

**Working
Paper**

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**ADAPTIVE APPROACHES TO
GROUNDWATER GOVERNANCE:
LESSONS FROM THE SAURASHTRA
RECHARGING MOVEMENT**

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**ADAPTIVE APPROACHES TO GROUNDWATER
GOVERNANCE:
LESSONS FROM THE SAURASHTRA RECHARGING
MOVEMENT**

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Abstract

Increasing water scarcity leads to the adoption of adaptive approaches and strategies, which sometimes include collective actions. People who organise such collective responses need to be aware of the complexity of water resource management from the 'physical' as well as from the social behavioural points of view. When people intervene in processes like water flow, they need help in understanding the technical aspects of the physical resource, which is where the concerned technical agencies as one of the key stakeholders in resource management need to step in and play a proactive role. This calls for breaking up the technology as a black box and bringing it as close to the people's comprehension as possible.

This paper examines the Saurashtra recharging movement as a response to growing water scarcity conditions and increasing agrarian-based livelihood challenges. A variety of socio-technical actions have been carried out by the movement participants, which have resulted in increased agrarian-based livelihood incomes, primarily through increased groundwater availability and with it an improved quality of life. The paper identifies the key drivers of the recharging movement and the factors that have sustained it. Through a case study of a village, Ambaredi, in Rajkot district, the paper quantifies the additional water captured through primary data and analyses the scope for further enhancement through standard methods of groundwater assessment based on the computed stage of groundwater development after due allocations have been made for environmental flows and domestic use.

Locating the recharging movement within the theory of adaptive management, the paper emphasises the harmful effects of the absence of stakeholder participation, that is, government agencies with proactive policies, technical expertise, and financial support. The paper focuses on groundwater governance from the above points of view and draws some conclusions on what needs to be done to increase the effectiveness and success, both ecologically and economically, of the adaptive efforts of agrarian communities such as the participants of the Saurashtra recharging movement.

Keywords: Adaptive Strategy, Check Dam, Groundwater Assessment, Groundwater Governance, Innovation, Natural Recharge, Ecological Resilience, Saurashtra Water Recharging Movement, Watershed.

List of Abbreviations

CGWB	Central Ground Water Board
CV	Coefficient of Variation
DRDA	District Rural Development Agency
GIS	Geographic Information System
GL	Ground Level
GW	Ground Water
GWRE	Ground Water Resources Estimation Committee
MCM	Million Cubic Metre
NGO	Non-government Organisation
NR	Natural Recharge
PRA	Participatory Rural Appraisal
PVC	Poly Vinyl Chloride (pipe)
RS	Remote Sensing
VPST	Vruksh Prem Seva Trust
WEM	Water Extraction Mechanism
WL & SY	Water Level and Specific Yield Method

ADAPTIVE APPROACHES TO GROUNDWATER GOVERNANCE: LESSONS FROM THE SAURASHTRA RECHARGING MOVEMENT

1.0 INTRODUCTION

In India, more than 85 per cent of domestic water supply in rural areas, about 50 per cent of water requirements in urban and industrial areas, and more than 55 per cent of irrigation water requirements are currently being met by groundwater (Romani 2006). Given the uneven distribution of rainfall in most parts of the country, groundwater has been subjected to great stress, resulting in the steep decline of water levels and deterioration in the quality of water. Out of the total groundwater draft, 92 per cent is used for irrigation and 8 per cent is used for domestic and industrial purposes (Romani 2006). Over the past few decades, the number of overexploited and dark categories (from the groundwater stage point of view announced from time to time by the Central Ground Water Board) has been increasing steadily, reflecting grave groundwater scarcity in the country.

Water-related issues are complex and scale-dependent. Complexity means that these issues are 'difficult to understand' and that they are 'complicated'. It also implies that the complexity arises out of different elements, which are related in diverse ways (Mollinga 2000). The major source precipitation is available to us in various forms, such as surface water (rivers, streams, reservoirs, lakes, ponds, minor and major dams, etc.), groundwater, soil moisture, and springs. There is great diversity in the occurrence of each of

these forms of water, which is dependent on several other factors such as soil, geology, rainfall, and other climatic conditions. The predominant thematic approach has, by and large, remained isolated from the social processes (Mollinga 2000). In view of the enormity of water scarcity today, the socio-technical nature of irrigation water demands the participation of formal governance constituencies in order to promote, encourage, and build up on the social resource management movements.¹ The degree of success in tackling the uncertainties arising from natural causes and man-made actions depends on how well the stakeholders collaborate with each other as well as on the strength of the relationship between and among the constituent stakeholder groups.

Recognising variability and change as inherent characteristics of the physical and ecological processes, communities and civil society organisations (including non-governmental organisations) in recent decades have responded to water scarcity in a variety of innovative ways. The biggest adaptive response has been in livelihood sectors at different levels, beginning from the individual level and extending to the global level (Moench and Dixit 2004). Local people perceive 'livelihood sectors' of water use differently from the conventional economic definition of these sectors. They manage their water resource in ways that are different from the way in which the lines of authority manage it (Vincent 2000).

In Saurashtra, a semi-arid region of Gujarat, the water-recharging movement began as dug well-recharging activity by a few farmers two decades ago. Over the period, farmers from many local villages started recharging their own wells inspired by emerging local leadership. Today, the movement has spread to hundreds of villages in Saurashtra, covering a

range of innovative soil and water conservation activities. While dug well recharging is no longer practised, perhaps due to its adverse effects of siltation, check dam construction is most favoured. Interestingly, the contribution of people towards the cost of check dam construction in the popular district watershed programme is three-fourths of the total cost, while the remaining one-fourth cost is from the project. The Saurashtra recharge effort has acquired the characteristics of a social movement wherein the common ideology is enhancing water availability. In the process, the Saurashtra movement has built up significant social capital and has captured 'enough' additional water in its own 'catchments' to make considerable positive socio-economic changes in the quality of life of the participating families.

A better understanding of the complex nature of water as an essential resource also helps water-related social movements assess how their efforts are being rewarded and where they stand in terms of resource use and development. This profound interaction between water (in its different forms) and humans (Uphoff 1986: 4, quoted in Mollinga 2000) has implications for the long-term governance of the water resource at different scales. Governance also has implications for policy making, implementation, monitoring, and practice. Effective governance is based on two requirements: (1) a proper understanding of the complexity of the issue; and (2) the involvement of at least the key stakeholder groups in a well-coordinated manner.

Unfortunately, no in-depth studies of economic gains have been done from the point of view of the mass practice of well recharging (Athavale 2003). There has also been no systematic and scientific appraisal of the approach towards, nor have estimates been made of, the additional water

'generated'. To what extent has the recharge movement succeeded in tapping the aquifer potential? How much more aquifer potential is available? How does this compare with the actual potential? How is the upstream-downstream water relation affected (including the provision for environmental flows)? These are some of the questions that this paper addresses.

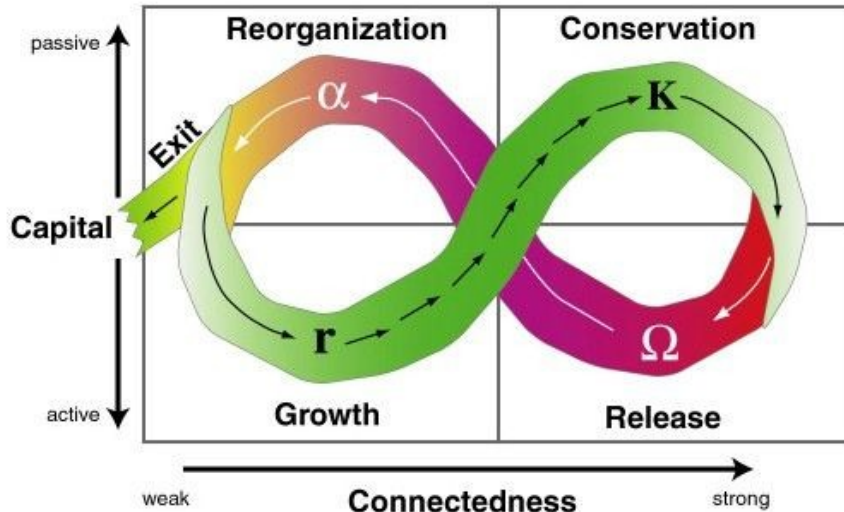
This paper examines the theory of adaptive management (Holling 1986) which describes nature's resilience in the resource-regeneration process, the human actions that tend to affect the resilience, and the adaptive strategies and innovations adopted by communities to address the problem of water scarcity. The paper also looks at the community's efforts towards achieving equity and sustainability. The study also discusses the shortcomings of policy making and the absence of institutionalising the lessons learnt, in particular by the state. In addition to estimating the quantity of water recharged into the ground, the paper also examines the potential for further groundwater development in the study village. In the given semi-arid conditions, with high coefficient of rainfall variation and hard-rock geology, the issue of how to maximise agrarian-dependent livelihood gains by the 'groundwater turnover' of the aquifers is also examined.

2.0 NATURE'S RESILIENCE AND THE HUMAN FACTOR

Nature comprises many ecosystems that are in a certain state of equilibrium. When this state is disturbed beyond a certain elastic point, nature tends to renew or reorganise itself. If nature manages to restore its earlier form, size, position, content, and function, then complete ecosystem resilience is said to exist. Resilience in social systems has an additional element, that is, the capacity of humans to

anticipate and plan for the future as their livelihood adaptations span areas from the local to the global. Adaptive strategies are based on the recognition that variability and change are inherent qualities; these strategies are often desirable features of physical (natural) and human systems. Resilience, therefore, is a property of these linked social-ecological systems (Holling 1986, Holling *et al.* 2002; Moench and Dixit 2004).

