Farmer Management of Groundwater Irrigation in Asia

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Editors: M. D. C. Abhayaratna, D. Vermillion, S. Johnson and C. Perry.

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

Groundwater and Electricity Co-Management: Generating New Options

Marcus Moench[13]

ABSTRACT

GROUNDWATER OVERDEVELOPMENT IS a problem throughout Northern Gujarat. In India, horsepower (hp) based electricity charges encourage inefficient water and energy use in overdeveloped areas. Pumping accounts for 30 percent of electricity consumption in Gujarat and underlies the state's power crisis.

The social conditions necessary for farmers to manage groundwater overdevelopment are difficult to meet. User group and resource boundaries are poorly defined, information is not available, private well ownership complicates free rider control, and large heterogeneous groups utilize aquifers. Government regulatory attempts have not been successful. Institutional structures which address groundwater problems need to be created at the required scale to meet the necessary social conditions, and rectify pumping incentives.

Cooperatives have been proposed as a response to the state's electricity crisis. Electricity to village-level organizations should be metered. They can then meter membership consumption. Since pumping is often the primary end use, unit charges should create incentives for electricity and water conservation at organization and end-use levels. As a result, the organizations could provide an appropriate nucleus for water management activities. Defining management entities using the electrical system could address many of the free rider, user group, and information issues complicating emergence of farmer-based groundwater management systems.

INTRODUCTION

This paper presents an overview of groundwater problems in Gujarat (India), their linkage with energy supply issues, and potential management alternatives. The paper argues that new institutional approaches are required to address emerging groundwater problems. Electricity and water co-management is presented as one possibility. The paper is organized linearly. Groundwater problems are identified first and then linked with power supply and pricing patterns. Specific power supply problems are discussed subsequently. Attention is then re-directed to existing management alternatives and the social factors influencing user groups' ability to manage groundwater. Following these proposals creation of electricity cooperatives are described and

13 Pacific Institute—VIKSAT Collaborative Project, Gujarat, India.

their potential utility for groundwater management is examined. Conclusions are drawn in the last section.

Groundwater Overdevelopment

Groundwater resources are overdeveloped in many hard rock and arid sections of India. Isolated problem areas such as Mahasana District in Gujarat are well known (see Figure 5.1). The extent of overdevelopment is, however, poorly documented and potentially greater than what the estimates suggest.

Groundwater maps prepared by the Central Ground Water Board (CGWB) for the period April 1979 to May 1987, show drops of more than 2 meters (m) throughout most of Gujarat excluding canal command areas. In large areas the decline was more than 4 m and water levels in the unconfined aquifers were more than 20 m in depth. Water quality in most areas with shallow water tables was poor with TDS more than 1,000 milligrams per liter (mg/l) (often more than 3,000 mg/l), and bicarbonate more than 500 parts per million (ppm). Although May 1987 was a drought period, the decline is long term in extensive areas. For example, depth of the water table declined from 4-16 m in May 1978 to 8-28 m in May 1990 in Ahmedabad, Sabarkatha, Mahasana, and Banaskatha districts (High Level Committee 1991).

Official groundwater availability estimates (the primary guide for development finance) paint an optimistic picture. According to these estimates only 31 percent of utilizable recharge to unconfined aquifers was extracted in 1986 and a further 3.2 million hectares (ha) could be sustainably irrigated from groundwater (Government of Gujarat 1986). Extraction exceeded recharge in only 5 out of 182 Taluks and was greater than 65 percent of recharge in a further 14. These estimates are unreliable (Moench 1991a,b; Dhawan 1991). CGWB and the Gujarat Water Resources Development Corporation (GWRDC) scientists note that extraction estimates are based on old well census statistics, poorly known crop water duties, and well yield-irrigated area assumptions.[14] Recharge estimates are based on Taluk (not hydrologic) boundaries, water table fluctuations, assumed infiltration levels, and specific yield estimates (Government of India 1984; Narasimhan 1990; Moench 1991a,b). Senior scientists indicate that they are as uncertain as the extraction figures.[15]

