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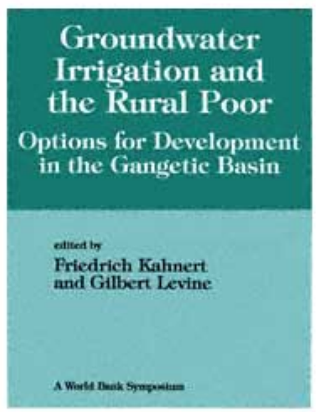

Groundwater Irrigation and the Rural Poor

Groundwater Irrigation and the Rural Poor

Options for Development in the Gangetic Basin

edited by
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FOREWORD

This volume reports on a concerted effort to analyze and reflect on the possible role of groundwater development in helping to address the persistent rural poverty problem in Bangladesh, Nepal, and eastern India, an area in large part coincident with the Gangetic Basin. The work was initiated by the World Bank and cosponsored by the International Irrigation Management Institute, which contributed substantially to its success. Papers were presented at the World Bank Colloquium on Groundwater Irrigation, held April 1214, 1989, in Washington, D.C.

Groundwater remains the largest natural resource endowment of this region that is not yet used to its full potential, even though this potential cannot be identified with certainty for the basin as a whole or for its constituent parts. In addition to an incomplete data base, a problem common to many development challenges, a great deal of uncertainty arises from the unresolved riparian issues affecting the use of the water from the Ganges river system. These concern not only the three countries of the region but also the division of the water resources among the Indian states in the basin. Given the close interaction between surface water flows and groundwater availability, resolution of the riparian issues will place as yet unknown political limits on groundwater development in many parts of the region.

While improving knowledge of the behavior of the system as a whole and of local conditions as well as resolution of the riparian issues must remain priority objectives, attempts to harness groundwater development more directly for the alleviation of poverty cannot wait. The resource is being developed and appropriated apace and time for influencing this process is running out.

It is from this perspective that a number of unequivocal conclusions and action recommendations are put forward, namely:

Farmers need a full range of equipment options in order to respond efficiently to local groundwater development conditions and to their specific requirements. Controls on equipment choice produce inefficiency and inequity and should be abolished.

Tube well spacing regulations are largely unenforceable and futile; they are often harmful to the poor who are the only ones unable to circumvent them. They should be abolished.

The subsidies in place distort the comparative advantages of different technologies because the degree of subsidy varies both by type of pumping energy (electricity / diesel) and by type of pumping equipment (deep tube wells/shallow tube wells/hand tube wells). What is more, these subsidies often benefit the relatively rich rather than the poor. Where subsidies have to remain in force, they should at least be scale− and energy−neutral.

The provision of dedicated power for groundwater pumping to the improved deep tube wells first supported by the World Bank is questionable if all externalities are taken into account; where dedicated power is to be used for this purpose, it should be more specifically targeted at the poor. This should also be done with power connections where these remain scarce, as in large parts of Bangladesh and Nepal.

Technical solutions to the well−known problems of public deep tube wells, such as the improvements incorporated in the design supported by the World Bank, are only part of what is needed. Much more attention must be devoted from the very beginning to farmer participation in such tube well investments and to the formation and sustained operation of water user groups. Because there is evidence that, the larger the capacity of the tube well, the more severe the operation and management problems, the smaller deep tube well models should be given preference over the larger ones wherever deep tube wells have to be installed.

Water markets are developing rapidly both inside and outside the study area. Competitive water markets have positive efficiency and equity impacts; they can and should be promoted. In areas where electricity is available for pumping, a switch to flat−rate and progressive power pricing based on the horsepower of the connected motor can be a powerful tool to promote competition in the water market.

The persistence of severe poverty in the study region is of concern not only to the World Bank and the three governments concerned but also to all those who devoted time and energy to producing the material in this report, not to mention the very large number of people suffering from deprivation in this area. In addition to the conclusions highlighted above, the body of this report contains a host of other suggestions, recommendations, and ideas for policies, other actions, and research. It is my hope that all this will contribute not only to the ongoing discussion of the problems but above all to policy reform and action to address them.

Finally, I would like to express my sincere thanks to all the contributors to this project, especially to Friedrich Kahnert and Gilbert Levine. From the inception of the project to the end, it was Friedrich Kahnert whose dedicated work ensured that the vast experiences with and analyses of this topic could culminate in this volume; and we are obliged to Professor Levine, without whose expert support and assistance the project could not have been brought to a successful conclusion.

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OVERVIEW

Friedrich Kahnert
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Objectives and scope

This study on groundwater development arose from concerns about the magnitude and persistence of poverty in a region that probably contains the largest concentration of rural poor in the world. The World Bank, which has financed a number of groundwater−based projects in the region, shares this concern with the governments of Bangladesh, Nepal, and India, which have all made the alleviation of rural poverty an important policy target.

Beyond the issue of poverty, interest in groundwater development is heightened because:

The Ganges Basin area is endowed with fertile alluvial soils.

The area has abundant groundwater resources (although the magnitude of the unexploited potential is not certain).

Parts of the area have experienced rapid development of groundwater exploitation.

State, national, and international policies and financial interventions strongly influence the utility of the resource.

The main objective of this report is to identify, on the basis of existing knowledge, feasible policy options and institutional and organizational approaches that show promise for improving the poverty impact of presen and future groundwater use for irrigation. An additional objective is to identify priority subjects for research aimed at improving policy and project design for this same purpose. The work is thus aimed at the concerned governments, World Bank staff, and the research community.

The method of inquiry consisted of a literature search (see the appendix), the preparation of papers by researchers and practitioners in the region, and a colloquium where these researchers and World Bank staff debated the issues in an informal setting. Although no fieldwork was sponsored specifically for this report, the researchers brought with them extensive recent experience and new insights into field realities with considerable policy and research implications. No attempt was made to develop statistically significant quantitative information on the various issues of interest.1 And to keep the report manageable some important and complex issues were excluded from in−depth investigation, including drainage, flood control and conjunctive water management, groundwater mining, the availability of complementary inputs other than credits in the study region, and crop diversification issues. These issues are referred to only incidentally.

The report first sets the framework for poverty alleviation through groundwater exploitation by offering reflections on its overall scope and unresolved issues in relation to physical parameters and the economics of irrigation, and by laying out the benefits that are normally expected to result from irrigation, particularly groundwater irrigation. A statement of the key findings of the colloquium and

a set of action recommendations, including a statement of research needs, follow. The bulk of the paper, arranged in three parts (on Bangladesh, Nepal, and India), reproduces the colloquium papers on groundwater issues in the study countries. (The papers were presented at the colloquium and most were subsequently revised and updated by their authors.) Finally, the appendix presents the literature review prepared for the colloquium.

The target group for this study comprises landless and asset−poor farmers. Asset−poor farmers, who are sometimes subdivided into small, marginal, submarginal, or functionally landless farmer categories, are defined as those with holdings of up to one hectare. This corresponds to the definition of a small farm in Bangladesh and a marginal farm in India.

To ensure clarity in discussing the various types of wells and pumps we have used the following nomenclature:

Hand tube wells —wells with manually operated pumps; may be installed in wells of different depths.

Shallow tube wells —wells that are usually accessed with surface−mounted pumps (maximum depth to water surface is about 7 meters); discharge is usually 1522 liters per second.

Deep set shallow tube wells —wells with the pump set in a pit to permit access to deeper water depths using simple centrifugal pumps.

Deep tube wells —wells that are accessed by pumps set in the well; lifts are variable to 100 meters; discharge varies between 3090 liters per second.

Public tube wells —wells, usually deep tube wells, that are owned and operated by a governmental entity.

World Bank tube wells—wells, usually deep tube wells, characterized by integrated well/pump/distribution technology, as illustrated by the World Bank−supported pump systems in India.

Background

The poverty status

By almost any measure of income or well−being—average annual income, life expectancy, literacy rate, child mortality—the area encompassing most of Bangladesh, eastern India, and substantial parts of the Terai of Nepal contains a large proportion of the world's poor. In a modest extension of Robert Chambers' phrase for East India, the region is a "polygon of poverty." This is no exaggeration. In 1986 more than 50 percent of Bangladesh's rural poor did not have enough food to meet minimum calorie needs. And it is likely that the situation is worse now as a result of recent floods, increased unemployment, and a slowdown in agricultural investment. In the eastern districts of Uttar Pradesh, in Bihar, and in West Bengal, similar percentages of the population live below an already very low Indian poverty line. Data for Nepal are not readily available, but conditions in the Terai are not likely to be significantly better.

Although the poverty status of the region is clear, specific data on living standard characteristics in the countries might be helpful in thinking about their individual needs as well as their overall similarities. Table 1 illustrates the 1988 average income, life expectancy, and infant mortality for Bangladesh, Nepal, and India and provides similar data for a few other countries for comparison. Table 2 offers similar data for the states of eastern India.

The severe poverty in the region, then, explains the geographic focus of this study. But the potential for poverty alleviation through groundwaterbased irrigation is not as obvious. One problem has to do with the nature of the groundwater resource—there is uncertainty about its extent, areally and temporally, and there are problems with its accessibility because of technical, social, and economic factors. Another problem relates to questions about the utility of irrigation for poverty alleviation, in contrast to its utility for increasing agricultural production.

Table 1 Living standard characteristics in selected countries

		Life expectancy (yrs)		
Country	*Average income (US$)*	*Male*	*Female*	*Infant mortality (/1000)*
Bangladesh	170	51	51	118
Nepal	180	52	51	126
India	340	58	58	97
Sri Lanka	420	68	73	21
Indonesia	440	59	62	68
Congo (P.R.)	910	50	56	117
United States	19,840	72	79	10

Note: All data refer to 1988; Income is gross national product.

Source: World Economic Indicators, Tables 1, 28, 32 in *World Development Report 1990.*

Table 2 Living standard characteristics in eastern India

	Average income (rupees		*Life expectancy (yrs)*		*Infant mortality (/1000)*
			Male	*Female*	
Bihar	1,904	(57.4)	58	57	97
Orissa	1,983	(59.7)	57	55	122
Uttar Pradesh	2,146a	(71.7)a	54	60	123
West Bengal	3,193	(96.2)	60	60	70

Note: Figures in parentheses indicate income in eastern India as a percentage of all India.

a. 198687.

Source: India, Central Statistical Organization, 198889.

Groundwater as a resource

Groundwater is a complex water source. Although it has many of the characteristics of surface reservoir sources—most notably the interaction of reservoir volume and inflow/outflow rates as determinants of irrigation utility—it has characteristics that make its utilization both more difficult and of relatively greater value. First in difficulty is determining the magnitude of supply. The study does not address the question of resource magnitude in detail, but assumptions about the size of the supply under different conditions will implicitly underlay much of the discussion. Thus, it is useful to understand some of the physical characteristics that influence its availability and utility, for example, recharge rates and the size and transmission characteristics of the aquifers. (Maps at the back of this volume provide overviews of the major sub−basins and aquifer characteristics in the Ganges Basin.)

Ultimate potential

For assessing development potential, there is great interest in the best estimate of the ultimate groundwater reserve. In simple terms, this potential is determined by the rate of recharge of the aquifer reservoir. When water extraction exceeds the rate of recharge, water tables decline. Declines may be local, as characterized by the "cone of depression" associated with pumping; they may be of wider geographic extent or for longer time periods, depending on the area and rates of pumping. When extent and rates of pumping are such that the water table declines for years, water "mining" is taking place. Thus, under different conditions groundwater can be considered either a "renewable" resource or a "fund" resource.

Notwithstanding the critical nature of recharge rate information, there are few instances where reliable data are available, even in a crude form. There appear to be few estimates of recharge rates for the Terai in Nepal, although the assumption is that the rate is relatively high. There seem to be reasonable estimates for some aquifers in India, but data for the Gangetic region are scarce. Surprisingly, as a result of recent studies, Bangladesh may have reasonably accurate estimates (this will be discussed in part 1); and evidence suggests the recharge rateis high.

Useful supply

Although a reasonable picture of ultimate potential is valuable for long−range planning, of more immediate interest and concern are estimates of "useful supply," that is, the supply that can be extracted economically and with minimum adverse impact on the rural poor. To estimate this supply, it is necessary to have an understanding of the extraction/drawdown relationships that characterize the aquifer under different rates of extraction. This information is critical, not only because it provides a basis for predicting changes in the economics of groundwater−based irrigation, but also because it is necessary to evaluate other potentially adverse impacts. In many parts of the region of concern, base flows in streams—flows that result primarily from groundwater outflows during low rainfall periods—are the source of water for irrigation and labor for some of the poorest people in the region. The "swing baskets" and "dhones"[2] frequently used for lifting water from these base flow sources create significant employment and provide irrigation to meet small, but critical irrigation needs.