Figure 1 depicts the internal changes in a systems cycle through four phases: rapid growth (r), conservation (K), collapse (Ω), and reorganisation (α) (Holling 1986, Gunderson and Holling 2002). The r-phase of growth in the adaptive cycle represents capital accumulation (actual and potential resources, and information) followed by a K-phase that develops “systems” of internal organization and linkages while conserving capital. When naturally embedded systems tend to become isolated, with loss of internal and external connections, then the system enters a sudden Ω -phase of disconnection. Significantly, these changes result in even extant capital loss affecting the dependent society. This leads to efforts at re-organization or restoration in the α -phase during which innovations and experiments are also conducted. The re-organisation may or may not be able to trace the original growth path; there may be partial or total re-organisation. (Gunderson and Holling 2002).



**Figure 1:
The Adaptive Cycle**

Source: <http://www.sustainablefutures.net/>

Holling (1986:3) describes adaptive management as the interdependency of physical and social systems (that is human and human environment), which is indicated by change at one level cascading up or down to either support or disturb the linked systems either below or above in the dependency hierarchy. Therefore, any model of growth should be linked to ecological and social systems. Failure to link will result in a shortfall in the expected outcomes, and sometimes in a transformation that may be irreversible.

The inherent capacity of diverse species in nature, including humans and animals, for the natural processes of evolution, competition, and succession forms the foundation of ecosystem resilience. Considerable evidence exists, more so in current times, to show that human 'management' has 'succeeded' in taking some of these processes beyond the

elastic limits of the connected eco-subsystems, so that imbalances have occurred either in parts or across parts of the entire ecosystem.

The demands of humans—whose numbers are rapidly growing—are increasing not only in quantity but also in diversity; material science has produced various combinations of nature's elements to satisfy these demands. Such demands exist at the individual as well as at the collective levels. The former is not necessarily inclusive of the latter, while the latter is not necessarily or wholly representative of the former. Further, a great deal of evidence exists to show that resource use and adaptive strategies become rooted in cultural practices and traditions over a period of time (Agarwal and Narain 1997). Governance becomes particularly important in matters of scale from the point of view of both agglomerations of habitats and resource use.

In complex societies, the capacity for adaptation or resilience depends significantly on the vibrancy of the political process, which is in turn determined by the extent and intensity of participation of multiple stakeholder groups. In other words, the time duration needed for resilience to occur depends primarily on how closed or open the prevailing political system is to the efforts of its constituents responding to adverse ecological occurrences. Social movements can effectively prevent ecological degradation depending on the clarity of their purpose, organisation, scale, technical and social strengths, and the social capital at their command. They can challenge the dominant political systems successfully not only in accommodating marginal voices but also in deciding to carry out ecological functions that are best for the community. In other words, when innovation is

promoted and encouraged, it tends to build in flexibility in resource management, thus accumulating the experience and wisdom (Mudrakartha 2003) needed for protecting the systems against sudden collapse; the physical and the human systems thus would possess resilience for effective adaptive management. Not only is innovation important, but the strategic implementation of these innovative approaches is equally important. Holling points out that a holistic view of system interactions during the design of implementation plans is very important if innovations are to succeed or to make any difference.

3.0 ADAPTIVE RESPONSES TO WATER SCARCITY

Adaptive strategies for addressing long-term water management problems may be defined as approaches that respond to variability and that work with change processes to achieve socially desired goals. However, these approaches do not provide much practical direction for goals that require greater specification (Moench and Dixit 2004: 11). Such strategies, therefore, need to be a function of the cumulative experience, enriched from time to time by learning from and exposure to proper and efficient resource management to be useful in a practical sense. Thus, historical experience, a rising learning curve (including knowledge of scientific and technological advances in the field), and robust civil and governance institutions together make a real difference to efforts aimed at bringing about ecological resilience through social movements. Forest management in India is a classic example where communities in certain states have been managing local forests successfully for many decades; the experiential learning has been passed down through the generations.

This brings us to the question of how to link civil society and mass movements such as the Gujarat well-recharging movement with that of ecological resilience. This is because it is natural for individuals and groups to react or respond to a crisis situation such as water scarcity. However, the key to ecological resilience here lies in the resilient livelihoods of communities that demonstrate a strong adaptive capacity involving continuous learning and adapting, as already stated.

Further, not all initiatives are converted successfully into useful movements for various reasons. Many of these diverse responses are also peripheral and ineffective (Shah 1998), as their success depends on a host of factors, such as the emergence of leadership, the ability of the leadership to envision the future, a whole set of alternative approaches and technologies, and the response of the governance machinery. Other factors such as the degree of social cohesion in the community and enabling externalities play a great role in the case of various subgroups or collectives, aiding them to reflect upon the situation, to identify options, and then to act (Mudrakartha and Madhusoodhanan 2005; COMMAN 2005). Studies reveal that the key reason for the failure of many good projects and schemes launched by the government over the years is the adoption of single-track, one-dimensional approaches (Mudrakartha 2003). It is, therefore, imperative that policy makers should move beyond one-dimensional theories of change and adopt a more holistic approach.

The past six decades in India have witnessed the emergence of water as the key driver of development. The initial focus after independence was on harnessing rivers through the construction of dams and reservoirs to ensure flood control

and irrigation. Most of these dams and reservoirs were constructed as part of multipurpose projects, including those designed for the production of hydroelectric power, while the canal network from the reservoirs provided irrigation. This strategy also aided the Green Revolution, launched during the mid-1960s to address the problems of hunger and poverty.

However, as the population grew and the pace of urbanisation increased, demands on land multiplied. There was increasing demand for water for various uses, such as drinking, irrigation, livestock, and town and city drainage. The surface water harnessed in reservoirs was preferentially allocated for meeting the drinking water needs of towns and cities, especially during periods of water scarcity. Arid and semi-arid regions, which in particular experience frequent acute water scarcity conditions, saw drastic declines in groundwater levels, including areas in western India (Mudrakartha 2007). Combined with low, erratic, and poorly distributed rainfall (with respect to time and space), some of the irrigation schemes were reprioritised to meet the emerging drinking water demands of humans and animals.² So much so that the past three decades have seen an increasing dependency on groundwater both for agriculture and for drinking water supply, particularly in arid and semi-arid regions.

4.0 THE SAURASHTRA GROUNDWATER RECHARGE INITIATIVE

In such a scenario, farmers, in particular, were hard-pressed to irrigate their crops. Saurashtra farmers recognised that their situation was far worse than the situation of farmers elsewhere in the country because they had to contend with

not only an unfavourable rainfall pattern but also difficult topographical conditions. Seasonal depletion of groundwater had become a widespread problem, exacerbated by limited aquifer storage capacities (Mudrakartha 2002). In the mid-1980s, after the farmers had suffered a particularly severe three-year drought (1985–87), they realised that while their wells had remained dry, huge quantities of rainwater had flowed away from their farms, which housed these dry wells. This fact—and its life-changing implications—caught the imagination of some progressive farmers in Saurashtra, who adopted a simple method of direct recharging by diverting run-off water into their wells through a small pit, which trapped silt and delivered fresh water. The predominantly black cotton soil of Saurashtra has facilitated a low rate of silt accumulation. Gradually, the dug well-recharging movement was converted into a groundwater-recharging movement through water-harvesting structures such as check dams, farm ponds, tanks, and earthen bunds.

Water is a key element not only in livelihood enhancement but also in ecological resilience and sustainability. Water regenerates weakening livelihood production systems, which support society both directly and indirectly. In the case of Saurashtra, the livelihood production systems mainly comprise agriculture (including animal husbandry), which depends to a large extent on rainwater directly and indirectly (in the form of groundwater). Water-harvesting activities carried out in hundreds of villages covering thousands of wells are found to have made a significant impact on the local ecology in various ways, for example, in the form of increased biomass, enhanced vegetative growth in the upper catchment, and developing micro ecosystems in the soil, in forests, and on common lands. Ecological considerations were initially, however, not of primary concern to the

collectives engaged in water harvesting. Their priority was coverage of contiguous villages as well as coverage of as many families as possible. Over the years, their work with water conservation—adopting various innovations and then sharing and disseminating this knowledge and expertise—has deepened their understanding of the mutuality of physical systems, the well-being of which is linked with the quality of their life.

4.1 The Saurashtra Initiative and Groundwater Governance: Key Concerns

The recharging movement began with dug well recharging in the 1980s. It has since spread to thousands of villages and has benefited thousands of families. As the experimentation and village-level scaling-up continued, led by local leaders, many innovations were made along the way to include the now popular check dams as part of the watershed development programmes. These innovations are described in the following section.

However, no systematic, intensive study has been done (Athavale 2003; Kumar *et al.* 1999) on this immensely popular recharge movement to inquire into the impact of these efforts on people's livelihoods or to examine the social and technical aspects of this approach. At best, there have been a few anecdotal studies and back-of-envelope computations on the volumes of water recharged aimed at convincing the target audience about the efficacy of the recharging methods. There have also been no in-depth studies that look at the technology of well recharging, nor have there been adequate scientific inquiries (in terms of hydrogeology) into the recharging technology, which was primarily evolved and promoted by farmers, motivated

individuals, and institutions, with the adoption of some innovations along the way.

