Chasing the Watertable

Equity and Sustainability in Groundwater Management

Marcus H Moench

Degradation and depletion of groundwater resources is emerging as a major concern in many arid and hard rock sections of Gujarat. Depletion tends to disproportionately affect the poor by further limiting their access to the resource. Unfortunately, the same can be said for most management alternatives other than supply creation. Inherent tensions exist between equitable access to groundwater resources and management options to ensure sustai. able use. New institutional approaches—similar, for example, to those used in joint forest management—are required which can incorporate both equity and sustainability goals.

This paper reviews emerging groundwater degradation issues in Gujarat and their implications for equitable resource access. Current management practices and proposed alternatives are examined from both resource sustainability and access equity perspectives. Innovative institutional approaches based on user-groups are discussed and their viability is examined through lessons from the management of other common pool resources. It is argued that the dual goals of sustainability and equity may be best served through management institutions based on local user groups.

I

Introduction

THE state of Gujarat, in north-western India depends heavily on groundwater to meet municipal, industrial, and irrigation needs. Much of this dependence is due to the high variability of available precipitation.

The average rainfall in Gujarat ranges from nearly 1500 mm/yr in southern portions of the state to less than 400 mm/yr in northern districts such as Kutch. Surface water availability is limited throughout north Gujarat. In addition, rainfall distribution is erratic. There are, on average, eight-ten rainy days in the year and rain actually falls for a total of only 12-15 hours in Kutch [Pisharote 1992]. Half the annual rainfall typically occurs over a period of two-three hours during the monsoon season. Inter-annual variability is also great. The area near Mandvi received 654 mm over a four day period in July 1992 after receiving only 185mm total in 1991.[1] Under these conditions, runoff is intense and only lasts for brief periods. Even in high rainfall sections of the state precipitation is highly seasonal. Out of an annual average of 51 rainy days in south Gujarat, 48.5 (accounting for 94 per cent of the total rainfall) occur between June and September.[2] Surface streamflows reflect the high seasonality and variability of precipitation. Most rivers in north Gujarat are annual, while those in the south have high floodflows and low baseflows. Rainfall and stream flow variability result in high dependence on groundwater. Overall, groundwater accounts for over 76 per cent of the irrigated area in the state and is also the basic source of supply for many municipal and industrial uses [Phadtare 1989].

Groundwater extraction in Gujarat has grown exponentially over the past four decades. In 1950-51 there were roughly 900 electrified wells in the state, by 1990 the estimated number was 4,26,000 [Dadlani 1990]. The rapid growth in extraction has led to overdevelopment of groundwater resources in many parts of north Gujarat and along coastal areas. Water shortages are a common topic of debate each summer. Management needs are increasingly evident. How to address them is widely debated.

II

Overdevelopment

(a) Physical Aspects

Until very recently official estimates of recharge and extraction painted an optimistic picture of resource availability. According to estimates made as recently as 1986, only 31 per cent of utilisable recharge to unconfined aquifers in Gujarat was extracted and a further 3.2 million hectares could be sustainably irrigated from groundwater [Government of Gujarat, 1986]. Estimates made over the past few months change the picture dramatically. They suggest that, statewide, the net draft accounts for 58 per cent of the utilisable recharge and a further 1.23 million hectares can be irrigated [GOG 1992].[3] Extraction is now estimated to exceed recharge in 24 taluks and is greater than 65 per cent of recharge in further 36 taluks [GOG 1992].

It is interesting to contrast the 1986 estimates with those published in the last few months. In 1986, although estimated levels of development were low in unconfined aquifers, estimates of groundwater in confined aquifers suggested that they were approaching full development throughout north Gujarat. Extraction exceeded 70 per cent of recharge to confined aquifers in Ahmedabad, Gandhinagar, Sabarkantha, Mehsana, and Surendranagar districts and was over 40 per cent in Banaskantha (see Table 1).

Levels of groundwater development in unconfined aquifers estimated in 1986 were at odds with high levels of development in deeper aquifers. Why farmers would develop deep aquifers if substantial resources were available near the surface is unclear. Falling water tables also suggested that overdevelopment was a problem in surface aquifers (Table 1). Groundwater maps prepared by the Central Ground Water Board (CGWB) for the period April 1979 to May 1987 show drops of >2m throughout most of Gujarat excluding canal command areas. In large areas the decline was > 4m and water levels in the unconfined aquifers were > 20m below ground level. Declines are long term in extensive areas. Between May 1978 and May 1990 water tables dropped four-eight m over large portions of Ahmedabad, Sabarkantha, Mehsana, and Banaskantha districts [High Level Committee 1991]. Unconfined water table declines in parts of Banaskantha district have averaged one-two m/year [KON and GOI 1992]. Even higher rates of decline are common in Mehsana district. In 1981, Phadtare reported declines of 2-3.5 metres per annum in the confined aquifers of south Mehsana and 0.5 metres/year in east Mehsana [Phadtare 1981: p 45]. This has now increased to a rate of five-eight metres/year [GOG 1992: p 24]. Artesian conditions—which existed in deeper confined aquifers over large parts of the district as late as the 1960s—are now confined to areas near the gulf and Rann of Kutch [GOG 1986, 1992]. UNDP reports written in 1976 recommended reducing extraction by 25 per cent in parts of north Gujarat [UNDP 1976]. The problem of falling water tables is not just associated with irrigation in rural areas. In Ahmedabad drops in the water table of 1.5-1.9 m/year are common with outlying areas reporting drops of 3-6 m [CSE 1985: p 34]. As early as 1974 estimates placed the annual extraction from aquifers underlying Ahmedabad at 200 MCM/yr —2.5 times the estimated annual recharge of 80 MCM [Pathak 1985, p 12]. In sum, despite the rosy picture of availability prevailing until recently in official estimates, overdevelopment has been clearly emerging as a problem for the past few decades. Rates of water table drop now threaten agricultural and other users with scarcity in the near future.

