But let us think of the time beyond 2 years when the RO membrane will fail and think about who pays for the maintenance then. We need much more grounded technologies which can be maintained in villages or nearby towns at low costs. From our experience, such solutions are available for every water quality problem – for eg. AA for Fluoride removal. If the question of local maintenance is taken care of, such technologies will have some possibility of sustenance.

Finally, it is important to mention that there is a need of integrated plans over different such domains – technology, health, water quality assessment etc. Some such programs are now being considered in regional planning, and maybe in the future, some examples of such pilot programmes which can serve as model for water quality and health management across India will be seen.

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From Survey to Sustainability :
Groundwater Experiences of Maharashtra

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Introduction

Groundwater is a natural resource with both ecological and economic value and is of vital importance for sustaining life, health and integrity of ecosystems. This resource is however, increasingly threatened by over-abstraction which has insidious long-term effects. Scarcity and misuse of groundwater pose a serious and growing threat to sustainable development and livelihood. The availability of groundwater is extremely uneven, both spatially and temporally and so will be the case in future. The uneven distribution of groundwater can be mainly attributed to highly heterogeneous lithology and uneven distribution of rainfall.

Geology and hydrogeology

Geology of the Maharashtra State is practically the Geology of Deccan Traps, which covers 82% area of the State and occurs in all the Districts of the State. (*Figure 1*) Besides this, 10% of the area is occupied by metamorphic rocks, 3% by sedimentary rocks and rest 5% by the alluvium. The rainfall pattern, physiography and geology decide the percolation rate, movement and availability of groundwater. The physiography is equally important because 28% of the area within the State is included in the run-off zone, 44% in the recharge zone and the remaining 28% in storage zone.

The physical characteristics of all the hard rock formations in the State play an important role in the movement and occurrence of groundwater. The weathering and jointing pattern in case of the Deccan Traps and Metamorphic rocks decides the availability of groundwater while the Sedimentary rocks and Alluvial areas form the excellent groundwater potential zones.

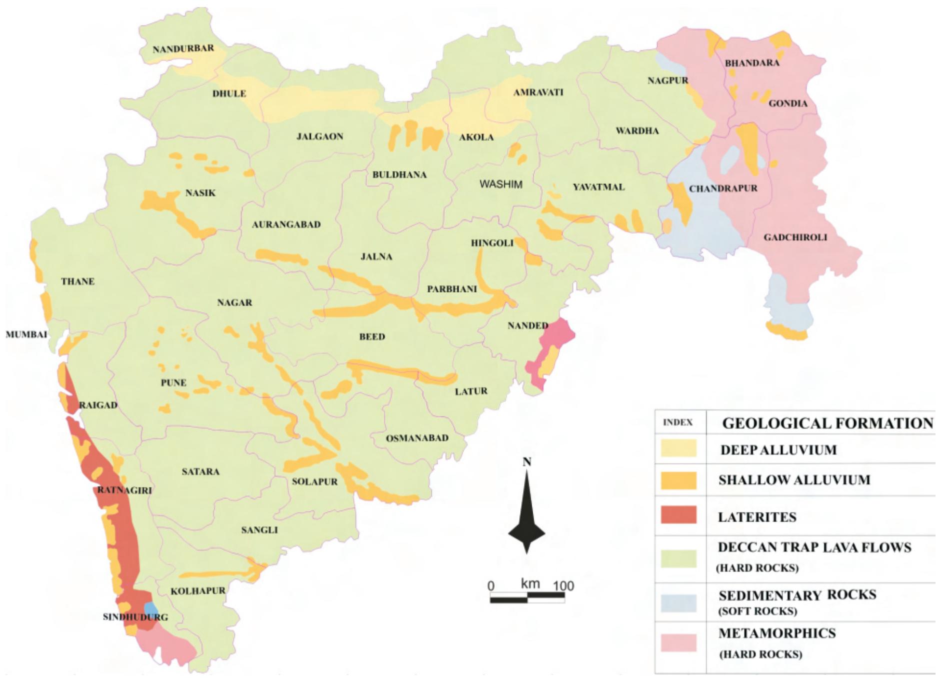

***Figure 1:* Geological map of Maharashtra** (*adapted after Geological Survey of India, 1997*)

Groundwater development in the State is mostly through dug wells, borewells in hard rock areas and through tubewells in alluvial areas. The main source of drinking water is dug wells. The yields of wells are considerably affected by two factors, namely the degree of weathering and the topographic setting. The coastal districts and eastern part of the State receives assured rainfall. The central region (1/3rd) of the State receives less than 750 mm of rainfall, which is mostly the drought-affected area. Though the coastal districts receive assured rainfall, due to steep gradient and hard formations, groundwater recharge in the area is meager.

Drinking water status

Almost 80% of the drinking water sources are groundwater dependent and a majority of these sources are within the recharge and storage areas. The groundwater resource being space, time and depth specific, the sustainability of groundwater dependent drinking water sources are of utmost importance for the State. Accordingly, government has decided to give priority to the source sustainability where drinking water is concerned. Hence the role of GSDA is very important in the security of drinking water of the State.

Role of G.S.D.A.

Since the last 37 years, G.S.D.A. is engaged in the development and management of groundwater resources in the State through various schemes. The main aim is to provide safe and potable drinking water to the community. The mandate of GSDA includes following -

1. Site selection for drilling of borewells/tubewells under Rural Water Supply scheme.
2. Detailed hydrogeological surveys on village scale for ascertaining area-specific hydrogeological conditions and to delineate the groundwater potential zones along with recharge worthy areas.
3. Identification of source for piped Water Supply schemes and open dugwells under Rural Water Supply Programmeme.
4. Survey for the drinking water source sustainability under *Shivkanlin Pani Sathwan Yojna.*
5. Implementation of unconventional measures, like hydrofracturing to increase the yield of poor yielding borewells, fracture seal cementation to arrest the sub-surface flow, bore blast techniques to improve and enhance the fracture porosity within the source area, for drinking water source sustainability under different plan schemes, like Shivkalin Yojana, Central Govt aided programmemes, etc.
6. Hydrogeological surveys for technical guidance and actual implementation of traditional water conservation and artificial groundwater recharge measures for strengthening groundwater resources along with the drinking water sources.
7. To carry out survey in the water quality affected villages for providing the least cost solutions for source sustainability and to implement the GSDA related measures.
8. To carry out survey for NC/PC villages and provide the least cost solutions for source sustainability and to implement the GSDA related measures.
9. Monitoring and implementation of World Bank aided aquifer based groundwater management projects, which envisages supply of sustainable drinking water with community participation.
10. In order to safeguard the drinking water sources, the Government of Maharashtra has introduced the Maharashtra Groundwater (Regulation for Drinking Water Purposes) Act, 1993 followed by Maharashtra Groundwater (Regulation for Drinking Water Purposes) Rule 1995. Various responsibilities like delineation of watersheds, preparation of technical report, and technical survey in notified areas etc. have been entrusted with GSDA as a technical officer under different sections of the Act.
11. Periodic monitoring of groundwater levels and groundwater quality within the State so as to assess the watershed wise groundwater potential and quality affected areas.
12. In order to support the hydrogeological surveys and to improve the success of drinking water sources in the difficult terrain, geophysical surveys using latest equipments like

WADI-VLF are being carried out.

13. The remote sensing studies along with the normal hydrogeological surveys are being undertaken by the Agency for resource development, especially in critical/difficult areas. GIS maps are being used to locate the potential areas on macro level.
14. During scarcity period, GSDA is carrying out the survey for suggesting the least cost measures for the supply of drinking water in the State.
15. Under disaster management like landslides, earthquakes etc, GSDA is carrying out the responsibility of survey and implementation of the measures pertaining to emergency drinking water.
16. For ensuring the optimum recharge to the drinking water source, land survey and recommendation is being done through GSDA.

Groundwater provinces and estimation

On the basis of geological formations, the State can be divided into the following groundwater provinces: -

I. Precambrian metamorphic groundwater province
ii. Proterozoic sedimentary groundwater province
iii. Gondwana groundwater province
iv. Deccan Trap volcanic groundwater province
v. Alluvial groundwater province

As per recent groundwater estimation carried out by Groundwater Surveys and Development Agency in March 2004, out of 1505 watersheds 76 are Over-Exploited, 20 Critical, 163 Semi-Critical, 4 Poor Quality and rest 1242 are Safe. *(Figure 2)* The total groundwater availability and district wise details are given in Annexure 1 and 2.

Groundwater would continue to be a dependable source for irrigation in the State in the near future. However considering the unscrupulous withdrawal of groundwater, particularly after the subsidised power tariff for agriculture, groundwater is over extracted in many areas in the State. Presently 96 watersheds (76 Over Exploited, 20 Critical) are over exploited or are critical and have no scope for further development. There are 7 OE, 1 Critical and 23 Semi-critical talukas where the groundwater is being over extracted. From administrative point of view in almost 10% of the talukas there are restrictions on construction of new abstraction structures or giving permission for new electrification.

In remaining parts of the State too, the prospects of sustainability of groundwater development are becoming increasingly questionable. These are manifested in steep and progressive decline of water levels, drop in agricultural productivity and uneconomical cost of water. Recent efforts by NGOs, private and government organization, to improve groundwater conditions through artificial recharge, are encouraging. These efforts are too inadequate considering the enormity of the problem. While watershed development programme would benefit a few farmers, the most appropriate attempt would be to

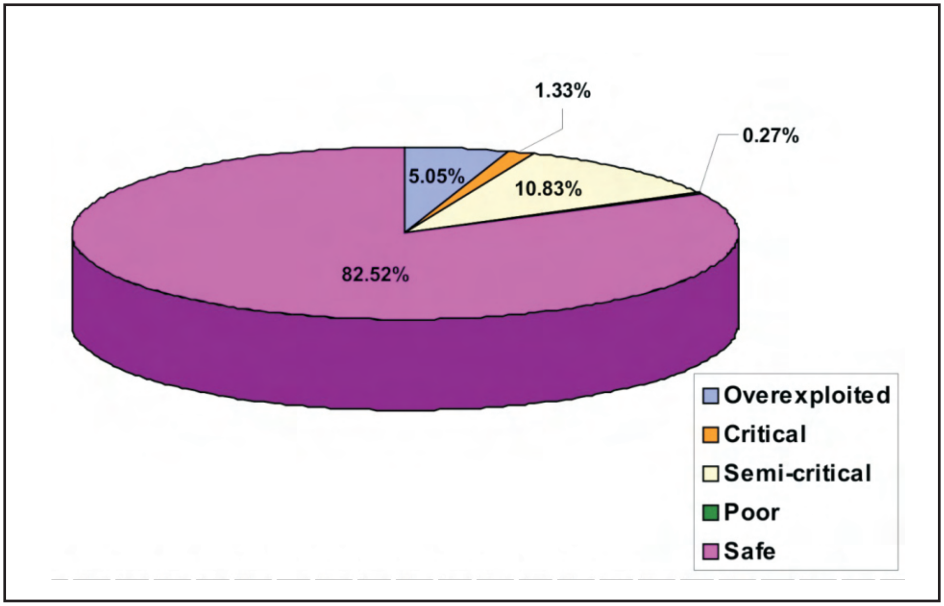

Figure 2: **Distribution of watersheds with respect to groundwater condition**

harness rainfall through farm ponds and other similar small structures. A massive emergency programme for water conservation and other recharge structures can bring results in short period.

Financial institutions and State government are funding large programmes of groundwater development annually. It has become imperative that the financial institutions should plan to fund at least 25 to 30 % of their lending for minor irrigation, should be preferred for groundwater recharge schemes, either on individual basis or on community basis. Further considering the point sources of groundwater development owned by individual farmers, such recharge structures are financed to individual or an informal group of farmers instead of a larger structure. The recently introduced dug well recharge scheme by Government of India is a first step in this direction and need to be monitored for its sustained benefits which would ease groundwater stress in the over abstracted areas within 31 talukas.

Along with the supply side management measures, demand side management measures are to be promoted on massive scale. The supply side management measures have limitations like availability of site/fund and limited capacity of the aquifers. Hence, the management of demand becomes imperative. The State of Maharashtra hosts many 'demand management' efforts at the scale of a village. These efforts have worked in many villages and resulted in rejuvenation of the traditional village level water management.

One such experiment of village Pondhe, taluka Purandar, District Pune is a pioneering example in the country. This village has adopted the concept of equitable distribution of groundwater by making the groundwater a common property resource. The villagers agreed to use only 30 wells out of 74 as community wells and decided to take groundwater on volumetric basis.

Maharashtra is the one of the pioneering States where groundwater management is being piloted on aquifer level. Actually, aquifer based water management with community involvement should be the crux of groundwater management in the near future. Six Aquifer Water Management pilots are being implemented under Jalswaraja and Maharashtra Water Sector Improvement Project, with community participation, through World Bank assistance. The objective of these projects is to develop and test approaches and practices for user-centered aquifer level sustainable groundwater management with demand initiatives and supply interventions.

Aquifer management

Pilots under Maharashtra Water Sector Improvement Project

In the State of Maharashtra three pilot projects on Aquifer Level Groundwater Management with community participation are being implemented with the World Bank Assistance. The objective of this project is to develop and test approaches and practices for user-centered aquifer level sustainable groundwater management in the hard rock terrain of the State of Maharashtra. This includes delineation of aquifer along with the establishment of: (i) a Gram Panchayat Level Committee (GPLC) in all the Gram Panchayats under pilot area; (ii) a Pilot Aquifer level Groundwater Management Association (GWMA), as a federation of GPLCs; and (iii) Technical Support Groups (TSGs), for its groundwater management.

The lessons from the pilots are expected to contribute in the development of appropriate groundwater use legislation and regulatory framework for implementation of users centered sustainable groundwater management models, and the subsequent up-scaling over time.

Pilots under Jalaswarajya Project

The Project is being implemented on a pilot basis in Buldhana, Pune and Aurangabad Districts of the State. The main objectives of the Groundwater Aquifer Pilot are as follows:

1. Build capacity of stakeholders in the pilot area for sustainable management of groundwater resources
2. Analyze current state of groundwater availability and use-patterns and their implications to source sustainability within the pilot area
3. Provide information to stakeholders on groundwater availability and sensitize them on the need for community-centered demand management of drinking water with a focus on sustainability

Photo 1: Community participation is important aspect of Jalaswarjya project

4. Develop sustainable groundwater aquifer management model that is community-centered, and managed to ensure drinking water source sustainability
5. Develop legal and regulatory framework that Government of Maharashtra (GoM) could put in place for scaling up groundwater resource management on a sustainable basis

Watershed Management and Rain-fed Cultivation

Even when all the irrigation potential is harnessed, a sizeable area of cultivable land will still remain under dry-land cultivation. Development of these areas with improved water management including soil conservation, soil moisture and rainfall management and better rainfall forecasting should receive high priority. This is very important for improving livelihoods of local people. Watershed management and water equity are important especially in non-command areas. Hence the second Irrigation Commission recommended treating it as a primary source of irrigation in non-command areas. The Second Irrigation Commission has recommended that the watershed development should be treated at par with irrigation in the rain-fed areas and GoM should give priority for such works. Accordingly, GoM has taken the initiative, but the effort needs support through budgetary provisions.

Equity among landowners at different contour levels is important while planning watershed development and deciding the measures of treatment. The roles of Pani Panchayat, watershed committees or water users' association are important in this regard. In dry land agriculture, it is the productivity per unit area of water and of land that must be maximised. The logic must influence other parameters. In future, planning dry land agriculture should obtain equal importance and priority as that of irrigated agriculture.

In villages like Ralegan Siddhi, Adgaon, Naigaon, Hivre Bazar, which have harvested their raindrop, the inhabitants have water to drink even after repeated droughts. People have been able to tide over the crisis, because they had built their water reserves. They had learnt to value the raindrop. All these villages are situated in the drought prone area of Maharashtra where annual rainfall ranges from 450 mm to 650 mm and villagers were once not even assured of one regular crop. After watershed development and water harvesting, even the last raindrop has totally changed the village scenario and this has become the starting point to eradicate rural poverty. The principles of integrated planning, co-ordinated approach, appropriate technology, utilization of local resources, proper leadership, partnership with the voluntary agency and community participation are the key players of their success. In the village of Hivre Bazar, the villagers have not only completed the supply side interventions but also scrupulously follow the demand side regulation like not to drill borewells for irrigation, and not to grow cash crops like sugarcane. This has drastically controlled the irrigation abstraction within the village. The increased and assured water availability has increased and stabilized the agricultural production along with improvement in the livestock productivities.

Augmenting groundwater resources

It is necessary to intercept the excess run off of high rainfall areas locally and try to divert it in drought/scarcity affected areas, by interlinking at local levels. Very good pilots have been implemented in Dhule, Jalgaon & Pune districts with local initiatives and the results are very promising. The excess runoff has been harvested by interlinking the local rivers and nalas. This has resulted in strengthening of the drinking water sources along with sustainability in irrigation sector too. This has not only augmented the surface water but also increased the groundwater resources locally.

The efforts taken by Groundwater Surveys and Development Agency in developing the innovative techniques for drinking water source strengthening are noteworthy and replicable in the irrigation sector too. Around 7000 projects have been implemented in 4000 odd villages and they have been made tanker-free. These unconventional structures have also been attempted for groundwater resource sustainability in Shivni village of Jalna district. The village has been made tanker free and the agricultural productivity has almost doubled within a year. Hence, these need to be replicated in the State as well as in the other hard rock States also.

Groundwater legislation

Under Indian law, the ownership of land carries with it the ownership of groundwater, subject to regulations and control by the State. It follows that, only those owning land can have right over groundwater and the landless including the community as such, who are using it for certain purposes can have no such right. This legal position has led to serious inequities and disputes. The need for groundwater regulation became necessary since groundwater in many areas has been over extracted and water levels decline is faster than expected. This has affected the economics of groundwater and scarcity of drinking water. Many States have enacted groundwater regulations but these are extremely limited and are applicable to certain specified purposes like protecting drinking water sources. Maharashtra is one of them. The State legislators enacted Maharashtra Groundwater (Regulation for Drinking Water Purposes) Act 1993. However it is exclusively for protection of drinking water purposes and does not cover irrigation use. Because of the constraints like non-control of irrigation and industrial use, non protection of quality and no involvement of community, it needs to be amended. The amendments to the present groundwater Act based on the provisions of the Model Bill circulated by GoI in Jan 2005 are under consideration.

Considering the present provisions of the constitution, there are limitations for framing the Groundwater Act. While framing groundwater legislation, it needs to be treated as a common pool resource and place it under community management. Similarly, issues like forming user groups for use and management of groundwater and its conservation, constituting regulatory authority, establishing conflict resolution mechanism etc should also be thought of as per the recommendation of the Water and Irrigation Commission. There still are inherent problems in implementing negative sanctions and potential for abuse, alternate theoretical approaches to the management of sanction by involving community in the regulatory process. It is necessary to ensure that more positive and conciliatory sanctions are relevant for regulation and management.