What are the key drivers that have sustained the recharging movement so far? Does the movement have the necessary characteristics that will allow it to continue in the future? Does recharging groundwater remain a mere activity, or do the people and the authorities (policy makers, administrators, and officials of technical departments such as water, groundwater, and agriculture) understand their roles and duties, and do they fulfil these responsibilities efficiently and honestly? How does recharging groundwater contribute to building ecological resilience in local communities? These questions remain unanswered and hence need to be explored.

5.0 RESEARCH METHODOLOGY

This paper seeks answers to the above questions through a case study of Ambaredi village, in Jamkandorna taluka, Rajkot district, in the Saurashtra region of Gujarat state. The study forms part of the author's doctoral research. The present paper covers a sample of 28 farmers from Ambaredi, constituting 10 per cent of the total households, through stratified random sampling. The data was collected through structured questionnaires (household and village level), personal interviews, and focused group discussions. For the purpose of drawing larger lessons, data and trends from other study villages were also included. The field surveys were carried out during 2001-03; the changes were then analysed, comparing these with the situation as it existed prior to 2001.

6.0 THE INNOVATIONS OF THE SAURASHTRA RECHARGING MOVEMENT

Before we examine the details of the village case study, it is important to understand the Saurashtra movement in terms of its origin, hydrogeology, and groundwater conditions.

The leaders of the Saurashtra movement have undertaken a series of experiments and innovations from time to time. These few individuals and institutions have continued to spearhead the movement, adapting and modifying their strategies and methods as and when necessary.

Saurashtra suffered a severe drought during 1985–87. At the end of this period, almost all the wells went dry. The region received good rainfall during the next year's monsoon, resulting in huge run-off from farmlands. Some farmers observed this phenomenon and thought of diverting the run-off water into their dry wells. The diversion of run-off water resulted in higher yields compared to those of other farmers; the wells retained more water for rabi. Neighbouring farmers were enthused by this and started adopting dug well recharging from the following year.

Visionaries such as Shyamjibhai Antala, Pandurang Shastri Athavale, and Premjibhai Patel have spread the idea of water recharging through the written word, individual action, and social mobilisation.

One of the earliest innovations was that of Shyamjibhai Antala, president of the Saurashtra Lok Manch Trust, Dhoraji, Rajkot, who introduced a new technique involving the use of plastic pipes with pores. When water flows through this pipe, it oozes out and is absorbed by the surrounding earth until the soil is saturated. The saturated soil around the pores acts as a counter to the spread of soil moisture and facilitates the

further movement of water in the pipe to other areas. This technique provides moisture content to the soil that is necessary for cultivation. It requires negligible maintenance; it is easy to install and simple to use; it results in minimum water loss and does not present any problem of blockage.

Since the cost of transporting the pipe from Bombay was high, Shyamjibhai Antala encouraged his son to set up a factory for manufacturing PVC pipes in Dhoraji (in Rajkot district). This has helped bring down the cost of the pipes (Rs 10-12 per foot), which farmers can afford. Before starting to manufacture the pipes, the father and the son tested the efficacy of this pipe on different crops, such as groundnut and cotton, on a pilot basis and demonstrated the same to the farmers. They also demonstrated the technique on tree crops within their factory premises for everyone to see and appreciate the results.

The Swadhyaya movement led by Shri Pandurang Shastri Athavale has also promoted a set of innovations, the primary one being well recharging. This consists of digging channels to direct all the rainwater into a sump or pit, whose dimensions are typically 4' x 3' x 3', from where the water flows automatically into the well through a small pipe. The sump or pit acts as a sediment trap too. The Swadhyayees as well as others improvised the filter system to address the problem of clogging of the pit. Premjibhai Patel advocated the use of a desilting chamber in place of a filter.

Another innovation relates to the improvisation of khet talavadi (farm pond). This is a tank usually of dimensions 20' x 30' x 3'. The run-off from the catchment is trained into the farm pond through a number of channels. From here it flows into the well through a PVC pipe of 9" or 12" diameter or through a channel dug into the earth.

As the recharge movement picked up pace and a significant quantity of water was harvested year after year, wastage of water also took place. It was noticed that almost 20 per cent of the water pumped from wells was used for meeting domestic requirements such as bathing, washing utensils and clothes, and drinking water for both humans and animals. The 'waste' water as also the excess irrigation water accumulated in low-lying areas. While the use of water for drinking and other purposes could not be avoided, some people thought of ways of redirecting the excess waste water into the ground, such as soak pits.

Interestingly, the soak pits (of 8'-10' diameter) were not only constructed for soaking up the excess water but the idea was also extended to recharging river or stream water into the underground. Further modifications included the provision of vertical extension bores of 4"-6" diameter into the soak pits from the bottom. A pipe with pores was connected to the bore, with about 5' long portion protruding above the bottom of the pit. This pipe was also covered with a mesh to prevent clogging of the pores in the pipes. The pit was then filled with filter material of varying grades of pebbles and gravel. This technique prevents silt or sediment from getting into the bore and clogging it.

By virtue of its topography, Saurashtra has hundreds of rivulets and streams that run-off due to the gradient. Hundreds of modified soak pits were constructed at intervals of half a kilometre in the river bed or along the river as per the convenience of the local people.

Prominent social workers like Chunibhai Vaidya have also constructed hidden (subsurface) check dams across the river below the bed. This has helped in creating additional storage, which has increased the subsurface flow to the wells in the

neighbourhood, thus enhancing groundwater recharge in the area.

Yet another important innovation is the use of tanks to hasten the pace of groundwater recharge. The tanks are developed so as to 'restore' the permeability of the bed soil. A bore is drilled from the bottom of the bed deep enough to penetrate the potential (implying dry) aquifer. The tank also has necessary provisions, such as an air vent and a filter arrangement. Often, more than one bore is drilled in the tank bed to augment recharge.

Another experiment was tapping rooftop water to connect with tankas (small tanks) inside the house to address the problem of scarce drinking water. Arrangements were also made to avoid the first rains. Material such as lime and charcoal was also used.

While the Swadhyaya Parivar effectively captured the modifications and propagated them through ingenious ways (Shah 2000), Shyamjibhai Antala promoted them through his writings in the press, including under a syndicated column. The Parivar employed very effective methods of communication. Shri Pandurang Shastri Athavale used to address huge crowds, often between 100,000 and 200,000, exhorting them to adopt innovative ways of water conservation. The Swadhyayees, who are followers of the Parivar and who provide service purely on a voluntary basis, picked up the thread from here; they not only described various techniques but actually demonstrated their working in the villages.

The Saurashtra Lok Manch under Shyamjibhai Antala has compiled data about all such experiments and their impact and has disseminated this information among the people.

They have also prepared leaflets with innovative illustrations to facilitate easy comprehension by the generally illiterate farmers. Shyamjibhai Antala also regularly contributes articles to a popular vernacular daily in which he describes all the experiments and offers his own assessment of their successes and failures. This has motivated people to reproduce these experiments on their own to see the results as described.

All these innovations, and many others (for more details see Shah 2000; Athavale 2003), have strengthened and deepened the recharge movement in Gujarat in terms of knowledge and practice. The promoters of the recharge movement have mostly carried out systematic experimentation on their own while learning from each other. Yet they have maintained their 'individuality' in experimenting with 'different' ideas. This diversity in thought, converted into a menu of innovative actions, has helped to sustain the movement by retaining the interest of the so-called implementers. These action experiments range from making simple earthen bunds to recharging dug wells, to constructing check dams. It is a credit to the ingenuity of some of the promoters that they have 'treated' the entire drainage of a village, which maximises the effectiveness of these interventions.

As the above account shows, these experiments, and the social energy that they have mobilised on such a scale and intensity, may be described as 'self-propagating' (Shah 1998) drawing upon their own internal energy to sustain themselves. The major reason for this success, it seems to me, is that in most cases, there has been at least one local leader who has taken up the cause, promoted it by first adopting it himself or by having others adopt it. Some funds

were also raised from local industrialists and business houses, which helped farmers who could not afford to participate in the movement. An honesty of purpose was thus demonstrated for the larger good. Not all such experiments met with success, but each project was built on the achievements of the previous one, thus signifying progress. The movement has also been strengthened by an inherent spirit of entrepreneurship and determination aimed at improving the livelihood of farmers by tackling the problem of water scarcity. These characteristics have imparted resilience and strength to the movement, preventing it from a sudden collapse, as it is based on practice, knowledge, commitment, skills, and wisdom.

In order to examine the groundwater-recharging movement, it is important to understand the topographical and geological setting of the Saurashtra region in which the case study village Ambaredi is situated.

6.1 Climatic Conditions of Saurashtra

Saurashtra occupies one-third of the geographical area of Gujarat state. The typical topography of the region consists of elevated central portions with an altitude ranging from 75 m to 300 m above sea level, giving rise to diverse slopes between 5 m and 20 m per kilometre (0.5 to 2.0 per cent slope) in general and around 3 per cent in certain places. The central elevated portions display rugged features with sharp hills and valleys. Many small rivers originate from here and flow away in radial directions, particularly in the eastern, western, and southern directions. The region has predominantly hard rock, basalt. The steep slopes and limited storage potential due to the shallow thickness of overburden result in aquatic inequilibrium conditions. Most of the

Saurashtra region (Amreli, Jamnagar, Banger, Rajkot, and Surendranagar) has arid to semi-arid climatic conditions, except the coastal Junagadh district (also called south Saurashtra), which has a sub-humid climate.