In addition to long-term drops in the water table, seasonal depletion—wells running dry for substantial portions of the year—is emerging as a major problem in many hard rock sections of Gujarat. Since well levels are monitored only twice a year, available data do not capture seasonal dynamics. The problem of wells running dry relatively rapidly after the monsoon is, however, a common complaint of farmers in most hard rock areas I have visited during the past two years of field work.

The essential dynamics of the seasonal depletion problem are as follows: Lacking significant primary porosity, groundwater storage in hard rocks depends on the degree of weathering and fracturing. Specific yields typically decline with depth since weathering and fracturing are most intense near the surface [UNESCO, 1984].[4] As a result, the overall aquifer storage capacity in hard rock areas tends to be much more limited than in other geologic environments. Groundwater availability is, as a result, often limited by aquifer storage capacity not infiltration rates or the volume of water potentially available for recharge. As well numbers grow, high extraction rates in hard rock areas can result in a rapid seasonal drawdown of water levels. In this case, although aquifers may be fully recharged at the end of each monsoon, increases in the number of wells can simply increase the rate of seasonal depletion with little or no increase in the actual amounts of water extracted.

The emergence of groundwater quality problems is also often related to overdevelopment of the resource. Data collected by CGWB and GWRDC indicate that saline intrusion related to overpumping affects substantial coastal areas in Saurashtra and Kutch. In addition, the deep unconsolidated sediments in central Gujarat are made up of interbedded marine and alluvial deposits. As a result, fresh and saline aquifers are often found at close proximity. Most of these aquifers are leaky and pumping in fresh areas has caused the migration of saline water into fresh systems [High Level Committee 1991]. The net result in many areas has been a decline in the quality of groundwater.

(b) Equity Implications

Falling water tables and declining water quality have strong equity implications. In alluvial areas dug wells are often limited by wall stability to relatively shallow depths (20-30 feet). As the water table declines these go out of production and farmers who cannot afford to construct tubewells lose direct access. The GWRDC monitors a network of over 80 dug wells in Mehsana district. In May 1973 none of these wells were dry. By May 1990, 43 per cent of the 86 wells for which data are available were dry.[5] Similar patterns are present in other districts. In Banaskantha, the number of dry wells in the monitoring network increased from 0 to 78 per cent over the period 1979-1991. In Ahmedabad the increase was from 2 per cent to 34 per cent. The construction of tubewells in areas such as Mehsana is expensive due to overdevelopment of the upper aquifers and the consequent deep drilling depths required to reach fresh water. Discussions with farmers in Mehsana district indicate that tubewell depths of 400m are not uncommon and construction costs exceed Rs four lakh ($ 13,000-14,000). Given the high cost of developing new water sources, less wealthy farmers are at a distinct disadvantage in their ability to compete by "chasing the water-table". Most new wells in areas such as Mehsana are constructed by partnerships consisting of up to 100 farmers and water markets are common. Even given these factors, however, the increasing cost of obtaining access to water places a larg... :ount of pressure on marginal farmers.

Quality problems can have similar equity implications. Importing fresh water has been a typical farmer response to saline intrusion. Farmers in Husseinabad, a village affected by saline intrusion in Saurashtra, have purchased small plots of land 1-3km inland, installed wells, and piped the water out to their fields. One co-operative in Lohej imports water over a significant distance for its 150 members [Shah, 1989a, pp 13-14]. Except where co-operatives exist, the ability of farmers to respond to quality problems in this manner depends on the financial resources they can muster for land purchases and long-distance pipeline systems.

III

Traditional Management Options

(a) Supply

The most common response to water shortage problems in Gujarat, as elsewhere in the world, is to seek new external sources of supply. The Sardar Sarovar project (SSP) is a typical case in point. Although portrayed and viewed by most residents of the state as a "final" solution to Gujarat's water problems, even the most ardent proponents admit it will not address groundwater depletion in many areas. The total overdraft in the districts of Ahmedabad, Sabarkantha, Gandhinager, Mehsana, and Banaskantha districts alone is estimated at roughly 0.9 MAF/year [High Level Committee, 1991]. This is equivalent to 10 per cent of Gujarat's entitlement from the SSP at full development. Even if this amount could be freed from other commitments, many areas suffering from water table drops (such as most of Sabarkantha and Mehsana districts) do not fall into the project command. Furthermore, estimates suggest that the number of wells in areas such as Mehasana are growing at roughly 10 per cent per year.[6] Demands on groundwater resources are clearly increasing. This will necessitate larger allocations for groundwater recharge if reliance on a supply-focused approach continues.

Aside from the SSP, alternate sources of supply for groundwater recharge are limited. Most streams in north Gujarat are annual and relatively little water goes unutilised. Even in south Gujarat, where rainfall and stream flows are much higher, there is a major debate over the existence of 'surplus' water for allocation to water short regions.[7] In sum, large sources of surface supply are approaching full development and are unlikely to be available for groundwater recharge. Reliance on inter-basin transfer as a response to overdevelopment is thus unsustainable.