Community management of groundwater resources

National level consultations on sectoral reforms and on empowering the community, indicate that planning, development and management of water resources need to be decentralized and shared with autonomous and accountable agencies i.e. the community, for sustainable use and conservation of water resources and protection of environment, with incentives, regulatory control and capacity building to respond effectively to changing needs at community level. The basic principles of this new approach are:

- Demand responsive approach that ensures full participation of the community in deciding the choice of the scheme, planning, design, implementation, control, investment and O&M.
- Full ownership of the assets created.
- Partial sharing of the capital cost, and total O&M responsibility by the community.
- Shift in governmental role from developing and managing the resource to only assist and facilitate the community to take over greater responsibility.
- Capacity building of the community for service delivery.

Maharashtra has made a beginning in holistic transfer of resource management to the community. If this institutional model succeeds, it has the potential to be replicable on a State wide basis. Since 2004, the State has taken an initiative of keeping the water account at village watershed level. Many villages like Shivni, Hivre Bazar, Bamni etc. have rejuvenated the village water management concept and became self sufficient in food grain and other agriculture production. These promising results have attracted the attention of various financial institutions like UNICEF and started partnership with GSDA in all Tehsils of three districts of the State, viz. Nandurbar, Latur and Chandrapur.

Conjunctive use of surface water and groundwater

The main objective of conjunctive and integrated use of surface and groundwater is to achieve optimal utilization of water resources and maximize agriculture production. To achieve this, it is essential that each crop irrigated is supplied with a requisite quantity of water at various critical stages of its growth. The total number of watering required, quantity and time-wise, are usually not met fully from either surface water or groundwater individually. However, integrated and conjunctive use of the two sources helps to meet the requirements both with respect to quantity and time. Other secondary objectives, which are achieved through conjunctive use, are control of groundwater overdraft and reclamation of waterlogged areas or arresting its occurrence and expansion.

A study has been carried out to evaluate and articulate the successfully practiced methodology of conjunctive use of surface water and groundwater, at Ozar, Nashik district through Water Users Associations (WUAs). Till 2003, there were three WUAs managing the irrigational activity in an area of 570 hectares at village Ozar in the command of the Waghad Dam. Presently the entire command area of Waghad irrigation project has been handed over to the WUA for irrigation management. In this area, surface water is received in measured quantities by the WUA for irrigation as well as for storing in the specially built surface bandharas. The rotations of irrigation cycles are managed in such a way that, between two consecutive canal water rotations, groundwater is utilized for irrigation by pumping from dug wells, which also receives induced recharge from bandharas. By following the traditional quantification technique, the groundwater used by members of WUAs is quantified and accordingly charged. Thus, the farmers through planned and coordinated use of surface water and groundwater, optimally utilize the entire quantity of water received from the dam. Encouraged by the success, the concept of conjunctive use of surface and groundwater is being attempted elsewhere in the State.

Groundwater quality assessment

The chemical quality of groundwaters from the shallow basaltic aquifers within the State is good (electrical conductivity ~501-1000 s cm^{-1}). In most samples the pH values range from 7.5 to 8.5 indicating the alkaline nature of the groundwater. In Maharashtra, the saline groundwaters (electrical conductivity ~2001-3000 s cm^{-1}) are present in three geographically distinct areas viz. the coastal areas of Konkan, the Purna alluvial basin and the upland (Drought Prone Area Programmeme – DPAP) areas. The chemical quality of groundwater for deeper aquifers however represents a different picture. Saline groundwater patches (electrical conductivity > 2001 s cm^{-1}) are reported from the Konkan coast (Thane, Raigad, Ratnagiri districts), Purna (Buldana, Akola, Amravati districts) and the DPAP areas (Pune, Sangli,). The hardness of groundwater ranges between 100 and 500 mg/lit, which is suitable for drinking purposes. The fluoride concentration in groundwater from the Precambrian basement rocks and Proterozoic sediments are above prescribed limits. Such occurrences have been reported from districts such as Chandrapur, Nagpur, Gadchiroli, Yavatmal, Bhandara and Sindhudurg where groundwater is not suitable for consumption. However, these are treated as point sources and not applicable to the entire watershed.

Drinking water source sustainability

(Shivkalin Paani Sathvan Yojna)

In the rural areas, groundwater is the main source for drinking water in Maharashtra State. The reasons for the drinking water scarcity can be mainly attributed to sources going dry in summer. For this purpose, it is necessary to recharge groundwater artificially. The main objective of this scheme is to recharge groundwater by using rainwater and to strengthen the existing drinking water sources and make them sustainable throughout the year. GoM has released a government resolution in the year 2002, with the following list of measures.

***Photo 2:* Uninterrupted drinking water supply to rural villages through dual pumps**

Measures proposed

1) Rooftop rainwater harvesting.
2) To collect rainwater in a tank and use it drinking water and domestic purposes.
3) To use rooftop rainwater for recharging groundwater through dug wells and bore wells.
4) Spring development in hilly areas.
5) Surface water runoff to be collected and artificially recharge through dug wells.
6) Implementation of conventional measures like tanks, check dams, well deepening for strengthening drinking water sources.
7) Unconventional measures to strengthen existing drinking water sources like Jacket well, Bore Blast Technique, Fracture Seal Cementation, Stream blasting etc.

Dual pump

The Agency has developed and implemented the 24x7 drinking water supply through dual pump concept in rural areas. A low capacity power pump along with the hand pump is fitted on a moderate to high yielding borewell. Water is stored in 5000 lits tank and distributed through a local stand post. During non-availability of electric supply, the hand pump is used for obtaining water.

Other issues

1. Artificial recharge is a solution to augment groundwater recharge, which was never attempted wholeheartedly until recently, when NGOs and farmers' bodies took up such initiatives and the government supported such initiatives wholeheartedly. Currently, government is propagating rainwater harvesting but the incentives to go for it are not coming forth particularly from the financing institutions who are still playing it safe. The State government has taken up a programmeme of artificial recharge in overexploited areas with the help of the Government, NGOs and community under watershed development and water conservation programmes. This has reduced severity and brought some relief. But in some parts of the State, the rise in water level resulted in greater extraction of groundwater from old and new wells. The total extraction continues to exceed the recharge from natural and artificial recharge works, resulting in progressive decline in the water level. This is because of an unscientific approach and lack of community control on development. Demand management measures are called for drastically. The situation could be transformed into a success story through IEC, for the user groups. Thus IEC needs to be considered as a component of the artificial recharge programme and should normally precede actual execution of recharge structures.

2. Groundwater is considered a major source of irrigation and drinking water in the future and still continues to be a subject that is secondary to surface water in the State; this is so even atthe Centre. Considering the multiple activities and tasks assigned and entrusted to groundwater organizations, there is need to have proper coordination among groundwater and surface water issues in the State. Presently numerous schemes involving groundwater utilization is being implemented by the government through different departments and rarely or casually do they consult the State groundwater organisation. A mechanism has to be evolved so that every scheme, be it for irrigation, drinking water, watershed development, conjunctive use, environment, industrial needs or any other use, must pass through this nodal agency for better monitoring of the resource.

3. Power is another important subject that vetoes agriculture growth. About 28 to 32 percent of power generated is used by agriculture and future demand of this sector would increase to 40 percent of generation. Unfortunately, State Electricity Boards are unwilling to help agriculture, because it yields only 4 to 5 percent of the total revenue.

Non availability or restricted availability of electricity is a major bottleneck in agricultural growth. Situation in respect of water supply schemes is also not different. System efficiency, transmission and distribution losses, pilferage, thefts and above all subsidised power have forced State Electricity Board to incur losses. Authorities are aware of the serious repercussions of the situation and know that charging for service improves efficiency and service. The saved power can be used for new connections without extra burden. Similarly farmers are not going to stop agriculture if charged extra for more reliable and guaranteed power supply. Similarly, the consumer is not going to refuse drinking water supply if charged more. On the contrary, farmers would struggle to grow more to meet higher cost of power and endeavour to increase production for more profitable farm income. Hence it is necessary to have a uniform policy in the country for the power so that the sustainability can be thought of in the groundwater irrigation sector too.

4. Once benefits are established and realised by the consumers, financial intermediaries, private agencies and even the public and consumers would come forward to share the cost. What is more challenging is change in attitude, commitment, accountability and answerability. Decisions by the implementing agency are often influenced by politicians. Therefore the biggest task is to free the water sector from political influence and create political will for reforms. Enabling the community and entrusting them the task of resource management could be a step towards sustainable development of the depleting groundwater resources. Sudden transformation is neither possible nor contemplated. What is urgently required is accepting the reforms and beginning implementation.

ANNEXURE- 1

Information at a Glance of 6th Groundwater Assessment as per GEC 1997

Sr.No	Description	Details
1	2	3
1	Total No.of Districts in the State (As per 2002 -33)	29
2	Total No.of watersheds in the State	1505
3	Total No.of Talukas in the State (As per 2002 - 353)	318
4	Total No.of Assessment Sub Units	2316
5	Annual Groundwater Recharge (BCM)	32.96
6	Net Groundwater Availability (BCM)	31.21
7	Gross Annual Withdrawal (BCM)	15.09
8	Groundwater Irrigation Draft (BCM)	14.24
9	No.of Existing Irrigation Wells with Pump sets	1511797
10	No.of Existing Irrigation Wells with Mhots	4745
11	No.of Existing Irrigation Borewells with Power pump	41936
12	Total No.of Irrigation dug wells and bore wells (9+10+11)	1558478
13	No.of Existing Domestic Wells with Pump sets	38980
14	No.of Existing Domestic Wells with Mhots	88004
15	No.of Existing Domestic Borewells with Hand pump	134214
16	No.of Existing Domestic Borewells with Power pump	11389
17	Total No.of Domestic Wells (13+14+15+16)	272587
18	No.of Existing Industrial Wells with Pumpsets	641
19	No.of Over Exploited Assessment Watersheds / Talukas	76 /7
20	No.of Critical Assessment Watersheds / Talukas	20 / 1
21	No.of Semi Critical Assessment Watersheds / Talukas	163 / 23
22	No.of Safe Assessment Watersheds / Talukas	1242 / 287
23	Unclassified Assessment Watersheds due to entire Poor Quality	4

ANNEXURE – 2

Districtwise Net GW Availability and Draft Details of 6th Groundwater Assessment as per GEC-1997

(Unit - Ham)

Sr. No.	District	Annual GW Recharge	Natural Discharge	Net GW Availability	Gross Draft			Net GW Balance	Requirement Upto 2025	Dom.+Ind. Allocation	Net GW Avail for Future Irrg.
					Irrigation	Domestic	Total				
1	THANE	37790	1914	35875	6133	1232	7365	28510	2464	2460	26051
2	RAIGAD	15984	816	15168	5388	1614	7001	8166	3227	2541	5626
3	RATNAGIRI	24852	1247	23605	4702	1128	5830	17775	2255	2229	15546
4	SINDHUDURG	10569	539	10030	5293	1781	7074	2956	3563	2201	755
5	NASHIK	192518	10435	182083	88012	2960	90973	94266	5921	5188	89078
6	DHULE	208920	13775	195145	83623	2627	86249	110347	5253	3680	106666
7	JALGAON	131076	6554	124522	80618	5596	86213	45105	11191	8467	36638
8	AHMEDNAGAR	197476	9899	187577	134143	4278	138420	58044	8555	6799	51245
9	PUNE	151979	7691	144288	98797	2738	101535	49154	5476	3958	45197
10	SOLAPUR	148543	7534	141009	91463	4941	96404	47246	9882	8150	39096
11	KOLHAPUR	87821	4391	83430	53241	1256	54498	28932	2512	2432	26500
12	SANGLI	94028	4701	89327	64949	2456	67405	23732	4912	3716	20016
13	SATARA	123012	6264	116748	66566	5103	71668	45311	10204	9348	35963
14	AURANGABAD	120825	6206	114619	60585	2687	63272	51347	5375	5375	45972
15	JALNA	96584	4855	91728	38533	694	39227	52501	1389	1389	51113
16	BEED	127502	6596	120907	48817	4632	53448	67396	9263	9234	58225
17	PARBHANI	216595	10830	205765	42619	1891	44510	161255	3781	3781	157474
18	NANDED	144957	7467	137490	37038	1460	38498	98992	2919	2919	96073
19	OSMANABAD	114163	5764	108398	68345	1776	70121	38278	3551	3472	34806
20	LATUR	120363	6729	113634	81373	1633	83006	33708	3266	2780	30928
21	AMRAVATI	99421	4971	94450	70759	2510	73270	29776	5021	3863	25913
22	YEOTMAL	134562	6728	127834	25863	5572	31435	96399	11143	11143	85256
23	BULDHANA	73257	3663	69595	38758	2886	41644	29824	5772	4970	24855
24	AKOLA	76997	3863	73135	25330	2566	27896	45253	5132	5094	40159
25	NAGPUR	110228	6039	104189	39431	5865	45295	60582	11729	10603	49979
26	BHANDARA	112314	6339	105975	19751	5052	24803	82239	10104	9926	72313
27	WARDHA	99680	5295	94385	24767	1681	26448	68011	3363	3342	64669
28	CHANDRAPUR	92582	4629	87953	9762	4568	14331	73622	9137	9106	64516
29	GADCHIROLI	131513	8971	122542	9302	1372	10674	111868	2744	2719	109149
	TOTAL	**3296110**	**174706**	**3121404**	**1423960**	**84553**	**1508513**	**1660595**	**169106**	**150884**	**1509774**

Synthesizing informal and formal science towards water resource management:

Case studies from Kachchh

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Abstract: Even as there are hakims and vaids (traditional doctors) every region has rural experts with specialization in water resources. A combination of their informal science and knowledge of the region with engineering and geological principles can create a strong people's movement towards water self - sustainability. This paper will go through several case studies of villages working with geologists and engineers, towards solving their water problems.

A typical village in Kachchh has several geological formations, most of them impervious or saline. The art of aquifer identification and developing comprehensive water management strategies for the village requires a well developed methodology, where rural youth work with young engineers and geologists. Examples of three villages, will be discussed in which, the methodology was learned and formalized. This was then developed into training programmes for a large number of rural youth. They went on to develop the regional plans for drinking water securities, covering clusters of 25 to 165 villages in different parts of Kachchh. Khari was the first village in which, a rural expert, Rupa Kaka, worked with the author to make a glossary of rock formations and their characteristics. Based on this understanding, the first well was dug to provide drinking water to a village that often had to walk several miles to get sweet water. This understanding set forth the principles for watershed development in complex geological situations, leading to the development of a drought-proofing strategy with the Ministry of Rural Development. The second case study revives the lost traditional wisdom of water security for Bhuj city by studying the complex remains of canals, tunnels and tanks (an integrated system of Hamirsar Lake). This complex plan is being revived today to try and achieve water self sufficiency for the city. The third case study will look at the development of six month training programme for 'para

water technicians'. A group of school drop outs, recommended by rural experts went on to acquire this knowledge, based on, informal and formal science resulting into the creation of drinking water management plan of Abadasa Taluka (165 villages). This cultural synthesis of knowledge has given confidence to the government and the local people of being self reliant in their water needs.

Background

Like *Hakims and Vaids (Traditional doctors) every region has rural experts with specialization in water resources*. A combination of their informal science and knowledge of the region when combined with engineering and geological principles can create a strong people's movement towards water self sustainability. Keeping strong faith in this philosophy, author has made an attempt to generate and transfer the knowledge of geohydrology, in arid to semi arid region - Kachchh of Gujarat to the community. The main aim of this exercise is to demonstrate *people centeric decentralized sustainable natural resource management* approach through integrating formal and informal scientific knowledge. The present paper includes the author's experiences on gaining local knowledge from rural experts, utilization of such knowledge in community's confidence building, in decentralized planning and finally converting it in to knowledge transfer process through training of barefoot geo-hydrologists. The paper also explains how such barefoot geo-hydrologists are currently helping communities in water resource management at the village or block levels.

Village experience

The author himself was a fresh Master of Geology, when he started work on water resource management in the region. The author's first experience of understanding of geology through local knowledge was with Rupakaka –sarpanch of Khari village of Pachchham region of Kachchh district. The village Khari is located 70 km north of Bhuj in Pachchh Island, surrounded by the Great Rann of Kachchh. Rupakaka is 75 year old man, having magnificent understanding of geology, salinity and groundwater of his own village. The only difference between Rupakaka and the author's knowledge was in the use of terminology of rock formation and scale of information. It was the first exciting experience of learning geohydrology from the peoples' point of view. The learning had started when a geological mapping process was going on in the village during water resource planning. Rupakaka had shown some rock formations like *Rati Davdi, Dholi Bittu* (mixture of these is known as laterite), *mulai* (Shale) *kamp* (alluvium) pakal pan (crystalline limestone) along with their characteristics and relationship with water quality. The important outcome of this mapping, was a convergence of understanding of both the author and Rupakaka.

Such converegence helped in convincing the villagers, for taking further action through a small experiment of groundwater recharge, in an aquifer with a potential salinity threat from three directions. The experiment was simple. A small rivulet of the main river had been tapped through a small percolation tank. A subsurface check dam was constructed on the main river, slightly downstream of the tank. A well of 54 feet depth was dug between these two structures (*Figure 1*) The whole experiment was conducted in 1995, when only two and half inches of rainfall was received. The water level in the well, before the monsoon was about 48 feet; the level rose up to 23 feet immediately after monsoon. The rise was significant because the rise in the water level in the nearby area, with a similar kind of terrain and aquifer conditions, was very negligible and there was no change in the water quality, even after monsoon. The results of this experiment boosted the process by two ways,

1. Building confidence within the community about such interventions and
2. Developing self confidence of the author for deriving strategies for water harvesting in saline areas, based on strong scientific principles.