Analysis of rainfall data for Saurashtra covering 95 years (1902–97) indicates that for 45 years, the rainfall was either below average or was normal, and that rainfall occurred in high-intensity, short-duration spells. The mean annual rainfall over the period (1902-97) varied from a minimum of 493 mm to a maximum of 701 mm. The average number of rainy days is 27; the mean rainfall is 592 mm (Phadtare 1998). Dry spells last for many years, thus posing a huge challenge to agrarian livelihoods. For instance, more than half of the decade (of 1987–97) was 'dry' for the Saurashtra region.

This rainfall pattern combined with topography of high slopes and hard rock results in large surface run-off. The typical topography does not provide run-off with adequate time for recharge to the weathered zone and the fractured zone (where occurring).

The wide variation in the annual rainfall and its uneven distribution, the small number of rainy days, and the hard-rock hydrogeology of the region render the Saurashtra population highly vulnerable to water scarcity conditions. The ecological consequences of water scarcity in such a situation are two-fold. First, there is an adverse impact on vegetation (including crops) because of soil-moisture depletion, often leading to significant migration of population and livestock. Second, due to increased demand for, and decreased recharge of, water, long-term water decline has set in, affecting the whole domain of livelihoods.

6.2 Groundwater Conditions in Saurashtra

Although Saurashtra occupies 36 per cent of the geographical area of Gujarat, the surface and groundwater availability of the region constitutes only 17 per cent of the state's total water resources. In contrast, south Gujarat, which occupies only 14 per cent of the state's geographical area, has 66.3 per cent of the total water resources. Barely one-third of Saurashtra's demand is met by the total water resources available (see Figure 2).

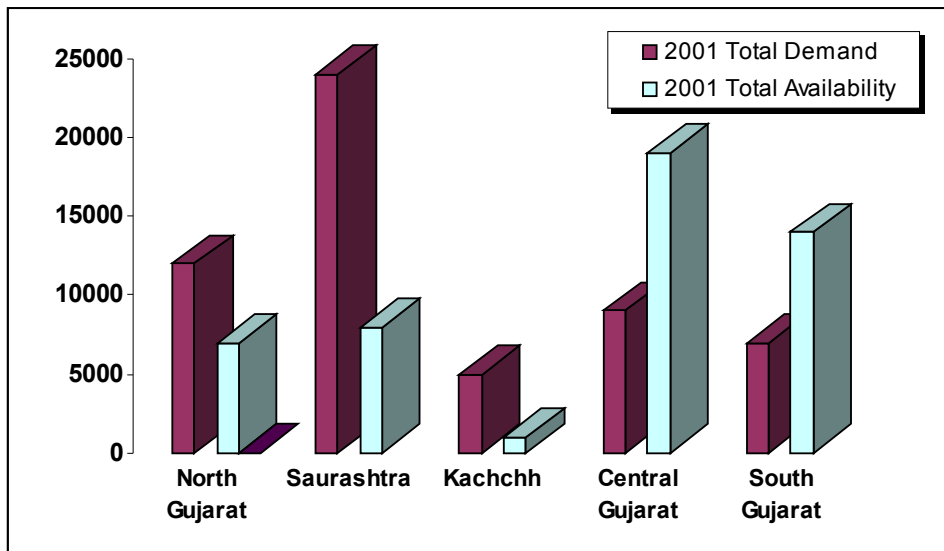


Figure 2:
Total demand versus total water resources availability

Source: <http://www.gec.gov.in>
Note: Figures in million cubic metres.

Eighty per cent of Saurashtra is covered by basalts. The occurrence and movement of groundwater in basalts is controlled mainly by weathered zones, vesicles, fractures and joints, inter-trappeans, infra-trappeans, and contact zones.

The porosity in hard and massive basalt is not more than 3 per cent, while in vesicular basalt it is up to 16 per cent (Mudrakartha 1987). Massive basalts have a tendency towards spheroidal weathering, which itself creates an important water-bearing zone. Secondary porosity is represented by fractured/jointed formation. The compact and fissured nature of rocks tends to give rise to discontinuous aquifers with moderate yield potential. The top weathered zone is usually thick and has good potential for groundwater storage. The contacts between layers invariably give rise to weathered zones as there is a time lag between any two basalt flows. The thickness of these zones has a direct relation to the period of weathering to which the bed had been subjected, before a subsequent volcanic flow erupted and enveloped it. Often, the weathered zone has proved a potential yielding zone for wells, depending upon its thickness and lateral extent and subject to hydraulic connectivity. The yield depends on the clay content in the weathered zone and on the presence of red boles³ or green earth⁴ (Mudrakartha 1987).

The weathering of basalt also gives rise to landforms because weathering tends to hasten through structurally weak zones, such as joints, contacts, shears, and fractures. The columnar joints, which are vertical and hexagonal in shape and which are formed during the process of the cooling of lava, also enhance permeability. Secondary fractures in basalts (Deccan traps) are caused due to tectonic disturbances and intrusive dykes. Tectonic activity in Saurashtra has given rise to several faults, both small and of regional extent. Intrusives such as the dolerite dykes also cause fractures, although on a small scale. When subsequent flows occur, the fractures are concealed either partially or completely. Such fractures when occurring below massive basalt, when hydraulically

connected and when not fully filled up with lava or any other geological material, yield significant discharges. The specific yield⁵ of basalts is low, between 1–3 per cent. The yields also vary within small distances, especially when tapping deeper aquifers. However, shallow zones, including weathered zones, yield a good quantity, and can be dependable when connected with a source such as a tank or a river.

Groundwater dependency for agriculture in Saurashtra is quite high. Wells constitute the main source of irrigation for more than 95 per cent of the irrigated area. Sufficiency of groundwater, therefore, is a basic requirement for sustainable agriculture in the region (Nagar 2002).

In short, it may be said that diverse physiographic and tectonic activities have given rise to heterogeneous hydro-geological conditions in most parts of Saurashtra. It may also be stated that groundwater availability is highly dependent on rainfall, which is erratic and low, and on aquifer characteristics. Both these parameters are not highly favourable in the case of Saurashtra. Hence, an innovative approach is essential to make the most of the existing conditions. According to the Minor Irrigation Census 1986, more than 60 per cent wells and tube wells in Saurashtra were not in use. These included failed wells as also those that go out of use because of physical reasons and seasonal fluctuations. Visionary leaders of the Saurashtra recharge movement saw dry wells as an opportunity literally to be tapped. It did not take much effort to convince farmers that water in their wells alone could make a big difference to their primary livelihood income. This belief is borne out by the case study of Ambaredi discussed in the following sections.

7.0 AMBAREDI: THE CASE STUDY VILLAGE

Ambaredi village is located in the south-west portion of Rajkot district, about 80 km from Rajkot. It is easily approachable by all-weather road. It is located 15 km from Jamkandorna, the taluka headquarters. The village falls in the Survey of India top-sheets 41 J/9 and 41 K/12. The maximum temperature is around 48 degrees Celsius during summer. The coldest night temperature hovers around 3–4 degrees Celsius. The average annual rainfall is 508 mm.

Ambaredi has a total of 364 families (population 2,550). The residents earn their livelihood working as tailors, labourers, cobblers, electricians, animal caretakers, potters, and masons. The Patels are the most dominant caste, followed by the scheduled castes. Two-thirds of the population is literate. The average family size is 6.

The Phophal river is a tributary of the Bhadar river. The Phophal originates in the Lodhika hill ranges in central Rajkot, travels in a north-south direction for 40 km and joins the Bhadar (dam) near Meswa village in Jamkandorna taluka. Phophal is fed by streams originating in the low-rise basaltic hills trending approximately north-east-south-west. It flows through Ambaredi which has varying slope of up to 3 per cent. The farmlands along both (littoral) sides of the Phophal river have a minimum slope of 0.6–1.0 per cent.

The top zone comprises predominantly black cotton soil whose thickness varies from a few centimetres on the hill flanks to a few metres along the river. The soil is fertile, and is ideally suited for cotton and groundnut cultivation. In addition to these two crops, til, bajra (*Pennisetum glaucum*), mung, a type of bean (*Phaseolus aureus*), jowar, and wheat are also grown.

Generally, open dug wells are the most popular source of groundwater abstraction. Prior to the launch of the check dam recharging movement as part of the watershed project,⁶ that is, until as late as 2001, most of the wells used to dry up after the monsoons. However, by the end of 2005, all the 165⁷ wells were yielding throughout the year due to the check dam activity under the watershed project supported by the district rural development agency. The depth of the dug wells ranged from 10 metres in the lower reaches (along the Phophal river) to 18 m near the foothills of the Lodhika hill ranges. For improving the yield, almost 90 per cent farmers have drilled radial bores at the bottom of the wells to a depth of around 30–60 m. While 4–5 radial bores are common, the minimum number that a well has is 2. The water level, too, similarly varies according to the topography and the season. The water level fluctuation is approximately 8 m.