Shallow wells and village tanks provide the domestic water resource for millions of the rural poor. When these sources are reduced or eliminated, the effects are severe. In 1984, drought, combined with accelerated pumping in parts of eastern India, lowered water tables to the point that reasonably sanitary domestic water supplies were lost and the poor were forced to use highly polluted sources. As a result, thousands of people died from dysentery and other diseases. Useful supply, then, is a function not only of the source characteristics, but also of impacts at different levels and times of extraction.

The second half of the equation in determining useful supply—the economic half—is affected by factors that are unique to groundwater and factors that are associated with irrigation more generally. A fundamental difference between surface water irrigation sources and groundwater sources is the energy required for their utilization. For surface water, there usually is an energy "output" associated with the water delivery, representing the potential energy of elevation. In contrast, groundwater usually requires energy "input" for its utilization. Thus, uncertainty in the availability and cost of energy becomes a major difficulty in projecting useful supply.

Surface and groundwater resources also have different degrees of operational flexibility, with differing potentials for taking advantage of economic opportunities. Surface irrigation systems usually are constrained by the need for elevation (potential energy) to permit flow to take place. Constraints of channel size, shape, slope, character of bed materials, water sediment conditions, and type and degree of control infrastructure combine to limit potentials for changes in water delivery amounts and time, thus constraining adaptation to new production needs. Groundwater−based systems, by contrast, have the potential for more options in physical location, in size of system, and in operating policy, and, thus, have the potential to permit more rapid adjustment to new needs that may emerge with new agricultural opportunities. Thus, uncertainty about the degree to which the unique beneficial characteristics of groundwater sources can be utilized is another factor that makes assessment of "useful supply" difficult.

In addition to the uncertainties related to groundwater as an irrigation resource, there are uncertainties associated with the economics of irrigation more generally. Technological advances in crop production can increase profitability unexpectedly; market conditions that favor productive changes in cropping patterns can have similar effects. Thus, planning groundwater use to meet any specific objective is an undertaking fraught with uncertainty; and groundwater use to achieve the complex goal of alleviating poverty is especially challenging.

Notwithstanding all these difficulties, groundwater has been demonstrated to be a valuable resource in the region. In Bangladesh, for example, the total area irrigated by modern methods tripled in the past decade, with minor irrigation responsible for about 90 percent of all irrigation and tube wells of all types now probably accounting for close to two−thirds of the total. However, some areas of the region have been bypassed by this development; and other areas have seen the benefits go disproportionately an more rapidly to the relatively rich rather than the poor.

Poverty alleviation bias

The difficulties of planning specifically for poverty alleviation through agricultural development are well illustrated in the experience of the past twenty−five years, the era of the Green Revolution. In South Asia, and probably more broadly, four assumptions provided the basis for development investment strategy:

Increases in agricultural production were critical if the basic food development needs of rapidly expanding populations in developing countries were to be met.

There was great potential for increasing agricultural production through the development and application of new technology.

Productive technology, or the methodologies to develop such technology, existed.

The benefits from improved production technology would be shared in a way that would materially improve the livelihoods of the rural poor.

The first three assumptions have proven reasonably valid, although not universally so throughout the region; the last has proven demonstrably false.

Experience with the application of modern agricultural technologies has shown that access to productive inputs is the key to effective utilization of these technologies. Customary access results in a de facto bias toward more favored areas and people, making the opportunities for privileged access to these inputs a logical focus of concern for the poor. Access to land, either through ownership, reasonable rental, or equitable sharecropping, offers an opportunity for a bias toward the poor.

But, in addition to the land tenure opportunity, access to water is critical. The water environment is recognized as a fundamental determinant of agricultural potential in the region. In the context of the colloquium's groundwater focus, the issues narrow to the questions of how access to groundwater can be biased to the poor and how this access can be made economic and effective.

Reflections on groundwater irrigation

Groundwater irrigation cannot be a panacea for alleviating rural poverty in the Ganges Basin area. In much of the region flooding and impeded drainage are priority constraints on improved agricultural production. It is also probable that the rate of growth of productive agricultural employment will not significantly exceed the rate of population growth. This suggests that a major improvement in the economic status of the rural poor will depend on the growth of nonagricultural employment.

However, groundwater is the most important underutilized natural resource in the region. There is significant potential for expanding agricultural production and diversification in parts of the area, as well as considerable scope for rectifying the biases against access by the poor to the resource and its potential benefits. Developing this potential will be a difficult task, from both technical and political perspectives. Understanding of the Ganges Basin geohydrology is deficient, both on basinwide and more localized levels. The basin is geologically and hydrologically complex, and includes parts of three countries, making basinwide study extremely difficult. Yet, this understanding is necessary for a strong and rational foundation to the solution of the complex riparian issues between the countries and among the Indian states. There is the professional and technical capacity to develop this understanding, but there is a need for corresponding political will. A coordinated multicountry effort to develop the necessary understanding, free of political interference, would be a critical contribution to the resolution of the larger political issues as well as a necessary condition for effective use of groundwater for poverty alleviation.

Physical basis for groundwater utilization

Ultimate potential. Water is likely to be the ultimate development constraint for agricultural as well as nonagricultural activities in the region. With this perspective, long−range planning of groundwater exploitation requires an understanding of the groundwater regime of the overall Ganges Basin, which covers the bulk of the study area. But it must be recognized that the basin contains local water regimes that can vary considerably over relatively short distances. These local hydrological conditions must be key determinants of policies that are both appropriate and effective for groundwater exploitation in general, and for groundwater use in poverty alleviation in particular.

Complicating the problem of determining ultimate potential is the uncertain nature of the linkage of groundwater in the basin with surface flow conditions and with subterranean transboundary flows. In many areas there is a link between surface water flows and the groundwater table, through groundwater recharge in the wet season, recharge from surface water channels during irrigation, and return flow of groundwater into rivers during the dry season. Estimates of net usable groundwater potential must be adjusted to reflect the abstractions from the surface water system that adversely affect the water users of that system or the natural ecology of the area.

Unfortunately, the methodologies for estimating ultimate potential without reasonably detailed information on the hydrologic regimes lack precision. This results in different estimates from different sources and changing estimates over time. This complicates both long−range planning and efforts to deal with groundwater from a basinwide perspective. This is especially problematic when the basin comprises three countries. Table 3 illustrates the temporal variability of groundwater estimates based on inadequate data.

Typically, as with many subterranean resources, potential is defined by exploration and extrapolation and, thus, is characterized by variable data (depending on one's willingness to extrapolate) and by estimates of increases in potential with increases in drilling. This is clearly illustrated by the data for India between 1969 and 1988. The increase in ultimate potential for Bihar is 91 percent, for Orissa 79 percent, for Uttar Pradesh 180 percent, and for West Bengal 59 percent.

Local mapping of the water regimes is more advanced in Bangladesh than in eastern India and

Table 3 Changing estimates of groundwater potential in eastern India
million hectare meters)

	1969	*1972*	*1976*	*1981*	*1983*	*1988*
Bihar	1.77	2.6	2.70	2.03	2.86	3.38
Orissa	1.30	1.9	1.97	2.06	2.15	2.33
Uttar Pradesh	2.88	4.3	4.38	7.12	9.27	8.05
West Bengal	1.30	1.9	1.99	1.22	1.64	2.07

Source: For 1969, R. Rao and others, cited in Sinha 1983; 1972, Sinha 1983; 1976, Sarma and Nathan, cited in Michael 1978; 1981, Pathak, cited in Sinha 1983; 1983, India, Central Board on irrigation and Power 1983, Table 8; 1988, India, Central Groundwater Board 1990, adapted from Table 23.

Nepal. But the evidence suggests that a consistent and comprehensive effort needs to be undertaken to cover the study area more thoroughly. Considering the expense associated with this type of effort, it will be critical to identify the most useful data and the institutional arrangements to obtain, analyze, and share them.

Useful supply. As suggested previously, although reasonable estimates of ultimate potential are essential for long−range planning, the present need is for information on the economically useful supply. For this purpose, relatively detailed information on the water yield−water table drawdown relationships must be available. The lowering of the water table under different pumping rates can be determined by actual pumping experience over time or by extrapolations from test wells using geologic and hydrogeologic information. Neither approach is easy.

Monitoring existing wells can result in valuable information about the hydrogeologic characteristics of the aquifer, and it provides a basis for decisions about the effects of additional extractions. But even though the techniques of well monitoring are relatively simple, the information system that would guide data collection, analysis, and reporting for a large number of operating wells over time is not. Collecting data from a more limited set of test wells is relatively straightforward and lends itself to a project mode, which is easier to implement and sustain for the monitoring period. However, successful extrapolation is dependent on the extent and accuracy of the hydrogeologic information in the region and the representativeness of the test wells. As noted earlier, information of this type is relatively expensive and difficult to obtain. Thus, there are likely significant errors in the estimates of useful supply. The problems identified with the determination of ultimate potential occur even in relation to shorter−term planning. Errors in planning groundwater projects are inevitable and must be compensated for through effective monitoring and response programs.

Groundwater extraction technology. Four types of technologies are associated with the extraction of groundwater: well types, well installation, pumps, and power sources. A variety of well types are used, from simple open wells to simple cased (tube) wells to radial wells.3 The appropriate type for a given situation is dependent on the characteristics of the aquifer—particularly, its depth, thickness, and static water level, the type of installation equipment available, and energy and equipment requirements to pump the water to the surface. Special techniques are available for locating appropriate sites for wells in areas of localized water sources, but these are unlikely to be necessary in the region under study because of the prevalence of the groundwater.

Well location is determined more by land ownership and area for utilization than by characteristics of the aquifer, although there are potential problems of well "interference" if the wells are spaced close enough to overlap their "cones of depression." Where density of well spacing is such that there is substantial overlap, pumping yields decline and costs increase. Whether and how to control well spacing are potentially important issues in the region.

Well installation technology can vary from simple to complex, again depending on the characteristics of the aquifer and the availability of equipment, energy, and financial resources. In many, if not most situations, however, relatively simple technology, often indigenously developed, can be utilized effectively. Percussion equipment, with and without mechanical power assist, is used widely and successfully,4 especially for shallow aquifers. Where the aquifer is deep, simple well−drilling technology can be used, but this is relatively difficult and tedious and there are incentives for using higher technology equipment. This contributes to the much greater degree of "lumpiness" of the irrigation investment associated with deep aquifers.

Pumps have been the subject of intensive study and development for many years. As a result, a broad spectrum of types, sizes, and characteristics in lifting equipment can be suited to almost any condition. There are positive displacement pumps, propeller pumps, surface−mounted centrifugal pumps, turbine pumps, and submersible pumps. Some can be manually operated or animal powered. Many can be electrically driven, diesel powered, or solar powered. Thus pump technology ranges from the most simple to the most sophisticated and complex. But in reality the full range of technology is not universally available. In most situations there is only a very limited choice; the result is often significant technical inefficiency, as well as the introduction of technology and scale requirements that may create a bias against the poor. Matching pump characteristics to aquifer characteristics, available power, financial condi−

tions, and social structure is one of the more significant problems in providing appropriate access to groundwater.

An additional major problem throughout the region, and one that received much attention during the colloquium, has to do with the energy required to lift water. The nature, availability, and cost of pumping energy all markedly influence the physical accessibility of groundwater by the poor. Electricity and diesel power together are the main−stays of pumping energy; human and animal power, although still important, are declining and may continue to do so under all but very specific sets of conditions. Other renewable sources of pumping energy are of negligible significance so far. Both electrically powered and diesel−driven pumps have specific technological and economic advantages and drawbacks for the small and marginal farmers in the poverty target group. But where both are accessible and appropriate, electric motors are probably cheaper to buy and certainly cheaper to operate and maintain than diesel engines.

This general conclusion is clouded by the distorting impact of taxes and subsidies on the competitive position of the various forms of pumping energy. In general, electric power is substantially subsidized and diesel fuel frequently is taxed. The bias to electric power is offset in many parts of the region where it is either unavailable or highly unreliable, both in timing and in terms of voltage fluctuations. Stability of electric production is a serious problem in eastern India, and availability is a major need in Bangladesh and Nepal.

Economic issues

Groundwater irrigation, whatever its overall or localized potential, produces benefits that can help alleviate poverty. Some benefits, such as higher agricultural production or increased employment in agriculture, can be captured as water control becomes available. This occurs whether the irrigation is through surface or groundwater, although it might be noted that these benefits appear to be greater under groundwater irrigation.