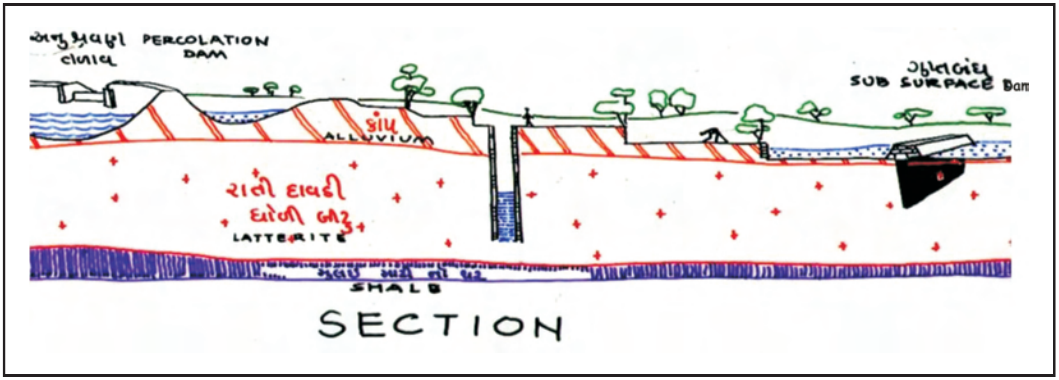

Figure No. 1: **Sketch Showing design experiment in Khari Village.**

This experiment was then followed by a detailed village planning exercise, based on geohydrological considerations. The village has been categorized into distinct zones, based on salinity and permeability of the rock formations, with appropriate strategies for water harvesting and aquifer management. (*Figure 2*)

The whole action plan has been implemented and regularly monitored in the pre and post monsoon season, to observe the changes in ground water quality as well as quantity. In the year 2005, the groundwater condition of village can be judged through the following:

- About 22 wells were providing irrigation facilities to about 90 acres of agriculture land. In case of year 1995 there were about 17 abandoned wells.
- TDS value ranges from 1500ppm to 3000 ppm. In 1995, these values were between 6000 ppm and 11000 ppm.
- Khari village now has its own drought proof drinking water source.
- Experience of Khari village has build strong confidence on potential of local aquifers (mainly shallow aquifer) and the planning process of water management by integrating local and advance knowledge system.

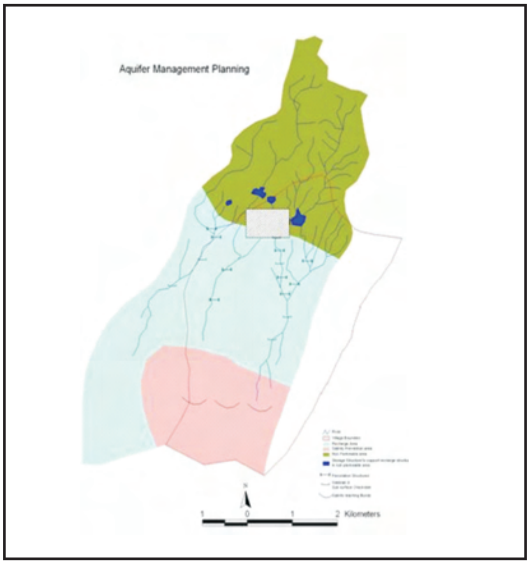

Figure 2: **Aquifer Management strategy for Khari village**

Derived understandings

Dador Sandstone Planning: It is a well known fact that Kachchh region is underlain by thick marine sedimentary rock formations; it has undergone regular crustal deformation by tectonic activities. These two characteristics attribute a certain complexity to the area in term of geohydrological aspects. Therefore, the experience from village Khari was not enough to develop proper understanding on the geohydrology, from a water resource management point of view. Therefore, a similar kind of aquifer identification, mapping and development process has been carried out in village Dador, located at the northern fringe of Kachchh Mainlandat its junction with the Banni grass plain. Here, the main aquifer is sandstone, but the spread of this aquifer was not restricted to Dador alone, but was shared by five more villages.

Water resource development planning for this aquifer was carried out for a cluster of villages. The learnings from the 'Dador sandstone planning' helped device a methodology for cluster level planning, especially in terms of sharing the shallow aquifer. The approach for this cluster level planning was similar to Khari, but at a different scale.

Hamirsar Lake Revival Plan: Unlike Khari and Dador villages, water resource management planning for Hamirsar Lake and its catchment of Bhuj city was a somewhat different experience. In this case, Khari and Dador experience helped understand this 450 year old urban water management system in the drought area. It helped understand the water balance and demand based approach of the people. The catchment system has been planned in such a way that a lake can be filled with water even with 7 inches of rainfall. With probability of rainfall of this intensity being almost 90 percent, except during a very severe drought, the system works quite efficiently. Besides water balance, design techniques of catchment diversion work through canals and tunnels along with flood control system clearly reflect upon the in-depth understanding of water resources within the local community. Interesting combinations of buffer reservoir, percolation structures, domestic water ponds, reservoir for birds etc. clearly show their understanding on geohydrology, relationship of rock with water, engineering skills etc. Decreased inflow of water into the lake due to changes in the landuse within the catchment area (during the last several years) point to the fact that during the course of development, we tend to forget traditional knowledge-based water management practices. However, the author was fortunate that experiences with rural experts helped plan such system from people's point of view.

All such experiences (with rural experts and of traditional knowledge systems) helped derive critical regional-level understanding on problems and perspectives of geohydrology of the region. This understanding can be expressed by three types of learning, which are as follows.

Types of salinity threats to these aquifers

1. Salinity ingress from inherently saline rock formations;
2. Sea water intrusion due to over-exploitation and ;
3. Salinity ingress from the Rann area and through (*Figure 3*)

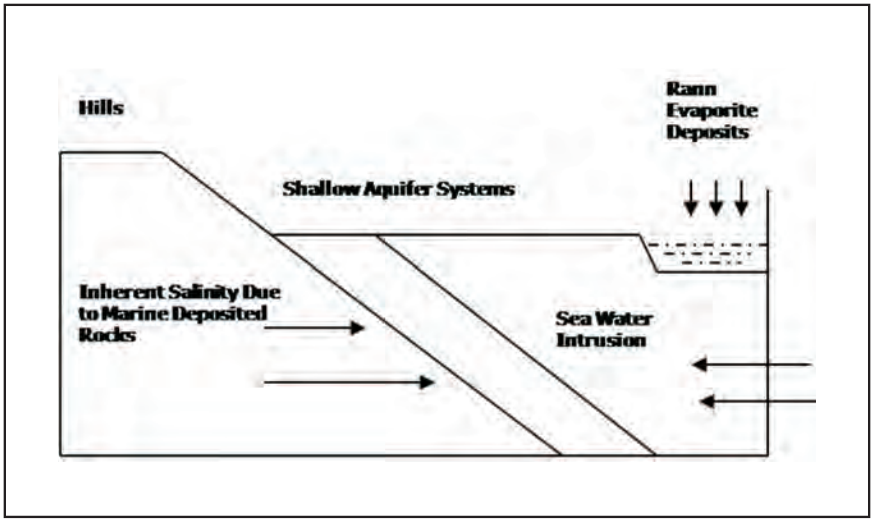

Figure No. 3: **Salinity threat to Shallow Aquifer**

The district has four main shallow aquifers (sandstone, alluvium, weathered zones of basalts and laterite), with every village underlain by at least one of them. (*Figure 4*). A simple matrix for water resource development strategies was developed. By using this matrix one can prepare decentralized water management plan for any village in the region. (*Table No. 1*)

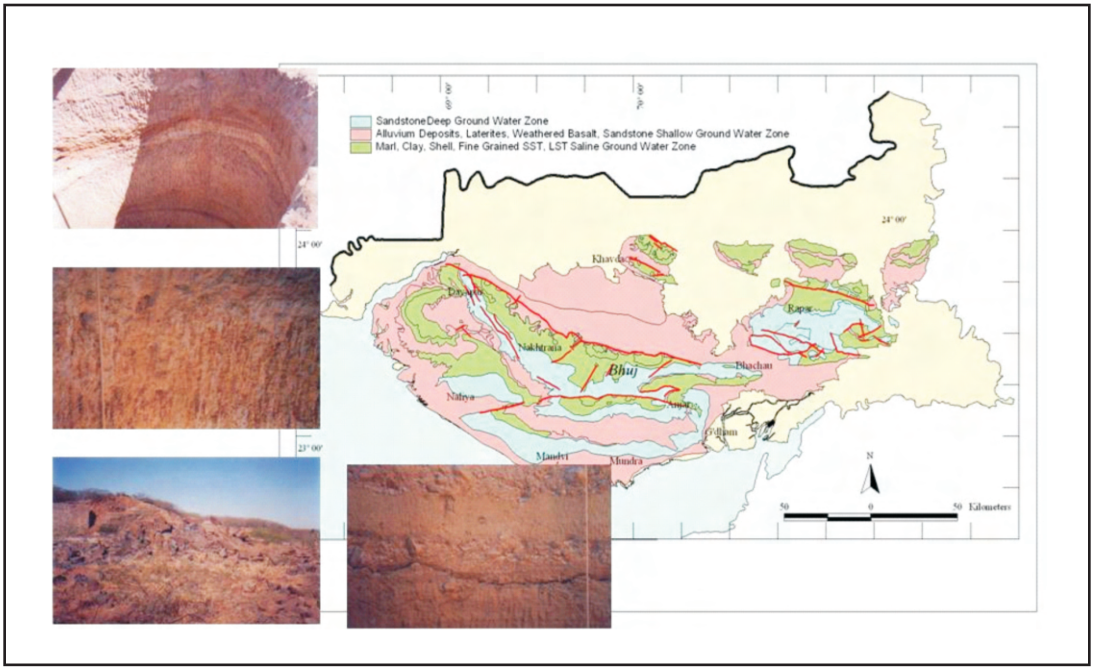

Figure No. 4: **Geological map of Kachchh district showing aquifers status**

Table No. 1: **Matrix for Water Harvesting Techniques**

Catchment Description		Water Harvesting Techniques			
Location	**Geomorphic Unit**	**Permeable Stratum**		**Impermeable stratum**	
		Non Saline	**Saline**	**Non Saline**	**Saline**
Upper Catchment	Hills, Rocky uplands	CD	GS	ST Large	ST Large
Middle-Upper Catchment	Undulating Plains	GS(U/S) SD (M) SCD (D/S)	STp - STr	ST Large	GS & Stp
Middle-Lower Catchment	More or less even Plains	GS (U/S) & PT (M) SCD (D/S)	GS (U/S) & PT (D/S)	GS (U/S) & ST (D/S)	GS &Stp
Lower Catchment	Flat lands	FB & WW	FB & WW	ST Small	ST Small
		SCD	SCD	FB &WW	FB &WW

Key

Groundwater Recharge	CD	Check Dam	ST	Storage Tank
Soil Moisture Conservation	GS	Gabion Structure	FB	Farm Bund
Surface Storage	PT	Percolation Tank	STp / STr	Silt Trap/Staggered Trench
Salinity Prevention	SCD	Subsurface Check dam	WW	Waste Weir

Utilization of derived understanding

This whole understanding of integration of traditional knowledge system with an advanced knowledge system poses two challenges. One, the decreasing numbers of rural experts and two, the very acceptance of the approach is being increasingly questioned.

Para Professional's Training: With passage of time, rural experts possessing traditional knowledge systems are decreasing from the communities. The newer generations are directionless regarding maintaining and sustaining such systems and bodies of knowledge. Also because of improper withdrawal strategies, even after proper social mobilization, maintenance and management of natural resources are proving difficult for the community. Considering this as a challenge, the whole experience has been converted into para-professional's training programme for the rural youth. The modules have been designed for two levels of training programmes - general understanding and advanced training.

General Understanding Level Training Programme is training where rural youth have been educated for understanding their water resources, aquifer and groundwater potential, salinity process and strategies for their water resource planning. The training method is through assignment of one village plan. Gained knowledge from Khari, Dador and other such villages has been documented and converted into simplified training materials. Whereas in case of Advanced Training Module, rural youth is trained for engineering skills required for water resource development and management. Both the training programmes are of 45 days.

Table No.2 : **Details of Paraworker's Training Programme**

General Training Programme	Advance Training

Objective: To Develop ability, for Conceptualization of Water Resource Planning
 	
Qualification: Writing and reading ability, with little work experience of water resource development as supervisor etc. / at least appeared in secondary school
 	
Inputs:
Understanding Base
• Understanding Regional Geohydrology
    o Perspectives
    o Problems
• Hydrological Cycle
• Integrated Approach for Planning
 	
Skill Base
• Mapping
• Rock Identification
• Map base calculation
• Estimation of Runoff
• Identification of Recharge / Runoff Potential Areas
	Objective: Technical ability to implement water resource development programme with technical competence of designing, costing, site management etc. along with community
	
	Qualification: Should have passed General training or Secondary / Higher secondary / Graduate in any subject
	
	Inputs:
	Understanding Base
	• Use-wise water resource development
	• Cost benefit analysis of respective structure
	• Impact assessment
	• Water resource management
	• Feasibility analysis
	• Social and economic dimensions
	
	Skill Base
	• Designing, Surveys, and estimation of water resource structures
	• Computer literacy
	• Appropriate site identification for particular water harvesting structure
	• Site Management, Supervision
	• Water quality analysis

For easy communication, especially for technical terms in geohydrology, a common dictionary has been developed as a part of training material. (*Table No. 3*)

Table No. 3: Local and scientific name of different rocks

Informal Science			Formal Science	
Use Based Classification	**Type**	**Sub Type**	**Type**	**Sub Type**
Aquifers	*Sagpan*	*Zina Dana valo sag*	Sand stone	Fine grain sandstone
		Mota Dana Valo sag		Coarse grain sandstone
		Rato Sag		Ferruginous sand stone
		Dholo Sag		Calcareous and siliceous sandstone
	Kalmindh		Basalt	Weathered basalt
	Davadi	*Rati Davadi*	Laterite	Red layer of laterite
		Dholi Davadi		White and soft layer of laterite
	Danto		Dyke	
			Fault	
	Kamp		Alluvium	
	Barad		Alluvium with coarse material	
Rocks utilize as Building Material	*Kamrai*	*Toda*	Calcareous fine grained compact sandstone	Rubble of limestone, and sand stones
		Chhipar		Regular shaped stone
	Padadhi	*Rati Padadhi*	Sandstone	Ferruginous fine grained compact sandstone
		Dholi Padadhi		Siliceous fine grained compact sandstone, Milliolite
	Gajiya			Calcareous compact machine cut stone
	Pakal Pano		Crystalline limestone	
	Chunano Paththar		Limestone	
Mineral Deposits	*Mung matti*		Bentonite	
	Chinai Matti		China clay	China clay, ball clay, fire clay
Saline Formations	*Mulai*	*Kali Mulai*	Marine deposited Shale	Carbonaceous shale
		Pili Mulai		Calcareous shale
	Kanyo		Iron oxide	

Regional planning : As far as the second challenge is concerned, it required strong implementation and demonstration support. And therefore, strong advocacy work was required with rural natural resource management programme. There were two programmes, one was Drought Proofing Programe (DPP) supported by Rural Development Ministry and the other was drinking water development programme by WASMO. In case of DPP, 28 villages were selected and in those villages various water resource development activities had been implemented. But as the villages were scattered, cluster or block level impact was difficult to demonstrate. However, the activities implemented in the villages were accepted by communities and local NGOs. The DPP programme is coordinated by Kachchh Nav Nirman Abhiyan and is implemented by its partner organizations from all over Kachchh.

To prove the concept further at block / cluster level, a collective initiative has been taken by WASMO, and various other social and technical organizations (Sahjeevan, ACT, VRTI, KFFFT) for village wise decentralized drinking water planning for 165 villages of Abadasa taluka of the district. This planning now has entered the implementation phase, where about 70 villages have proven that, their local drinking water sources still have potential, to make them self reliant for their drinking water.

The present programme is named as *"Pani Thiye Panjo"* i.e. water belongs to us. One of the objectives of the programme is to set up a block level water service center, where a team of para professionals come together and render their services to the community, NGOs, Government, Panchayat etc. Under this programme, 9 youths of Local Abadasa Taluka have set up center *"PARAB"* and serving to all *"Pani Thiye Panjo"* programme partners and pani samitis.

In addition to PARAB, ACT in collaboration with Kachchh Nav Nirman Abhiyan, is running regular training programme for Para water and Para Agriculturists. Today, 119 para water engineers and 48 para agriculturists have been trained by ACT, Out of them, 27 para professionals have gone through advance training.

Conclusion

Today in present technological world, when we are running behind large and complex technological solutions, we are overlooking our traditional and local resources which were very well managed by our ancestors with integrated knowledge system. Through citation of experiences from Kachchh, an attempt has been made to throw light on integration of rural youth professionals along with young engineer/geologist for better results.

Acknowledgement

The author is thankful to all partner organizations i.e. Sahjeevan, Kachchh Nav Nirman Abhiyan, Kachchh Mahila Vikas Sangatha, for providing opportunities to work with them and to derive and prove such experiences. Author is also thankful to ACWADAM and

Groundwater regulation: *Need for further reforms*

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Abstract: The legal framework for access and control over groundwater has been governed by rules that link access to groundwater and control over land. The limitations of a framework that relies on individual landowners for achieving socially equitable outcomes and environmentally sustainable mining of groundwater became apparent several decades ago after the introduction of mechanised pumping devices. Reforms of groundwater law have been proposed since the 1970s. The existing reform framework focuses on giving a centralised body more power over the use of groundwater. It does not, however, address the underlying problems stemming from a legal regime relying on individual preferences to regulate a substance common to everyone.

Introduction

Groundwater has become over the past few decades, the main source of water for all the main uses, particularly domestic uses and agriculture. This tremendous increase in the use of water has had significant impacts on water availability and on access to water.

The current regulatory regime is in large part still based on principles inherited from the colonial period. These are both outdated and inappropriate. They are dated because they were developed at a time when groundwater was a marginal source of water and when humans were not able to affect the level of the groundwater table through their use which was largely limited to drawing water from wells. They are inappropriate because the basic nexus between access to groundwater and land ownership, on which these rules are based, make common law rules socially inequitable and environmentally unsustainable.

There have been attempts to reform the existing framework since the early 1970s. Yet, current reforms are inappropriate. Firstly, they fail to sever the link between land ownership and access to groundwater, a precondition for ensuring that groundwater law contributes, for instance, to the realisation of the fundamental human right to water. Further, they add a layer of governmental control to a largely privately regulated framework but fail to recognise the constitutionally sanctioned rights of the panchayats in controlling local sources of water. While groundwater is not static, it remains the body of water most closely associated with a specific locality. As such it is the primary body of water over which panchayats have been given rights of control under the decentralisation mandate of the Constitution[1].

The limitations of the 'old' colonial framework and the proposed reforms call for new proposals for the reform of groundwater law. This has been made all the more necessary in the context of disputes like the Plachimada case where the two decisions already taken in this case gave two completely different readings of the rules applying to groundwater[2]. While the Supreme Court may lay a new framework in its forthcoming decision in this case, this may not alleviate the need for a broad-based rethinking of groundwater rules, beyond the specific dispute arising in the Coca Cola case.

Access to and control over groundwater under common law rules

Groundwater has usually been treated separately from surface water *(Swatuk, 2005)*. Historically, this can be ascribed in part to a lack of understanding of the connections between surface and groundwater and of the relationship between groundwater abstraction in different places. This also reflected the unavailability of pumping devices allowing large-scale groundwater withdrawals to the extent of significantly affecting the water table level.