Based on a detailed inventory of the wells, the geological section of a typical dug well in Ambaredi comprises a top black cotton soil followed by a weathered zone which gradually turns into weathered rock. The weathered rock often changes into a partially or highly fractured rock or into a fresh rock. The well section is represented in the following figure:

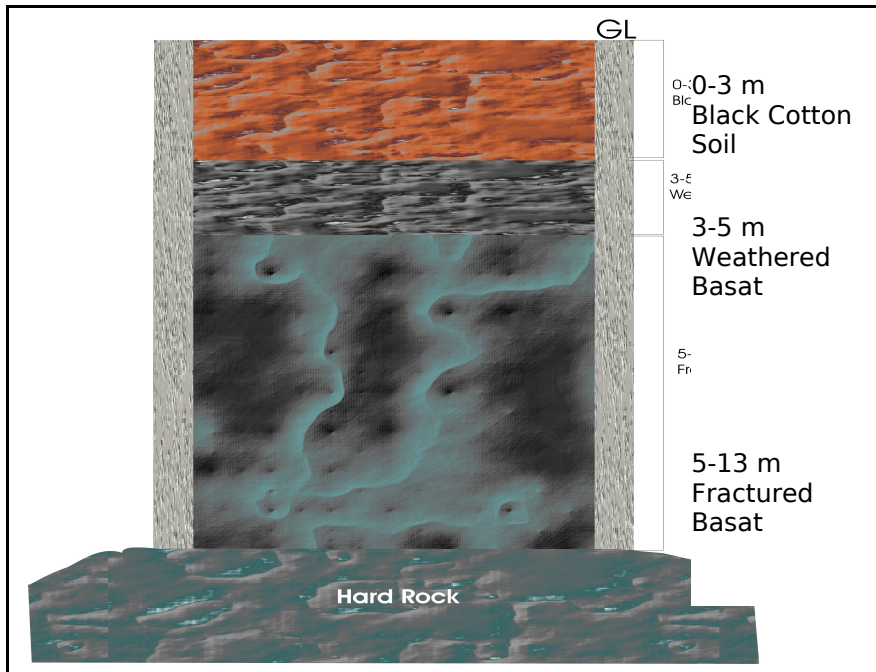


Figure 3:
Geological cross section of a typical dug well in Ambaredi village

Source: Mudrakartha 2004

The dug well-recharging movement in Ambaredi has been promoted by the Vruksh Prem Seva Trust (VPST) under the leadership of Premjibhai Patel. Premjibhai Patel is a well-known innovator of Saurashtra. He has been leading the water-recharging movement in Rajkot district since 1962. In 1968, he recharged his own well. Until 1994, he was engaged in his own business of supplying explosives for well-deepening purposes, and later in the supply of pipes for recharging purposes. Since then, he has become involved in development work, leaving his business. Having promoted dug well recharging for many years, he has been engaged in

promoting check dams through watershed development programmes since 2001. He has constructed more than 500 check dams until now. In addition, in 1995, under the water supply project, he constructed 1,200 small and big check dams in 20 nearby villages. He encouraged farmers to desilt the check dams every year and to use the silt as manure on their farms. One of Premjibhai Patel's significant contributions has been constructing a check dam at one-third of the estimated cost approved by the government as per the Standard Schedule of Rates. With the savings, he constructed more check dams. He could achieve the lower rate of cost of construction because of the following reasons: [1] he convinced farmers that by constructing check dams, their returns from crop yields would increase significantly, in addition to gaining assured crops; [2] he motivated them to contribute as much labour as possible; this made a significant contribution to cost savings as labour constitutes at least half of the cost; [3] he used the ingenuity of the local masons in the design and construction of the check dams; and [4] he did not employ any supervisor for monitoring the construction, but made the farmers themselves responsible for the quality of construction, thus reducing overhead costs. In this way, Premjibhai Patel could have tens of check dams constructed simultaneously. Such is his charisma and stature that he commands respect and honesty from the farmers, with the result that the check dams were built at low cost while also being of assured quality.

In 2001, Premjibhai Patel extended his work through his organisation, the Vruksh Prem Seva Trust, and took up watershed projects supported by Rajkot DRDA. Given the track record of VPST, the watershed project was allowed more flexibility in its operation. Under this project, Premjibhai Patel constructed the first few check dams in Saurashtra with

the help of those who approached his organisation. He spent more than 80 per cent of the project budget on the one-point agenda of impounding rainwater by constructing check dams across the seasonal streams and the main Phophal river.

There were no fixed criteria or preferences for any particular caste or community. Of course, members of the Patel community were the first to seek funding for the construction of check dams, which supplied their wells with a lot of water. Seeing that the Patels had obtained good crop production, many more farmers came forward to build check dams. Thus, there was a tremendous demand for check dams (Table 1), which can be seen from the fact that in one year (2002) alone, 42 check dams were constructed. Out of the total of 100 check dams in Ambaredi village, 70 were constructed by VPST and the rest by DRDA (undated).

Table 1:
Year-wise progress of construction of check dams in Ambaredi village

Year	No. of Check Dams
2001	3
2002	42
2003	11
2004	3
2005	6
2006-07	35
Total	100

The watershed programme has also led to collective action by neighbourhood farmers, who come together in small batches, construct a check dam, and form a user group around it. Together these farmer groups have contributed 30 per cent of the cost of the check dams. This user-group-based

approach was the first of its kind in the entire Saurashtra region; it has laid the foundation for a groundswell of support for many similar collective efforts in various parts of the region. This approach has successfully addressed many nagging issues, such as determining the ownership of check dams and assigning responsibility for their repair and maintenance. The silt deposited in the river course/bed is lifted by the user group members and used on their farms. Thus, the storage capacity of the river course/bed continues to remain more or less unaffected.

7.1 Expansion to Other Villages

VPST has covered 27 villages around Ambaredi, as shown in Figure 4. This approach has resulted in a transformed area, rejuvenating the drainage lines and increasing the soil moisture that supports plant growth in non-agricultural land.

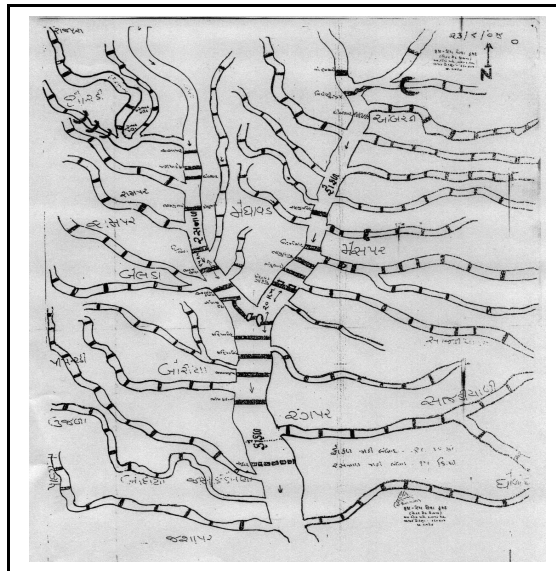


Figure 4:
PRA map showing the location of water-harvesting structures

in the Phophal river basin

Source: VPST records.

Another interesting aspect is that there has been neither competition nor conflict over the use of the river water. Most of the farmers have joined the user groups, and have lifted water. One reason for the smooth operation of the lifting systems, irrespective of caste considerations, is the plentiful availability of water along the river course in the check dams. No farmer or farmer user group has felt threatened by the shortage of water.

With so many water-harvesting structures in place, the 40-km-long Phophal river has been regenerated; it now flows for more than nine months in a year. Even during the peak summer months of May and June, large portions of the Phophal have impounded water, which meets the drinking needs of livestock and the domestic requirements (bathing, washing, drinking, and cooking) of families from the riparian villages. Prior to 2001, when the check dams were not in existence, the river had water flowing only until November, that is, when there were good rains. But now, the water flows until March–April.

7.2 Distribution of Recharge Nodes

The large number of check dams—constructed on almost every stream and river course—has led to the distribution of recharge nodes across agricultural land. Data show that these check dams have enhanced the rate of recharge, as natural recharge through the predominantly black cotton soil does not happen easily. The recharge is also aided by three factors: (1) the availability of water in the river or stream course for most of the year; (2) continuous flow into the check dams aids recharge through the river beds; and (3) the

bottom of the check dams reaches the weathered zone, often bypassing the black cotton soil.

Underlying the weathered zone is the fractured zone, which also becomes saturated. In other words, the distribution of recharge points is spread across all the village agricultural land, and hence all the wells receive water. The quantity of recharge may, however, vary depending on conditions such as the elevation of the well, the thickness of the weathered and fractured zone, and hydrogeology.

One of the main issues concerning check dams has been the question of equity. A check dam normally has limitations in terms of the extent of the area that it can recharge and the number of wells that it can influence. Although particular drainage line treatment spreads the benefits of recharge, the spread is restricted to the river sides up to a certain distance. However, in the case of Ambaredi, since all the water courses right from the hills and the main river have been fully treated, the recharge is adequately spread throughout the village. Nevertheless, wells along the river tend to get the maximum benefit because of favourable topographical conditions, while the rest of the wells get water sufficient for at least two crops.

Further, along the banks of the Phophal, where the land slope is around 1 per cent, maximum recharge takes place, as can be seen from the fact that the water level is less than one metre below ground level. Nevertheless, farmers cannot pump for more than 8 hours per day as power supply is not available. The recovery of the one-metre drawdown after pumping for 8 hours is achieved within an hour. This change in water availability is nothing short of a miracle for the local people, who suffered for want of critical irrigation water for decades.

7.3 Evidence of Adaptive Strategies⁸

7.3.1 Crops, Cropping Patterns, and Land Use

The success of any water-based intervention is judged by the impact that it has on agrarian livelihoods, which still form the majority occupation in India. Agrarian livelihoods here mean agriculture and livestock or animal husbandry. The livelihood systems are quite complex, and adaptation means not only increasing the land under crop cultivation but also enhancing the farmers' ability to go in for improved seed varieties, expanding the land under cultivation, selecting suitable crop combinations for the three growing seasons on the basis of market demand while also maintaining household food security and fodder security, and enhancing the quality of production elements (pumpsets, pipelines, land development measures, agricultural implements, farm animals), etc.

Ambaredi, which is predominantly an agrarian village, has witnessed the above-mentioned changes, and much more, as a result of the water-harvesting projects carried out post-2001. For the purpose of comparison, the period prior to 2001 is considered as control period, while 2001-2003 represents the study period during which data has been collected and analysed. The changes witnessed relate to the study duration.