Others benefits, such as job opportunities in pump repair and maintenance, are specific to groundwater irrigation. And some benefits, such as land value increases (with the introduction of irrigation) or revenues from water sales, accrue in the poverty target group only to those who own land or lifting equipment. The key issues for poverty alleviation revolve around, first, access to the resource itself and, second, access to potential benefits. The benefits may not be realized unless other inputs are also accessible. For typical groundwater situations, improving access by the poor on both these levels is the goal for policies that aim to increase the contribution that groundwater irrigation makes to the larger objective of poverty alleviation.

Access. Access by the poor to the groundwater resource can take two basic forms: ownership or management of tube well equipment and purchase of water from governmental or private suppliers. To be effective, access to the resource not only has to be technically and financially feasible, it has to be economically profitable. Economic profitability of groundwater irrigation is fairly well established, but cannot be taken for granted everywhere, nor over time, nor under all farming systems or water management arrangements.

Financial considerations have a major impact on the ability to directly access groundwater in much of the region. As suggested earlier, wells and pumps are relatively "lumpy" investments, in contrast to seeds, fertilizers, and other components of modern agricultural technology. To purchase a well and pump requires access to a relatively large amount of money, usually beyond the means of individual small and marginal farmers and the landless. The governments in the region have a variety of credit programs designed to make financial resources available to the poor, but there is a substantial history of problems with these programs. Frequently, credit programs include a significant subsidy,5 which provides an incentive for the more powerful to intrude. Problems with such programs, such as poor repayment rates and nonproductivity of the loans, are well−documented. But a major part of the problem, although occasionally mentioned, usually is not discussed critically. The cost of the loan to the borrower frequently is much greater than the nominal interest specified, reflecting the additional "transaction cost" associated with the process of getting the loan.

The need for financial feasibility, therefore, highlights the importance of credit, subsidies, and transaction costs for access to the resource by the poor. These will be addressed in succeeding sections.

Access to groundwater through purchase from a water supplier is an option that is utilized in Bangladesh and parts of India and Nepal. In all three countries the supplier could be the government, through a public tube well and water fees;

and in Bangladesh and India there are group water suppliers and private water sellers. In all of these situations, the value to the purchasers is dependent on the reliability and cost of the water. This cost is influenced by the net monetary cost and by the transaction costs associated with obtaining the water. The poor delivery performance of many public tube wells has provided a strong incentive for nongovernmental water suppliers, and in some areas competitive water markets have developed. The growth of these markets and their potential for additional growth raise important questions about how or if they should be fostered and about their effects on agricultural performance and on other aspects of the agricultural sector, such as employment and land tenure arrangements.

Some of the issues raised in trying to gain better access of the poor to the benefits of groundwater irrigation (as opposed to just the resource itself) are similar to those just mentioned. For example, credit availability is a key to providing access to the complementary inputs required to generate the full production benefits of irrigation. And if transaction costs borne by the poor are too high, the profitability of groundwater irrigation for them will be impaired or lost. This, however, can also happen for other reasons, such as the level and nature of water charges.

Subsidies. Subsidies are widely used to provide resources to the poor at costs deemed appropriate considering their needs and government capacity. However, as stated earlier, experience in the region suggests that subsidies frequently are accompanied by relatively high transaction costs and can distort technological choice in ways that lead to inappropriate decisions. The subsidy on electric power is a clear example, where artificially low prices of electric energy relative to other forms of energy place a premium on electric pumping over diesel. This occurs not only for private decisions, but also in decisions about public tube wells when project economic analyses use electricity rates at the project boundary without consideration of actual electricity costs.

An indirect subsidy is in place when a particular project or area is given priority for the delivery of electricity, as is the case for the World Bank tube wells in India. When there is scarcity of power, the opportunity cost of that dedicated use may represent a substantial subsidy that is not included in the evaluation of the technological appropriateness of those tube wells.

Access to institutional credit often is a precondition for getting access to subsidies and the evidence is strong that the poor often have severe difficulties in obtaining such credit. The skewed distribution of ownership of tube well equipment is one indication that the poor have not had equitable access. This has happened despite the fact that credit repayment from members of the poverty target group clearly is superior to that from richer farmers.

The combination of distortions in technology choice arising from subsidies and the difficulty the poor have in capturing them suggests that the use of subsidies for development of groundwater irrigation should be questioned. This is a significant issue for any program that aims to benefit the poor through groundwater irrigation.

Transaction costs. The importance of the costs of obtaining credit, pumps, power connections, power deliveries, and other components of groundwater irrigation has been implied in earlier sections of this overview. These transaction costs often are the result of procedures and practices that are not essential or are totally superfluous to the stated purpose. The collection of numerous signatures to validate official papers and regulations that basically require circumvention are two examples. The transaction costs in these dealings are paid in lost time and effort, in transportation costs and, not infrequently, in cash payments to intermediaries or government functionaries, or both. Because the poor are especially vulnerable to these types of transaction costs, the implications of this situation are relevant to any consideration of using groundwater to alleviate poverty. Many of these problems are well known—as are many of the remedies.

Although the transaction costs cited above are readily recognized, there is less familiarity with the costs inherent in group activity, a type of activity widely associated with groundwater irrigation in the region. The small and fragmented holdings that characterize much of the region dictate that many pumps serve more than one water user. Where there are private water sellers in competitive water markets, transaction costs may be relatively low. Where there is little or no competition, the transaction costs as well as the direct water price may increase substantially. In the case of group−managed groundwater irrigation, substantial effort is needed to form groups and to sustain their operation, often requiring technical and managerial assistance. Cooperation among relatively large

numbers of farmers is virtually unavoidable to operate deep tube wells successfully, and the social transaction costs may be extremely burdensome. These have direct effects on the technical efficiency of deep tube wells and on their economic viability. The fact that transaction costs specific to group activity exist is widely recognized, but the magnitudes and forms of these costs in different situations are less clearly understood.

Institutional issues

At least two types of institutional issues are important in groundwater irrigation: those that relate to legal access to the water and those that have to do with social and organizational issues.

Legal issues. Although being able to physically access the water is fundamental, having the right to do so is a factor in implementing that physical capability. In contrast to surface water rights, which frequently are well−defined, groundwater rights often are ambiguous and difficult to enforce. In India the central government assumes that groundwater is the property of the nation; the states' views of these rights are not clear. In Bangladesh a similar assumption holds. In Nepal there is no clear expression of the legal status of groundwater. However, notwithstanding the legal views, in none of these countries is there an effective mechanism for exercising a national or even state view of ownership.

Groundwater rights take on much more of the character of riparian right—groundwater access is the prerogative of the owner of the land above, and as long as he does not extract the water in a way that is markedly detrimental to others, he is free to do so (the degree of "damage" done to others before action is taken against the offending party is a function more of the social system than of me legal one). Access to the water is "tied" to the land in the riparian sense, but amount of extraction and location of use is not a function of land area. Thus, to obtain de facto legal access it is only necessary to be able to physically access the aquifer.

Under a riparian rule, however, access to the aquifer can, in theory, be regulated to prevent adverse impact on others. Typically, this impact is considered in two time frames—during actual pumping, and seasonally or yearly. Drawdown interference—the overlapping of cones of depression during simultaneous pumping, resulting in lowered pumping efficiency—can be minimized or eliminated by restricting the spacial density and pumping capacities of the wells. Restricting spacial density, however, gives a form of "monopoly" access to those who first sink wells. Restricting pumping capacity through limitations on size of pump or timing of pumping could also reduce drawdown interference, with less of a monopoly implication. There is evidence from Pakistan that farmers voluntarily work out arrangements to share the timing of pumping and thus avoid conflict.[6]

From a legal perspective, longer−term lowering of the water table is more difficult to control than drawdown interference because it is much more difficult to connect the source of the problem with an individual. This is a classic case of "the commons" externality. However, in reality, neither situation—the localized drawdown or the generalized lowering of the water table—is dealt with easily through exercise of legal rights. This is true in almost all parts of the world and is not limited to South Asia. Indirect control, including economic measures, social pressure, and restrictions of available technology (especially power), can be effective.

The question of groundwater level control becomes even more difficult when the rules for that control appropriately should be different in different parts of a country or region. This can be the case when there are differences in susceptibility to salt water intrusion into fresh groundwater or when different opportunities exist for utilizing the groundwater aquifer as a reservoir for the capture of excess surface water. In these situations, a policy for optimal utilization of the groundwater may result in nonuniform rules for implementing the policy.

The need for groundwater regulation in the future (to the extent it does not exist now) is likely to be significant throughout the region. Clarification of the legal bases for regulation, bearing in mind the equity implications of different approaches, is a clear need. Additionally, the identification of practical types of regulations for the different physical and social situations is an issue to be addressed.

Social and organizational issues. Social and organizational issues must be viewed from three perspectives, that of the individual, the group, and the government. From the standpoint of the individual, personal power is an important factor affecting one's ability to directly access the groundwater resource. Frequently, this power comes from land ownership; it might also come from political influence or from family stature. Whatever its source, it enhances the ability to obtain financing, to avoid the bureaucratic "sharks" who take their bite of subsidized loans, and to utilize the resource productively.

Because the size of farm holding in the region is generally small, frequently with fragmented, noncontiguous units, groundwater from a pump often is used on land belonging to different owners. The conditions under which this access is obtained and maintained vary widely. They may be exploitive or relatively favorable; they may be reliable or highly unreliable. The social relationships between adjacent landowners influence how those owners obtain access to the groundwater. In areas where many smallholdings could be served by more than one supplier, competitive water markets have often developed. In this situation, the influence of social relationships becomes smaller as economic factors increase in importance.

Where social closeness exists, as in some extended family groups or in effective cooperatives, there may be joint ownership of a well and pump. However, joint ownership and operation usually involves substantial transaction costs and these are frequently difficult for the poor to bear. Where private, nongovernmental organizations have been working with the poor to obtain access to groundwater, the organizations typically absorb a major portion of these costs. The landless pump groups of Bangladesh[7] are examples of a special form of group ownership in which nongovernmental organizations played important roles in overcoming the transaction costs of joint ownership.

For the governments in the region, there are significant social and organizational issues relating to factors that influence the ability of the poor to access groundwater. For physical access to and preservation of the resource, questions arise about how the responsible agencies should organize to maintain adequate oversight of groundwater status, both from the standpoint of water levels and water quality. With respect to water quality, salinity has been the major concern, but as more agricultural production inputs are used there is increasing concern about other types of quality degradation. Monitoring for these is much more difficult than monitoring for salinity or water levels, and it raises questions about the need for new procedures and organizational structure.

For financial and economic concerns, the delivery of services needs to be organized in ways that reduce associated transaction costs. This may mean improved accountability of government functionaries, more effectively decentralized distribution, or other changes from customary practice.

The need for monitoring, obvious in relation to the physical dimension of groundwater utilization, is equally important for achieving equity for the poor. To determine the impact of specific government policies and activities on the ability of the poor to gain access to and benefit from the groundwater resource, it is necessary to know the circumstances in the field. The current monitoring capability in the region is unlikely to provide the relevant information. What information is necessary, and how it can be obtained with reasonable accuracy, appropriate precision, and minimum cost, are significant questions.

Colloquium objectives and challenges

The study had four basic objectives:

To increase understanding of the needs for and potentials of utilizing groundwater for poverty alleviation in the Gangetic region.

To explore the technical, economic, and sociopolitical factors that influence the ability of the poor to access and benefit from groundwater−based irrigation.

To identify policy options for groundwater−based irrigation that might be differentially more beneficial to the poor.

To identify gaps in data and understanding that might be rectified by additional study and research.

These objectives were amplified during the colloquium by a set of six questions, the answers to which were assumed to provide important specific direction for those concerned with the alleviation of poverty in the region:

What are the fundamental requirements for successful, sustainable utilization of groundwater for irrigation in the various parts of the region?

Considering the current state of our knowledge, what are the options for meeting these requirements?

Which of these options has the highest probability of effectively biasing access to groundwater irrigation toward the poor?

What changes in governmental policy and practice would be necessary for implementation of the appropriate option(s)?

What changes in international lender or donor policy and practice would foster implementation of the appropriate option(s)?

What areas of concern need further understanding before appropriate policies and practices can be identified with confidence?

The degree to which these questions were answered is suggested in the key findings section and elaborated on in the country chapters that follow.

Notes

1. Throughout the subcontinent there frequently is a serious discrepancy between official irrigation statistics and field reality, and this is not overcome by most field appraisal and evaluation missions. Short visits by outsiders, frequently orchestrated by the host irrigation agencies, are not conducive to accurate assessment of the field situation.