Apart from sustainability, approaches focused on the development of major new supplies are not without their equity implications. Major inter-basin water transfers, as the SSP illustrates, often result in the displacement of large populations. These populations are frequently marginal in the first place and are rarely resettled in areas that benefit from the water transfers. Even where inter-basin transfers are not considered, the development of supplies high in a basin is often to the disadvantage of downstream users. The Dharoi Dam on the Sabrimati river has caused water levels in unconfined aquifers to rise in its command, an area which had previously suffered from overextraction [CPCB, 1989, p 4; Pathak, 1985, p 10]. At the same time, retention of water by the dam during the non-monsoon

Table

District	1986 Estimated Per Cent Development		1992 Per Cent Development	Water Table Decline in Meters	
	Unconfined	Confined	Total	Unconfined 78-90	Confined 78-90
Ahmedabad	23	97	87	4-8	to 20
Gandhinagar	30	97	83	4-8	to 20
Banaskatha	33	40	90	4-8	to 20
Sabarkatha	43	97	71	4-8	to 30
Surendranagar	37	72	55	na	na
Mehasana	66	88	194	4-8	to 40

Column 1 and 2, from Government of Gujarat (1986).
Column 3 from Government of Gujarat (1992).
Column 4 and 5 from High Level Committee (1991) text and maps.

period has reduced flows from 50-150 m^3/s to less than 1 m^3/s just below the dam [CPCB, 1989, p 38]. Reduction in base flows has had a major impact on pollution levels and drinking water availability in Ahmedabad. Data collected by Sanchetna, an NGO, indicate that slum communities receive as little as 7.5 lcpd from municipal supplies. These communities and many downstream villages used to depend on the river as a clean source of drinking water [Matzger and Moench 1992]. Some official publications now describe the river as a "sewer" and local residents do not drink from it.

Overall, attempts to develop major new sources of water supply often involve impacts on populations in source or downstream areas. Those portions of the population most affected are generally poor. In sum, most large supply development options have strong equity implications.

Local approaches to supply augmentation are often discussed as alternative to inter-basin water transfers in Gujarat. Recharge structures in Kutch have been shown to directly benefit local communities under the appropriate geological conditions [Raju, 1992]. The amount of water possible to capture using local recharge structures is, however, untested. High intensities and the extreme variability of rainfall patterns may limit the amount of precipitation structures can capture and therefore the amount of recharge it is reasonable to expect. In precipitation regimes where most of the annual rainfall occurs in a few hours, it is difficult to safely construct structures capable of capturing significant portions of flood flows. Furthermore, land availability for recharge structures is often limited, particularly in the vicinity of major agricultural areas. As a result, the actual extent of recharge it is possible to achieve under prevailing geologic and climatic conditions is a key uncertainty in the local recharge approach. Furthermore, recharge structures require maintenance. Most government programmes are directed at structure development and contain minimal maintenance provisions. Local communities generally display little interest in contributing to maintenance of structures they view as government owned. As a result, maintenance is a perennial problem and existing recharge structures probably make a limited contribution to available supplies.

Despite the limitations of current recharge efforts, local recharge activities should be a key component not just in new supply but also in increasing the efficiency of water use. Recharge high in a basin can enable water to be utilized multiple times before it flows to the sea or declines in quality limit its usability.

(b) Credit and Electricity Access Limitations

Aside from supply creation, Gujarat has attempted to address groundwater depletion problems via regulating credit for well development and limiting access to electricity connections. Groundwater recharge and extraction estimates are made on the basis of blocks and talukas (local administrative units). Where extraction exceeds 65 per cent of recharge the area is declared 'grey' and access to government subsidised credit is limited, where it exceeds 85 per cent most credit is cut off. In addition, the installation of new electricity connections for pumps is supposed to be contingent on approval by the GWRDC in groundwater problem areas.

Neither credit limitations nor restrictions on electricity connections have proven particularly effective in limiting the growth of groundwater extraction. Farmers, particularly wealthy ones, can often tap private sources of capital for well construction. Discussions with individuals in numerous parts of Gujarat suggest that credit availability from the banks is rarely a major factor in the decision to dig or drill a well. Electricity connections are also not a strong limiting factor. Where the groundwater table is still relatively shallow farmers utilise diesel pumps when electricity is unavailable. Where submersible pumps are required, as in Mehsana district, farmers state that electricity board officials will forget the GWRDC approval requirement for a bribe of roughly Rs 1,000/- ($ 33). This is a small fraction of the total cost of developing a well in those areas where submersible pumps are required.

Credit and electricity restrictions have significant equity implications. Access to sources of private capital and interest rates are often dependent on wealth and the borrower's social status. Thus, any limitations on access to groundwater resources imposed by cutting formal sources of credit will not apply to the wealthy. Credit limitations through financial institutions may also lead to proportionately higher costs of capital for borrowers who are perceived by private lenders as less reliable. Where electricity connections are concerned, wealthy and 'progressive' farmers often obtained them early. They receive electricity at highly subsidised rates.[8] Less advantaged sections of rural communities often did not obtain electricity connections early on and are now forced to depend on diesel, a much more expensive option. Overall, the primary effect of credit and electricity restrictions appears to be an increase in the cost of access to groundwater particularly for the poor.

(c) Centralised Regulation

The central government circulated a model groundwater act to all states in 1970 [Dave, 1983, p 505]. Gujarat passed groundwater legislation in 1976 but the act was only brought into force for certain areas in 1988 [Jacob, 1989, p 3]. Gujarat's act defines terms, and allocates power to regulate and license tubewell construction, control groundwater use, prevent waste, and make regulations [Sinha and Sharma, 1987, p 12].