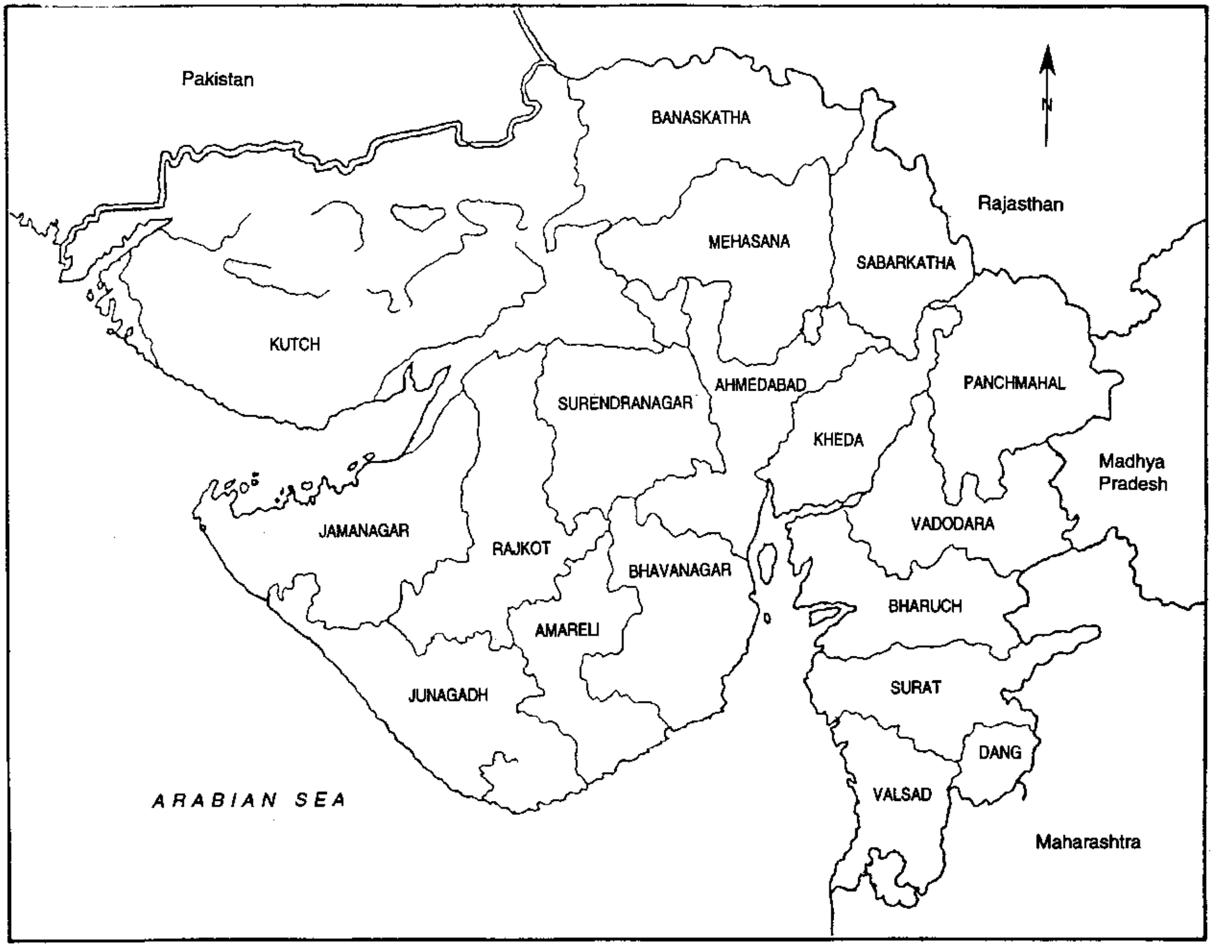
Official estimates suggest that groundwater in confined aquifers is approaching full development throughout North Gujarat. Extraction exceeds 70 percent of recharge in Ahmedabad, Gandhinagar, Sabarkatha, Mahasana and Surendranagar districts and is 40 percent in Banaskatha (see Table 5.1). Of the remaining five districts having significant resources in confined aquifers, three are high rainfall and irrigation is rare in the remaining two.

Officially estimated levels of groundwater development in unconfined aquifers are at odds with observed water table declines and high levels of development in deeper aquifers. The extent of overdevelopment is unknown, and it appears to be widespread. The current focus on development must evolve into a management focus.

14 S. C. Sharma (GWRDC); K. C. B. Raju (CGWB) and others.

15 Discussions with Dr. K. C. B. Raju and T. N. Narasimhan.

Figure 5.1. Districts of Gujarat State, India.