2. The "swing basket" is a lifting mechanism consisting of a shallow basket hung from four lines, held by two individuals. Water is scooped by swinging the basket through the water source (usually a small stream) and lifted a short distance, usually less than a meter. The "dhone" usually is a hollowed log, similar to a boat, pivoted at the elevation to which the water is to be lifted. The opposite end is counterweighted to provide the force to lift the water. The counterweighted end is pushed below the water surface (usually by foot power), causing the water to enter the dhone; releasing the foot pressure causes the counterweight to lift the water, which is then released at the higher elevation.

3. Radial wells are those with horizontal collectors radiating from a central well; a single pump is placed in the central well, extracting water from the larger zone defined by the radial collectors.

4. Experience in the Terai of Nepal has shown that very simple, locally built well drilling equipment has been utilized, with very few well failures, as reported in " An Impact Evaluation Study of Bank Operations in the Agricultural Credit Subsector in Nepal," Asian Development Post−Evaluation Office Report IE, September 1978.

5. For example, in India, the interest rate for those identified as poor is 4 percent, substantially below the normal bank loan interest and greatly below money−lender rates.

6. Personal communication (January 1989) from Robert Johnson, IIMI Research Associate, based on preliminary studies of private pumping of groundwater in the Punjab of Pakistan.

7. A full description of the landless pump groups can be found in G.G. Wood and PROSHIKA 1983, "The Socialisation of Minor Irrigation in Bangladesh," *ADAB News* 10(1), Agricultural Development Agencies in Bangladesh, Dhaka.

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KEY FINDINGS, RECOMMENDATIONS, AND SUMMARY

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The colloquium on groundwater irrigation in the Ganges Basin areas of Bangladesh, Nepal, and eastern India was structured, generally, to address the overriding objectives of groundwater development in alleviating rural poverty, namely:

To increase understanding of groundwater potential for poverty alleviation.

To explore factors that affect access of the poor to the benefits of groundwater irrigation.

To identify groundwater irrigation policies that can benefit the poor.

To identify gaps in knowledge that require further research.

This statement is structured along the same lines, beginning with a presentation of key findings, followed by a statement of policy options and recommendations and concluding with a summary that draws more explicitly on the literature review. The summary is not intended to be a complete "document for the record," but to highlight and interpret major findings and conclusions.

Key findings

Need for groundwater utilization

There is a clear need to address the poverty problem in this region—an area that perhaps has the largest concentration of poor in the world. In colloquium discussions there was disagreement about the extent to which farming, or more broadly the agricultural sector, could provide sufficient employment and income to solve the poverty problem.

More specifically for groundwater−based irrigation, discussants voiced uncertainty about the relative importance of improvement in farm income, increase and improvement in agricultural labor opportunities, and opportunities for income benefits from ancillary activities such as the sale, maintenance, and repair of pumping equipment, post−harvest processing and marketing, and so on.

Although there are clearly benefits from groundwater irrigation, the poor do not seem to have benefited substantially. Available evidence suggests that the *absolute* level of well−being of the poor has increased, but that their *relative* status has declined with the advent of irrigation.

Potential for groundwater utilization

Groundwater irrigation cannot be a panacea for alleviating rural poverty in the Ganges Basin. In some areas drainage and flood control constraints are more critical than water shortages. In much of the region an increasing share of the rural labor force will have to earn a living from nonagricultural activities.

There was substantial discussion and some disagreement about the potential of the groundwater supply. Three factors contributed to the disagreement: the lack of definitive data on the magnitude

and characteristics of the resource, especially in eastern India and Nepal; differences in perspective; and the lack of information about drawdown effects on the poor.

Although there are significant amounts of data about groundwater resources in the region, with the possible exception of Bangladesh the data are inadequate to evaluate the potentials of the resource under different development conditions. The lack of information results in divergent estimates of the groundwater resource and disagreement about its potential for exploitation.

Procedures for systematic and accurate collection, analysis, and dissemination of groundwater hydrology information necessary to improve planning in the future do not seem to be in place. And what data there are reveal substantial variability in groundwater conditions over the region, often within relatively short distances. This implies the need to establish policies and practices for specific and differing conditions, that is, to tailor policies to particular zones.

As one example, the data show significant seasonal variations in both the water table and the flow of the Ganges in its lower reaches. Concern was expressed about the potential impact of increased groundwater extractions on the base flow into the Ganges at low flow periods, and there was an implication that the extent of permissible extraction had been reached.

The data apparently are insufficient to define the zone of extraction that would influence the flow of the Ganges during the critical period. Information of this type would permit the implementation of a policy limiting extraction in the critical zones, without preventing continued groundwater development in other parts of the basin.

Opportunities for managing the aquifer were discussed. The differing perspectives of colloquium participants were obvious from their views on the opportunities inherent in the annual recharge that brings water tables back to previous levels, versus the dangers of within−year drawdowns. For example, the potential for increasing the useful supply of groundwater in Bangladesh—through extractions to depths beyond the capability of shallow tube wells (9 meters [m])—was identified in a very positive way.

At the same time, however, it was made clear that extractions of this magnitude mean that during significant parts of the year, shallow tube wells, including handpumps, would not be functional. Depending on one's view of the relative importance of the temporary drawdown, there was a different perception of the magnitude of supply and the opportunity for increased utilization.

The lack of consensus was fostered by the paucity of hard data on the effects of different degrees and durations of drawdown on different segments of the population. Most of the discussion was based on studies of individual cases and anecdotal information.

Notwithstanding the information gaps, groundwater is the most important natural resource in the region with large potential for expanding agricultural production. Moreover, groundwater development offers an opportunity to rectify the biases against access of the poor to irrigation benefits—biases that have been prevalent in groundwater exploitation in the past.

Factors affecting access by the poor

Technical factors. Three types of technical factors influencing access by the poor were discussed, namely, factors related to the aquifers, to the technology for drilling and pumping, and to the energy for pumping. Questions about energy—particularly electrical energy—received the most attention.

The interconnectedness of the *aquifers* with the surface waters and the magnitude of local variability require both basinwide and local planning and evaluation. Much of the discussion about the aquifers focused on drawdown problems and, as noted earlier, on the lack of information about effects on the poor. The link between surface waters and groundwater (each is an input and an output for the other at different times of the year), the opportunities for conjunctive use, and the necessity of thinking and planning in a basinwide context arose repeatedly during the meeting. The narrow focus of project−based thinking, planning, and design is inadequate for effective utilization of the waters of the region.

The discussion of the link between *pump technology* —sizes and types of wells and pumps—and suitability for the poor revealed a complex picture, with no one type of technology being appropriate under all conditions. Technology issues included:

Hand tube wells were clearly more appropriate for the poor, for scale, cost, maintenance, and the like, but had the potentially serious adverse effect of an increased labor burden on the family—a burden often carried by women and children for very low wages.

Deep tube wells with their larger pumps have, in theory, the capability of providing better access of the poor to groundwater than do smaller tube wells. But this potential is rarely achieved because of operational problems.

Small bore deep tube wells and modified pumps offer potential opportunities for smaller−scale access to greater depths. More experience with these wells and pumps is required to make definitive statements.

The need for a wide range of *equipment and spare parts* —and expertise in their use—could pose problems for the support system. It was argued that difficulties of this type, currently encountered in Bangladesh, are transient and will disappear as the private sector support system matures.

Inter−well interference, which results from close spacing of wells, might have significance from a theoretical perspective but has minor significance in practice. Moreover, there was a general sense that well spacing regulations are a waste of effort, as private availability of well drilling and pumping equipment make such regulations practically unenforceable.

Electricity and diesel power are the mainstays of pumping *energy*. Human and animal power are still important but are declining and likely to continue to decline except in very specific conditions. Other renewable sources of energy are of negligible importance at the present time. Both electrically powered pumps and diesel pumps have advantages and disadvantages for small and marginal farmers but, where available, electric motors are usually cheaper to buy and operate than diesel engines.

The relative advantages and disadvantages of electric and diesel power are distorted by differential taxes and subsidies. Failure to consider the heavy subsidy usually accorded to electric power results in a strong bias toward electric power. This is seldom evaluated for its potential effect on access of the poor to groundwater.

Notwithstanding the bias toward electricity and the advantages of electric pumping, there is an increasing reliance on diesel power. Electric power is not available in large parts of the region and where it is, it is highly unreliable both in timing and in voltage. In eastern India, improving the reliability and quantity of electric power is critical to any significant expansion of groundwater irrigation. In Bangladesh and probably in Nepal, expansion of electric service to areas with significant untapped groundwater potential should have a beneficial effect.

Economic factors. The economic profitability of groundwater irrigation is well established, but it is not a given under all conditions. Physical, social, and economic factors make it necessary to evaluate each situation carefully.

The key issues for poverty alleviation have to do with access to the resource itself and access to benefits that may not be realized unless other inputs are also accessible. Access by the poor to the groundwater resource can be through ownership or management of the well and pump or through purchase of water from government or private suppliers. To be effective, access must be technically and financially feasible, as well as economically profitable. Access to the benefits of groundwater irrigation are markedly affected by factors that influence access to complementary production inputs, chief among them credit availability at a reasonable cost.

Subsidies for groundwater investment, and especially for operation and maintenance, are of dubious value for poverty alleviation. In only a few cases are subsidies effectively targeted at the poor, and access to them frequently is accompanied by significant transaction costs.

The priority access to the resource provided to World Bank tube wells through provision of dedicated power is of questionable value if all externalities are taken into account. If dedicated power is to be utilized for groundwater pumping, it should be more explicitly targeted at the poor. This is also true of power connections generally, in areas where they continue to be scarce.

There is evidence that flat−rate, progressive demand−charge (based on connected horsepower) power tariffs might be effective in making more water available to small users at lower cost. This has been demonstrated in situations where competitive water markets exist.

Flat−rate pricing of electricity does not necessarily reduce use efficiency or net revenues to the power authority. Other costs associated with pumping will tend to reduce overpumping, and there will be reduced losses of revenue from pilferage and reduced costs of rate collection.

Water markets are growing in many situations, apparently at a rapid pace. This is because of the lack of surface water availability, unsatisfactory performance of many government tube wells, and the potentials for profit in water sales.

Payment for water takes the form either of a monetary payment based on a quasi−volumetric delivery or a share of the irrigated crop. The volumetric water charges can be based on hours of pumping, number of waterings, area irrigated per watering, and so on. Sharecropping rates vary across the region and over time, but on the whole this payment system has been shown to have an adverse effect on groundwater system efficiency. Studies comparing the performance of deep tube wells under the sharecropping system and under other systems consistently show that wells operating under the crop share payment system perform less well in command area, yield, and gross output.

As water markets develop, the crop share payment for water tends to decline, and the use of volumetric pricing increases. In Bangladesh early rates of 50 percent have fallen to one−third or one−quarter of the crop as competition has increased, but even this represents an impediment to optimal use of groundwater for poverty alleviation.

In general, there is evidence that competitive water markets have positive efficiency and equity effects. But the effect of water markets on other factors that affect poverty, such as tenancy arrangements and land concentration, is unclear.

The determination of efficiency should be based on output per unit of water, as well as output per unit of land. Although output per unit of land is an appropriate measure in areas of land scarcity, in areas where water is a scarce resource, output per unit of water is more appropriate. In much of the region, however, both land and water are scarce and thus both measures should be considered in evaluating efficiency.

Social factors. Many procedures and practices for obtaining access to groundwater and to the benefits of groundwater irrigation result in transaction costs to which the poor are particularly vulnerable. Requirements of numerous signatures from government functionaries and repeat visits to obtain approvals are examples. As a solution, group approaches to obtaining access have been tried, often with success. The small farmer/landless pump groups pioneered in Bangladesh, for example, have had very positive equity impacts. But these groups face a number of problems, including membership attrition, takeover by powerful individuals or families, and increasing competition from private or public water suppliers.

Although poor farmer groups probably will not expand to be a quantitatively large force in groundwater management, the poverty alleviation impact of such groups suggests they should receive continued and expanded support. A variety of techniques, including those used by PROSHIKA (a nongovernmental organization), the Bangladesh Rural Advancement Committee (BRAC), and the Grameen Bank in Bangladesh, the Ramakrishna Mission in eastern India, and the Agricultural Development Bank of Nepal (ADB/N), should be evaluated and supported as appropriate.

Transaction costs associated with group−man−aged groundwater irrigation can be significant: substantial effort usually is required to establish and sustain the groups, and external assistance is often needed. Nongovernmental organizations have been an important source of support.