Implementation of regulations under the Gujarat legislation has proved difficult. Political opposition has blocked all attempts in areas where the act has formally been brought into force. How regulations limiting groundwater extraction could actually be enforced even if the political will were present is open to question. With wells in private hands and a firmly entrenched tradition equating groundwater use rights with ownership of the overlying lands, centralised enforcement would require development of a major and highly intrusive organisation. Given what Dhawan (1989a, p 9) calls the "inadequate administrative set-up in the countryside, and eroded state of ethics" the development of effective and impartial state institutions for implementing groundwater regulations appears unlikely.

Equity is also often an issue with centralised regulation. Less wealthy or otherwise advantaged sections of society generally lack effective representation in the government organisations charged with developing or enforcing management systems. Furthermore, influential sections of society are often able to bypass regulations.

Overall, the problem enforcement raises significant questions over the effectiveness of centralised regulatory approaches. As a result, these approaches are unlikely to have a significant effect on the sustainability of groundwater use patterns. Given the ability of wealthy sections of society to bypass regulations, this approach may simply serve to allocate resource access to them.

(d) Energy Pricing

Various economic levers have been proposed as tools for encouraging groundwater management. Chief among them is the manipulation of energy prices. These serve as a proxy for water prices because pumping costs are directly dependent on energy rates.

Electricity for pumping is currently provided for an annual fee based on pump horsepower. Once the fee is paid, farmers can utilise as they wish with no change in costs. In fact, as they pump more the average cost of each unit declines linearly. This creates a strong disincentive to invest in either electrical or water use efficiency measures.

Pump energy efficiencies measured in the field typically range from 13-27 per cent as opposed to the 50 per cent efficiencies regularly achieved in other parts of the world [Patel 1991]. Where water use is concerned, farmers often depend on unlined channels for carrying water to the field and flood irrigation—both of which are relatively inefficient in terms of water delivery to crop roots and pump energy. While a portion of seepage 'losses' may ultimately be available for repumping, it is not clear how much they actually are in situations where the water table is deep and confined aquifers are being tapped.[9] Furthermore, in many areas where the water table is high salinity is a problem—damaging the usability of water recharged through seepage. Since these situations are common in much of northern Gujarat, seepage losses probably represent a major overall inefficiency in the end use of irrigation water. Additional inefficiencies result from problems in power supply. Due to uncertainties in availability and the rotation of power to different areas at night, farmers state that they apply as much water as they can when power is available.

Unit pricing of electricity is widely advocated by academics and donor agencies as a method to improve the efficiency and sustainability of energy and water use. It is unclear how much effect this would by itself have. Comprehensive data for estimating farmer water use responses to changes in the energy price structure are unavailable. Discussions with farmers in a variety of areas over the past two years suggest, however, that the effects of price changes alone would be limited.

Farmers dependent on diesel engines face unit pumping costs that are an order of magnitude higher than the equivalent electricity charges.[10] Diesel-powered irrigation is, as a result, carefully managed. According to farmers, the cost of diesel can reduce crop profits by 90 per cent. Most of those using diesel claim to apply water as carefully as possible. At the same time, farmers dependent on diesel generally follow the same cropping patterns and use the same open channel-flood irrigation techniques as those using electricity. The cost of irrigation energy is only one among a variety of factors influencing crop choice or the use of efficient irrigation technologies. In the US, commodity prices have been found to play a greater role in water use decisions than the energy costs associated with falling water tables [Sloggett and Dickason 1986]. There is little reason to expect different results in India. As a result, approaches dependent primarily on energy pricing may not contribute greatly to changes in the sustainability of groundwater use.

Where equity is concerned, studies suggest that current highly subsidised annual fee-based electricity pricing structures may encourage relatively equitable access to groundwater in areas where water markets are present [Shah and Raju, 1987; Shah, 1989b,c,d]. Water sellers having electrical pumps generally charge lower hourly rates than those using diesel. Field work in Mehsana district indicates that in some cases where commands overlap well owners also compete for water sales as a way of making back fixed electricity costs. Both these factors increase access to groundwater for the poor. Shifting to higher consumption-based electricity charges could have negative effects on access to groundwater for poorer farmers.

In sum, shifting to consumption-based electricity price structures may encourage water use efficiency. Given the lack of clear differences in cropping patterns between farmers dependent on diesel and those using electricity, energy price changes alone appear unlikely to have much effect on cropping decisions and thus the overall sustainability of water use patterns. This does not, however, negate the importance of rectifying electricity tariffs.

Changes in energy pricing structure might have a much larger impact if used in conjunction with other measures designed to improve water use efficiency. Additional measures are available. In the western US, for example, utilities often promote and subsidise efficient water and energy use technologies. Electricity bills there arrive with pamphlets describing measures that individuals can take to reduce their energy costs and programmes that the utility has developed to help individuals install the measures. A similar approach could be used in Gujarat to promote channel lining, drip irrigation, or other efficient water delivery technologies. The important point here is that establishing an incentive to conserve (via electricity price increases) is combined with an increase in access to conservation techniques. Neither price increases nor the promotion of efficient technologies is likely to have much impact in isolation. The combination could, however, produce significant improvements.

Another approach would be to increase the economic impact of inefficient practices beyond what is possible through energy prices alone. Taxes based on crop water consumption could, for example, be used in water short areas. Pricing electricity at rates great enough to significantly affect crop economics is probably not politically feasible. Combining unit-based electricity charges with taxes or other measures affecting crop economics could be much more feasible.