Water-Electricity Linkages

Estimates for 1990/1991 suggest that agriculture accounts for roughly 32 percent of all electricity consumption in Gujarat.[16] Gujarat State Electricity Board (GSEB) officials state that 30 percent of total power production now goes for pumping.[17] These percentages are much higher than the official 18.4 percent agricultural consumption figure reported for Gujarat in 1986/1987 (Dadlani 1990).

Table 5.1. Estimated development of aquifers and water table decline by district.

District	Estimated development (%)		Water table decline (m)		
	Unconfined	Confined	79-87	78-90	78-90
Ahmedabad	23	97	2-4	4-8	to 20
Gandhinagar	30	97	2-4	4-8	to 20
Banaskatha	33	40	2-4	4-8	to 20
Sabarkatha	43	97	0-4	4-8	to 30
Surendranagar	37	72	0-4	na	na
Mahasana	66	88	2-4	4-8	to 40

Sources: Column 1 and 2, Government of Gujarat 1986.
Column 3, Central Ground Water Board.
Column 4 and 5, High Level Committee 1991.

Note: na = Not available.

Agricultural pumpset efficiency is very low. Surveys by the Institute of Cooperative Management indicate typical efficiencies of 13-27 percent in farmers' pumping systems (S.M. Patel 1991). Efficiencies of more than 50 percent could be achieved with readily available and affordable technologies. Electricity for pumping is, however, priced at an annual rate according to pump horsepower. According to GSEB officials, current charges equal 0.15 Rupees/kilowatt-hour (Rs/kwh) (US$0.0054/kwh) while generation costs are 1.18 Rs/kwh (US$0.0421/kwh).[18] Given the pricing structure and subsidies, farmers have little incentive to invest in pump or water use efficiency.

In Gujarat, unlike the rest of India, official figures suggest that the number of diesel pumps is double the number of electrical ones (CGWB 1991: Tables 34, 35). Pump numbers give a misleading picture of the importance of electricity in pumping. Virtually all pumping from confined aquifers use electricity to run submersible pumps. In addition, farmers prefer electricity for pumping because of its low cost. Diesel pumping costs have been estimated at a Rs 1.9/kwh equivalent (US$0.068/kwh), much higher than the Rs 0.15/kwh (US$0.0054/kwh) which farmers

16 Discussions with World Bank officials.

17 C. S. Chatper, GSEB Headquarters 1992.

18 A. H. Dhebar, GSEB Office, Sabrimati 1991.

pay for electricity.[19] Many farmers have both types of pumps and use diesel only as a backup when electricity is unavailable. As a result, where sufficient connections are available, electricity is the primary motive power for pumping.

Power sources influence water management practices. Due to insufficient generation capacity utilities power shedding has become a general practice. Electricity is often rotated so that farmers receive it at night. In response, they leave pumps switched on so that irrigation starts whenever power comes. Uncertain power availability and night rotations make careful irrigation management difficult. Farmers tend to apply as much water as possible when they can. Diesel powered irrigation is, in contrast, carefully managed. According to farmers, the cost of diesel can account for 90 percent of crop profits. Most of those using diesel claim to apply water as carefully as possible.

The cost of power also influences water sale rates. Field work in Mahasana District indicates that farmers having electric pumps generally charge 1 rupee per hour per horsepower (Rs/hr/hp) during the dry season. This is often halved in the monsoon to maximize profits relative to fixed electricity charges. Since most costs of electrical pumping are fixed, maximizing water sales maximizes profits. In contrast, diesel pump owners charge seasonally uniform water rates.

On the whole, the cost of pumping appears to influence farmers' water use and pricing decisions. Flat-rate electricity charges encourage extraction and create disincentives for efficient use. Unit prices do the reverse.

Power Problems

A variety of problems affect the rural electricity system. Voltage fluctuation is common and often causes pump damage. Rural lines are overloaded and the GSEB is often only able to provide connections 4 to 5 years after applications are received. In rural areas, about 9 percent of the total power generated is lost to theft and collections are a major problem.[20] The GSEB shifted from metered rates to annual charges due, in part, to theft and collection losses.