These factors contributed to the development of separate legal principles for control over and use of groundwater. Since groundwater has a direct link to the land above, a link was established between land ownership and control, if not outright ownership, of the water found underneath the plot. While no specific groundwater legislation arose until the past decade, basic principles of access and control can be derived from the Easements Act, 1882. Under these principles, landowners have easementary rights to collect and dispose of all water found under their land[3]. There is thus an indissociable link between land ownership and control over groundwater. This implies that groundwater is mostly controlled by individuals or legal entities that own or occupy land. Where the common law principle is strictly applied, landowners are not restricted in the amount of percolating water they can appropriate. *(Moench, 1994)* It can, however, be argued today that, even under common law principles, owners cannot exploit groundwater beyond the replenishable level (*Planning Commission, 2007*).

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1. *This is subject to States taking up the mandate of Article 243G of the Constitution*
2. *Perumatty Grama Panchayat v State of Kerala 2004(1) KLT 731 (High Court of Kerala, 2003), available at http://www.ielrc.org/content/e0415.pdf and Hindustan Coca-Cola Beverages v Perumatty Grama Panchayat 2005(2) KLT 554 (High Court of Kerala, 2005), available at http://www.ielrc.org/content/e0515.pdf.*
3. *Halsbury's Laws of India – Volume 29(2) (New Delhi: Butterworths, 2000) 447.*

The link between groundwater and land ownership is important for different reasons. Firstly, groundwater has been and is an increasingly important source of drinking water. This is due, both to the existence of increasingly powerful pumping devices as well as to an increasing bias against the use of surface water as a source of drinking water to ensure that it is of better quality. Secondly, groundwater has been an increasingly important resource used by landowners in different types of economic activities. In fact, groundwater has now become in certain regions, as important as or even more important than land itself *(Janakarajan and Moench, 2002*). Besides agriculture, large-scale water abstraction is also carried out by certain industries, as in the case of water or soft drink bottling plants.

Where control over groundwater is linked to land rights, there are neither any incentives for individual landowners to sustainably use the resource nor any way to implement policies that take into account the welfare of a broader community and the environment. In what is for all practical purposes an unregulated system, there is, for instance, no authority that can determine how many wells, handpumps and other tubewells can be sunk in a given area. Some form of regulation that takes into account the broader aspects of groundwater use is thus necessary. Regulation is also required because the increasing use of groundwater, controlled by private individuals, may shift away control over water from communities. Thus, in the case of tank irrigation in Tamil Nadu that are often largely community managed, increased use of groundwater and the lesser importance attached to tanks seems to have shifted the determinants of water access away from communities into the hands of individuals[4].

The dramatic increase in groundwater use and importance of groundwater as a source of water have led to significant debates but relatively little by way of concrete policy decisions. To-date, the most significant initiatives at the union level have been the drafting of a model bill for adoption by the states and the setting up of the Central Ground Water Authority mandated to regulate and control the use of groundwater *(Ministry of Environment and Forests, 2000)*. Its mandate includes the notification of 'over-exploited' and 'critical' areas and the regulation of groundwater withdrawal in such areas but it does not have a broad mandate to regulate groundwater in general. The Authority is not credited with having had much impact in its decade of existence (*Shah, 2008*).

This amounts to relatively little, since, unlike irrigation water where the introduction of formal legislation started more than a century ago, groundwater was largely governed by principles that assumed self-regulation. The dramatic changes that have taken place in the past few decades and turned groundwater into the major source of water are not reflected in the existing legal framework, including in the few states that have adopted the model bill as a prototype for their legislation, since this is not a comprehensive regulatory response. This can be partly ascribed to the fact that falling water tables can be 'fixed' for some time by simply digging further down has provided an opportunity for governments to avoid facing some difficult political choices. In fact, in a number of states, the answer to

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4. ibid 2.

falling water tables has been not to address the issue itself. State governments have thus often chosen to increase power subsidies to make extraction of ever deeper layers of groundwater possible rather than tackle the underlying cause of depletion. The limits of an approach that not only refuses to control access to groundwater but seeks to encourage it with specific subsidies have been clearly understood. The unavoidability of a different response has dawned on most states but the fact that it is a politically extremely sensitive issue implies that some states may still further delay necessary measures by a number of years.

Ongoing reforms of the legal regime concerning groundwater

Groundwater regulation is one of the areas in most need of reforms. This is due to the fact that groundwater is now the main source of water for most water users and that the current outdated framework can do little more than adjudicate claims that may arise between two landowners over their respective use of groundwater under their plot and in its vicinity. The challenge that groundwater poses has been recognized for quite some time, as witnessed by the fact that the union government already put out a model bill for adoption by the states in 1970. This relatively early date of adoption of the model bill is reflected in its approach to groundwater regulation. Indeed, in the early 1970s, there was comparatively little discussion of the need for control by panchayats over natural resources or water and environmental concerns had only just made an appearance on the agenda of policy makers. It is thus not surprising to find that the 1970 model bill reflects the concerns and perceptions of that period. What is more surprising is that, despite several revisions, the model bill (re)proposed in 2005 is still based on the same premises.

Groundwater law reforms are noteworthy for several reasons. Firstly, the proposed changes conform to a model that is neither directly in line with water sector reforms nor influenced by the 73rd constitutional amendment, human rights and environment principles. Secondly, they perpetuate the sectoral treatment of surface and groundwater, perpetuate a system that links access to groundwater and land and fail to acknowledge that groundwater is the primary source of drinking water and thus primordial in the realization of the human right to water. Thirdly, ongoing reforms are based on suggestions for reforms that date back several decades. This implies that they are not directly influenced by new notions such as the idea that water should be seen as an economic good. This may be positive because it constitutes at least some sort of an alternative to the current policy framework for water law reforms (*Cullet, 2009*), but at the same time is not a solution that can be recommended because of its lack of social and environmental perspective and because it perpetuates a sectoral model of water law development.

The proposed reform model

A model bill for groundwater regulation was first proposed by the union government for adoption by the states in 1970. It has been revised several times but the basic framework of the latest 2005 version retains the basic framework of the original bill. Recent legislative activity by states indicates that they are generally ready to follow the framework provided by the model bill. This is the case of states adopting a generic groundwater legislation like Kerala[5], or states focusing on its drinking water aspects like Karnataka, Madhya Pradesh and Maharashtra[6].

The basic scheme of the model bill is to provide for the establishment of a groundwater authority under the direct control of the government. The authority is given the right to notify areas where it is deemed necessary to regulate the use of groundwater. The final decision is taken by the respective state government[7]. There is no specific provision for public participation in this scheme. In any notified area, every user of groundwater must apply for a permit from the authority unless the user only proposes to use a handpump or a well from which water is drawn manually[8]. Wells need to be registered even in non-notified areas[9]. Decisions of the authority in granting or denying permits are based on a number of factors which include technical factors such as the availability of groundwater, the quantity and quality of water to be drawn and the spacing between groundwater structures. The authority is also mandated to take into account the purpose for which groundwater is to be drawn but the model bill does not prioritize domestic use of water over other uses[10]. Basic drinking water needs are indirectly considered since, even in notified areas, hand-operated devices do not require the ostentation of a permit[11].
The model bill provides for the grandfathering of existing uses by only requiring the registration of such uses[12]. This implies that in situations where there is already existing water scarcity, an act modeled after these provisions will not provide an effective basis for controlling existing overuse of groundwater and will, at most, provide a basis for ensuring that future use is more sustainable.

Overall, the model bill extends the control that the state has over the use of groundwater by imposing the registration of groundwater infrastructure and providing a basis for

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5. *Kerala Ground Water (Control and Regulation) Act 2002, available at http://www.ielrc.org/content/e0208.pdf.*
6. *Karnataka Ground Water (Regulation for Protection of Sources of Drinking Water) Act, 1999, Madhya Pradesh peya jal parirakshan adhiniyam, 1986 and Maharashtra Ground Water Regulation (Drinking Water Purposes) Act, 1993. On the Maharashtra Act, S Phansalkar & V Kher, 'A Decade of the Maharashtra Groundwater Legislation', 2/1 Law Environment & Development Journal 67 (2006), available at www.lead-journal.org/content/06067.pdf.*
7. *Model Bill to Regulate and Control the Development and Management of Ground Water 2005, s 5.*
8. *ibid s 6.*
9. *ibid s 8.*
10. *ibid s 6(5)(a) only provides that the purpose has to be taken into account while Section 6(5)(h) which is the only sub-section referring to drinking water only considers it as an indirect factor.*

introducing permits for groundwater extraction in regions where groundwater is over-exploited. It is the brainchild of an era that promoted governmental intervention without necessarily thinking through all the checks and balances that needed to be introduced alongside. As a result, the model bill is not adapted to the current challenges that need to be addressed (*Planning Commission, 2007*). It fails to include specific prioritization of uses, does not specifically address the question of domestic use, does not differentiate between small and big users, commercial and non-commercial uses and does not take into account the fact that non-landowners/occupiers are by and large excluded from the existing and proposed system which focuses on the rights of use of landowners. It is thus surprising that states are still drafting acts based on this outdated model. What is required is legislation that recognizes that water is a unitary resource, that drinking water is the first priority as well as a human right and that panchayati raj institutions must have control over and use of groundwater.

What are the reforms being implemented by states?

A number of states have either adopted groundwater legislation in the past decade or are in the process of developing it. While most states are yet to adopt legislation, the need for one seems to be generally acknowledged. However, in an interesting twist, a state like Punjab that has 85 percent of its land under cultivation is not contemplating the adoption of groundwater legislation because of the impacts it would have on farmers[13]. Instead, Punjab is proposing to give incentives for crop diversification, to invest in artificial groundwater recharge, to meter electricity supply in critical areas and to promote micro-irrigation.

The states that have adopted legislation that specifically focuses on groundwater include Goa, Himachal Pradesh, Kerala, Tamil Nadu and West Bengal[14]. They differ in their coverage since some apply only to notified areas while others apply to all groundwater (*Koonan, 2009)*. As noted above, Karnataka, Madhya Pradesh and Maharashtra have adopted limited groundwater legislation focusing on drinking water[15]. The only state that has consciously put groundwater in a broader framework is Andhra Pradesh where the groundwater legislation directly links surface and ground water in a general context of environmental conservation[16]. Apart from a conceptually broader framework for groundwater regulation and specific consideration of drinking water issues, the Andhra legislation addresses groundwater in a similar manner to other groundwater acts.

11. *ibid s 6(1).*
12. *ibid s 7.*
13. *ibid 29.*
14. *Puducherry and Lakshadweep have also adopted groundwater regulation instruments, respectively in 2002 and 2001.*
15. *Maharashtra is in the process of adopting a broader Groundwater Act.*
16. *Andhra Pradesh, Act to Promote Water Conservation, and Tree Cover and Regulate the Exploitation and Use of Ground and Surface Water for Protection and Conservation of Water Sources, Land and Environment and Matters, Connected Therewith or Incidental Thereto, 2002..*

The main institutional innovation proposed in the groundwater acts and the Andhra legislation is the setting up of a new authority or cell made of government civil servants and members nominated by the Government because of their expertise. The balance between civil servants and other members varies. In Goa, the act simply authorizes the government to nominate members without specifying their origin[17]. In West Bengal, the majority are civil servants. In Kerala only four of the thirteen members of the Authority are civil servants while the rest is made of a combination of people with different expertise[18].

The authority set up under the act is then tasked with different functions, such as notifying areas of special concern and granting permits to use groundwater in notified areas[19]. Among the acts that specifically focus on groundwater, the West Bengal legislation is the only one that gives the Authority a broader mandate that includes the development of a policy to conserve groundwater and organizing people's participation and involvement in the planning and use of groundwater[20].

Following on the steps of the model bill, most acts fail to clearly give drinking water priority of use even though most acts devote specific attention to the issue of drinking water[21]. The Himachal Pradesh legislation stands out insofar as it imposes on the Authority to give first priority to drinking water[22]. Additionally, some instruments specifically indicate that the use of groundwater as public drinking water source is not affected by any control measures[23].

An important aspect of most of these acts is to avoid altogether the thorniest question, which is the legal status of groundwater itself. Most acts avoid direct statements on this issue but the very fact of promoting the setting up of institutions controlled by the government that can regulate groundwater use in indirect and direct ways reflect a conception of water that sees it as being under the control of the government. The Himachal Pradesh legislation is rather forthcoming in this regard since it specifies that users of groundwater in notified areas must pay a royalty to the government for its extraction[24]. Additionally, the government is not even bound to use this royalty for groundwater-related activities, thus reflecting an understanding that groundwater is a

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17. *Goa Ground Water Regulation Act, 2002, s 3(2).*
18. *Kerala Ground Water (Control and Regulation) Act, 2002, s 3(3).*
19. *eg Himachal Pradesh Ground Water (Regulation and Control of Development and Management) Act, 2005, s 5, 7.*
20. *West Bengal Ground Water Resources (Management, Control And Regulation) Act, 2005, s 6(2).*
21. *eg Goa Ground Water Regulation Act, 2002, s 23.*
22. *Himachal Pradesh Ground Water (Regulation and Control of Development and Management) Act, 2005, s 7(3).*
23. *Goa Ground Water Regulation Act, 2002, s 9. Also Karnataka Groundwater (Regulation and Control of Development and Management) Bill, 2006, s 1(4).*
24. *Himachal Pradesh Ground Water (Regulation and Control of Development and Manage ment) Act, 2005, s 12(1).*
25. *ibid s 12(2).p*

resource controlled by the government[25]. This can be understood as an extension of the full control given by several irrigation acts adopted in the twentieth century to the government over surface water. It is, however, surprising for at least two reasons. Firstly, there has been only very limited debate on the status of groundwater and such a major change would warrant in-depth consideration. Secondly, if any change is warranted it would be to recognise groundwater as part of the public trust. Indeed, in the context of surface water, the Supreme Court has recognised that assertions of government power over water was not warranted anymore and declared that it was part of a public trust. This is also what the single judge determined in the first Plachimada decision.

Besides strengthening the control that the government claims over groundwater, the various acts adopt a non-confrontational strategy in refusing to tackle existing overuse of groundwater. Thus, in the main, acts provide for the grandfathering of most existing uses. This amounts to refusing to tackle the real problem affecting groundwater. Indeed, as long as it is landowners that have most control over groundwater, there will be no scope for groundwater regulation that is socially equitable and environmentally sustainable. There is no incentive in the common law rules or in the acts that are being adopted for individual landowners to use the water responsibly and equitably. There is also no mechanism to ensure that groundwater is shared with non-landowners. Further, without a broader perspective, no single water user has any reason to recognize environmental needs ensuring that all ecosystem functions are met in the long term.

The limits of the old common law regime and new legislative efforts are well illustrated in the context of the dispute between the Perumatty Grama Panchayat in Kerala and the Coca Cola Company. The controversy erupted after the panchayat that first granted the exploitation licence decided not to renew it because of the lowering of the water table in neighbouring properties, as well as decreasing water quality to the extent that the local government primary health centre had concluded that the water was not potable (*Bijoy, 2006)*. The issue was brought to the courts and is now pending in the Supreme Court. The two decisions given by judges in Kerala gave two opposed views of groundwater regulation. On the one hand, the first judge found that even without groundwater regulation, the existing legal position was that groundwater is a public trust and that the state has a duty to protect it against excessive exploitation[26]. Additionally the judge made the link between the public trust and the right to life[27]. It was thus recognized that a system which leaves groundwater exploitation to the discretion of landowners can result in negative environmental consequences. The next decision took a completely different perspective and asserted the primacy of landowners' control over groundwater[28]. These two contradictory decisions illustrate the need for a framework that effectively ensures the sustainability of use of groundwater and the prioritization of drinking water over all other uses.

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26. Perumatty Grama Panchayat v State of Kerala 2004(1) KLT 731 (High Court of Kerala, 2003).
27. ibid.
28. Hindustan Coca-Cola Beverages v Perumatty Grama Panchayat 2005(2) KLT 554 (High Court of Kerala, 2005) para 43.

Reliance on old common law principles is only able to justify individualized control but cannot in any way provide a broader framework of analysis. The inapplicability of the groundwater legislation to this dispute was noted by the judges. However, what is apparent is not the fact that the new legislation is not applicable but the fact that it would not have provided a framework for a more socially equitable and environmentally sustainable decision. The application of the act to future similar disputes may clarify matters in terms of institutional decision-making but it would likely lead to results fairly similar to the decision of the second judge. What is needed is a radically new perspective, something that the first judge perceptively understood. The Supreme Court now has the chance to provide a boost towards a new framework for groundwater regulation.

Reforming the Reforms

Ongoing reforms of groundwater regulation fail to bring in a regulatory framework that is either adapted to the needs of the twenty-first century or compliant with existing constitutional principles. Firstly, existing groundwater reforms fail to implement basic constitutional principles related to water that apply without doubt to groundwater. This is the case of the fundamental human right to water and the decentralisation amendment (73rd Amendment). With regard to the fundamental right to water, its application to groundwater is essential because groundwater provides most of our drinking water. Yet, groundwater legislation has only exceptionally focused on drinking water and never from a fundamental right perspective. With regard to the 73rd Amendment that gives panchayats control over water management at the local level and minor irrigation, ongoing reforms conceived before 1992 are simply not in tune with the new constitutional requirements.

Secondly, existing reforms fail to address the core issue of the legal status of groundwater. The failure to abolish common law rules giving landowners overwhelming control over groundwater – as was for instance undertaken in post-apartheid South Africa – does not provide scope for bringing in a legal regime that is socially equitable and environmentally sustainable. The need for a drastic change in legal status is, for instance, illustrated by the fact that the first judge in the Plachimada decision felt that he could not take a just decision without asserting the extension of the principle of public trust to groundwater.

In addition to their failure to implement constitutional provisions, ongoing reforms also fail to take into account important objectives. Groundwater legislation is to-date conceived largely as a natural resource legislation that fails to integrate the key social dimension of groundwater. Similarly, groundwater legislation fails to integrate existing environmental law principles, such as the precautionary principle. While water and environment are partly separate branches of law, they are also intrinsically linked as reflected in the fact that the Water Act, 1974 was conceived as an environmental legislation. The dismissal of environmental principles from the rest of water law is thus unwelcome and inappropriate.

The stringent limitations of current groundwater regulation reforms call for a new conceptual paradigm and a new set of reforms. This goes against the advice of the Expert Group set up by the Planning Commission that 'no change in [the] basic legal regime relating to groundwater seems necessary' *(Planning Commission, 2009)*, but is called for by the limitations highlighted above. The new set of reforms needs to be based on the basic principles of the national legal framework as it exists today rather than what was prevalent in 1970. Two of the important novel aspects are the explicit recognition of the fundamental human right to water and the decentralisation amendments. Integrating both these elements requires a complete rethinking of the basic structure of groundwater legislation. In other words, an entirely new set of reforms is needed to ensure the implementation of these basic principles. Such reforms must, for instance, ensure that delinking land and water rights is undertaken in the framework of the human right to water that requires restricting or eliminating individual entitlements to water.