Overall, electricity price mechanisms are unlikely to have much impact if used in isolation. If used in conjunction with other measures that increase their impact on crop economics and/or increase access to efficient technologies they could have a much more significant impact.

(e) Equity and Sustainability Tensions

Inherent tensions exist between equity and sustainability goals with most water management options. Well off farmers are generally able to bypass regulations and obtain credit or access to electricity connections. They often already have wells and if power charges are increased are able to afford them or make investments in efficiency. Overall, most traditional management actions that could reduce rates of groundwater extraction in overdeveloped areas are likely to disproportionately affect the poor.

The balance between sustainability and equity goals needs greater examination in the debate over management actions. Most management actions are focused on sustainability considerations. Their effectiveness is often unclear. In some cases where, for example, recharge rates are negligible, sustainable use is an unrealistic goal. In this case limitations on access to groundwater could be equivalent to allocating the entire resource to wealthy sections of society. In some cases, it may be more appropriate to focus on equity goals, in others on sustainability.

IV

The User Group Alternative

Decentralised groundwater management through user-groups is increasingly discussed as an alternative to approaches traditionally considered by the government.[11] User-group management of natural resources has always existed in some form in India. It is gaining new attention through programmes for joint forest management and farmer association control over irrigation minors. Given the high degree of private participation in groundwater development, whatever groundwater management is presently occurring is *de facto* through users. User-group management may, therefore, be more feasible to implement than management by governmental agencies.

(a) Option Description

User-group management of groundwater resources covers a wide range of potential situations. At the micro level, it could simply involve a small group of farmers organising themselves to jointly construct a well and distribute its water among themselves. This is already occurring in areas, such as Mehsana district, where rapidly falling water tables have made construction by individuals unaffordable [Moench, 1991a]. At higher levels the user-group concept would encompass implementation of sophisticated management systems by quasi-governmental user-controlled associations such as the water districts of the western US [Moench 1991a, b].

The ability of user groups to address groundwater depletion problems necessitate organisations capable of undertaking actions beyond simple resource development. At a minimum, organisations would need to be able to manage and maintain recharge or other supply supplementing structures built by the government. In most cases this would not be sufficient and associations capable of developing systems to limit water use to sustainable levels would be required.

(b) Organisational Issues

Groundwater management through user-groups faces a variety of challenges from the perspective of common property resource management experiences. Local institutions tend to require certain conditions to establish effective management systems under common property conditions. Management often occurs when: (1) user group and resource boundaries are clearly defined; (2) resource use and condition information is available; (3) free riders can be controlled and management decisions enforced; and (4) broad support exists for management (Reviewed in Moench, 1986). These conditions become difficult to meet as group size and heterogeneity grow. In a study of 93 groundwater management groups in India, Nagabrahmam (1989) found average sizes from three to 21 members. Several groups identified small size as a factor in their success. Group homogeneity (economic and caste) also influences community well nanagement success [Ballabh and Shah, 1989].

The physical characteristics of groundwater depletion problems often run directly counter to social factors needed for effective user-group management. Aquifer boundaries are often poorly known making resource and user group boundaries unclear. Resource condition and use information are difficult to obtain. As a result, it may be difficult to establish broad support for management. Free rider control is also likely to be difficult. Wells are generally private and use rights strongly entrenched. How user-groups could enforce extraction limitations is open to question. Finally, management scale is likely to be a major issue. Unless resource use patterns can be managed at an aquifer scale, depletion problems will be impossible ... address. Physically appropriate management areas will often contain large, heterogeneous, user-group populations.

Overall, to use Tushaar Shah's term, an appropriate "design concept" for user-group based organisations to manage depletion problems may be difficult to identify. Farmer organisations tend to form where individuals feel a strong immediate need and perceive a clear direct benefit from organising. Partnerships to construct wells in areas where groundwater depletion has made construction by individuals unaffordable are common and serve as a prime example. Management attempts to address depletion will often lack directly traceable benefits for individual members. Since overdevelopment rarely affects water levels or quality in all parts of an aquifer equally, individual perceptions of need will also vary greatly.

The above considerations imply that direct management by user-groups stands the greatest chance of success where groundwater conditions can be directly influenced by local actions. This might be the case where, for example, recharge structures, check dams, or tanks can be shown to directly benefit a limited number of wells. Farmers should have an incentive to organise for the construction and maintenance of such structures. A similar situation would exist where use reductions lead to directly observable improvements in water table levels or quality by those practising water conservation. As benefits become progressively more diffuse, for example in the management of aquifer systems covering large areas, the organisational complexity of management through user-groups will increase. In order to overcome the limitations on group action suggested by common property experiences, user-group management would probably require the evolution of quasi-governmental water-user associations, similar perhaps to water management districts in the US. These could be governed by user-group representatives and might have a permanent professional staff. Their primary theoretical advantage over governmental institutions would be direct control by user representatives over management and policy decisions. With this, the organisations might be able to establish a stronger base of support for difficult management actions than government organisations are able to achieve.