Opportunities to reduce transaction costs for poor farmer groups include establishing more congenial environments for group formation, encouraging group formation with more compatible members, and providing timely technical assistance. Costs associated with group formation appear to rise disproportionately as group size increases. This suggests that command areas should be kept to the minimum size consistent with the requirements for economic investment and operation. The deep set shallow tube wells developed in Bangladesh are examples of a technology that increases access to deeper aquifers without requiring substantially increased command areas.

Serving large groundwater irrigation command areas poses such significant problems that the installation of public deep tube wells in areas where shallow tube wells can operate should be preceded by a social feasibility analysis as well as a hydrological impact statement.

And even so, the problems with existing public deep tube wells suggest that new deep tube well projects should be put on hold until these problems have been studied and techniques for resolution and prevention identified. Priority should be given to improving the performance of the existing stock of public deep tube wells.

Research needs

The research needs are listed here generally in the sequence of the topics discussed earlier, not in order of priority.[1] Priorities should be set by relevance to policy and action needs, which are discussed in the section on "Policy options and actionable recommendations."

Effective use of the groundwater resources of the eastern Gangetic region for the alleviation of poverty requires substantive understanding of the physical, economic, social, and political factors that affect that use. To gain this understanding, systematic studies are needed. Although an interdisciplinary approach is essential, it is possible to identify narrower research needs that can then be evaluated and synthesized from the broader context.

These studies must consider regional, as well as local issues. Many issues about use of the aquifers, for example, transcend local conditions; at the same time, local circumstances are important in determining the effects of local water use, as well as the effects of more general policies and programs.

One imperative is a better definition of the hydrogeologic and use characteristics of the aquifers in the region, especially in areas currently subject to over−exploitation, quality deterioration, or both.

Evaluation of the potential groundwater resource should include consideration of economic and social implications. In parts of the region it might be possible to use the aquifer as an expanded groundwater reservoir to absorb excess monsoon rainfall. However, the increased dry−season drawdown necessary for this expansion might have adverse economic and social impacts on the poor if the drawdown results in reduced performance of small shallow wells or reduction in the base flow of streams.

It is important to identify and broaden the technological options available to small users and to minimize the distortions in access to these technologies caused by subsidies, taxes, and transaction costs. The distributional impacts, as well as appropriate technologies, of the agricultural opportunities made possible by groundwater irrigation should be studied. There are likely to be significant impacts on landless labor as well as on the distribution of labor between men and women.

The appropriateness of different sources of pumping energy, and the impacts of price, quality, and reliability of energy, should be evaluated for different parts of the region. The relative merits of flat−rate and pro rata electricity pricing should be studied in the context of different situations of water availability. Furthermore, different forms of payment for water should be evaluated more completely for their effect on profitability and efficiency and for secondary effects on land ownership and tenancy.

Increased understanding of the effects of various types of incentives and disincentives on the availability of groundwater to the poor is essential. Subsidies, credit availability, licenses, and regulations are among the governmental devices used to encourage or discourage actions by individuals and groups. There is little field−based knowledge of how these instruments affect groundwater development and utilization.

Although groundwater development has potentially important effects on social conditions, relatively little about these effects is known. Certainly employment opportunities, land ownership, and tenancy arrangements are affected, but the scope and magnitude of the effects are not clear.

The relative merits of public and private (individual and group) groundwater development under different environmental situations have not been analyzed. Of particular concern is the past emphasis on relatively large publicly operated deep tube wells, particularly in view of their requirement for scarce resources such as power connections and maintenance funds.

Factors influencing the success of pump groups should be evaluated for different conditions in Ganges Basin areas. Adaptation of forms of group ownership and management of wells and pumps, as currently practiced by PROSHIKA, BRAC, and the Grameen Bank in Bangladesh and the Ramakrishna Mission in India, should be explored and tried in other parts of the region.

Ways of reducing transaction costs that are especially burdensome to the poor must be identified and given further study, including such means as obtaining governmental services—credit, agricultural inputs, and the like—and group formation and maintenance.

Policy options and actionable recommendations

Policy options and supporting recommendations fall into at least two areas: those that determine the potential for groundwater exploitation and those that affect the utilization of the resource, both in general and specifically for poverty alleviation.

Although some of the recommendations are not supported by research as conclusively as one would wish, it must be remembered that groundwater development in the region is proceeding quickly—it is not waiting for more research results to become available. The opportunity to secure a fair share of groundwater benefits for the target group might be passing. Even though there are risks in pursuing the poverty alleviation objective, action should be taken where risks appear tolerable compared with potential benefits.

Potential for groundwater exploitation

Lack of information about the groundwater resource is a major deterrent to the development of appropriate policies. Moreover, availability of the resource and potential for utilization can vary over short distances, making information collection and application very difficult. So it is important to identify the technical and policy relevance of specific types of information and concentrate data collection on the relevant factors.

For policy, the variability of groundwater conditions and of social and economic conditions in each country and across the region means that uniform policies for groundwater access and utilization are unlikely to be satisfactory. Rather, some form of *zoning* —on the basis of important geographical, agro−ecological, and socio−physical factors—will be important to the application of differential policies and practices. Decisions about the appropriate form of zoning and related policies and practices will require an accurate, relevant information base. The type of information required will be influenced by the type of zoning considered useful.

A high priority for the information base is the identification, systematic collection, and analysis of information necessary to determine usable groundwater potential. Information gathering should be on a scale that allows assessment of local conditions. Government monitoring and statistical services must be strengthened.

Increased groundwater use is going to occur, whether through private development or through governmental programs. Considering the lack of up−to−date information and the potentially serious consequences of inappropriate groundwater development, an effective system for monitoring groundwater levels, quantity, and quality is critical.

The data show interconnectedness of the aquifers and between the aquifers and the surface waters in the three countries of this region. Although there are provisions for bilateral examination of surface water linkages and their implications, it is not clear that groundwater is addressed sufficiently, if at all, in those examinations. *The degree to which this need should be pushed is a policy option.*

Utilization of groundwater

Among the many factors that influence groundwater utilization, a critical one in much of the region is the availability and quality of energy for pumping, particularly electrical energy but also diesel fuel. This prompts the following recommendations:

In view of present policies, improvement in the quality and quantity of power supply in eastern India is critical. This should receive top priority, at least in areas where law−and−order problems would not seriously impede the adoption of electricity−driven pumps by farmers. Waterlogged areas in canal commands not presently electrified might be given priority for drainage pumping. The fact that such improvements could take a decade or more to become widely available only increases the urgency of starting now.

Rural electrification in Bangladesh (and perhaps Nepal) should be accelerated and given priority in areas with the largest, as yet unused, groundwater exploitation potential.

The appropriateness of providing dedicated electricity to irrigation, and specifically to public tube wells, should be evaluated.

The matching of pumps to aquifer conditions and of power units to pumps should be improved. In some cases this recommendation could be met by providing information, technical assistance (as is being done by the ADB/N), or both. In other cases, restrictions that limit the availability of a more appropriate range of equipment might have to be modified or removed.

The use of a flat−rate, progressive tariff (connected−horsepower basis) should be evaluated, and where appropriate tried out. The tariff level should not be set so low as to erode water sellers' incentive to expand sales and lower prices, or so high as to encourage farmers to switch to diesel pumps.

Preferential access to electric connections should be given to the poor; and if connections are limited, they should be given preferentially to landless and near−landless pump groups. This has implications for international donor policies.

Public versus private development

The issue of preferential access raises the larger question of the relative roles of the public and private sectors in groundwater pumping. The unsatisfactory experience with public tube wells, and the more successful experience with private tube wells, might argue for a policy of complete private−sector groundwater development. However, some of the virtues of public tube wells—the potential benefits to the poor and the ability to control water extraction in sensitive areas such as salt water intrusion zones—make total dependence on private sector development a questionable course to follow. This also has implications for international donor policies.

The appropriate balance between public tube wells and private development should be evaluated in relation to specific needs of the physical and social environments. It is not a forgone conclusion that the management of public tube wells cannot be improved, given sufficient government commitment and appropriate technical assistance. It is worth noting, for example, that the World Bank−supported National Water Management Program in India is yielding significant improvement in surface system performance, which is a more difficult operation.

One form of private development that has the potential to minimize adverse effects on the poor is group tube well ownership by small landholders and the landless. With appropriate assistance in building capacity and access to credit, there have been substantial successes. Encouragement of this form of development is recommended to test the replicability of this approach. Implementation could include preferential access to electric connections, as suggested above.

Finance

Access to sources of finance other than moneylenders is crucial for poverty alleviation. The two complementary and partly substitutable instruments being used to provide this access are subsidies and credit. Experience with a number of programs that target direct subsidies to the poor to enable them to acquire productive assets has not been satisfactory. Where the level of subsidy has been high, a significant portion has gone to the more powerful. Although the available information on experience with subsidies is not comprehensive, the direction reform should take is reasonably clear:

Improve targeting of the poor, for example, by adopting the ADB/N's practice of providing subsidies on the basis of household income surveys.

Eliminate the distortional effects of subsidies on technological choices, in particular, discrimination against human−and animal−powered devices in Bangladesh and India, smaller−capacity tube well equipment in Bangladesh, and diesel power in India. This does not appear to be a problem in Nepal. On the same nondiscriminatory basis, consider subsidies to renewable energy sources for pumping, such as solar and wind power and bio−gas systems.

Reexamine the economic and social justification for subsidies being provided for groundwater irrigation in cases where this has not been done, for example, in Bangladesh. Implement a program to reduce subsidies for tube well investment and to eliminate subsidies on operating costs of both tube well and surface irrigation systems.

Consider providing subsidies, on a pilot basis, for lined or buried water conveyance systems to promote the development of water markets.

Reforms that can be suggested for credit delivery are:

Relieve credit institutions of functions other than those related to credit delivery and collection. In particular, eliminate their role in implementing government regulations for well−spacing norms and in enforcing the ban (in Bangladesh) on using diesel engines for purposes other than irrigation.

Encourage or instruct credit institutions to offer services not only for investment but also to meet such seasonal production needs as water purchases and, perhaps, culturally essential consumption expenditures. Services of this kind are already being implemented by the ADB/N and in West Bengal in connection with cooperative societies and other groups.

Experiment with changing credit institutions' present requirements that land be pledged as collateral. Instead, permit the pledging of crops as collateral and provide advice on improved cultivation practices (an effective crop insurance scheme for individual farmers might have to be part of the system). Complement this by offering farmers the option of making credit payments in kind at government procurement prices, where these are in place. This practice is being followed by the ADB/N.

Tighten procedures for loan recovery and seizure of collateral by instituting streamlined procedures, specifically for tube well purchase credits.

Use incentives rather than regulation to en−

courage appropriate individual participation in the groundwater irrigation sector.

Transaction costs

Transaction costs, whether avoidable or unavoidable, bear particularly heavily on the poor. Unavoidable transaction costs arise whenever group action is the only or the most promising instrument to channel groundwater irrigation benefits to the poor. Avoidable costs arise where government regulations restrict access to the means of production or where a necessary service is not freely available. They also arise where approval procedures are overly complicated or lengthy. Reducing these costs wherever possible and helping the poor bear the costs that remain are important objectives. Most actions that can be taken will also benefit the less poor, thus improving the overall efficiency of the system.

The following actions should be taken:

Reduce the scope for extraction of under−the−table payments for electricity connections and well licensing by abolishing spacing norms and making connections freely available in areas where there is no immediate danger of over−exploitation of groundwater resources.

In Bangladesh the ban on using diesel engines for purposes other than irrigation should be lifted. The ban is imposed by credit institutions on those who need credit to buy such engines. Those who do not need credit, typically the rich, escape this interdiction.

Reduce transaction costs in group formation and operation by following "best practice" in membership selection as tentatively identified in group formation typologies.

Reduce transaction costs associated with credit delivery by streamlining and expediting approval procedures by credit institutions. Induce nongovernmental organizations to expand their role as honest brokers and to shoulder some of the transaction costs of credit delivery.

A number of actionable recommendations arose from the discussion of World Bank tube wells. Some can be implemented under ongoing projects; others are primarily relevant for projects being prepared:

Unavoidable costs for the formation and continued functioning of day area committees and other farmer groups that manage World Bank tube wells must be adequately funded and receive the sustained attention they require. This might mean setting up a specific service to perform this task in ongoing and future projects.

Modified shallow tube wells developed in Bangladesh, which operate at the same aquifer depth as the present model deep tube wells, but command smaller, perhaps more manageable areas, should be tried out as replacements for the deep tube wells. Again, this could be undertaken in both ongoing and forthcoming projects.