The above problems have led to near financial collapse of the GSEB. As a result, the organization is now "actively considering" the involvement of private companies or cooperative agencies in generation, transmission, and distribution.[21] Metering and rate increases are also contemplated. Given the diesel pumping costs, ability to pay is not a major issue for many farmers. How to enforce metering and collection is the main issue facing the GSEB.

Groundwater Management Questions

Groundwater management responses to depletion must address efficiency incentives. As long as strong incentives for inefficiency remain, little basis exists for management. Power subsidies mask water costs and constrain the evolution of a management system. Since (excluding well investments) it costs no more to pump from deeper levels, individuals have little incentive to conserve or participate in management.

Even with incentives for efficiency, the evolution of effective management systems would be difficult. In many cases, management will make little difference to well water levels unless it functions at an aquifer scale. Aquifer characteristics are often difficult to determine and vary

19 Discussions with World Bank officials.

20 C. S. Chatper, GSEB Headquarters 1992.

21 Personal communication, GSEB officials in Baroda.

greatly between areas. Where groundwater availability and movement are topographically defined, "village" management systems may make a significant impact. In the large aquifer systems that characterize many geologic environments, management must cover extensive areas to address depletion.

Groundwater Management Alternatives

Regulation is the primary groundwater management approach being considered in India. The central government circulated a model bill to the states in 1970 (Dave 1983). Only Gujarat has passed legislation and that has yet to be enforced. Gujarat's Act allocates power to license tubewell construction, regulates groundwater use and prevents waste (Sinha and Sharma 1987). Acts proposed in other states, create "authorities" staffed by individuals from state organizations (Moench 1991 a,b). These authorities are given regulatory powers within notified areas. Enforcement is through fines, search and seizure of provisions, and (in some cases) electricity denial. None of the Acts allow for the inclusion of local representatives in the management structure or devolution of authority to local groups.

Regulation is unlikely to be successful. In Mahasana, for example, declining water tables led to the closure of groundwater development financing in 1976 (Ghosh and Phadtare 1990a: p. 319). New wells are also regulated via limiting electricity connections. Neither financial nor electricity limitations have proven effective. Private financing is available and illegal electricity connections can be obtained. Drilling companies in Mahasana estimate that over 2,000 wells are drilled in the district each year.

Existing regulations have probably limited groundwater access for those who cannot afford private financing or do not have the influence to obtain illegal connections. They have done little to slow the use of groundwater by the wealthy. Since most wells are privately owned, regulations are difficult to enforce. They also have strong equity implications. Depending solely on regulation for groundwater management is not feasible.

The primary alternatives to regulation are indirect management through economic levers or development of local institutions capable of evolving socially feasible management systems.

Energy pricing is the main economic lever which influences pumping directly. Numerous discussions with farmers suggest that they will be unwilling to pay higher rates unless voltage and supply timing issues can be remedied. Theft will also remain a problem. In addition, differentiating between the needs of management areas through electricity pricing will be difficult. Depletion necessitates prices which encourage conservation. Where waterlogging is present, prices should encourage higher pumping rates. Politically it would be very difficult to charge high unit electricity rates where water is scarce and low annual rates where it is plentiful. Finally, it is far from clear how much impact an approach based solely on economics would have. In the Western United States, energy prices are a factor in farmers' willingness to invest in water conservation but play a minor role in crop choice, and therefore, the overall water use decision (Moench 1991c).

Local institutions tend to require certain conditions to establish effective management systems. Management often occurs when: (i) user group and resource boundaries are clearly defined, (ii) resource use and condition information is available, (iii) free riders can be controlled and management decisions enforced, and (iv) broad support exists for management (Moench 1986). These conditions become difficult to meet as group size and heterogeneity grow. In a study of 93 groundwater management groups, Nagabrahmam (1989) found average sizes from 3 to 21 members. Several groups identified small size as a factor in their success. Group homogeneity (economic and caste) also influences community well management success (Ballabh and Shah 1989).

The above considerations suggest that farmer-based groundwater management institutions will face significant difficulties in addressing depletion problems. Aquifer boundaries are often poorly known making resource and user group boundaries unclear. Condition information is difficult to obtain since local water levels may indicate little about the overall water balance. 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 user 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 to address. Physically appropriate management areas will often contain large, heterogeneous, user group populations.

In isolation, none of the management alternatives identified above can address emerging depletion problems. These problems threaten the viability of many communities. Institutions must be evolved to meet social requirements for management, to address the physical resource problems, and to rectify water use incentives.