In addition, further reforms must benefit from advances in the scientific understanding of the water sector. This should lead to the development of laws that do not make artificial divisions between surface and groundwater for instance. This is problematic because the disconnect does not exist in practice and leads today to absurd results because the basic principles governing surface water and groundwater are different.

Finally, the reforms must be based on recent legal developments within water law and in related areas. This includes the need to extend the principle of public trust, a principle that has been repeatedly confirmed by the Supreme Court for more than a decade, to groundwater and the need to integrate the precautionary principle, a basic principle of environmental law that is directly relevant in the case of groundwater.

All these measures may be adopted at the state level in keeping with the constitutional mandate. There is, however, also a need for a legislation setting out the basic principles of water law at the national level. This may provide the backbone for groundwater regulation at the state level that is more compliant with the constitutional framework than is the case today.

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Megh pyne abhiyan:
Facilitating in evolving water issues in North Bihar

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Abstract: This paper describes the actions initiated by the Megh Pyne Abhiyan (MPA) in trying to solve a problem of safe drinking water in North Bihar. Inability to access safe drinking water during flood is one of the most serious problems confronted by people staying in safe locations during floods. In the absence of safe source of drinking water people have to depend on unclean flood and river water. The nuances of social, economic, political and governance insecurities and challenges are deciphered by MPA through regular interactions with villagers across five districts of North Bihar. MPA's motivation is to construct a congenial social environment through sustainable technological innovations and adaptation of methods like the rain water harvesting, local methods of water testing and revival of dug wells in order to ensure a shared, sustainable and effective management of water.

Background

An uninterrupted field action research (beginning March 2005) by a group of grassroots organizations (Gramyasheel, Kosi Seva Sadan, Samta and Ghoghardiha Prakhand Swarajya Vikas Sangh) and the development practitioner resulted in the formation of an informal network – Megh Pyne Abhiyan (MPA) – henceforth also referred to as the "campaign" - in December 2005. The group was cognizant of the challenges it would be confronting in laying down processes and practices in the villages. Therefore, they decided against re-inventing the wheel of existing social and economic issues; instead they agreed upon highlighting the issue of safe drinking water during floods. Most of the existing hand pumps during floods get submerged in water or else get silted up or are damaged by the gush of the flood waters. With many people having to live on embankments or trapped in elevated regions under marooned conditions, access to hand pumps is further hindered. Perforce, people use unsafe drinking water which is used for multiple purposes, such as – defecation, immersing the dead and drinking of course. Such multiple uses during a natural calamity, results in its own set of health related problems. People trapped in floods have regularly fallen victim to diarrhea and gastro-intestinal problems leading to high morbidity and mortality especially amongst infants, women and the elderly. According to the villagers, a substantial chunk of their annual income is spent on health services primarily due to contaminated drinking water.

The strained scenario further strengthened the resolve of the alliance to initiate work by addressing a fundamental problem frequently confronted by people along with the possibility of being addressed locally. Due to the prevailing disgruntlement and impression of hopelessness amongst people, the alliance felt that addressing a complex problem could be counter productive. Hence, it was agreed that the introduction of

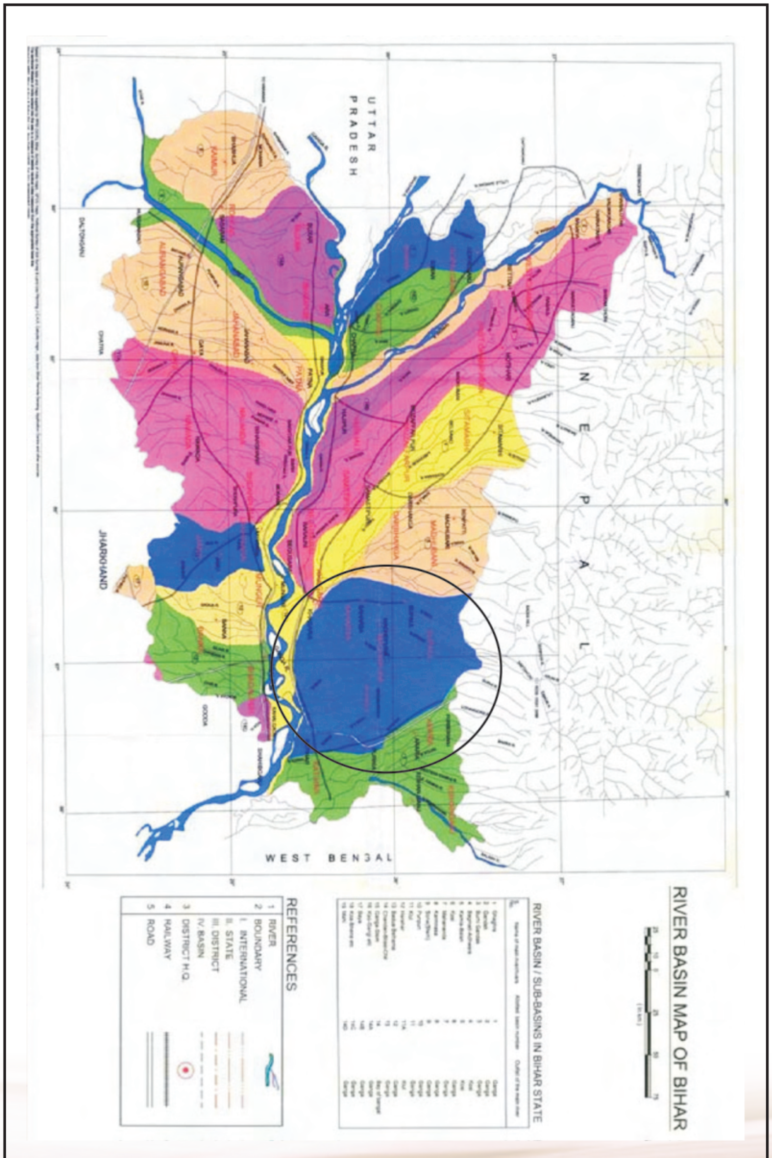

Figure 1: **River basin map of Bihar, circle indicating the study area**

rainwater harvesting as an alternative technique for accessing safe drinking water could become an effective medium for initiating a process of *swa-nirnay, swa-prabandhan* and swa-raj in the region. Therefore, MPA has been active in the North part of Bihar, mainly in the five districts of North Bihar - Supaul, Saharsa, Khagaria, Madhubani and West Champaran. (*Figure 1*)

In this campaign, MPA tries to reverse these trends by bringing people and their time tested ways of water management by the close association with the grass root organisations. The organisational design is structured for a transparent, decentralised development, wherein organisations follow a planned work schedule yet have the freedom to take forward the process of building the capacity of communities and build their sense of ownership over their natural resources in their individual manner.

The strategy

During the first phase the campaign had intentionally concentrated on nurturing faith within people with regards to rainwater harvesting as a feasible option to access safe drinking water. In the second phase, an additional component i.e. of rainwater storage, was added to the rainwater harvesting strategy. With the increase in the area of operation, the campaign adopted a strategy that would address the concerns of the new panchayats as well as consolidate on the experiences of the four old panchayats. Formation of a village level committee was a step towards developing and establishing grassroots institutions.

Since the beginning, the campaign has emphasized alternative approaches that would help prevail over the perpetual threat and control by external sources. This, it believes, will promote a participatory paradigm of development, which is fundamental for the survival and evolution of rural society. The strategy to stimulate involvement of local communities was purposefully not kept limited to rainwater harvesting alone. The idea was to involve them in developing a larger argument with regard to the problems and appropriate solutions for the region. There were a lot of unplanned interventions during the course of the second phase, and it was possible because of the stage that the campaign had prepared in collaboration with the people. It was a challenging task to alter their outlook and develop the confidence of addressing local problems internally. Adequate measures were adopted to evolve their participation with specific responsibilities for all the activities that were undertaken in the panchayats. There were instances that indicated a gradual shift in the nature of expectation of the people with regard to the campaign from a 'service provider to a partner'. The sustenance of this partnership depended on the capacity of both in partnering groups, of complimenting each other and in strengthening their endeavour towards instituting pro-poor interests.

1. Rainwater harvesting

The average annual monsoon rainfall in north Bihar is estimated to be 1250 mm. Out of the 120 days of monsoon season, the region, in general, experiences 56 days of rains from June to September. The annual rainfall pattern indicates that harvesting and storing of rainwater for the entire monsoon period, is possible and can provide sufficient drinking water for the entire season. In the absence of industrial setup in these five districts, the perceptible threat to the quality of rain is minimal.

In all the campaign area, with the help of hamlet-level *jal samitis*, rainwater harvesting installation was done. At the same time, a system for community contribution was established. MPA has and continues to strive towards reviving the potential traditional and local wisdom, in context to the work that is being implemented through the campaign. For instance, during the initial phase, MPA had propagated use of plastic containers for storage of rainwater. Despite its feasibility in terms of its portability and management during floods, the use of plastic container was not widely accepted due to various reasons like non availability of quality containers in remote areas or incidence of foul smell entering the water if stored for a longer duration.

In the second phase, the plastic container was substituted by earthen pots simply because of reasons like portability, availability, manageability and cost effectiveness of this local and environment friendly system. However, there were some problems related to the earthen pot as a storage facility, which were discovered during the recent monsoon/floods. The concrete field based experience has once again compelled the campaign to re-strategize its approach towards the storage facility. In the quest for a plausible and sustainable storage facility, the campaign has made several attempts to develop one or more sustainable storage facilities. The age old grain storage structure, popularly known as 'kothi' has been further innovated and developed as a water storage facility. The Supaul team developed one such structure and named it as *'Jal Kothi'*. Presently, the storage facility is being closely monitored and developed in other districts so that a clear package of practice gets developed which will help in constructing a robust water storage structure.

At the outset a thinly meshed bamboo frame is made, which is the water storage space. Later, a thin layer of cement-sand plaster is applied from both outside and inside the frame, in order to bind the cement along with the frame, making it robust and water resistant. *Photo 1* depicts the temporary rainwater harvesting structures constructed for safe drinking water during floods.

Photo 1: **Temporary rainwater harvesting structures constructed for harvesting safe drinking water during floods**

Outcome of rainwater harvesting initiative

- Large scale acceptance of rainwater as a safe drinking water source – In 2006, approximately 13,000 people out of a population of 46,000 across four panchayats drank rainwater. During 2007 floods, a total of 36,352 households had accessed rainwater. In Khagaria, approximately 6,255 people, external to the campaign panchayats, benefited from rainwater harvesting during the floods.
- Acknowledgment of rainwater harvesting as an effective approach on the basis of concrete facts and experiences
- Winning 'peoples' trust on the campaign and its belief systems, which led to resurgence of peoples' faith in self administered micro-initiatives and in alternative systems
- Growing understanding and sensitivity towards water, specifically for drinking purpose, amongst the villagers, social activists, panchayat functionaries and government representatives
- Developing a sound foundation for future work
- Emergence of a new strength within the campaign to take up similar challenges

Water testing

The preparatory stage for the second phase experienced partner organizations advocating the development of a comprehensive plan for addressing water and sanitation issues in the campaign panchayats. Their eagerness to establish a *water and sanitation model* stemmed from the concerns of the primary stakeholders regarding

- Identification of definite practices that would ensure safe drinking water throughout the year
- Knowledge about the quality of drinking water
- Impact of consuming contaminated water on human health

On one hand, lack of knowledge and technique to check groundwater, and on the deteriorating health conditions of people in the rural areas, prompted the campaign to take up the challenge of spreading 'informed scientific knowledge' to the people, about the status of groundwater and its impact on the human body. As a strategy, the campaign first decided to take up water testing in order to develop an understanding about the quality of groundwater and other water sources in all the five districts. At the beginning, the field associates were trained twice to test water scientifically during two training workshops held in partnership with Development Alternatives, Delhi.

The drinking water sources for carrying out water testing were carefully selected from more than thousand sources on the basis of their usage by the trained field associates. A rigorous testing procedure was designed and shared along with the field workers. The water testing results indicated that most of the villages in the 21 panchayats had contaminated groundwater. It ranged from pH, Coliform, Fluoride, Residual Chlorine, Nitrate, Iron, Hardness, Chloride and Ammonia. Arsenic was found as well, even in places were it was not traced before. The results clearly demonstrated high level of contamination from Iron, contamination from Arsenic and Fluoride. Very diffuse microbiological contamination was prevalent in the 21 panchayats. The test results were strategically shared amongst the villagers with the intention of making them sensitive towards the groundwater scenario at the village and panchayat levels.

Out of all the perceptible water problems, excessive iron in groundwater remains to be the most prevalent and pervasive in the region, resulting in sizeable population suffering from gastro-intestinal problems. The burgeoning of chapa kals in the region (marketed as affordable, uncomplicated, trouble-free, undemanding and secure drinking water technology) coupled with total obliteration of local drinking water systems (yielding water with iron far less than the permissible limits) are considered as reasons for the spread of gastro-intestinal problems in the region.

Greater consciousness within the campaign about iron contamination in groundwater, and its related impact on health, along with the mounting pressure from villagers compelled the campaign to locate a local solution. A simultaneous exercise was carried out in the field by MPA to identify practices that were being adopted by villagers to overcome the problem of excessive iron in drinking water. Locally developed home-made filters were designed, termed as matka filter by MPA. The matka filter is similar to the much publicized water steel filters. It requires frequent cleaning to ensure that the purification process remains effective. (*Photo 2 –B*)

Local technique of water testing

The indigenous 'Guava/ Black pium leaves testing' technique is an indicative method to detect iron in water. This technique had an immediate impact on peoples' perception of their 'safe drinking' water source. Fresh leaves of either guava or black pium are crushed with hands. The crushed leaves are then dipped inside a container with the water that needs to be tested. The colour of the water changes depending upon the extent of iron content in it. Various shades of purple define the extent of iron in water. If the iron content is less, then the water will have light traces of purple. The water turning black is an indication of iron content being excessive. The entire procedure takes just a few minutes and can be easily carried out by anyone. The outcome of the indigenous technique has been corroborated with the scientific water testing procedure and there have been no discrepancies concerning the test results. (Photo 2-A)

Despite countering different challenges, four out of five partner organizations were able to introduce the initiative in Supaul, Saharsa, Khagaria and Madhubani districts, which included 25 panchayats. More than 150 filters were installed through which more than 27000 individuals benefited. Presenting a modified version of the matka filter in the campaign panchayats was a thorough experiential effort. The following learnings have helped in streamlining future interventions

(A) (B)

Photo 2: **(A) Local method of iron water testing using guava leaves; (B) Locally developed matka filter**

Outcome of the initiative

- The increasing demand for individual matka filters is an indicator of the local acceptance of the remodeled version of the filter.
- Installation of matka filter in schools and play schools has generated consciousness within the rural households.
- The inclusive approach of the campaign was responsible for the introduction and acceptance of the filter in areas where the technique was either not present or popular.
- The local experience of accessing safe water during floods provided confidence to people to accept an alternative technology.
- Demand for *matka* filters has provided the local potters with an opportunity to strengthen their traditional livelihood practice.

Dug well revival

The process of engaging with the revival of dug wells has been a natural progression for Megh Pyne Abhiyan (MPA), largely due to its commitment for instituting local practices that overcomes social and economic barriers and ensures safe drinking water to all. Over past two years, alternative options have proven to be an effective way of not only accessing safe water but also in stimulating communities towards a process of collective thinking and related action. The progression has not been easy though; nor will it be in the future, owing to the vested social, political, and economic hierarchies that continue to perpetuate a governance pattern – a pattern that institutionalizes discrimination leading to fragmentation of and nepotism within the society. In many ways, marginalization of the distressed population occurs as the eventual consequence of such perpetuation.

According to the strong local belief, the quality of groundwater sourced through handpumps (throughout the year) remains undisputed. There are various enabling factors that have contributed towards the concretization of this unquestionable belief with regard to handpumps as a safe source of drinking water in the region. Claims and perceived 'ancillary benefits' of the 'technology' gaining control over the minds of politicians, administrators, recipients and development organizations can be substantiated through the example of how shallow handpumps have been made a standard procedure for accessing drinking water during floods, despite the obvious that the source itself remains highly contaminated during floods, and surely, after it too. Just because people are able to access water through this 'technology' during floods, the system has endorsed it as the only antidote to the existing drinking water problem. The quality issue is conveniently ignored, both during the floods and during periods thereafter.

With floods being an annual feature in north Bihar, it is difficult to estimate the total cost incurred by the state and the aid agencies in popularizing a 'technology' that ultimately yields impure water. Interestingly, a new stage was been prepared for overcoming drinking water problems in Madhubani district, during 2007 floods. An aid agency had started distributing packaged drinking water (through tankers) to the affected population under its initiative of providing access to safe drinking water. This beginning later motivated other aid agencies and even the state government to adopt such a bizarre approach of distributing packaged drinking water in plastic pouches to the affected population. Is an approach of distributing such drinking water to people for days they remain marooned or displaced is really innovative? How frequently do people receive package drinking water or is it just a one-off intervention? How do people store this water, when the packaged water is supplied through tankers? Questions like these remain unanswered, yet such 'innovative' practices continue to steer and dominate the drinking water discourse.

Undoubtedly, recurrent floods have facilitated the deterioration of drinking water scenario in the flood plains of north Bihar. But the question that requires to be asked is whether the drinking water scenario remains abysmal only during those 3-4 months or does the drinking water problem surface in the non monsoon period as well? The single-minded approach of all the proponents (state, politicians, and social development agencies) of safe drinking water, continue to endorse handpump technology as the only safe source of drinking water, thereby establishing a strong positive impression amongst the local people about the quality of groundwater. Doubts being raised though over the quality of groundwater in certain pockets but without any tangible outcomes due to lack of supporting scientific data, claims of improved access through the hand-pump technology in North Bihar remain to be popular. As a result, the problem continues to exist without any adequate interventions.

The enduring support to the handpump technology as well as the incessant reports/feedback about the deteriorating groundwater quality (perceptible) prompted MPA to explore this existing contradictions in Supaul, Saharsa, Khagaria, Madhubani and

West Champaran districts.

Dug wells, usually a common property resource in most villages, are an excellent and clean source of drinking water as it is equipped with natural filters to remove impurities. Presently, there are three categories of dug wells in the flood plains of north Bihar, those that are:

- More than 30 years old with a depth of 50 -55 feet with damaged bricks structure
- Approximately 20-25 years old with super structure
- Constructed between 10-15 years

***Photo 3:* Revival of dug well in one of the project area**

Unfortunately, some of them have been transformed into waste bins, toilets pits and partly/fully covered with soil or reclaimed for construction of houses (built over them). The trend continues to date, despite proof of hand pumps being a main source of infirmity in rural Bihar.