The kharif crops generally raised are cotton, groundnut, pearl millet (bajra, that is, *Pennisetum glaucum*), and maize; the rabi crops comprise wheat, chilli, garlic, and jeera (*Cuminum cyminum*). The cropping pattern has undergone significant changes as evidenced by a shift of land cover under different crops. Interestingly, the shift has been made by almost all the farmers of the village across castes, including the scheduled castes. The combination of crops for kharif and rabi varied

according to the economic status of the community, which also is directly related to awareness levels and risk-taking ability.

Analysis indicates that there has not been a major shift during the pre- and post-2001 periods in terms of cash crops for the Patels as they were already cultivating cash crops such as cotton and groundnut. The shift was basically in the use of improved seed varieties, which with improved and assured water availability has led to a tremendous increase in production and productivity. On an average, each of these crops has given at least twice the income because of increased production. Wheat was not a major crop but was raised by many farmers after the availability of water in the check dams was ensured.

Crop productivity has also increased: from 8.31 mann⁹ to 17.25 mann per bigha¹⁰ (207 per cent) for cotton; from 6.1 mann to 15.9 mann per bigha for groundnut (260 per cent); and from 3.7 mann to 9.3 mann per bigha for wheat (251 per cent). In other words, there has been a net increase of at least one to one and a half times in agricultural productivity, which may be attributed directly to the availability of water. However, when we compare these productivity values, we find that these are still far behind what could be achieved. This is one area where support from the agriculture extension department (which is a key stakeholder) will be very useful.

Other crops such as jeera, garlic, chilli, and vegetables are cultivated in small patches of land more to meet domestic requirements. Interestingly, these are water-intensive crops, but farmers do cultivate them in small patches for domestic use.

The other major change is the emergence of wheat as a second crop over a large area post 2001. The analysis indicates that the area under wheat has increased from 30 bighas pre-2001 to 390 bighas during 2001-03, with the result that income has increased manifold from Rs. 8,000 to Rs. 125,000 for the same reference years. Productivity has also increased from 2.67 mann pre-2001 to 3.24 mann per bigha during 2001-03.

The scheduled castes and communities other than the Patels used to grow bajra and jowar, which met their family food security requirements, and the excess of which was sold. The availability of water has led these communities also to take up cotton and groundnut cultivation, thus getting into the mainstream agriculture production system.

7.3.2 Pattern of Spending on WEM

Availability of additional water resulting from recharge has led to additional expenses in terms of running water extraction mechanisms (WEMs). WEMs in Ambaredi comprise diesel and electric pumpsets in the ratio of 3:1. Farmers prefer diesel pumpsets because of the erratic and limited electricity supply (8 hours per day). The village witnessed an increase of more than 70 per cent in the spend on fuel and more than 74 per cent on electricity during 2001-03 from the levels existing in 2001.

Farmers believe that water conservation and water-harvesting activities have brought about reasonable stability in the availability of soil moisture, which is critical for crops. The general practice in this region is to sow all the land at the advent of the first rains. The farmers found that even low rainfall helped in soil moisture availability, particularly in between spells of rain, due to the dispersed location of the

check dams. The 165 well structures provide irrigation support to the dispersed farms. Prior to the check dam phase, there was no assured irrigation support from the wells, and hence both production and productivity were low. However, after the construction of the check dams, with water being available more readily, farmers gained confidence and spent money on diesel pumpsets for lifting water from wells. While most of the Patel farmers already had installed pumpsets and pipelines running from the wells to their farms, a few spent some money on replacing damaged pipelines and pumpsets. However, the Kolis and other farmers have invested in installing pipelines in addition to the infrastructure that was already present.

Similarly, farmers were no more using conventional flood irrigation methods; the entire transportation was now through pipelines. Some well-to-do Patel farmers, who had old, damaged pipelines have replaced with new ones. Farmers were strongly desirous of at least taking two assured crops every year. They have also spent more money on diesel pumpsets. Some farmers have also obtained electricity connections and purchased electric motors. The farmers in general aimed at achieving an overall increase in water use, thereby reducing significant losses due to leakages.

7.3.3 Income and Expenditure

Analysis of data indicates that the average annual income per family was Rs 1.77 lakhs during the years 2002-03 from all sources. This included income from livestock, which also increased as farmers added 18 per cent to the existing herd population, mostly cows, buffaloes, goats, and bullocks. This income, compared to the pre-2001 (when average rainfall occurred) income of Rs 70,000 per farmer per year, indicates

an increase of one and a half times. Those who bought cattle included not only upper-caste farmers but also farmers from the other castes. Income from milk provided them a regular cash flow and contributed to raising their confidence. With an increase in their overall income, the villagers also witnessed a general improvement in their socio-economic conditions, which is seen from the investments made in purchasing domestic electronic appliances such as televisions and refrigerators, hosting relatively lavish weddings (12 per cent families), undertaking pilgrimages (8 per cent), and purchasing vehicles. In addition, farmers have constructed new cattle sheds or have renovated the old ones. This was evidenced across all castes. Interestingly, the number of tractors in the village has jumped from 4 to 44; the number of two-wheelers has increased; at least ten people own four-wheelers today. Where necessary, farmers have also taken loans and repaid them at the earliest. For example, a sample of 28 farmers who took loans amounting to a total of Rs 12.96 lakhs have already repaid a fourth of the sum within a couple of years. Part of this sum was spent on replacing old pipelines or laying new ones and on buying, replacing, or repairing pumpsets.

7.4 Limits of Water Harvesting

How much water can a given village harvest without affecting the users downstream? This is a critical question in any water-harvesting activity. Further, it assumes great significance because in water-harvesting programmes a catchy slogan exhorts the people to 'catch water where it falls', in the farm and in the village. There are limitations on computing the harvestable quantum of water because storage is a function of aquifer characteristics. Aquifer delimitation is a very complex, time-consuming, and cost-

intensive exercise. Nevertheless, it helps to have a fair idea of how much water can be, and is being, harvested through a water-harvesting activity so that certain decisions on water-wise use and management can be taken. The Water Level & Specific Yield Method and the Regression Methods have been successfully employed in areas of unconfined aquifer to determine the recharge potential of rainfall (Bhattacharjee 1983, Athavale *et al.* 1983; and Athavale 2003).

For such a computation, the following steps were adopted and produced encouraging results for the villages under study. However, the present discussion is limited to Ambaredi.

- [i] The natural recharge values using the Water Level Fluctuation & Specific Yield Method (WL & SY) and the Regression Method (RE) were computed.
- [ii] The actual total volume of groundwater extracted by farmers in the year under consideration was computed based on primary data.
- [iii] Again, using the recharge factor obtained using the Regression Method, the total volume recharged was computed.

Natural recharge is a function of a number of parameters, such as rainfall, rainfall intensity, soil and climatic conditions, hydrogeology, depth of aquifers, and topography. An important consideration is the coefficient of variation (CV) of rainfall. The coefficient of variation is the ratio of the standard deviation of the average annual rainfall, computed for a large number of years (often 50 to 100 years), to the mean annual rainfall.

7.4.1 Computation of Natural Recharge for Ambaredi Village

[i] Water Level Fluctuation and Specific Yield Method:

Data on the water levels of wells belonging to 28 farmers from Ambaredi village were collected through a well inventory. One of the standard basic assumptions made is that the water levels reflect the changes that occur due to rainfall and recharge, and that the water level fluctuation is representative of the rainfall-recharge interaction. There are no other sources of recharge that would influence the water levels.

The Natural Recharge (NR) is given by the following equation (Athavale 2003: 24, Athavale et al. 1983):

NR = area (sq km) x average of difference of maximum and minimum water levels from wells (m) x specific yield (%) of the geological formation.

(1)

[ii] The Regression Method:

Based on a review of a large amount of data covering four rock types, namely granites, basalts, sedimentary, and alluvium, across 36 basins distributed all over India, regression equations describing the rainfall-recharge relationship were deduced (Athavale 2003: 27-29). The y-axis intercept of the least square fit denotes rainfall beyond which the surface run-off begins. In other words, this amount of rainfall is used up by the soil zone as moisture. Therefore, the natural recharge RE (in mm) can be computed using the regression equation given as (Athavale 2003):

RE = 0.174 (rainfall in mm)-62.

(2)

Next, the recharge factor obtained by the above equation was multiplied by the area of the village to arrive at the

volume of natural recharge for the year 2003.
(3)

[iii] Computing Groundwater Extraction:

It is also important to examine how the actual volume of groundwater extracted by farmers in the village through the wells compared with the above-mentioned natural recharge values. The primary data collected on the WEMs, pumping hours, etc. in all the three seasons for different crops were used to compute the total amount of water extracted for the year under consideration.

7.5 Analysis and Discussion

The average water-level fluctuation (denoted by the difference between the maximum and the minimum water levels in the wells) based on the field data was 8.1 metres. Using equation (1), the volume of rainwater that has been recharged into the ground was computed as 2.224 MCM and 6.67 MCM for specific yields of 1 and 3 respectively for basalt. The volume of water that has been recharged into the ground using the Regression Method is estimated as 1.83 MCM.

The volume of water pumped out by all the wells in Ambaredi village in the period following the construction and completion of the check dams, as computed based on the primary data collected on the pumpsets and their working hours and discharges, is 0.4661 MCM. The corresponding figure for the period before the recharge activity took place was 0.1506 MCM.

Table 2 shows the methods employed to arrive at the groundwater recharge based on the 1997 (GoG 1998) and 2002 (GoG 2004) norms and guidelines.