Groundwater ownership rights will probably be a critical issue facing any organisation attempting to implement a management system. At present, groundwater rights are attached to land ownership. Anyone who owns land has the legal right to drill wells and use as much water as they desire. As a result, any management system attempting to directly regulate groundwater extraction would be open to legal challenge. On a practical level this means that there is no legal basis for taking action against individuals or groups who damage groundwater availability for others or violate management agreements. Groups investing in recharge structures would have no direct legal means of preventing overlying landowners from exploiting the newly created resource. Indirect regulation of water use (by, for example, crop choice restrictions) might be less vulnerable to challenge. There is no doubt, however, that the lack of clear property rights over groundwater will greatly complicate any management group's ability to protect resource improvements gained through their efforts. Reforming the structure of groundwater rights may be a critical first step if user-groups are to play a significant role in groundwater management. This could be done in at least two ways: direct privatisation of water rights or through laws (such as prohibitions on waste or excessive pumping) that empower local groups to protect resource condition.

(c) Potential Management Mechanisms

Assuming effective organisations could be established, there are a variety of ways in which they could manage groundwater resources. Local organisations are well situated for developing and maintaining structures for supplementing supplies. Detailed knowledge of local conditions should enable organisations to construct structures in the most favourable locations. In addition, if direct linkages can be established between recharge actions and observed benefits, local organisations should be able to mobilise resources for structure construction and maintenance.

On the end-use front, local user-groups could play a major role in the adoption of efficient water use technologies. NGO and government extension activities could use local organisations as a focal point for disseminating knowledge concerning the availability of different technologies and any programmes supporting their adoption. With support, user-groups could also become involved in the redesign and adaptation of technologies to suit local conditions. In the western US, active participation of farmers in the modification and development of new water application technologies through farmer-controlled organisations has been a critical feature in their adoption [Moench, 1991]. The same model could prove significant in India. Finally, local user-groups could serve as a venue for promoting water conservation values.

Beyond supply augmentation and the promotion of water conservation, user-groups could attempt more direct management of groundwater resources. Water allocation and use could be regulated directly by user associations or indirectly through market mechanisms. Direct regulation of groundwater by large user associations could face many of the same implementation and equity problems previously identified for more traditional management approaches. Where the need is clearly evident, representative organisations at the village level might be able to develop a high degree of consensus and support for water allocation or use regulation. Management associations functioning at the scale of many aquifers might not, from an individual's perspective, be particularly different from the government. Effective support for use regulation or water allocation could, in this case, be difficult to generate. Management scale would not probably be as important where market mechanisms are concerned. User-groups could exert a fair degree of direct influence if they were given the ability to influence water use costs. This could be done, for example, through water-use based crop taxes, irrigation technology-determined water fees, or efficiency subsidies. Some of these measures, such as the water-use based crop taxes, might require legislation or water rights reform to establish their legality. Furthermore, as suggested in the energy price discussion, the effectiveness of attempts to influence water use through market mechanisms depends on their importance relative to the variety of other factors influencing water use and cropping decisions.

In addition to market mechanisms, water markets themselves could be developed by user-associations as means of encouraging efficient water allocation. Water markets in the western US are increasingly used as a way to meet needs within the limitations of sustainable resource availability. This function depends, however, on the presence of volumetrically defined use rights. Groundwater markets are common in India. Under the current rights structure, access to groundwater depends directly on ownership of overlying lands and individuals can pump as much as they desire. In this situation, the presence of a water market generally results in more extraction than would be the case in its absence [Shah 1989b]. To use water markets as a means for addressing depletion problems, user-associations would need to evolve some means of limiting the total volume of extraction and apportioning extraction limitations between individuals. This would probably necessitate defining and enforcing rights on a volumetric basis or some proxy thereof [Shah and Bhattacharya 1992]. Given existing patterns of ownership and use, this approach faces a formidable range of legal, social, and practical obstacles.

Despite obstacles, the water market approach may be worth pursuing. Over the long run markets could provide a mechanism for the continuous shift of limited water to the most productive uses. In addition, assuming rights were initially defined equitably, their presence could provide a lever for protection of less advantaged sections of society. At present, rights are defined by the ability to chase watertables. If you can afford to deepen your well, the water pumped from it is yours. Defining use rights volumetrically could protect holders from being outbid in an unproductive well deepening war.

(d) Equity and Sustainability

The equity implications of groundwater management through local user-group associations are poorly known. Existing well development partnerships and the water markets associated with them tend to function relatively equitably in Gujarat [Shah and Raju 1987; Shah 1989b,c,d]. Water is generally provided both to partners in wells and others in the command area at the same hourly rate. Except at times of extreme scarcity where well partners generally have first call on available supplies, water purchasers appear to be treated equally to others in terms of the timing and reliability of supplies. The actual equity balance in existing organisations is, however, unknown. Local institutions are well known to be susceptible to capture by local elites. This has been noted with the pani panchayats in Maharastra [Sathi 1989, p 5] and has been a common experience in my field work. Local institutions tend to reflect the social context in which they function. There is nothing inherent in the local institutional approach that ensures higher degrees of equity.

Although local organisations do not ensure equity, they have the potential to address equity concerns at a level of detail impossible in governmental approaches. In theory, local communities could evolve a myriad of responses suited to local conditions and concerns. If broad-based community representation in decision-making is incorporated, then, the approaches they evolve should contain a fair degree of equity.

Equity in groundwater management through local institutions will, in all probability, depend on the intensity of management required and institutional structures. Actions to increase supply are likely to increase access for everyone within their command. Some efficiency-oriented steps, such as the promotion of different technologies by local institutions, are also likely to have minor equity implications. More intrusive measures to reduce use, on the other hand, have a greater potential for inequity. Whenever institutions gain the authority to manipulate resource use or access the potential for abuse exists. Overall, as the need for efficiency and use reductions increasingly necessitate limiting access or use patterns, the tendency toward inequity will increase. Counteracting this will require institutional designs that promote effective representation for all sections of local society. While there is no guarantee that this can be achieved, a better chance exists than with government organisations that are effectively isolated from local communities.