The decision of reviving dug wells was taken after an internal review by the campaign, of the groundwater status across all the five districts. Before commencing work on dug wells, a package of practice for well revival was developed by the campaign *(Photo 3)*. While initiating the dug well work, the MPA team had to confront tremendous resistance from people as the *bait of handpumps in their backyards was preventing them from accepting the dug well as an effective alternative*. People were unwilling to make well revival a community enterprise as they had got used to a readymade product delivered to them. They were naturally not very open to contributing their services to cleaning the well, and in many cases, even deliberately under-reported the number of wells in their village. The MPA team members persisted. They used the same logic as before, explaining why community solidarity to rejuvenate wells is essential and how such a process could facilitate easy access of safe drinking water throughout the year, and minimize the risk of diseases. They underscored how wells could be turned into *a community resource* over which community rights and ownership could be re-established. In order to strengthen their argument, they used the water testing results, which at least forced people to rethink their alliance with handpumps. As a result, within a span of 4 months, 38 dug wells were cleaned and 18 repaired as a collaborative effort between MPA and villagers.

The internal review carried out by MPA of their dug well work yielded mixed findings. On the whole, the dug well work had created conducive atmosphere, which was instrumental in bringing people together to deliberate and develop a collective strategy to overcome their drinking water problem. Villagers got sensitized regarding the limitations of the present drinking water system and became conscious about the 'alternatives' that had the potential to yield safe and secure drinking water. Revival of dug wells facilitated intergenerational transfer of indigenous knowledge, which to a large extent was on the brink of extinction. The resurfacing of the knowledge further impacted on the general perception regarding dug wells. The perceptible change in the drinking water quality prompted some of the villages to consistently maintain the quality of the dug well water through frequent conservation measures. The campaign also experienced a few reversals. The grasping attitude owing to material gain had prompted some of the communities to undertake the revival work. As a result, after the initial euphoria subsided, communities went back to handpumps, despite their knowledge about the groundwater contamination. The reason stated by them was of convenience. Regular maintenance was considered as a daunting task in comparison to the handpump facility, therefore a mood of indifference crept in. Access to individual water sources inhibited people from substituting it with a common source. Associating with a common source was considered lowering of a status recently acquired through the handpump. Deep rooted caste dynamics was also seen as a deterrent.

Outcomes of the dug well initiative:

- Skepticism regarding the probable shift from a normal practice of accessing drinking water to an alternative source (considered as old fashioned) was partially removed.
- Dug well water started to get preference on the basis of certain local indicators for instance, facilitating digestion, odourless and pleasant taste, sparkling clean.
- Local practices of dug well management were being revived through this initiative and simultaneously new operative systems were introduced to ensure the quality of dug well water.
- The dug well revival created opportunity for the elderly to participate and contribute towards the initiative.
- Initiation of addressing internal community conflicts collectively.

In conclusion:

MPA's main aim in North Bihar is to initiate work by addressing a fundamental problem frequently confronted by people along with the possibility of being addressed locally. MPA's motivation is to construct a congenial social environment through sustainable technological innovations and adaptation of conventional wisdom in order to ensure a *shared, sustainable and effective management of water*. However, much beyond that, the wider mandate is to stimulate *collective action and accountability* towards a 'common good' amongst the local habitants for grassroots cooperation, by

- Developing community based practices for challenging the present trend of dependence on external sources and proposing an alternative approach of self-reliance.
- Instigating a behavioural change of rural communities with regards to common property resources and institutions, building self management as an attitude towards local problems.
- Building a *critical mass* of human resources for dealing with the local problems and in executing need based interventions while aiming at innovations.

Finally, the campaign's effort is towards perpetuating a notion of a life with 'dignity, determination and self-reliance'.

Empowering farming communities to collectively manage their Groundwater resources

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Abstract: Most attempts at groundwater management focus on the supply side, whereby efforts are focused on augmenting water availability through watershed development and recharge augmentation. APFAMGS focuses primarily on the demand side groundwater management. This paper describes the core concept of APFAMGS whose main focus is the sustainable management of groundwater through "demystifying science" and making it accessible to poorly literate groundwater user through participatory, non formal modes of learning. Five years of project implementation in seven drought prone districts of A.P, has successfully demonstrated complete awareness on the current groundwater crisis and future threats encouraged several thousand farmers to voluntarily reduce groundwater pumping and improve water use efficiency while at the same time increased wealth generation.

Introduction

The Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) Project is a Nationally Executed (NEX) Project of the Food and Agricultural Organization (FAO) of the United Nations implemented in the southern state of Andhra Pradesh, India. The project is being implemented by a federation of nine NGOs. Bharathi Integrated Rural Development Society (BIRDS) acts as the thematic and administrative leader of the coalition. The project covers about 650 villages in seven drought-prone districts of Andhra Pradesh (South India): Anantapur, Chittoor, Kadapa, Kurnool, Mahabubnagar, Nalgonda, and Prakasam. Location map of APFAMGS project area with respect to Andhra Pradesh and India is given in *Figure 1*.

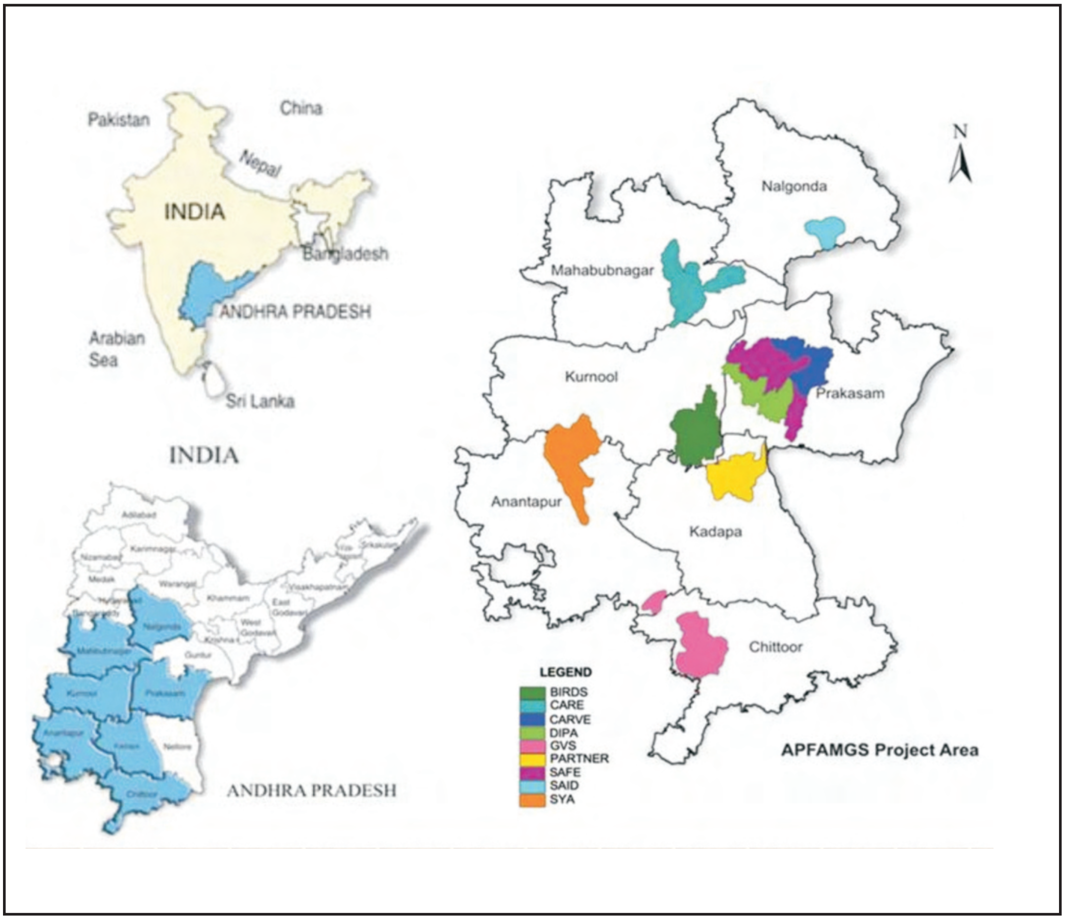

Figure 1: **Location map of APFAMGS project area with respect to Andhra Pradesh and India**

The APFAMGS approach

Most attempts at groundwater management focus on the supply side, whereby efforts are focused on augmenting water availability through watershed development and recharge augmentation. APFAMGS focuses primarily on the demand side, wherein farmers are encouraged to understand their groundwater system adequately so that they can make informed decisions about their water use. The core concept of APFAMGS is that sustainable management of groundwater is feasible only if users understand its occurrence, cycle and limited availability. In order to achieve this, the project has adopted a "demystifying science" approach – translating the scientific concepts from hydrogeology and groundwater management and making them accessible to poorly literate groundwater users. The education is participatory and emphasizes non-formal modes of learning. Unlike the standard practice where the targeted community is a mostly passive recipient of technical information on the status of their local resources, the APFAMGS approach engages the farmers in data collection and analysis, and through that, in understanding the dynamics and status of groundwater in the local aquifers. The project provides farmers with the equipment and skills to collect and analyze rainfall and groundwater data. APFAMGS farmers are measuring and keeping daily track of rainfall, water levels and well yields, understanding local rock formations and estimating groundwater recharge from the monsoons, and also estimating their annual water use based on planned cropping patterns. The project is essentially transforming farmers into "barefoot hydrogeologists".

An important aspect of the project is that it does not offer any incentives in the form of cash or subsidies to the farmers. In addition to demystifying the dynamics of groundwater, the project also facilitates access to information about water saving techniques, improved agricultural practices and ways to regulate and manage farmer's own demand for water. The assumption is that access to scientific data and knowledge will enable farmers to make appropriate choices and decisions regarding agricultural practices and the use of groundwater resources.

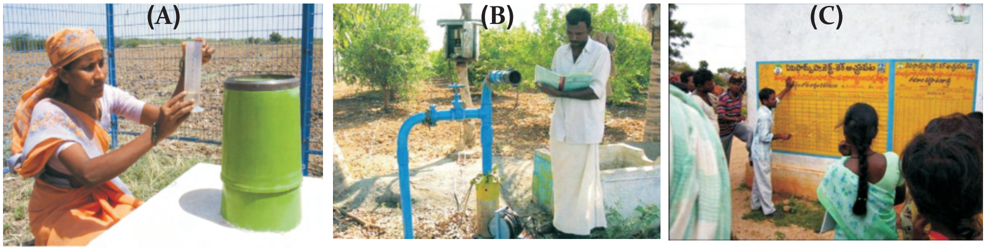

Photo 1: **(A) Data collection, (B) Data recording and (C) Data sharing is done by the community**

The APFAMGS process

The two principal processes employed by the project are Participatory Hydrological Monitoring (PHM) and Crop Water Budgeting (CWB). The project operates through community- based Institutions: Groundwater Management Committees (GMC) are village-level institutions of men and women farmers, comprising all groundwater users in the community. The GMCs of all the villages sitting atop an aquifer are federated into an aquifer-level institution called the Hydrological Unit (HU). It is through these institutions that the communities in the project areas are collecting and analyzing data, and managing and implementing decisions for sustainable groundwater management.

On a first look, the complex hydrogeology of hard rock aquifers and the barely literate levels of population engaged make Participatory Hydrological Monitoring seem too ambitious. However, keeping focus on education as the core objective of the project and employing creative non-formal modes of learning has made this not only possible, but also successful in achieving unprecedented outcomes on groundwater management. The implementation methodology of APFAMGS is shown in *Figure 2*.

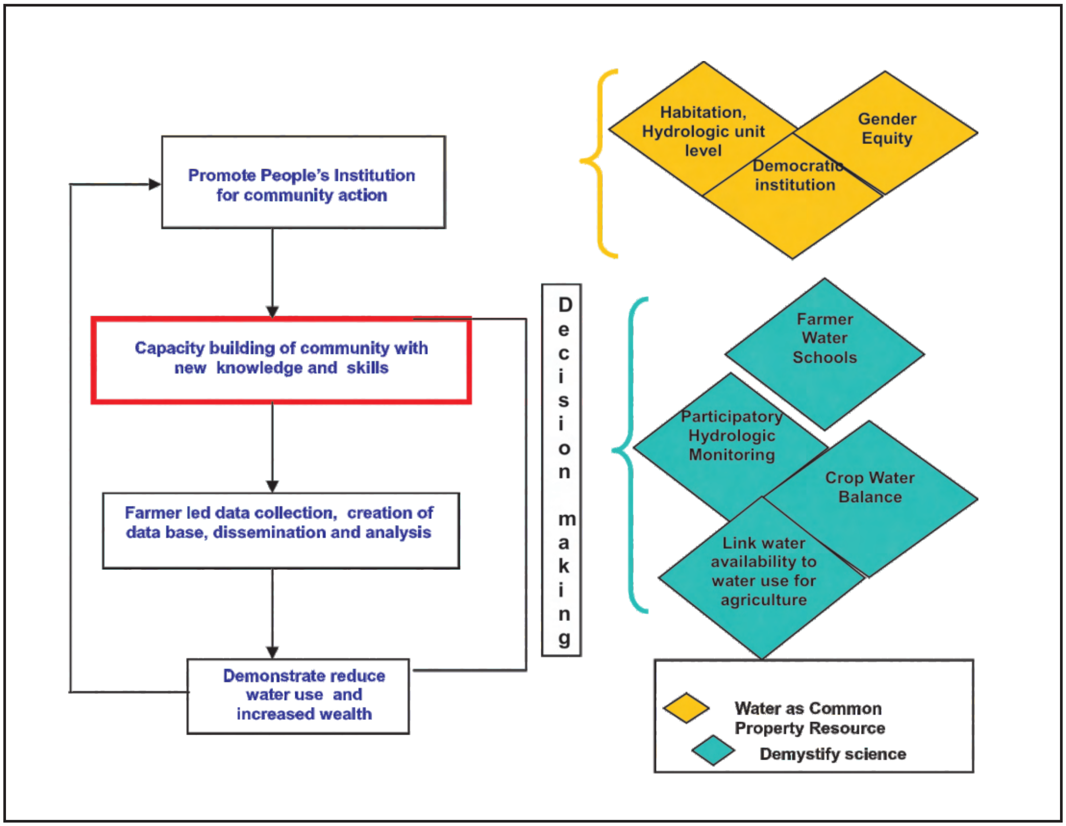

Figure 2: **Implementation methodology of APFAMGS**

Crop water budgeting

The complement to Participatory Hydrological Monitoring is Crop Water Budgeting (CWB), whereby the quantum of water required for the proposed Rabi (winter) planting is assessed at the aquifer level, and compared with the amount of groundwater actually available. The proposed water use is derived by aggregating the information collected from each farmer on his/her intended Rabi planting. The comparison of proposed water use with the available groundwater reserve gives the aquifer budget, which permits the groundwater users to see the net balance of water. CWB is a process bound in time, starting at the end of the summer monsoon and culminating before the Rabi planting in an aquifer-wide meeting when the budget is produced with thousands of farmers in attendance. Carrying out this process at the aquifer level is consistent with the physical scale of the challenge, and also becomes a vehicle for creating an "aquifer community". Well-trained facilitators manage the exercise, and the CWB budget result is reported back in all habitations. The groundwater budget, arrived at through broad-based collective action in the aquifer community and disseminated similarly through the community, crystallizes in one number the state of the aquifer and the gap between what is available and what is cumulatively desired.

The awareness of this number brings into the decision-making world of each individual farmer the knowledge on the status of aquifer reserves, something which has historically been a black-box for the farmers. Around the world, farmers have learned to look at the sky, soils and perhaps the possibility of profit in the local market before deciding what crops to plant, but for the first time now the farmer can take into account the availability of water in the shared aquifer, and plan his/her risk accordingly. It is important to note that unlike most other attempts at community groundwater management; APFAMGS does not seek an agreement from communities to reduce their water use. Farmers are free to make crop planting decisions and extract groundwater as desired, and there is no collective agreement by communities on self-regulation of groundwater use. The project therefore relies solely on the impact of groundwater education to influence individual decisions of thousands of farmers regarding which crops and how much of each crop is grown in the ost-monsoon season. The savings achieved in different crops through water saving practices is shown in *Figure 3*.

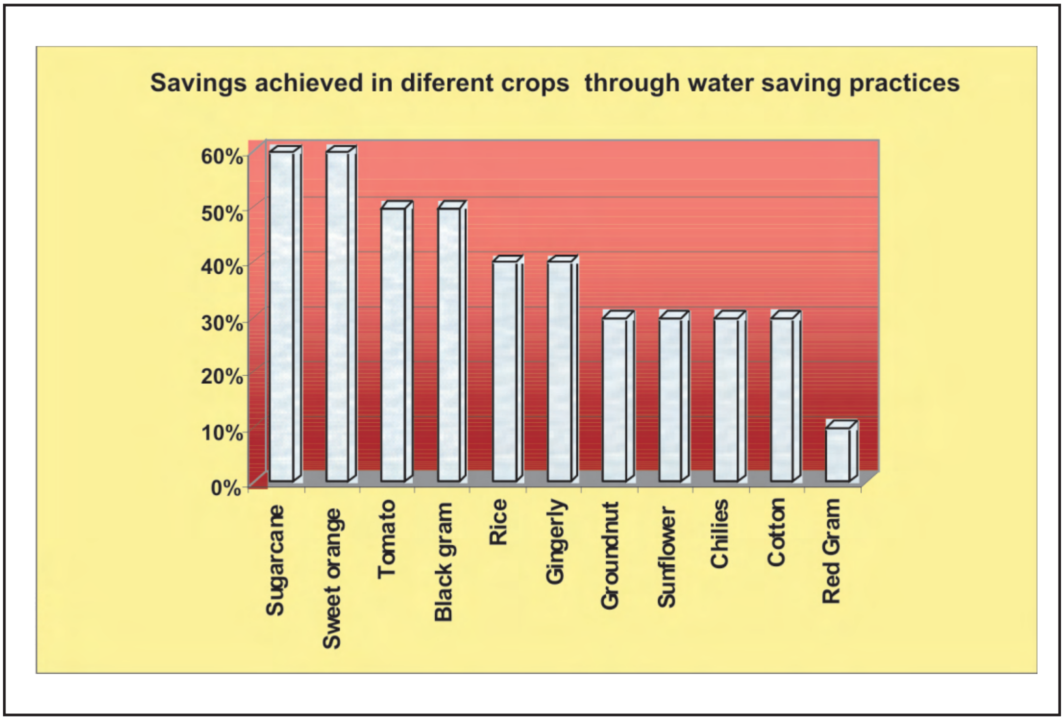

Figure 3: **Savings achieved in different crops through water saving practices in the project area**

Farmer water school

Sustainable change can happen only through empowering people to collectively manage their existing resources. For this, the APFAMGS Project engages all water users in a given Hydrological Unit in judicious use of groundwater.