ELECTRICITY: GROUNDWATER CO-MANAGEMENT OPTIONS

Electricity Cooperative Proposal

The formation of cooperatives has recently been proposed as an answer to electricity supply problems by the National Dairy Development Board (NDDB).[22] This proposal, widely supported in Gujarat, faced opposition from the Central Energy Authority.[23] The idea is being revived following recent encouragement of private participation in the power sector. It should be noted that electricity cooperatives, although new to India, are common elsewhere. They are, for example, one of the main sources of rural electricity in the United States of America.

The NDDB proposal, developed for Kheda District, envisioned electricity supply through a nested series of cooperative organizations. Village cooperatives would buy electricity from an "Apex Rural Electricity Cooperative Society." The Apex Society would have society unions at substations and a peak generation organization. This structure should provide regional representation for villages. Local societies would: (i) maintain low voltage supply lines; (ii) distribute electricity; (iii) keep connected load within line capacity; and (iv) collect dues. The Apex Society would have one meter at each village and charge unit rates. Village societies could meter members, impose flat tariffs, or follow other pricing systems.

The primary incentive for farmers to form electricity cooperatives would be improving the quality and timing of power supplies. In Kheda District from 1981 to 1987, rural electricity supply during the nonmonsoon period averaged 15-16 hours/day and was less than 9 hours/day in some months (Tata 1991). Voltage fluctuations also necessitate frequent pump repairs. Problems with power availability, quality, and access to connections are constant complaints of farmers. High quality power supply to cooperatives would be essential.

The GSEB is interested in rural electricity cooperatives for financial reasons. Low electricity charges, theft, and nonpayment of dues in agricultural sector underlie the GSEB's precarious

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22 This section is based on Tata (1991) and interviews with Mr. Sen and Dr. Kurian at NDDB on March 4 1992.

23 Dr. Kurian, personal communication.

financial position.[24] Without some new institutional structure, metering and electricity rate increases may not be possible. Selling bulk power to user groups would greatly reduce the number of meters requiring monitoring. Since local groups would have primary responsibility for collecting electricity charges, theft and nonpayment problems should also be reduced.

Local distribution organizations could provide avenues for increasing efficiencies. Metering supplies to village groups and, if done, to individuals should create incentives for efficient use. Furthermore, line capacity limits possible connected load. Readily available pump improvements can reduce connected load by about 50 percent (S.M. Patel 1991). Local organizations could, thus, increase cônnections through pump rectification. They could invest directly or grant connections if individuals rectified other's pumps.

Groundwater Management Linkages

Electricity cooperatives could provide a flexible means of rectifying ground water use incentives and a potentially appropriate institutional structure for management.

Electricity distribution by user groups could enable rate manipulation in response to groundwater conditions. User groups would have the freedom to experiment with different rate structures. Unit rates or increasing block pricing would establish, respectively, uniform and rising marginal costs for water and could be used to create differing incentives for conservation in shortage areas. Where waterlogging is present, uniform annual charges would establish declining average costs and encourage extraction. Efficiency arguments advanced in the preceding section for electricity would also apply to water. Irrigation service is the "real" end use of pump energy. Individual or institutional investments in water conservation could reduce energy consumption and connected load required. They could be used to reduce power costs or increase connections.

Establishment of farmer-based institutions for electricity distribution could create options for managing groundwater through pumping economics. It is important to recognize, however, that encouraging water use efficiency is unlikely to solve depletion or other complex management problems. Rectifying the incentive structure may be a necessary precondition for the establishment of management systems but it is probably not a sufficient one.

Management Institutions

Farmer-based electricity distribution organizations could form an appropriate institutional nucleus for groundwater management. Local institutions should have incentives to ensure water use efficiency and, thus, become involved in water management. Incentives to initiate management could also exist where groundwater problems are a major local concern or threatened the institution's viability.

Managing groundwater through electricity distribution organizations could have advantages over institutions created specifically for that purpose. First, access to electricity is a much more tangible and immediate benefit to individual users than managing a nebulous "groundwater resource." Second, user group boundaries are clearly defined (those having connections), information on use patterns is readily available (metering), and there are avenues for free rider control (connections). These factors address some of the management limitations suggested by experiences with other common property resources.

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24 Discussions with GSEB officials in Baroda.

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