Experiments should be set up to develop systems of charging for water that remove the variability and unpredictability of seemingly arbitrary water charges and that reduce the operator's ability to dispense favors.

Deep tube wells yet to be installed under ongoing projects should be confined to the smallest economically feasible model, because the larger models appear to perform even more poorly than the smaller models.

Any future public tube well project should contain a statement showing the effect of the investment on the hydrology of the project area. The installation of deep tube wells in areas where shallow tube wells can operate successfully should require full justification.

Finally, certain specific recommendations would promote the group approach to groundwater irrigation and to development of more competition in water supply, namely:

Expand the formation of landless groups for groundwater irrigation in Bangladesh by assisting the organizations already active in this field, such as PROSHIKA, the Bangladesh Rural Advancement Committee, and the Grameen Bank.

Identify suitable nongovernmental organizations or other organizations to conduct pilot programs that would replicate the landless group approach in eastern India and Nepal and adapt it to local conditions.

Support extension of the Ramakrishna Mission approach in those parts of the study area where suitable organizations can be found and where cultivable land is unsuitable for groundwater irrigation for natural or technical reasons.

Encourage credit institutions in eastern India and Bangladesh to promote joint liability farmer groups, along the lines of the ADB/N method.

In areas where natural water supply monopo−

lies are unavoidable, experiment with competitive bids for the right to exploit the groundwater. Potential system managers might be cooperatives, landless groups, water "corporations," or individuals.

Renew efforts to find ways to overcome the lack of cooperation from farmers whose fields have to be crossed by water conveyance systems to reach potential buyers. A legal mandate for this purpose that was given to the Comprehensive Area Development Corporation in West Bengal proved impossible to implement.

Summary

Need for groundwater utilization

The study revealed no disagreement about the need for poverty alleviation in the Ganges Basin area, recognizably one of the poorest regions in the world. There was less unanimity of opinion, however, about the utility of groundwater irrigation for this purpose. Although the potential for using groundwater irrigation to improve the well−being of the poor has been identified (Chambers and Howes 1980), there was skepticism that the policy and attitudinal changes necessary to bias groundwater development and utilization toward the poor would take place (Carruthers and Stoner 1981). The primary rationale for the belief that groundwater irrigation could alleviate poverty was thought to be the relatively uninstitutionalized nature of groundwater utilization and the resultant potential for providing an important productive resource to the poor. (The literature offers examples of both views, which were reflected in colloquium discussions.)

There was general recognition of the benefits of irrigation, regardless of the water source: higher crop production income per unit of land from increased cropping intensities, higher yields, and the ability to use modern productive technologies with lower risk; increases in land values; and increases in and more regular employment. There also was recognition of the special potential benefits associated with groundwater irrigation: income from the sale of irrigation water and secondary employment opportunities in servicing wells and pumps. However, the magnitudes of these benefits are not quantitatively defined for different parts of the region. Moreover, the magnitudes of important, though indirect potential benefits, such as reduction in the need for employment−based migration and improved access to safe water for domestic purposes, were not known with any degree of precision.

Potential for groundwater utilization

Groundwater utilization potential was considered from the technical perspective—that is, the potential of the aquifers as determined by the hydrogeology of the region—and from socioeconomic perspectives—other factors that determine the ability to utilize groundwater.

There was universal agreement that data were insufficient to determine the potential safe yield of the aquifers. This is reflected in significant changes in estimates of potential over time.2 Assessing groundwater potential in the region is complicated by a number of variables: a range of aquifers at different depths, a high degree of local variability, the interconnectedness of the surface hydrologic system and the subsurface system, multiple sites of groundwater recharge (some at substantial distances from extraction sites), and local vulnerability to salt water intrusion and waterlogging.3

Notwithstanding this lack of information, the general view was that the region had substantial unutilized groundwater potential. At the same time it was recognized that in specific local situations overdraft and rising water table conditions may exist.4 Whether overdraft was seen as a serious problem had to do with the relative values accorded to impacts of short periods of overdraft and of longer−term increases in net recharge. It was recognized that opportunities existed to increase the effective storage capacities of the aquifers by drawing down the water tables during the dry season, thus providing increased storage capacity for the succeeding monsoon season.5 However, this method increases the potential for adverse effects on low flows in the surface streams of the region and on the yields of shallow tube wells. Thus, the magnitude of potential supply is determined by a combination of natural conditions and aquifer management practices, rather than by hydrogeology alone.

Similarly, the problem of a rising water table arises from a combination of natural conditions and management practices. In this case, seepage from irrigation canals and fields contributes to an increase in the supply available in the aquifers, particularly in the shallow aquifers.6 When the water table interferes with plant growth or agricultural practices the increased groundwater supply is a

problem. Solutions include channel lining and improved irrigation practice, but these preclude increasing conjunctive use of groundwater and surface water. The colloquium recognized the need for improved conjunctive use management and the implications for ultimate potential.

Lack of information was identified as a critical inhibitor of appropriate planning for the development and use of groundwater. The exception is Bangladesh where results of a major study of groundwater resources seem to offer adequate information for establishing policies and project plans.7 However, colloquium participants thought that groundwater development in the region should be based on a combination of a regional perspective that considers the interconnectedness of the various parts of the system and a local view that recognizes the geographic variations in groundwater specific to particular areas. The necessity for a regional perspective is strengthened by the international nature of the connected surface and subsurface water systems.

Although planning for longer−term development of groundwater irrigation will require a better understanding of ultimate physical potential, the determination of economically and socially usable potential was thought to be of immediate importance. The study showed that in many situations, groundwater irrigation is profitable at both national and farm levels.8 However, it was clear that this did not hold for all situations, nor was it consistent over time. Examples were the deteriorating economic situation for irrigated boro rice in Bangladesh, and for areas in eastern India where groundwater irrigation was being inhibited, leading occasionally to a reversion to rainfed production.

The extent of usable groundwater must also be considered from the standpoint of the externalities associated with its use. If, for example, the water table is lowered, it could adversely affect the water yields of shallow tube wells, to the point of making the wells nonfunctional. The lowered water tables could also reduce stream base flows to the point where traditional water−lifting devices cannot be used. This can have severe economic and social impacts on smallholders and landless laborers who depend on these traditional methods. Thus, the externalities of groundwater use cannot be ignored in determining usable potential.

These externalities extend beyond purely economic effects and the context of irrigation. There was recognition at the colloquium of the potential for adverse impacts of groundwater irrigation on domestic water supplies and human health—just as there was recognition of the possibilities for positive contributions. Many villages in the region depend on groundwater for their domestic water supplies, including for household gardens. These supplies can be drawn from wells or from village tanks that are fed from groundwater. Lowering the water table can adversely affect these supplies and produce serious health consequences, as occurred in eastern India in 1984 when villagers were forced to use polluted water sources for domestic purposes.

Considering the complexity of groundwater utilization issues and the local nature of many of the relevant factors, it is not possible to determine the level of economic utilization of the groundwater potential, but it is at least possible to identify the direction of impacts as changes are made in the parameters of the groundwater system.

Factors affecting access by the poor

Colloquium participants agreed that crucial to the utilization of groundwater for alleviation of poverty was the ability of the poor to access and gain control of the groundwater or of groundwater benefits. Thus, much of the discussion of the written material focused on factors affecting access by the poor.

Technical factors. Three types of technical factors were identified as important: aquifer characteristics, well and pump types, and energy sources.

The *aquifer characteristics* of primary importance were considered to be the depth to the aquifer and the dynamic pumping lift. The depth to the aquifer influenced the type of technology that could be economically utilized—shallow aquifers are accessible with manual drilling equipment, deeper aquifers require mechanically powered equipment. Shallow aquifers not only make the water more easily accessible, they also offer an opportunity for the poor and landless to be involved in drilling.9

Pumping lift affects the cost of pumping irrigation water and influences decisions on well size and type of pumping equipment based on economic feasibility. It was recognized that deep aquifers with relatively high pumping lifts almost in evitably would require public investment to make the water accessible to the poor.

The location of the aquifer with respect to sources of saline intrusion, waterlogging, or both also had more general impacts on the type of utilization of the groundwater, with corresponding impacts on the ability of the poor to obtain benefits. Because of the geographically variable nature of the aquifers in the region, "safe yield" will vary from one area to another and, in time, have a variable influence on the opportunity for access of the poor. When safe yield is estimated to be low in an area—because of low recharge, the possibility of salt water intrusion, or low hydraulic conductivity—there is increased potential for monopoly development, often in the hands of the more powerful.10

It was also recognized that opportunities to benefit from groundwater potential will vary within the region, depending on the agricultural environment in each locale. Areas with more productive soils, more production services, climatic conditions suitable for year−round cultivation, and low probabilities for natural disasters will have greater opportunities for benefit.

When the discussion turned to *well and pump types*, it was clear that the choice of appropriate technology from among a wide range of options is a complex one. For example, for dynamic suction lifts of less than 7 m it is possible to use a variety of manually operated pumps or surface− or pit−located mechanically powered centrifugal pumps. For lifts greater than 7 m it is possible to use hand−operated reciprocating pumps, diesel or electric turbine pumps, or electrically driven submersible pumps. The financial appropriateness of hand−operated pumps was clear, but the net benefits to the poor were not as obvious. And the potential for negative health effects associated with dependence on manually operated pumps, especially for women and children, was apparent from experience in Bangladesh.11 Moreover, the economic justification for manually operated pumps frequently was less than that for mechanically powered pumps.

Conventional decisions about appropriate well and pump sizes for deep aquifers were questioned during the study. Typically, relatively large wells are installed in the deeper aquifers because the cost of drilling to greater depths usually is a much larger fraction of the total cost of a well than is the cost of the larger pipe. Thus, installing a larger diameter well that permits a larger capacity pump is considered the appropriate design. However, the result is a large investment with a water delivery appropriate for a large command area. As will be noted later, the anticipated command area rarely is achieved, and there are significant difficulties in maintaining the large equipment. Colloquium participants identified the option of smaller bore wells with modified pumps to service the deep aquifers. They recognized, however, that there is little experience with this technology at this time. The problem of appropriate pump decisions was further complicated by the fact that matching a pump to an aquifer and irrigation command and matching a motor or engine to a pump to achieve reasonable technical efficiencies require the availability of a number of pump and motor or engine types and sizes.

It was concluded that groundwater conditions in the region vary sufficiently to require a relatively wide range of technological options, which should be made available with a minimum of institutionalized bias. It was recognized that although this range in technology carries with it problems of spare parts maintenance, repair capacity, and the like, these problems would be transient and would be alleviated over time.

Of all the technical factors, the circumstances related to *energy sources* were considered most important, not only for access of the poor but also for the viability of groundwater irrigation. The two basic advantages of groundwater irrigation over surface water irrigation are the relative insensitivity of groundwater to rainfall variability (seasonal or yearly) and the potential to obtain water more or less on demand. These advantages permit more secure agricultural planning and lower levels of risk and thus encourage investment in the inputs necessary to utilize new agricultural technologies.

Relative insensitivity is a function of the hydrogeology of the region, but the ability to use that characteristic and to respond to need depends on a secure and adequate pumping capacity. In much of the region this does not exist.

In the study area, electricity and diesel fuel are the predominant sources of pumping energy. Human and animal power play significant roles, and renewable sources, such as solar power, wind, and bio−gas systems, have negligible importance. The use of human and animal power is declining in most of the region. This is partly because of the requirements of the pumping process—harnessing large amounts of energy to efficiently carry out a continuous, mindless, repetitive activity at a fixed location is particularly appropriate for a mechanically powered machine. Pumping needs none of the thinking, mobility, and dexterity skills of human beings. As a result, the effective wage rate for a human being will be close to zero if mechanical pumps can be used instead. However, in specialized situations, such as low−volume pumping for domestic use or for home gardens and other small area irrigation, manual pumping can be an appropriate substitute for mechanically powered pumping.12

This rationale for the shift from manual and animal pumping is strengthened by the adverse effects on human and animal health from extended pumping. But another factor that has accelerated the shift from manual pumping has been government programs that have subsidized the introduction and operation of mechanically powered pumps. This combination of fundamental factors and government policies will mean the continued decline in importance of human and animal power for irrigation.

Government policies in much of the region tend to distort not only the choices between mechanically powered and manual− or animal−powered pumping, but also the choice between electrically powered and diesel−powered pumping. This distortion occurs in relation to both initial investment and subsequent operation. For example, electric motors and electric connections are highly subsidized for small and marginal farmers, at least in eastern India, whereas diesel engines are not subsidized in India. And in Bangladesh some diesel engines are subsidized, including certain types of high−technology imported models, while domestic, lower−technology, and often more easily maintained pumps do not receive the subsidy.