Although larger equity questions are open, local institutions could contribute to the evolution of sustainable use patterns. Construction and maintenance of local storage and recharge structures, although not a solution in itself, would be a significant movement toward augmenting resource availability. As previously noted, by enabling available supplies to be used more than once, local recharge activities could increase the overall efficiency of water use. Involvement of local user-groups in promotion and development of efficient water use technologies would also represent a worthwhile movement in the direction of sustainability. Beyond these steps, the ability of local user-groups to undertake more intensive groundwater management activities is untested. Numerous obstacles are present. At the same time, existing governmental approaches are unable to address emerging groundwater management problems. Experimentation and applied research regarding the ability of local user-groups to undertake intensive management actions are clearly warranted.

V

Conclusions

Overdevelopment is causing the emergence of groundwater problems in many arid sections of Gujarat. Water tables are falling and water quality is declining. These problems affect the poor first and raise questions regarding the sustainability of existing use patterns. Their emergence necessitates a shift from extraction focused development to water management approaches that address both supply and end-use factors.

Traditional centralised management alternatives—the import of new supplies, governmental regulation, limitations on credit and electricity connections, and pricing mechanisms—make little impact on resource condition or have proven so far impossible to implement. They also have major equity implications. Local recharge activities have fewer equity implications. The level of contribution to supply that they could represent is, however, undocumented. Maintenance is also an issue when construction is done by the government.

Development of user-group based institutions for groundwater management is currently gaining support as an alternative to reliance on government controlled mechanisms. The viability of this approach has not been tested in the groundwater case. In general, user-groups are most likely to be able to organise around actions which supplement resource availability, particularly where these actions result in direct improvements in resource condition. Most actions to achieve increases in efficiency or reduce use levels will be difficult to obtain support for. They also involve a variety of legal, social, and equity issues.

Despite clear difficulties, the local institutional approach deserves further attention. Locally rooted institutions are more likely to accurately reflect local conditions and the concerns of their members than government agencies. As a result, they may be able to achieve support for difficult management actions. In addition, if the institutions are designed in ways that ensure wide-spread representation, they may be able to counter tendencies toward inequity that occur in most situations where use-reductions are necessary.

User-group management is unlikely to represent a full solution to groundwater overdevelopment problems. It could, however, make a significant contribution to both the equity and sustainability of management approaches in many local situations. At this point, a variety of support is needed if the theoretical potential of local user-groups is to evolve into a practical option for addressing groundwater problems. Experiments involving user-group management need to be supported by both government and non-government organisations. The legal status of groundwater needs to be reviewed and a practical means of establishing some form of property rights system needs to be investigated. Governmental assistance may also be needed to allow user groups to attempt management using unconventional techniques. Some measures, such as the establishment of water-use based crop taxes, might require government orders if they are to be tried even on an experimental basis. Clearly, the specific steps that are needed will emerge once experiments are underway. Overall what is required, therefore, is a willingness to test new approaches, provide them with adequate technical and financial support, and respond flexibly as their needs emerge.

Notes

1 Personal communication, K C B Raju, Director, Central Ground Water Board (Retired).

2 Calculated from data in Phadtare (1989: p 7).

3 Utilisable recharge is estimated as 12277.6 MCM/yr [GOG 1992: p 15] and net draft at 7170.3 MCM [GOG 1992: p 51].

4 Specific yield is the amount of water that can be extracted per unit volume of rock per unit change in hydraulic head.

5 Well data supplied by GWRDC.

6 Interviews with private drillers suggest that they drill 1000-2000 wells in the district each year. The number of tubewells present in the district was estimated at roughly 15,000 in a discussion with S C Sharma, August, 1992.

7 Comments by Y K Alag at the Workshop on Water Management, Sadar Patel Institute, August 3-4, 1992.

8 According to electricity board officials, rates for agricultural pumpsets in Gujarat are equivalent to Rs 0.13/kwh as opposed to generation costs of Rs 1.18.

9 Piezometric levels in deep tubewells are continuing to decline even in areas recently supplied with new sources of surface irrigation such as the Dharoi dam command area [GOG 1992].

10 The cost of diesel is equivalent to roughly Rs 1.9/kwh as opposed to Electricity recovery rates equivalent to Rs 0.15/kwh. (Source: World Bank and Gujarat Electricity Board Officials).

11 For the purpose of this paper the term 'user-group' implies any organisation whose membership contains a large number of individuals who actively use the resource.

References

Ballabh, V and Shah, T (1989): *Efficiency and Equity in Groundwater Use and Management*, Workshop Report 3, Institute of Rural Management, Anand, Gujarat, India, p 51.

CPCB (1989): *Basin Sub Basin: Sabarmati Basin Report*, Central Pollution Control Board, Government of India, New Delhi, p 64.

CSE (1985): *The State of India's Environment 1984-85: The Second Citizens' Report*, Centre for Science and Environment, The Ambassador Press, New Delhi.

Dadlani, B K (1990): 'Status of Energisation of Irrigation Pumpsets' *Bhu-Jal News* 5(3):12-22.

Dave, K M (1983): 'Some Legal Aspects of Groundwater Development and Its Management - A Case Study of Gujarat' in *Seminar on Ground Water Development*, proceedings, vol 1, pp 505-512, Indian Water Resources Society, Roorkee, UP, India.