The main vehicle for education and capacity building in APFAMGS is the Farmer Water School. It comprises of around 25-30 farmers meeting once every 15 days, and the learning is grounded in the farmers' own fields. Following the hydrological cycle centered around the monsoons, the FWS runs from June to May. In addition to education on groundwater (PHM and CWB), the curriculum includes exposure to techniques and interventions that can enable farmers to get higher returns from agriculture, by switching crops, improving yields and reducing input costs. The farmers accordingly learn about vermi-composting, green manuring, bio-fertilizers, mulching, intercropping, improved irrigation methods, and SRI paddy (which can double the yields with only half as much water). FWS employs multiple learning cycles, and trained farmers learn further by becoming farmer facilitators and instructors for the FWS in their respective habitations. FWS has made organizers, planners and advocates out of farmers.

Groundwater availability is a critical factor in determining crop-yield in semi-arid areas. Farmers need to observe and analyze groundwater availability and discuss the situation with other farmers and make collective decisions. Over the past few years, the APFAMGS Project explored the possibility of adaptation of Farmer Field School (FFS) methodology to groundwater management to enable farmers a 'hands on learning' experience on various factors influencing groundwater availability and make rational decisions on crop-water management. Furthermore, it was felt that the adaptation of FFS approach would help sensitize all the farmers in a Hydrological Unit that the water resources in their basin are a common resource, and that there was a need for collective management of the resource for sustainability.

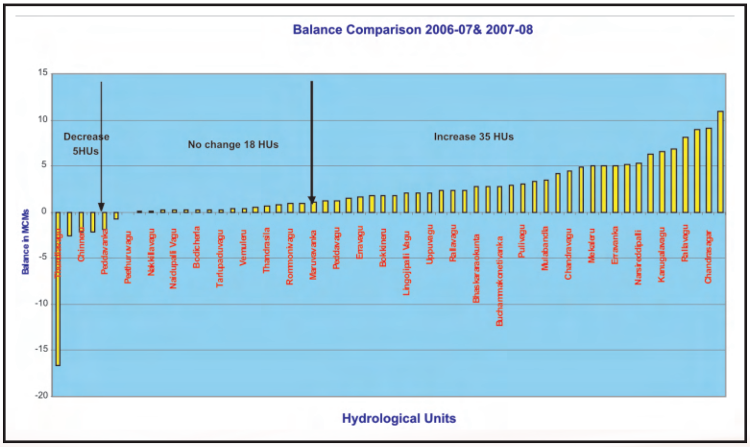

Figure 4: **Improved groundwater balance favorably altered in 53 Hydrological units altered by the demand side groundwater management**

To reach large number of farmers and tap the existing knowledge and skills of the farmers, the project came up with the idea of multiple cycles of implementation. In this process, the project staff facilitate a FWS at the hydrological unit (sub-basin consisting of number of habitations) level. After having participated in the session, the farmer participants form pairs to facilitate a FWS in their respective habitations with other farmer participants. The NGO staff participate in the habitation level FWS to observe and provide need-based assistance. The farmer institutions - the Groundwater Management Committees (GMCs) and Hydrological Unit Networks (HUNs) – are actively involved in the whole process. A comparison was made for two years, 2006-2007 and 2007-2008 which indicated that the groundwater balance has positively altered in 53 hydrogeological units altered by demand side groundwater management (*Figure 4*).

Database-HRIS

Habitation Resource Information System (HRIS) is the database developed by the project to act as a storehouse of information of all data generated in the project both at the habitation level and consolidated at the hydrological unit level. The data is organized at individual farmer level.

HRIS can capture all varieties of data including static information pertaining to habitation, land use, soil, geology as well as dynamic information related to meteorology, hydrology, agriculture, and cropping in an organized and efficient manner. To provide maximum value to the user, the software is GIS enabled; however, it can work without maps also in case they are not available.

Geographic Information System

Demystification of GIS applications have been taken up by the project. The aim is to customize GIS applications for use by rural communities. The focus is on the design and implementation of a farmer friendly GIS for accessing information about individual and shared resources without external facilitators. With new insight on their resources both in space and time it is expected that farmers will be enabled to take tough decisions with regard to natural resources and particularly in crop planning matching the water resource availability. GIS also will help avoid resource-related conflicts as they build consensus on their availability.

Information kiosk

Information Kiosk is a user friendly interface for accessing the HRIS data base by the farmers. A kiosk translates complicated set of data stored in the database in a way that the farmer can understand and appreciate. The Information Kiosk presents the data from the HRIS data base using predefined queries that is of concern to the farmer. The answer to the queries is presented in the form of analytical /graphical tools, GIS multi-thematic overlays, report etc. Issues of concern related to water use and its efficiency, cropping plan matching the resource potential, crop production, pumping efficiency, yields, markets, prices etc are computed and presented in a friendly graphical fashion.

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Rainwater Harvesting and Groundwater recharge in Urban centres :

Experiences from the field.

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Abstract: Bangalore is significantly dependent on groundwater and is increasingly facing water availability and quality issues. In this paper, some case studies have been described with an urban groundwater focus, encompassing community action on demand management, groundwater recharge, shallow aquifer use and groundwater contamination. This paper also attempts to summarize key learnings /observations in three dimensions – (a) from the perspective of people's participation, their motivation for action and its relation to the scale of intervention, (b) the key elements of the process by which the organisations like Biome are engaged with the people to aid and catalyse action and (c) issues of knowledge and capacity in this engagement, and the opportunity it presents for the creation of new knowledge of urban groundwater and its relation to the city's growth processes.

Introduction: Context

Bangalore has seen phenomenal growth rates in recent decades – both geographically and demographically. This has resulted in a large supply-demand deficit vis-à-vis water. It is estimated that around 40% of Bangalore's water needs are catered to by groundwater. Further, Bangalore's water utility has not been keeping pace with the growth of the city and large parts of Bangalore beyond what was earlier called the municipal area (under BMP) are not supplied piped water. The demographic growth has resulted in a booming real estate sector. Residential complexes such as gated layouts, apartment complexes are emerging as a result for demand on housing. Commercial and institutional real estate development has also seen a spurt.

These new developments are sustained by the local groundwater resources to meet their water demand. It is common place to find large layouts or commercial complexes completely run on two or three high yielding borewells. The importance of groundwater in the urban context is further evidenced by the thriving water and water related markets that are ubiquitous – tanker and bottled water supplies (whose source is groundwater), borewell rigs and household treatment systems dealing with quality issues primarily found in groundwater (eg: High TDS) are some examples. This has also created a stress on groundwater resources of Bangalore – it is common to find complexes with borewells whose yields are progressively declining and borewells which have completely stopped yielding. Many complexes have sunk investments in borewells which have failed to tap into an aquifer at the time of drilling.

In this overall context, the citizenry are becoming increasingly aware of the issues of sustainability of water resources. There is growing media and political attention to the issue. And with a history of some organizations' and individuals' sustained advocacy and campaigning on ecological water practices, the city is slowly but surely taking practices such as Rainwater harvesting seriously.

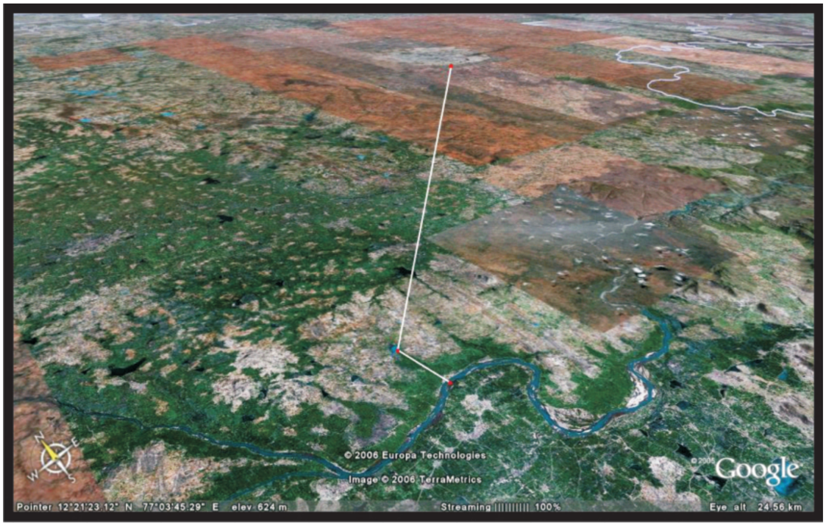

Figure 1 : **Google image of Kaveri basin and location of Banglore city**

Biome Environmental Solutions Pvt Ltd (Biome) has been engaging with the citizenry of Bangalore to drive the uptake of such practices. Among other activities, Biome engages with them in a process that delivers knowledge, education and implementation services (for practices such as rainwater harvesting and passive waste water treatment) for which they pay – that is a process wrapped into a business model. These citizens largely belong to the middle and high income socio-economic segments with property ownership. They have the wherewithal to adopt the relatively expensive coping strategies of water sourcing and treatment in the absence of the utility's services in their property.

Over the last few years, Biome has delivered hundreds of rainwater harvesting projects (the focus of this paper). During this period, there have been some generic learnings that this paper attempts to synthesize. However this is preceded by three case studies that provide a flavour of the individual projects.

Case studies : Working in the group housing context

Case Study 1 : Jyoti Meadows Apartments, Jeevanbhima Nagar, Bangalore

The Jyoti Meadows Apartments undertook Rainwater harvesting as the BWSSB placed it as a condition to increase the water connection size for the apartment. It is an apartment with around 45 households and has a gross demand of around 33 KL per day. The sources of water were multiple – piped water from the utility, tankers and local groundwater pumped from an owned borewell. The Apartment with around a 700 sq mt rooftop invested in rainwater plumbing modifications, an exclusive rainwater tank of size 11,000 litres and a recharge well of 3 feet diameter and around 15 feet depth. The plan for rainwater harvesting for Jyoti Meadows apartments is given in *Figure 2*. The recharge well *yielded water* (yield of about 500 litres per pumping in dry season and 1000 litres per pumping in the monsoon season with recuperation time in the range of 2 to 4 days). Rainwater and Shallow aquifer water are now a regular source of water.

(A) (B)

Photo 1: (A) **11,000 litre rainwater tank – Catchment roof area of 700 sqm – overflow to well; (B) Recharge/Open Well – 3ft dia, 15 ft depth – Well yielded at around 10ft.**

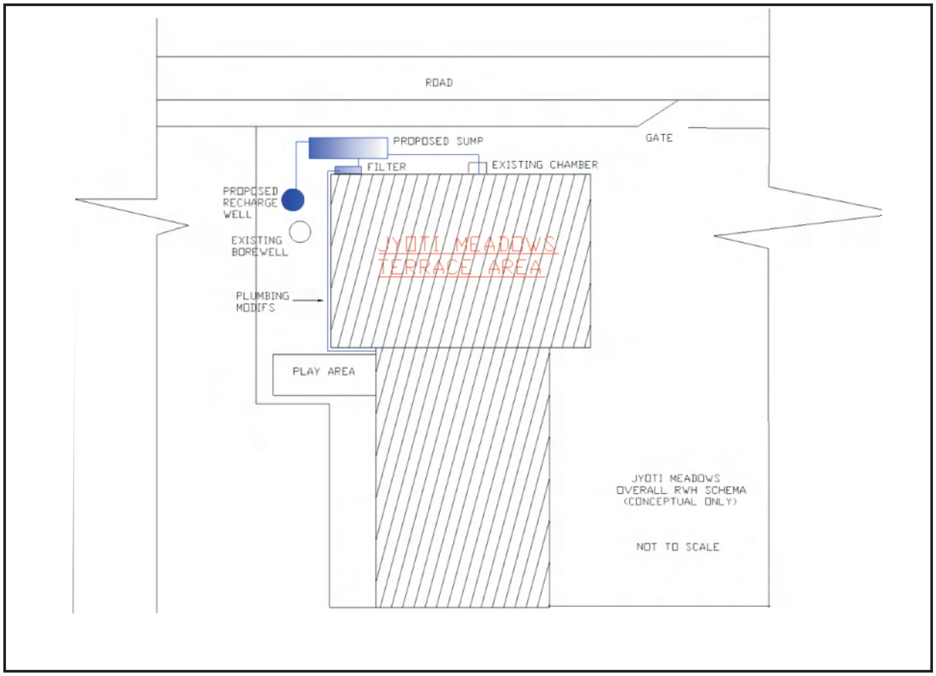

Figure 2: **Plan for rainwater harvesting for Jyoti Meadows**

Case study 2 : Tata Sherwood, Basava Nagar, Bangalore

Tata Sherwood is a multi-block apartment complex of around 375 households with a daily demand of around 200 KL/day. The complex is completely dependent on groundwater from 6 borewells. There exists a seventh borewell which is not being used. The water from the borewell is passed through a softening plant and then pumped to the overhead tanks for consumption. The complex has a large roof area of 11000 sq mts. Rainwater run-off from these rooftops were led into 7 storm water sumps. 3 out of these 7 sumps had sources of water other than stormwater (Such as car wash). All the water from these sumps was pumped out of the complex into municipal storm water drains.The plan for rainwater harvesting for Tata Sherwood complex is given in *Figure 3*. The community invested in direct aquifer recharge of the unused borewell in the complex. Only the stormwater sumps receiving pure rooftop rainwater (of total size 2 lakh litres) was redirected into a 7 feet diameter, 22 feet deep recharge well built around the borewell. Further the casing of the borewell was perforated and the recharge well was filled with aggregate upto 8 ft from the bottom. Recharge tests conducted on the site showed a recharge rate of upto 20,000 litres per hour. An ongoing monitoring of the site is necessary to determine if hardness levels of the water and the yields of other borewells to determine the impact of this rainwater harvesting scheme.

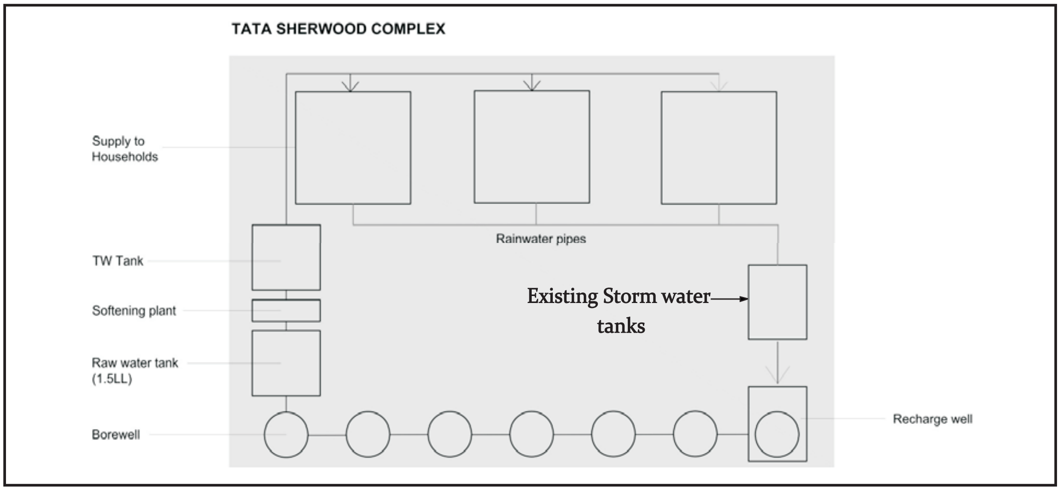

Figure 3: **Plan for rain water harvesting for Tata Sherwood Complex**

Case study 3 : Rainbow Drive Layout, Sarjapur Road, Bangalore

The Rainbow drive layout is a gated community with individual plots for households. It is a 34 acre layout with a total of 360 plots in the layout. The layout is completely dependent on 2 borewells with high yields and 1 borewell with a low yield. The layout originally had 6 borewells 3 of which have stopped yielding. The layout also has two overhead water towers from which a piped water distribution system is driven. The developer of the layout had, fortunately, metered every household. The Plot owners association (POA) was formed and took over the management of the property in 2004. By 2006 the POA discovered that water is among its foremost concern with borewells drying up and neighbouring complexes increasingly depending on tankers for water. The POA first banned the drilling of private borewells and then undertook a series of water management reforms.It launched a campaign to make all the residents aware of the water problems and then began a drive for groundwater recharge through rainwater harvesting.It also encouraged individual households to undertake rainwater harvesting at the household level.The result was the implementation of 55 recharge wells in the 34 acre area. *(Figure 4)* Around 20 of these wells were invested in as a collective and the rest through individual investments. Parallely, the POA restructured the tariff regime as a demand management measure. It managed to move from a flat rate of Rs 6 / KL to an increasing block tariff regime represented in the table.

Consumption slab	Tariff
Slab 1 (0-10KL)	Rs. 10
Slab 2 (10-20KL)	Rs. 15
Slab 3 (20-30KL)	Rs. 25
Slab 4 (30-40KL)	Rs. 40
Slab 5 (>40 KL)	Rs. 60

Figure 4: **Plan for rain water harvesting for Rainbow Drive complex**

This was arrived at on the basis of an analysis of consumption data and the production costs of water which was calculated to be in the range of Rs 15 to Rs 16 / Kilo litre inclusive of sewage treatment costs. With the support of the Arghyam Foundation Biome is currently monitoring the impact of these reforms and trying to identify and catalyse further reform possibilities such as waste water reuse. This particular case study also received significant media attention. Some examples of this are presented in the Appendix.

Learnings from the ground

This section summarises Biome's key observations and learnings in three dimensions –

(a) From the perspective of people's participation, their motivation for action and its relation to the scale of intervention

(b) The key elements of the process which are important for engagement with the people to aid and catalyse action and

(c) Issues of knowledge and capacity in this engagement, and the opportunity it presents for the creation of new knowledge of urban groundwater and its relation to the city's growth processes.

People's participation

Motivation: By far the most important factor to be acknowledged is the motivation that drives people into action. There is no doubt that it is a water stressed situation that is a key driver. Most residential complexes that begin action have a history of dried or drying borewells and/or dependence on water-tankers. There is a general sense of water insecurity that underpins such action. However, it is important to acknowledge that this is not the only driver. There is often genuine ecological concern and a romance for ecological practices. Biome has consistently attempted to showcase positive action in the media and given publicity to such action. This creates its own momentum and drive. In short, action is driven by a mixture of shorter term self-interest and an understanding, that in the longer term, water is a common property resource whose stewardship cannot always be subject to questions of return-on-investment. Reiteration that (1) building bye-laws mandate rainwater harvesting for new households and (2) that the BWSSB is now placing rainwater harvesting as a pre-condition for new water connections, adds strength to arguments for such community action. In the context of businesses and institutions, environmental audits of these institutions (especially given that climate-change debates are driving some of these initiatives) have an important role to catalyze action.

Champions / Anchors within a community: Every community has its anchor who is championing the cause of water in general and rainwater harvesting in particular. This champion plays a very critical role in ensuring community action. This anchor may or may not be a part of the management committee of the RWA.