Distortions in relation to operating costs are even more apparent. Electric rates in eastern India are substantially subsidized; diesel fuel is subject to taxation. Fuel costs for diesel engines usually must be paid prior to use; electricity bills are paid after use, and frequently not paid at all.

These policy−related distortions are reinforced by the fact that diesel engines are more difficult to operate and maintain. However, diesel engines have other characteristics that make them attractive as power sources. One advantage is that they are essentially under the complete control of the operator and, assuming the availability of diesel fuel, the decision to irrigate can be made at any time. By contrast, irrigation with electrically powered pumps depends on the availability of electric power in the lines. Diesel−powered pumps are also relatively portable and can be used with a number of wells to irrigate dispersed parcels, either within the same farm holding or on a rental basis. They can be moved to secure locations at night in areas where security is a problem. And diesel engines can be used for other purposes, such as powering threshers, mills, and the like. Although such uses were prohibited in Bangladesh on the basis that they would reduce employment opportunities, this has not been verified, and there is at least some evidence that the reverse is the case in some instances.13

Notwithstanding the potential benefits of diesel engines, from the perspective of farmers electrically powered pumps usually are both financially and economically preferable where electric power is available. But they might not be preferable from the public social perspective. If the full cost of power generation and transmission—including the opportunity costs for alternative uses of the available supplies—offset by balance of payment considerations associated with fuel imports are taken into account, it is not obvious that electrically powered pumps are more economic than diesel.

In addition to the foregoing issues associated with the selection of power source, the need to improve the quality and availability of electrical and diesel power was cited frequently in the literature and in the colloquium. The two sources are not equally available across the region; nor do they have the same economic and equity effects. Electricity is not available in many areas—most mechanical pumps in the Terai of Nepal and in Bangladesh, for example, must be diesel−driven. In eastern India there is a degree of rural electrification, but it is well behind most other parts of the country. And where electricity is available there are major problems of quality and reliability.

Problems of quality and reliability have both direct and indirect adverse effects. Low voltages and surges of electric power damage electric motors, frequently resulting in major breakdowns. Adulterated diesel fuel can have similar effects on diesel engines. Problems with the reliability of electric power have been such that those who could afford it, that is, the relatively rich, have invested in stand−by diesel power units. The lack of reliability increases the risks in irrigated agricultural production and, thus, inhibits full utilization of the potential of improved production technologies.

The colloquium participants (and the study more generally) concluded that the question of energy sources and supply presents opportunities and imperatives for research, technological improvement, and policy review and modification.

Economic factors. As suggested earlier, the poor can gain access to the benefits of ground water irrigation either by getting control of a significant portion of the resource itself or by engaging in activities that directly or indirectly capture the benefits of the use of the water. Gaining control of the water can be through direct ownership or through purchase of the water.

Direct ownership of wells and pumps by the poor is difficult in much of the region. Improved seeds, fertilizer, and labor are somewhat divisible inputs to the agricultural production process and are thus reasonably accessible to small and marginal farmers, though not necessarily in the amounts that would be optimal. By contrast, investment in wells and pumps tends to be costly, usually requiring access to credit and, in some instances, subsidies. The importance of subsidies is not clear, however, because of the different levels of profitability of groundwater irrigation under different conditions and because of the tendency for the more powerful to have greater access to subsidies. This is illustrated clearly in the privatization program in Bangladesh, where large numbers of shallow tube well rental pumps were sold at subsidized rates to organized groups of farmers, in an attempt to target the subsidy to marginal and small farmers. It turned out that many of these groups were either under the control of a dominant individual or did not exist.14

The subsidy picture in the region is complex and not entirely clear. Each country has its own subsidy programs, as does each of the Indian states. In general the investment subsidies to private tube wells, and particularly to manually operated tube wells, have been at much lower rates than direct and indirect subsidies to the publicly operated tube wells, especially the deep tube wells. In addition, groundwater subsidies tend to be much lower than the effective subsidy provided by most government−developed surface water systems. Where physical conditions facilitate access to the aquifer and where the water table is relatively shallow, private development can take place with very small investment subsidy.15

Operating subsidies vary across the region. Electric pumps receive significant indirect subsidy through the relatively low prices for electric power, although it has been argued that the poor quality and unreliability of the power significantly reduce the actual level of that subsidy. A special form of operational subsidy is evident in the priority access to power accorded to the World Bank tube wells.16 Receiving priority for electric power sixteen hours a day represents a substantial, if indirect, subsidy. The monetary value of this subsidy could be determined by considering the opportunity cost of the use of that electricity for other productive activities.

Access to credit was identified as essential for the poor to obtain access to groundwater and groundwater irrigation benefits. Credit is necessary to purchase pumping equipment, even relatively small equipment, and it is necessary to purchase the complementary agricultural production inputs required to take advantage of the production potential that arises with the availability of a reliable irrigation source. However, evidence in the literature and in colloquium presentation indicates that when the poor apply for institutional credit they incur higher costs than do the better−off, even when there are subsidies targeted to the poor. These costs include the substantial "transaction" costs of complex regulations that require time−consuming, frequently costly interaction with government functionaries. These regulations can cover not only questions about financial arrangements, but also regulations on well spacing, policies about pumping technology, and so on. The differential in credit costs between the poor and the rich is worsened by the relatively poor repayment of loans by the rich.17

In addition to the problem of transaction costs, the poor have difficulty providing the collateral usually required for credit access. There is evidence that changing collateral requirements and reducing transaction costs significantly improve access to credit by the poor.18

Access to groundwater can be through purchase of the water or through direct ownership of a well and pump. Because a large fraction of the target group of very small farmers do not own pumps, water purchase is a major form of access. There are both public and private sources for purchasing water in the region. Public supplies in the region typically are from state deep tube wells, although these have had severe problems over the years. Average hours of operation and area served usually are much below design anticipation and high maintenance costs are a serious concern. The energy problems discussed earlier plague state tube wells in much the same ways as they do the private wells. In addition, there are problems with inadequate conveyance systems, inadequate pump operator performance, low maintenance budgets, and poor repair services. To rectify these problems

the World Bank supported the development of technically improved deep tube well systems, with buried−pipe, automatic−delivery conveyance systems, dedicated power lines and priorities, and user committees. Unfortunately, these changes have not eliminated the problems, and although some improvement has occurred, the deep tube wells still fall far short of anticipation.19

However, a combination of economic profitability from groundwater irrigation, private pump owners with excess capacity, and willing buyers who can physically access the water usually results in the development of significant water markets, and markets have indeed developed in parts of the region. From social equity and economic efficiency perspectives these markets appear to be a positive development that should be fostered. However, there is a lack of information about longer−term effects on such factors as tenancy and land concentration.

Two basic systems of charges exist in these water markets—sharecropping and volumetric (equivalent) rates.20 These systems exist in a number of variants and the resulting rates can differ widely.21 From a variety of perspectives, including social equity and economic efficiency, some form of volumetric pricing was identified as being more desirable. With either system a critical element in the pricing is the degree of competitiveness among the water suppliers. For example, over time the sharecropping rate in parts of Bangladesh has declined from 50 percent to 33 percent to current levels of about 20 percent. Much of this change is attributed to the availability of multiple water suppliers. This clearly is beneficial to the marginal farmers, but it raises questions about the viability of landless pump groups. (This will be addressed in the section on social factors below.)

The absolute level of water charges is affected by the level of investment cost and the cost of pumping, as well as by the degree of competitiveness. Investment cost, although mainly determined by the nature of the aquifer location and type, is influenced by the subsidy policies of the government. Similarly, pumping cost is a function of water levels and the cost of energy. Government energy policy can have a major effect on the price of pumping energy and on the willingness of water producers to expand their markets. During the colloquium, there was substantial discussion of the potential benefits from flat rate, progressive demand−charge (based on connected horsepower) electricity tariffs, compared with pro rata use charges. Evidence from other parts of India suggests that flat rates result in expanded commands and lower rates, in the presence of competitive suppliers. The evidence also suggests that neither economic nor technical efficiency is adversely affected by flat rates and that net revenues to the electricity supplier do not decline.22 This suggests that in those parts of the region where electric power is the primary source of pumping energy, there should be further consideration of this option.

Opportunities for access to groundwater are not limited to individual ownership of wells and pumps or to purchase of water from a supplier. Group ownership of wells and pumps is encouraged in the region, both by governments and by nongovernmental organizations. The formation of groups presents additional problems, however, which are discussed in the following section.

Social factors. A number of approaches to the formation of groups for access to water have been tried in the region, some of which have been very successful, but many of which have failed. The formation of stable, productive groups usually is accompanied by significant transaction costs—to reduce social tensions within the group, to acquire the skills to manage the group and the pumping, and to take advantage of the various government programs intended to help the poor. These transaction costs tend to increase rapidly as the size of the group increases, as would be the case in most deep tube well projects.

Many of the more successful efforts at group formation have involved nongovernmental organizations who, to a significant extent, reduce and absorb the transaction costs. Although there are examples of valid self−generated farmer groups, frequently these are the result of efforts by wealthier, more powerful individual farmers interested in tapping the programs designed for the marginal farmers. Government attempts to establish water user groups have had little success; the failure of the "day area committees" in the World Bank tube well projects is an example.

In Bangladesh, the formation of landless pump groups by PROSHIKA, a nongovernmental organization, illustrates a successful approach to the organization of pump operating groups.[23] This approach has been used by other nongovernmental organizations and, in modified form and on a larger scale, by the Grameen Bank. In India, examples of effective groups associated with ground−

water irrigation can be found in areas served by the Ramakrishna Mission and other nongovernmental organizations. In Nepal, the Agricultural Development Bank has been successful in organizing groups using techniques that reduce the transaction costs that typically exist.[24]

Although evidence suggests that groundwater irrigation in areas served by groups is more efficient, for both the irrigation service provided and the technical efficiency of pump operation, there is evidence that the increased productivity results in changes in sharecropping percentages and even in the amount of land that is shared out. There is a lack of definitive data on the longer−term social impacts of the improved irrigation. There is also evidence that these irrigation groups go through a maturation process that tends to lead to dissolution. Lower water rates available from competing sources reduces the incentive to participate in the group; membership attrition also occurs as transaction costs are assumed by the group when the supportive nongovernmental organization reduces its input. There was general agreement in the colloquium discussions that there is a role for these pump operating groups, particularly in noncompetitive water supply environments. It was not clear under what conditions and time frame it would be best for the groups to phase out. There was consensus that more definitive research in this area would be important.

The colloquium discussion, coupled with the literature review and the presentation by Dr. D.E. Parker, suggested a number of research questions and potential policy changes. These have been discussed earlier in these colloquium findings and are not repeated here.

Notes

1. Much of this section has been taken from the colloquium presentation by Dr. D.E. Parker.

2. See table 3 in the overview of this volume.

3. See chapter 1 by G.T.D. Pitman in this volume.

4. See a forthcoming World Bank report by W. Barber and W. Price, "Water Resources of the Ganges Basin, an Assessment of Water Resources, Their Development, Availability, and Demands."

5. See chapter , Pitman.

6. See for example, R.S. Saxena and P. Singh, "Variations in Groundwater Conditions and Exploitation in Different Districts of Eastern Uttar Pradesh." Presented at the Workshop on Development and Management of Groundwater Resources in Eastern Uttar Pradesh, Narendra Dev University of Agriculture and Technology. April 1988, Lucknow.

7. See chapter 1, Pitman.

8. See the appendix to this volume, G. Levine, S. Abeyratne, and U. Pradhan, "Groundwater Utilization and Poverty Alleviation in South Asia," literature review, table 5.

9. See appendix, G. Levine, S. Abeyratne, and U. Pradhan.

10. See, for example, chapter 2 by M.A. Hamid in this volume.

11. For more detail, see chapter 3 by M.A.S. Mandal in this volume.

12. See chapter 3, Mandal.

13. See chapter 2, Hamid.

14. See chapter 2, Hamid.

15. See chapter 5 by S.K. Upadhyay in this volume.

16. The World Bank tube wells, a set of wells in India, are designed to eliminate a number of the previously identified causes of poor performance of deep tube wells. The design changes are both technical and organizational. For a more complete discussion see chapter 8 by N. Pant and chapter 9 by S. Kolavalli and N. Shah in this volume.