Dhawan, B D (1989a): 'Preventing Groundwater Over-Exploitation', paper presented at the *Workshop on Efficiency and Equity in Groundwater Use and Management*, Institute of Rural Management, Anand, Gujarat.

GOG (1992): *Report of the Committee on Estimation of Groundwater Recharge and Irrigation Potential in Gujarat State*, Narmada and Water Resources Department, Government of Gujarat, pp 57 + appendices.

—(1986): *Report of the Group on the Estimation of Groundwater Resource and Irrigation Potential from Ground water in Gujarat State*, Government of Gujarat, Gandhinagar, pp 15 + annexures.

High Level Committee (1991): *Report of High Level Committee on Augmenting Surface Water Recharge in Over-Exploited Aquifers of North Gujarat*, Vols I and II, Narmada and Water Resources Department, Gandhinagar, Gujarat.

Independent Review (1992): *Sardar Sarovar*, Resource Futures International, Ottawa, Canada, p 363.

Jacob, A (1989): 'The Existing Legal Regime of Groundwater: Some Observations', paper presented at the *Workshop on Efficiency and Equity in Groundwater Use and Management, Institute of Rural Management, Anand, Gujarat.*

KON and GOI (1992): Hydrological Investigations for the Santalpur and Sami-Harij RWSS, Regional Water Supply Schemes in Gujarat State, Kingdom of the Netherlands, Ministry of Foreign Affairs, and Government of India, Ministry of Agriculture, March 1992, pp 70 + Annexures.

Matzger, H and Moench, M (1992): *Groundwater Availability for Drinking in Gujarat: Quantity, Quality and Health Dimensions*, Forthcoming Monograph, Pacific Institute/VIKSAT, p 32.

Moench, M (1986): *Co-operative Resource Management in an Indian Mountain Village*, Working Paper, East-West Environment and Policy Institute, East-West Centre, Honolulu, Hawaii.

—(1991a): *Sustainability, Efficiency, and Equity in Groundwater Development: Issues in the Western US and India*, Monograph, The Pacific Institute for Studies in Development, Environment, and Security, Berkeley, California.

—(1991b): *Social Issues in Western US Groundwater Management: An Overview*, monograph, The Pacific Institute for Studies in Development, Environment, and Security, Berkeley, California.

Nagabrahmam D (1989): 'Small Groups and Groundwater Management', paper presented at the Workshop on Efficiency and Equity in Groundwater Use and Management, Institute of Rural Management, Anand, Gujarat.

Patel, S M (1989): 'Energy Conservation in Agricultural Sector through Proper Rectification of Inefficient Pumpsets', mimeo, paper presented at the National Workshop on Energy Conservation, New Delhi, February 7.

Pathak, B D (1985): 'General Review of Artificial Recharge Works in India' paper presented at the Seminar on Artificial Recharge of Groundwater, sponsored by the CGWB, UNDTCD and UNDP, Ahmedabad, January, p 17.

Phadtare, P N (1988): *Geohydrology of Gujarat State*, Central Groundwater Board, West Central Region, pp 103 + appendices.

Pisharote, P R (1992): 'Rainfall Regime of Kutch District, Gujarat State, India', paper presented at the workshop on Water Conservation and Management for Drinking Water and Agriculture in Drought Prone Areas, Vivekanand Research and Training Institute, Mandvi, Kutch.

Raju, K C B (1992): *Groundwater Resources of Kutch District and Necessity for Its Proper Management*, Sri Vivekanand Research and Training Institute, Mandvi, p 21.

Sathi, M D (1989): 'Pani Panchayat—A Theme in Common Property Resources of Water in Maharastra', paper presented at the Workshop on Efficiency and Equity in Groundwater Use and Management, Institute of Rural Management, Anand, Gujarat.

Shah, T (1989a): *Sustainable Development of Groundwater Resource: Lessons from Amrapur and Husseinabad Villages in Junagadh District*, mimeo, IRMA, Anand, Gujarat.

—(1989b): 'Groundwater Markets: A Review of Issues, Evidence and Policies', paper presented at the Workshop on Efficiency and Equity in Groundwater Use and Management, Institute of Rural Management, Anand, Gujarat.

—(1989c): *Efficiency and Equity Impacts of Groundwater Markets: A Review of Issues, Evidence and Policies*, Research paper 8, Institute of Rural Management, Anand.

—(1989d): 'Externality and Equity Implications of Private Exploitation of Groundwater Resources' in Custodio and Gurgui (eds) *Groundwater Economics*, Elsevier, The Netherlands, pp 459-82.

Shah, T and Raju, K V (1987): 'Working of Groundwater Markets in Andhra Pradesh and Gujarat: Results of Two Village Studies' paper presented at the Workshop on Common Property Resources (Groundwater), Roorkee, February 23-25, p 50.

Sinha, B P C and Sharma, S K (1987): 'Need for Legal Control of Groundwater Development—Analysis of Existing Legal Provisions', *Bhu-Jal News*, April-June, pp 10-13.

Sloggett and Dickason (1986): *Groundwater Mining in the United States*, US Department of Agriculture, Economic Research Service, Agricultural Economic Report Number 555, Washington DC, p 19.

UNDP (1976): *Groundwater Surveys in Rajasthan and Gujarat*, Technical Report, United Nations Development Programme.

UNESCO (1984): *Groundwater in Hard Rocks*, Studies and Reports in Hydrology 33, International Hydrological Programme Project 8.6, United Nations Educational, Scientific and Cultural Organisation, Paris.