Scale of intervention: The most important spontaneous but organized collective in the city is the "Resident Welfare Association" (RWA). These collectives form around property boundaries. Some of them may be formally registered and some of them may not be. However given that property ownership is the binding glue of such a collective, there is institutional sustainability. Further, the catchments for rainwater harvesting tend to be under the RWA's control (especially in the context of gated complexes) and therefore associated other measures such as solid waste management and drain management become easy to implement. Thus, the RWA is found to be the most appropriate scale of intervention. Of course the size of the land area varies depending on the size of the project. And in many cases, such as gated layouts consisting of individual plots, the intervention is really at two scales – at the RWA level and the level of the individual household.

Rainwater harvesting in popular imagination: The most popular understanding of rainwater harvesting is "recharge of borewells". Often there are questions of whether the harvesting structures will benefit "our borewell" or "someone else's borewell". It is in this context that it becomes important to educate on the common property nature of groundwater, on hydrogeology and the hydrological cycle. And despite answers to such questions not always being favourable to the specific community, many of the communities choose to continue with the action.

Process of engagement: key elements

A process of direct-dialogue and education: The most important element of the process is that of direct dialogue with the community. While the champion is the entry point, this invariably leads to a process of dialogue with the larger segment of the community (if not the entire community). The dialogue is a process of education on what rainwater harvesting is. And more critically, what it means in the specific context of the community, its land-use, demand, discharge, rainfall endowment, sources of water and its overall water management framework. The process often is driven by the champion with the help of Biome and has to respond to the questions, concerns and attitudes of the specific community.

While Biome is approached as a service provider, the process of engagement is equally a process of education. Not only is the dialogue centered around rainwater harvesting, but it is invariably a dialogue on the many dimensions of water. The larger picture of water in the city, water quality and treatment, waste water and waste water re-use, hydro-geology, water pricing policy, demand and demand management – all these are issues that covered during the process of dialogue. And this process of education is important to catalyze action.

Citizen-to-Citizen interaction: Biome also finds one community / citizen sharing their experience of having done rainwater harvesting with another catalyses action. Here again the role of champions and their willingness to put the effort of sharing these stories plays a critical role. Biome has, as already stated, used the media to bring stories of community action into the public. In an attempt to further this cause, it has established and is moderating a Bangalore e-group called "Voices for Water" which provides a virtual platform for such experience sharing.

A process that integrates services: If intent has to translate into action, the process of engagement with the citizenry has to deliver services that can enable implementation of such schemes. These services include design (and other knowledge) services and implementation & project management services. A "turn-key" service that addresses all details including civil and structural engineering issues is most demand responsive. Being cost sensitive and quality of the service delivery are extremely critical. Biome is increasingly discovering that post installation services (for maintenance and repairs) will play an important role in the longer run. The role of these services and their cost sensitivity cannot be over emphasized and is the single most important element that ensures intent is translated to action.

Knowledge and capacity

Integration of different knowledge streams: The key challenge in ensuring the success of the above process is the integration of different knowledge streams into it. Knowledge of civil engineering & architectural issues, water, storm water, waste water, water quality, treatment & management, geology & hydrogeology, plumbing, valving & pumping are all relevant for the process. And knowledge both from the perspective of pure science and in terms of commercial & project management are necessary to be brought to bear. This poses a challenge of human capital – across the various steps of engagement – from dialogue to implementation/post implementation engagement. Training of personnel with good communication skills is necessary for the dialogue process. An equal emphasis must be laid on the capacity building of the implementation teams and the "blue collar sector" – from contractors to plumbers, masons and their helpers.

The Best is the enemy of the Good: When all this knowledge is brought to bear on a specific project, the end result is often not the optimal or "best" solution. The key criteria that drives the final solution implementation is not just scientific or engineering knowledge. Financial, social, and cultural criteria are often more critical in the final solution that gets designed. The implementation approach more often than not, is incremental and phased. The key is to galvanize the community into initiating action. The role of more scientific rigor is to inform the aforementioned process of engagement rather than achieve perfection in specific projects.

The Opportunity for new knowledge: With each new project in the city, access to precious data is enabled and a new story of community or individual action unfolds. There is an enormous amount of information that this process of engagement generates. This for example, is with regards (1) water demand & demand patterns (2) waste water discharge (3) water levels and their seasonal variation in wells and borewells (4) yields of borewells and wells (5) groundwater and waste water quality (6) coping strategies of people (7) the different components of the production cost of water. Given the nature of the relationship, access to these sites over time, is available. Each project is also a story in itself of how a community came together and resolved internal differences. All these represent opportunities to understand urban water in all its dimensions – demand, groundwater, people and economics.

Appendix: Media links for the Rainbow Drive case study

1. Published in Citizen Matters – an online news platform that also facilitates citizen journalism (http://bangalore.citizenmatters.in/)
   Water supply from the bottom up
   RWH in a layout: getting started
   RWH in a layout: engaging the people
   RWH in a layout: What, how, why and how much
   RWH in a layout: Residents are water managers

2. Published in the Times of India, 20th October, 2008, Bangalore Edition.
   Drops of Hope

3. Published in the Livemint (The Wall Street Journal), 14th November, 2008,
   Water Water

4. Published in The Hindu (Supplement : Property Plus), 29th November, 2008, Bangalore Edition.
   Managing water in a Layout

5. Published in Time Out Bengaluru, 22nd January, 2009,
   Water idea, Sirji

6. Published in Bangalore Mirror, 16th February, 2009,
   Water at the end of the Rainbow

7. Published in Mid-Day.com, 12th September, 2009,
   Saved by the well

The importance of groundwater in urban India

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www.biome-solutions.com, www.rainwaterclub.org, www.arghyam.org,
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Abstract: Historically groundwater has been one important source of clean water for meeting urban water requirements. Since urban areas are by construct dense, groundwater here is subject to the twin threats of depletion and quality impairment. Understanding the role of groundwater in urban areas and factoring in its appropriate management is crucial to providing and meeting the overall human, social, ecological and economic requirements of water for our cities.

Urban ground water: some perspectives

Consider this view of the increasing water footprints of our cities and its implication for the region ...

'Urban Water Sector is a zone of serious mismanagement. Typically, the large urban areas represent concentrated demands, both due to large populations and large per capita use and waste. Most urban areas have depleted, polluted or destroyed their local sources of water like rivers, lakes and tanks and in many cases even groundwater. The rainfall is generally seen as a bane rather than boon as it brings floods because the drainage systems are seriously ill designed or mismanaged. Lack of provision of adequate minimum water for vast proportions of poorer segments on the one hand and wasteful use without paying even cost prices by more prosperous segments on the other hand is typical picture of most urban areas. Thus having exhausted, mismanaged and polluted the local sources and after continuing to neglect the local water potential, the urban areas increasingly look to existing large dams or new proposals of large dams to satisfy its water demands. Though water supply forms a minor component of the 3303 large dams constructed in India since Independence, in recent years it assumes significance.' (http://www.sandrp.in/watersupply/urbnwtr_assess_wcd.pdf).

It is clear that mismanagement of urban groundwater can have regional consequences such as the development of new surface water sources with its environmental and social consequences or the appropriation of surface water sources originally meant for agricultural purpose.

Groundwater dependency: India's overall dependence for its water requirements on groundwater as the source is around 60 %.
(Tushaar Shah - http://www.slideshare.net/indiawaterportal/gowing-role-of-groundwater-in-indian-irrigation-in-transition)

From being a hydrological society India is becoming a hydro-geological society. The clear role of groundwater in urban areas is a matter of 'guesstimation' rather than estimation since there is no specific institution keeping track of specific data. Most city level water supply institutions such as for example the Bangalore Water Supply and Sewerage Board (BWSSB) has not a single hydro-geologist on board. There is no hydro-geological cell in any of the 220 odd towns in Karnataka neither in the Karnataka Urban Water Supply and Drainage Board (KUWSDB), the para-statal institution mandated to design and implement water supply projects for these towns of Karnataka. 46 towns are fully dependant on groundwater in Karnataka and many other are partially dependant on groundwater. However even the imagery created on the website of the KUWSDB does not recognize groundwater as a sustainable source and as a matter of policy seeks to develop surface water sources eliminating ground water based sources.
(http://www.kuwsdb.org/how%20water%20works.pdf)

Entry point for groundwater understanding and management: Rainwater harvesting, groundwater recharge and conjunctive management of rain, surface and ground water should be the new mantra of water management.*(Tushaar Shah .ibid)*

Rainwater harvesting, understood as storage or artificial recharge of rainwater, has become a popular feature of water management with the National Water Policy and almost all State Water Policies including it as a prominent water augmentation measure to be considered even for urban water supply. Chennai was one of the first cities to make it mandatory. Many more such as Bangalore, Indore, Mumbai and Delhi have followed in varying degrees.

A National Institute for Urban Affairs study recommends ' Getting surface water sources from distant sources is proving to be very expensive. Ground water depletion can be controlled by undertaking rainwater harvesting in all urban centres. Specific programmes/schemes should be initiated for aquifer re-charge.
(http://www.niua.org/water/Executive_Summary_Water_English.pdf)

Without a proper understanding of lithology and hydro-geology with such basic features such as recharge zones and discharge zones, storativity, hydraulic conductivity etc rainwater harvesting cannot be optimally used to draw maximum benefits. However since rainwater harvesting is becoming mandated in many cities it provides an opportunity for the institution responsible for its implementation to develop a set of measures to understand groundwater and hence provide tools for optimization of artifical recharge in the particular context of the city.

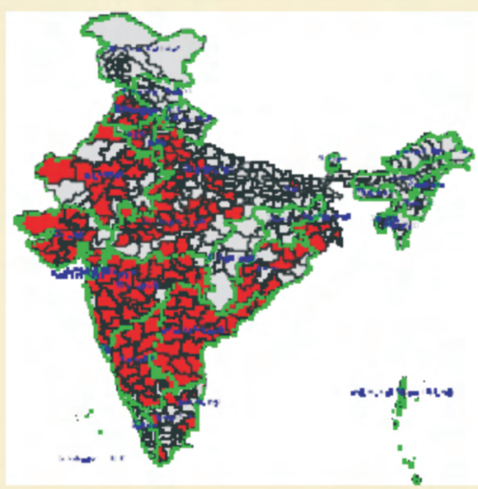
Service levels of water supply is constantly falling. Hours of supply are on the decline and intermittent supply is the norm rather than the exception.

If between 50% to 65% of ALL waters consumed in India annually comes from groundwater and over 80% of rural drinking water comes from groundwater, the importance of this source and the necessity to understand and manage it better cannot but be re-emphasized.

Further, since nearly 2/3rds of India sits on a complex hydro-geological terrain, it is important that groundwater be understood and this understanding translated to a simpler message for the many bore-well diggers and users to understand in a simple manner "How to manage it properly". Ground water depletion all across India is increasing, primarily due to agricultural abstraction. But in cities, groundwater depletion is predominantly in the periphery and due to a combination of domestic and commercial/industrial abstraction.

Water Policy outlook: The National Water Policy and all State Water Policies place domestic/drinking water on the top of the priority list for water uses. None of the water policies specifically mention groundwater in urban areas though overall they talk about groundwater recharge as for example the Orissa State Water Policy.

GROUNDWATER DEPLETION



The blocks shown in red are areas where, due to extraction of groundwater, especially for irrigation, the groundwater levels have fallen by more than 4 metres (@ > 20 cm/year) during 1981-2000.

Source: CGWB

Artificial recharge of ground water, including roof top rainwater harvesting, would be encouraged to replenish the utilizable ground water resources and improve its quality. The ground water recharge would be a conscious policy of all stake-holders . It would be the focus of the State Watershed Mission's activities.

Rainwater harvesting is being legislated in many urban areas- Chennai, Mumbai, Bangalore and Hyderabad are examples- and provides a means for groundwater recharge, if done scientifically and correctly. The romance of rainwater harvesting seems to provide a positive force for recharging groundwater and a better understanding of recharge and aquifers. Getting surface water from distant sources is proving to be very expensive. Groundwater depletion can be controlled by undertaking rainwater harvesting in all urban centres. Specific programmes/ schemes should be initiated for aquifer re-charge. *(Planning Commission)*

Urbanization in India : India is at a low level of urbanization at about 28 % based on the 2001 census. However the number of towns or urban areas has grown to 5161 with 285.30 million people living in urban India. (Census of India -2001) Urbanization, though slow, is projected to reach 41% of India's population in urban centres by 2021 . Around 38% of these, as a proportion of the total urban population, are already in metro cities in 2001. Point source of demand for water would be very high especially in the metro cities.

INCREASING URBANISATION

	1951	1991	2001	2021 (projected)
No. of Urban Agglomerations/ Towns	2795	3768	4378	—
Urban Population (In million)	62.0	217.0	285.00	550
As Percentage of Total Population	17.3%	25.72%	27.8%	41%

Source: CPHEEO

TABLE 2
GROWTH OF METRO CITIES

	1981	1991	2001
No. of Metro Cities (Population: 1 million +)	12	23	35
Population (million)	42	70	108
% of Urban Population	26	32	37.8

Source: CPHEEO

Most large cities depend upon surface sources for water supply, supplementing it with ground water sources to meet the demand. However, the share of ground water increases with a decrease in city size, with smaller size class of urban centres showing greater dependence on ground water for water supply. The large investments required to supply water from surface sources, could be one reason for this pattern. This also reflects in the existence of water treatment plants. While all metro cities using surface source have water treatment plants, there is a small percentage of urban centres in other size classes that use surface water but do not have water treatment plants – NIUA study

URBAN WATSAN DEVOLUTION

Following the 74th Constitutional Amendment, states may give the responsibility and powers for UWSS to ULBs. This has resulted in a multiplicity of institutional arrangements, varying from state to state. Such institutions may be state level specialist agencies with various jurisdictions varying from entire states (Kerala for example), small cities, or large cities. Others include metropolitan level specialist agencies such as in Bangalore, Chennai and Hyderabad, specialist municipal undertakings (such as in New Delhi), public health engineering departments with various jurisdictions (entire state in Rajasthan, small cities in Andhra Pradesh), and municipal departments. In many cases, responsibilities for capital works and O & M are split between two agencies.

Source: Planning Commission

Institutions

There is virtually no institutional management of groundwater in urban India. Take the case of Bangalore, there is no law preventing the sinking of a bore well by any resident in the city for any purpose.

In the absence of water supply being provided for building construction purpose by the utility, the Bangalore Water Supply and Sewerage Board, almost all new buildings sink a bore well for construction water needs. Later this bore -well gets to be used for domestic/commercial purpose. Unless there is a capability and skill set developed in the institution, ground water will continue to be un-managed.

Social issues

Since a large majority of the poor are not likely to be connected to piped water supply there propensity of dependence on groundwater is higher. In Bangalore no more than 40 slums of the 600 or more are connected to the piped water supply of the BWSSB. The vast majority depend on hand-pumps and motorized bore wells attached to cisterns, which are community access points to water Depletion of the groundwater table or impairment of quality through say nitrate contamination impacts on the poor first.

Rainwater harvesting has now become mandatory in the city of which a component is the making of recharge wells. Digging a recharge well of diameter 1 meter and depth of 6 meters is the norm. This calls for a labour deployment of between 8 to 12 man days. It is estimated that Bangalore city alone will build 1 million recharge wells. On an average 10 million man days of employment is expected to be created in this sector alone.

Ground water quality and pollution

The unique nature of urban groundwater is its high propensity for point and non-point sources of pollution. The decline of urban surface water bodies has impacted urban ground-waters negatively. The 'paving up' and hard surfacing or urban crusting too has impacted groundwater recharge negatively. Contrariwise leaking water lines and leaking sewage lines may contribute to increasing groundwater levels in cities.

At a general water pollution level, ' Even with strong legislative provisions such as the Water (Prevention and Control of Pollution) Act and the Environment Protection Act since 1974 and 1986 respectively, 851 defaulting industries were located along the rivers and lakes in 1997. The Water Cess Act, 1977 has also failed to act as a market based instrument in reducing the quantity of polluted discharge.' Planning Commission

While industrial pollution is a cause for concern, urban groundwater quality has negatively impacted the most by sewage mismanagement. A study in Cuttack, Orissa, suggests heavy Nitrate and Sodium Pollution near storm and waste water drains especially during low flow regimes. (*Urban Ground Water Pollution: A Case Study in Cuttack City, India Jyotirmaya Das, Rama Krishna Sahoo, B.K. Sinha*)

A study conducted in 2003 by the Karnataka State Mines and Geology Department on the 'Water Quality of Bangalore Urban Area and its Environs' found that 58 per cent of the city's groundwater is not potable and contaminated with Nitrates, Iron and Hardness. The study reveals that Nitrate contamination is rampant across the city's bore wells.

Towards understanding and management

As a matrix is developed for the management of urban groundwater some lessons learnt from Bangalore may be of assistance. Bangalore Water Supply and Sewerage Board – BWSSB- charges Rs 50/- per house per month on each bore well as a 'sanitary cess' providing a first official chance for understanding the number of bore wells in a metropolis. Since its meter readers visit the residences and buildings every month, it is possible for the meter reader to identify the presence of a bore well which is in use. As money is collected every month along with the water bill, the BWSSB has zone-wise records of bore-wells in all residences wherever it has provided a water connection.

It should thus be possible for the BWSSB, to insist on a meter being put on all bore-wells and a reading taken every month of the volume of water drawn. A volumetric tariff could then be arrived at for groundwater which could still be charged as sanitary cess. The total volume of groundwater drawn monthly would then be available. This will help put in place sustainability measures through appropriate recharge structures and through moderation or control of over withdrawal.

A systematic mapping and quality monitoring is urgently required. Creation of a legal and institutional framework is also a matter of urgency. The entire BWSSB does not have a single hydro-geologist in a city where anywhere between 100 million to 800 million litres per day may be coming from groundwater sources. Preventing pollution of groundwater, managing and recharging it and ensuring safe withdrawal is the challenge for a sustainable water management of cities.

Conclusions

Groundwater in urban areas need systematic management and integration with the overall piped water supply. Groundwater needs to be protected from anthropogenic sources of contamination through better management of point and non-point sources of pollution. Expanding the scope of our water supply institutions to include groundwater is necessary. Human resources and skill up-gradation in the hydro-geological sciences is also called for.

A legal framework which vests with the local water management institution would need to be put in place to manage this community resource. The legal framework can be independently drafted for urban areas with appropriate administrative and management authority to the water supply and sewerage management institutions. Technical management through hydro-geological studies as well as metering groundwater extraction needs to be in place.

A financial regime of rewarding good behaviour, such as good recharge practice or sustainable withdrawal as well as punitive measures such as unsustainable withdrawal and pollution needs to be in place.

Groundwater especially when drawn through hand-pumps is the cheapest and most easily available water for the urban poor. Its social equity role should be recognized and fostered so that access to water especially to the poor is ensured. The ecological sustainability of urban groundwater through artificial recharge, moderated withdrawal and pollution prevention is vital to its long term availability and must be encouraged