Table 2:

Computation of Groundwater Balance and Stage of Groundwater Development for Ambaredi Village

	Particulars	WL & SY Method	Regression Method
1	Gross GW recharge	2.2241	1.8331
2	For environmental flows @5%	0.1112	0.0917
3	Available GW recharge/year (1-2)	2.1129	1.7414
4	GW draft for irrigation from primary data	0.4661	0.4661
5	Domestic and industrial draft (15% of 1)	0.3346	0.2750
6	Gross GW draft for all uses (4+5)	0.7997	0.7411
7	Regeneration recharge @30% of (4)	0.1398	0.1398
8	Net GW balance (3-6+7)	1.4530	1.1402
9	Level (stage) of GW development (%)	37.9	42.6

Note: a) All figures in million cubic metres except for sl.no.9.
b) Minor mismatch in totals due to rounding off may exist.

Although the specific yield of basalt is estimated to lie between 1 and 3, in the present case, the value of 1 seems more acceptable¹¹ for the following reason. To begin with, the natural recharge values arrived at using the Water Level & Specific Yield (WL & SY) Method and the Regression Method [equations (1) and (3)] may seem to differ. However, when the stage of groundwater development is computed using these two values, the difference is less than 5 per cent, which is well within the prescribed 20 per cent (Table 2) in the GWRE 2002 guidelines.

Let us now consider how the natural recharge values arrived at using the WL & SY Method and the Regression Method compare with the total amount of rainfall incident in Ambaredi village. The total quantity of rainwater for the year 2003 for a rainfall of 740 mm works out to 20.322 MCM. The natural recharge values as computed by the two methods are

2.2241 MCM and 1.8331 MCM respectively, which constitute 11 per cent and 9 per cent respectively of the total. These figures compare very well with the recharge rates obtained by National Geophysical Research Institute (NGRI), Hyderabad, in basaltic conditions across India, that is, 8.14 to 13.3 per cent.¹² Looking at these figures, one may argue that not much benefit could be expected as the potential itself is so low. In the case of Ambaredi, if the natural recharge has reached 9 or 11 per cent, then the maximum scope is 13.3 per cent as per the available information. I believe that in the absence of water harvesting, the natural recharge rate would be much lower than this figure. The following data will help support my argument in more detail:

- [i] *Dry aquifers as an opportunity for storage enhancement:* The 9 or 11 per cent natural recharge rate has been achieved only in a good rainfall year, which is generally one out of a 4-5-year cycle. During this time cycle, whatever groundwater has been conserved is utilised. If some water is left over, then that tends to 'move away'. Therefore, the opportunity of dry aquifers to be recharged is completely open.
- [ii] *Check dams circumvent the recharge limitation of black cotton soil:* The above opportunity of filling up the dry aquifers becomes much more important because Ambaredi has black cotton soil, which does not facilitate recharge easily. Therefore, efforts to increase the number of recharge nodes in the form of check dams across rivers and rivulets (streams), combined with other soil and water conservation activities, will help in circumventing the recharge limitation of black cotton soil, as discussed earlier. The check dam movement, therefore, has

contributed to the enhancement of groundwater availability.

- [iii] *Environmental flows*: The computations take care of the question of environmental flows and drinking and domestic water requirements as per the official guidelines (GoG 1998 and 2004). The accounting of environmental flows also answers the oft-raised concerns regarding the denial of river flows to downstream users. This measure not only accounts for the flows but field observations also indicate that there are flows in the river for almost nine months of the year.
- [iv] *Other co-management activities*: Analysis of data indicates that the dispersed recharge activity has helped increase volumes not only to the soil but also to fill up the weathered and fractured zones. The recharge activity included farm bunds, gully plugs, and check dams, in addition to plantation on the catchment and wasteland areas. Since environmental flows are already accounted for, further innovations in the recharge activity along these lines would help convert part of the evaporation losses¹³ (especially during the monsoon) into usable water.
- [v] *Stage of groundwater development*: The stage or level of groundwater development is represented by the Gross Groundwater Draft from all uses/net available groundwater as a percentage. In the case of Ambaredi, the stage of groundwater development (post-recharge activity) for the year 2003 was around 40 per cent (see Table 2). This represents a twofold increase (that is, 309 per cent) compared with pre-recharge activity. It is clear that there is still further scope for groundwater development.

[vi] *Efficiency of water use*: People's initiatives—such as replacing open field channels by pipelines, replacing old and inefficient pumpsets with new and efficient ones, and replacing diesel pumpsets with electric pumpsets—also contribute to water use efficiency. Further, the farmers of Ambaredi have gone in for better seed varieties of cotton, groundnut, and wheat to increase their returns from agriculture. They have conserved water in wells for the rabi crop, which also provides them with fodder for animals. Vegetables, which form an important rabi crop, give them the necessary cash flow. Cultivation of summer crops is not too much in vogue because of the problem of neelgai (blue bull). However, some farmers have started cultivating fodder crops in the period following the construction of check dams because of the availability of water in their wells.

7.5.1 Can we further enhance aquifer performance?

This is a very difficult question to answer, but I would put forth my argument in the context of Ambaredi village as follows. For the purpose of simplification, and without going into the definition, boundary conditions, etc. of aquifers, we may equate the yielding zones as our aquifers contributing groundwater. Let us consider the WL & SY Method, in which the water level is an important basic variable. Even if we accept that the water level fluctuation has reached a maximum, and that it can result in no additional contribution if it reaches the hard rock depth, we can still manipulate the amount of groundwater that is extracted for agricultural purposes. How can we do this? As shown in Table 2, the stage of groundwater development indicates that there is still scope for 80 per cent increase in the harvesting and use of groundwater. One way to do this is by increasing the turnover of water extraction in a given year, in particular during the kharif and rabi seasons by suitable crop combinations. Second, the cropping intensity can be increased by expanding the area under summer crops (comprising fodder, bajra, and vegetables) by tackling the neelgai problem. A related strategy would be to augment flow into the wells by increasing the number, diameter, and length of the radial bores at the bottom of the wells, which is already being practised.

8.0 REVISITING THE KEY QUESTIONS

8.1 What Constitutes the Key Drivers?

The argument I put forward below to address this key question is based on a study of not just one village (Ambaredi) but is also based on a larger sample of a few

other villages, as described elsewhere. What comes out clearly is that it is not one factor but a set of factors that has contributed to driving the Saurashtra recharge movement.

- [i] *Adverse climatic conditions and committed leadership:* The adverse climatic conditions under which the largely agrarian community had to eke out a living, the limited number of options, and the demonstrated benefits of the initial dug well-recharging efforts have resulted in a captive following of the recharge movement. The size of this captive following went on increasing over time because of effective local leadership; more such nodes of recharge activity were established in other villages by local leaders.
- [ii] *Role of religious and social institutions:* In the mid-1980s, the promoting institutions, mostly belonging to spiritual and religious groups, played an important role in sustaining and propagating this movement. The whole environment was electrified by these strong spiritual and religious elements. The devotion and commitment of the torchbearers of these institutions (such as the Swadhyayees and the Swaminarayan Parivar) inspired the people, and a large number of local leaders did not hesitate to lead by example. The critical psychological barrier of 'the fear of the unknown' was thus broken, especially because most farmers generally prefer to play it safe. The risk taken by the upper-caste farmers also motivated the majority of the poor and marginal farmers, who generally looked to them for guidance.
- [iii] *Committed individuals:* The leadership of upper-caste individuals was gradually accepted by members of all castes as being important for the benefit of all. Premjibhai Patel, who belongs to an upper caste, and who was once

a businessman, is today a highly respected leader, well known for his service to farmers not only in Ambaredi but also in the whole of Saurashtra. He 'institutionalised' his activities by establishing an NGO (Vruksh Prem Seva Trust).

[iv] *Innovating innovations-Practice before precept*: The innovations made from time to time by individuals and institutions, often spending their own money and taking considerable risks, have managed to sustain the interest and curiosity of the Saurashtra farming community in the recharge movement. The innovators have gone one step further to prove their commitment by providing or arranging for the supply of essential material and equipment (such as small lengths of pipe, cement, and bricks) from local donors. Some local industrialists and business houses have not only contributed material but have also adopted villages. In some cases, the effectiveness of certain techniques was demonstrated in field tests, for instance, the experiment with porous pipes conducted by Shyamjibhai Antala, who also set up a production unit to bring down the cost of the pipes, which had hitherto been transported from Bombay at a cost that was 3-4 times higher.

[v] *Effective dissemination*: The role of some visionary leaders like Shyamjibhai Antala in capturing the various experiments and innovations and then propagating them through the local news media helped in keeping the formal communication channels open. Antala also collected and presented facts and figures to support his claims about the many benefits of the recharge movement. In addition, the local press played an important part. Several researchers also produced quick studies on certain aspects of the

movement. The leaders and representatives of the movement were invited to mainstream discussion forums (seminars, workshops, and other events) by various institutions; visits by scientists, development workers, and people from other areas imparted the necessary spirit and energy to the movement from time to time.

- [vi] *Watershed programme*: The recharge activity was connected to the watershed programme in 2001, when the Rajkot DRDA launched the programme. This brought the recharge activity into the official channels and was accepted by the government. However, nothing much has happened beyond that.

8.2 Factors that Sustain the Movement

The following are some of the factors that helped sustain the movement:

- [i] As in the case of Ambaredi, often the entire drainage area is treated with check dams and gully plugs. In addition, land is treated with bunds, farm ponds, and plantation. The approach may be loosely described as watershed with a heavy bias towards water-harvesting activity. This approach has distributed the benefits of the watershed programme in the form of increased water availability in wells even in the upper reaches.
- [ii] The immediate increase in returns from agriculture and livestock across castes, which was attributed mainly to the fact that the recharge activity 'hooked' the farmers to the movement and helped in its spread.
- [iii] People in Ambaredi have for long experienced prolonged periods of acute water scarcity and drought during which even drinking water became scarce. Even today, drinking

water supply in the towns of Rajkot district and under various village water supply schemes (where existing) is erratic; the supply becomes worse during the summer. In the case of dry years, drinking water is supplied once a week and families from rural areas migrate to other areas to escape hardship.

Premjibhai Patel, the torchbearer of the recharge activity in Ambaredi, is proud that the people of rural Saurashtra no longer have to contend with the problem of fluctuations in rainfall. Vast stretches of seasonal fallows have disappeared as water is now available in the wells even after rabi and the summer. Premjibhai Patel states that although there is plenty of water available for the summer crop, only around 30 per cent of the land is sown because of the neelgai problem. His contention is borne out by the fact that the stage of groundwater development (discussed in the Analysis section) indicates significant scope for further development. Vulnerability (to high CV) appears to have been reduced as the farmers are now cultivating crops every year.

- [iv] Water-harvesting activity is carried out by VPST in 27 villages around Ambaredi. This has resulted in the conservation of soil moisture and the growth of vegetation. The tree growth comprises predominantly babul (*Prosopis juliflora*) and neem (*Azadirachta indica*).
- [v] The movement has retained its 'independence' and self-sustaining character thanks to many motivated NGOs and other institutions. There has been no specific programme support from the government, except for the watershed programme. Even here, the contribution of the government project for a typical check dam is one-third, while the farmers contribute two-thirds. To top it all, the

project cost is 10 per cent less than the actual estimates as per the Standard Schedule of Rates for the Rajkot district, which is to be collected as local contribution. In effect, the local contribution is very high, totalling three-fourths of the total cost.

8.3 Missed Opportunities?

No funding agency has come forward to support the movement, as has happened in similar cases in states such as Rajasthan. The movement has continued with local support, mainly from industrialists and local entrepreneurs, and with people's contributions.

Very little scientific investigation has been done at a significant scale to assess the impact in quantitative terms in complex hydrological, hydro-geological, and topographical conditions. In terms of documentation too, except for a few specific studies that have focused on quick estimations of water recharge, economic returns from crops, and broad institutional analysis, no in-depth, large-scale scientific studies have been carried out. There is still scope and opportunity for a systematic and scientific study of the movement covering subjects such as institutional dynamics, the economics of agriculture and animal husbandry, and the importance of water balance. Longitudinal studies of the effect of the recharging movement on groundwater quality, *inter alia*, are important. Similarly, almost no studies exist on the adaptive strategies of the local rural communities where water-recharging activities have been undertaken. For all these studies, new scientific tools such as remote sensing, GIS, and perhaps mathematical modelling would be very helpful.

As mentioned elsewhere, support from the government has been very limited. At one point of time, the state government responded by first promising, and then at length withholding, a subsidy for the recharge of wells by private farmers. This led many farmers to abandon their ongoing recharging activities. This official dilly-dallying would have killed the spirit of the well-recharging programme but for the vigorous efforts of the Swadhyayees, the Swaminarayan Sampradaya, and well-meaning NGOs to divorce the well-recharging movement from the promise of government subsidies (Shah 2000). If the government is not to play a spoilsport, then a special programme designed exclusively for Saurashtra is required. Such a programme should have a perspective plan that describes the objectives, approaches, and expected outputs and outcomes. Needless to say, the preparation of this perspective plan must necessarily involve the protagonists of the Saurashtra movement as equal partners, and later as implementation and monitoring partners.

9.0 CONCLUDING REMARKS

The discussion clearly brings out the fact that although water harvesting started out as a simple well-recharging activity, the diversity of participating individuals and institutions, and the variety of innovations and methods adopted, have had transformed this activity into a wider social movement. The participation of local people and various institutions has contributed to it becoming a movement of social resource management. But can the movement be said to have achieved groundwater governance?

Viewed from the point of view of the total water recharged or extracted, and the difference made by natural recharge, all the efforts made by the entire village (Ambaredi) would

appear to be minuscule. Critics might use this fact to argue for the need to take the semi-arids out of the agrarian production systems. However, as shown by this study, the same minuscule amount of water has brought about some very significant and positive changes in the lives of the majority of the people of Ambaredi, mainly through water harvesting. The significant change in the socio-economic conditions of the residents of this predominantly agrarian village indicates the importance of groundwater as a key driver of livelihood improvement. That the water-harvesting approach adopted so far has been sustainable is, by and large, vindicated by scientific scrutiny. The commonly used indicator, the stage of groundwater development, for instance, reveals a large but untapped potential for further safe resource use and development. Adaptive management, after all, means resource management for the sustainable and long-term benefit of humans and animal stock. For Saurashtra, the case study of Ambaredi village reveals to the promoters and practitioners of the well-recharging movement where they stand in their efforts and what they have achieved so far. Most importantly, the well-recharging movement has succeeded in raising the self-confidence and risk-taking ability of the farmers, who have gained both socially and economically. And growth is all about taking risks.

Importantly, the case study also addresses one of the basic issues being debated of late in the area of resource management for livelihoods: *to adapt or not to adapt*, wherein long-term resource management, especially in the arid and semi-arid regions, is often neglected (or sacrificed) in favour of short-term gains (Mudrakartha 2007). There is an increasing demand for (and willing official consideration of) alteration in land use in such areas for non-agricultural

purposes, for example, for setting up special economic zones (SEZs). A majority of the agrarian families that are lured by tempting offers to sell their land is often reduced to penury; 12 out of 15 farmers who sold away their lands in for setting up a water park during early 1990s in the drought-prone Mehsana district in Gujarat later regretted their decision (Mudrakartha 2004).

The Saurashtra well-recharging movement is primarily an effort of the local community to conserve a depleting and degrading vital resource. The future development of the movement in the context of the theory of adaptive management (see Figure 1) will be determined by the strength of the resource-governance mechanisms.

The socio-technical nature of water management demands the participation of formal governance structures in addition to the involvement of civil society institutions. Resource governance, therefore, can happen only when the concerned stakeholders understand, appreciate, and fulfil their roles and responsibilities. Except for the flexibility provided in the Rajkot district watershed programme, the government sector has been more absent than present. Interestingly, the other stakeholders—religious and social institutions, village communities, NGOs, social reformers, certain individuals and local leaders, the local press, and, more importantly, some local private and corporate business houses—have all contributed to carrying the movement to its present level over the past two decades. Since certain resource control and regulation functions lie within the realm of the government, it becomes imperative that the stakeholder domain of this part of the governance should be strengthened. This means not only the control functions but also those that will enable the

strengthening of the movement. The following are some of the actions recommended in this direction:

- [i] Provide technical support to NGOs supporting the movement by carrying out studies to quantify the recharge and other parameters.
- [ii] Make available new scientific tools, such as remote sensing and GIS, to further monitor and improve the effectiveness of the interventions, such as check dams, gully plugs, and farm ponds. Enhance check dam efficiency by providing technical guidance to farmer in its selection.
- [iii] Other concerned departments, such as groundwater, agriculture (including research and extension), soil and water conservation, panchayat, women and child welfare, need to converge their activities to build on the tremendous social capital generated.
- [iv] Convergence with other programmes, such as forestry, wastelands development, and horticulture, would strengthen the adaptive capacities of the communities. In short, forward and backward linkages such as those with agriculture are essential.
- [v] Support awareness-raising and capacity-building programmes for local communities and institutions.
- [vi] Lastly, the pioneering individuals and institutions that have led the movement need to be represented in the formal governance structures to integrate and institutionalise their experiences, and thereby maximise social capital, in the long-term interest of conserving water resources. The core in the form of social capital is ready. It is only the peripherals that need to be worked on.

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Endnotes

- A social movement is an autonomous and self-conscious movement of people united by their support of an ideal or principle or goal rather than by the pursuit of their material self-interest (though material interests are generally not too far below the surface) (Encyclopaedia of Marxism).
- 2 One such example is Dharoi in Mehsana district, in Gujarat state.
 - 3 Red boles are relics of inter-trappean lateritisation. Another explanation is that red boles are formed as the result of the 'baking' of the pre-existing clay by the invading volcanic flow. In Deccan traps, red boles usually occur as thin beds and are useful as marker zones for delineating lava flows (Mudrakartha 1987).
 - 4 The basal portion of an invading lava flow is usually altered into green earth as a result of weathering. This green earth occurs not only between flows, up to 3 metres thick, but also as veins in cracks and fissures (Mudrakartha 1987).
 - 5 Specific yield is defined as the volume percentage of groundwater yielded by a saturated formation under gravity conditions.
 - 6 The watershed programme has been supported by DRDA since 2001.
 - 7 The number of wells has now increased to 210 (December 2007), including some 10 bore wells.
 - 8 Only some key aspects are discussed here, such as livelihood and some indicators of socio-economic conditions.
 - 9 1 mann = 20 kg.

- 10 1 acre = 2.5 bighas.
- 1 The same pattern was found for five other villages too. Hence, specific yield seems to be more appropriate in the case study taluka.
- 12 The values in the reference (Athavale 2003: 27–28) are given in millimetres (mm), which have been converted into percentages by the author.
- 13 The evaporation losses for Rajkot district are quite large, about 350 mm per year.

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