17. See chapter 11 by S. Chakraborty in this volume; chapter 3, Mandal.

18. See chapter 5, Upadhyay.

19. See chapter 8, Pant and chapter 9, Kolavalli and Shah.

20. Although it is feasible to meter the volume of water delivered by a pump, most volumetric deliveries are indicated by the time duration of pumping. Different pumps will deliver different amounts of water per hour; even the same pump with different water table levels, as frequently will occur during the course of a season, will deliver at different rates. Thus, timed delivery is only quasi−volumetric.

21. See chapter 14 by T. Shah in this volume.

22. See chapter 10, Shah.

23. For a more complete description of the PROSHIKA approach, see chapter 4 by Q.F. Ahmed in this volume.

24. For a description of the ADB/N approach, see chapter 5, Upadhyay.

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PART 1— BANGLADESH

The four chapters in this part make as good a contribution as is now possible to understanding issues of groundwater irrigation in Bangladesh. Because of the development of a National Water Plan, information on groundwater availability and potential is better for Bangladesh than for the rest of the study area. And yet, as Pitman notes in chapter 1, information is far from complete, particularly for the lower of the two aquifer sequences underlying the country.

Chapter 1 is based on work for the National Water Plan and on the findings of two surveys of groundwater development that were carried out after the National Water Plan was finalized. The author, who was intimately involved in preparing the National Water Plan, discusses groundwater availability throughout the country, examines the advantages and drawbacks of available pumping technologies, looks at groundwater development under the National Water Plan in relation to possible development strategies, and reviews the technological changes that must occur for groundwater exploitation to move closer to full potential.

Chapter 2 focuses on the benefits accruing to the rural poor from groundwater irrigation and the socioeconomic and financial issues that arise in improving access to such irrigation for the poor;

the author suggests policies and organizational or institutional approaches to increase the benefits flowing to the poor and the speed with which benefits can be captured.

Chapter 3 focuses on access to groundwater irrigation by small farmers, the emergence of water markets, and the evolution of the role of sharecroppers after the introduction of irrigation. The author briefly examines the experience of landless irrigation groups and the comparative performance and potential of handpump irrigation. Attention then shifts to competition in the groundwater market and the role of subsidies and electricity supply in distorting this competition. The chapter continues with a performance assessment of private versus rented tube wells and of different management and payment systems for groundwater irrigation.

Chapter 4 reports on the landless irrigation groups promoted by PROSHIKA, a nongovernmental organization that pioneered this scheme. The author traces the genesis of the landless irrigation concept, its implementation, and the achievements of landless groups in credit repayment, employment generation for the poor, access of small farmers to irrigation, and changes in the relations between the landless and other classes in Bangladesh.

1—
National Water Planning in Bangladesh 19852005: The Role of Groundwater in Irrigation Development

G.T. Keith Pitman

Bangladesh suffers from a chronic foodgrain deficit and widespread poverty. Agriculture, including forestry, fisheries, and livestock, is the dominant sector in the economy in gross domestic product, employment, and foreign exchange earnings. In 198788 agriculture accounted for almost 50 percent of the gross domestic product, of which rice contributed 25 percent and other crops 40 percent. In the medium term, national growth is almost wholly reliant on rapid growth of agricultural output because agriculture accounts for more than 80 percent of all tradable produce.

Population pressure on land resources is a major constraint to accelerated agricultural development, and the majority of the rural population is already near or below the poverty level. Average cultivable land area per capita will decrease from about 0.09 hectares (ha) in 198485 to near 0.05 ha by 2005. About 11.8 million, or 84 percent, of the 14 million rural households do not own the minimum one hectare of land needed to support a family using traditional methods. Consequently, 50 percent of the rural population lives in absolute poverty, unable to purchase a minimal diet of 2,200 calories a day, and 30 percent subsists at the extreme poverty level of 1,800 calories a day.

More than 80 percent of the population of 104 million relies on agriculture for livelihood. Directly and indirectly, agriculture accounts for about 90 percent of rural male employment and 80 percent of rural female employment. For most of the rural population the only means of enhancing income and welfare is to increase the productivity of the land.

The need to produce more foodgrains to feed an ever increasing population has meant that the development of water resources for agriculture has dominated all other considerations. Water is also important to other sectors of the economy, however, including inland fisheries, which produce most of the animal protein consumed domestically. So development of water resources cannot be limited to agricultural needs if national goals are to be achieved.

Variations in water supply by season and area restrict its contribution to the economy's development. An abundance of water during the monsoon results in widespread flooding that damages standing crops, while a lack of water during the dry season severely restricts agricultural production.

Considering the disparity between requirements for and availability of water, the government of Bangladesh, in association with the World Bank and the United Nations Development Programme, considered it essential to formulate a national water plan that would take into account the needs of all water−use subsectors. The task of developing a comprehensive national water plan for 19852005 was given to the Master Plan Organization in 1983 under the aegis of the Ministry of Irrigation, Water Development, and Flood Control.

This chapter describes how groundwater irrigation has been incorporated in the National Water

Plan completed in 1987. Groundwater irrigation is economically justified and provides the quickest way in the next decade to raise productivity and employment in the agricultural sector. The availability of irrigable land and groundwater poses few constraints to development of groundwater irrigation. A laissez−faire approach to groundwater development using small−scale, simple pumping technologies is probably the best way to accelerate growth in rural employment and incomes. But because rural populations are growing faster than projected growth of the agricultural sector, the problem of rural unemployment and underemployment cannot be solved in the agricultural sector alone.

Policy reforms were implemented in 198790 to deregulate importation and local purchase of fertilizers and pumps and engines used for groundwater irrigation. Government control of procurement and standardization of pumping equipment has been lifted; fertilizer importation is now primarily in the private sector. As a result, new private markets have developed, prices have fallen sharply, and irrigation has expanded at rates believed impossible in 1986.

The National Water Plan

The government of Bangladesh in the Prospective National Development Plan for 1983 to 2000 specified the following objectives: reduction of poverty, economic growth, population control, elimination of illiteracy, and energy development. A medium term goal underlying poverty reduction and economic growth is to achieve foodgrain self−sufficiency.

National Water Plan objectives, which encompass various sectors, are potentially conflicting:

To maximize value added in agriculture and fisheries.

To provide water on time and in sufficient quantities to all users when needed.

To manage and control damaging floods.

To achieve growth in equity.

Planning process

Trends in water development for agriculture since the mid−1960s and the corresponding growth in production were examined to evaluate how effective water development has been and to determine the potential for further development and innovation. Land and water resources were assessed, and the resources available to meet the water needs of each sector were computed. Based on these analyses, the National Water Plan was formulated to maximize value added in agriculture and fisheries through allocations of water and by establishing policies, investment strategies, and programs:

To meet domestic and industrial needs for water on a priority basis.

To maintain or improve water quality in critical areas.

To maintain effective water transportation.

To maintain and expand inland and coastal fish production.

To develop water resources to enhance agricultural production (thus contributing to foodgrain self−sufficiency).

To control flooding and improve drainage in a large part of the country.

The National Water Plan specified that maximizing value added in agriculture and fisheries is the primary objective and defined other sectoral objectives as constraints on the main objective. A corollary of this objective was maximizing foodgrain production. Constraints used in the plan included: land and water resource availability; water requirements of nonagricultural sectors, including salinity control, dilution, and navigation; regional balance in investment and socioeconomic equity; and institutional capacity and financial resources. Each of these constraints was treated as a planning objective that had to be satisfied before the value of the main objective could be maximized.

For the National Water Plan Bangladesh was divided into five planning regions and sixty planning areas that form 160 discrete watersheds. Groundwater was assessed within a hydrologic framework and was considered part of the larger hydrologic cycle pertinent to Bangladesh and the National Water Plan.

Land use

The net cropped area used in the 1986 National Water Plan was 9.56 million hectares (Mha); current fallow was 0.51 Mha and cultivable waste 0.23 Mha in 198485. With so little new land available for cultivation, additional productivity and agricultural employment must come from intensified land use.

The area under wet season (*Kharif)* crops in 198485 was 9.26 Mha compared with 3.23 Mha under dry season (*rabi)* crops. Rabi crops are restricted to areas where residual soil moisture is adequate or irrigation is available.

Rice is grown in all crop seasons and uses about 80 percent of cropped land. (Rice and wheat together use about 85 percent of cropped land.) Among rice crop varieties, Local Transplanted Aman (aman) is most prevalent with 36 percent of the net cropped area followed by B. Aus with 24 percent. About 73 percent of boro rice is in high yielding varieties. High yielding variety rice covers 29 percent of net cropped area. About 49 percent of high yielding variety rice is irrigated. Irrigated boro rice covers 36 percent, and irrigated aus 5 percent, of all high yielding variety rice.

The amount of land suitable for irrigation, based on soil and agroclimatic suitability ratings for wheat and boro rice, is 5.8 Mha, a potential increase of more than 300 percent over the estimated irrigated area of 1.92 Mha (21 percent of net cropped area) in 198485. Thus, the availability of irrigable land is not a constraint to agricultural expansion in the foreseeable future.

Foodgrain output, groundwater irrigation, and employment

Agricultural sector food output growth rates in excess of 3 percent must be maintained if the needs of the population are to be met domestically. With an estimated population increase from 104 million in 198485 to about 166 million in 200405, foodgrain output must grow at the rate of 4.5 percent to achieve foodgrain self−sufficiency targets of 25.1 million metric tons by 1995. Similarly, production of pulses, essential to a balanced diet, must grow at the rate of 3.8 percent.

Since the mid−1970s, growth in foodgrain output has been closely correlated to increase in irrigated area: first, because of the increased area under production, and second, because adoption of high yielding varieties and modern inputs is linked to a secure supply of irrigation water. Studies show that for every 1 percent increase in irrigated area, foodgrain production increases 0.6 percent. However, because some of the increased production can be attributed to better management, fertilizer use, high yielding variety rice, and flood protection of irrigated areas, the irrigation−specific increase in production is probably nearer 0.4 percent.

Groundwater irrigation has been the lead factor in increasing irrigated area since the early 1970s. Studies show that the area irrigated by groundwater increased from nil in 1970, to about 0.73 Mha by 1985, and that groundwater irrigation now equals in importance major irrigation systems and low lift pumping, which rely on surface water.

Initially groundwater was developed, financed, and owned by the public sector, using diesel−powered deep tube wells that can irrigate some 20 to 25 ha per well. Since 1975, privately owned, diesel−powered shallow tube wells, each irrigating about 5 ha, have dominated irrigation well technology. For foodgrain production Gisselquist (1991) estimates that each additional shallow tube well produces 10.8 tons of foodgrain and each additional deep tube well 48.6 tons.

The growth in the number of deep tube wells drilled and the number of shallow tube wells sold from 1973 to 1987 is shown in table 1.1. The Master Plan Organization estimated in 1987 that, in addition to power−driven pumps, as many as 285,400 manually operated hand tube wells were used in 1985. The dramatic fall in sales in 198586 was the result of a groundwater irrigation crisis precipitated by the failure in 1983 of shallow tube wells after the dry season monsoon of 1982, which affected large parts of the northwest region. (Such monsoons occur perhaps once in every twenty to thirty dry seasons.) Because of this apparent shallow tube well failure, proponents of large−scale, public sector surface water development argued that groundwater development had reached its limit. Accordingly, further groundwater development credits in twenty−six subdistricts (*upazilas)*

Table 1.1 Growth of tube wells for irrigation, Bangladesh, 197387

	Shallow tube wells		Deep tube wells	
Year	*Cumulative sold*	*Number of tube wells sold*	*Cumulative installed*	*Number of tube wells installed*
197374	1,000	200	1,800	1,200
197475	3,500	2,500	3,000	1,100
197576	4,800	1,300	4,100	700
197677	7,000	2,200	4,800	3,000
197778	14,100	7,100	7,800	1,800
197879	19,400	5,300	9,600	500
197980	23,900	4,500	10,100	300
198081	41,500	17,600	10,400	1,400
198182	68,600	27,100	11,800	2,300
198283	107,900	39,300	14,100	1,700

198384	141,000	33,100	15,800	1,400
198485	173,500	32,500	17,200	1,000
198586	177,800	4,300	18,200	900
198687	193,400	15,600	19,100	1,500

Source: Gisselquist 1991a.

were discontinued by the government and the World Bank for several years. Shallow tube well sales in 198586 fell sharply, and market confidence was undermined.

An inventory of installed shallow tube wells taken by the Agriculture Sector Team in the spring of 1987 found only 170,000. The difference of 23,000 is probably accounted for by replacement investment and nonirrigation use, for example, milling rice, powering country boats, and other applications similar to nonirrigation uses reported for low lift pumps in the early 1980s.

Reduced growth of groundwater irrigation severely depresses production and employment. Between 198081 and 198486, an average of 36,900 shallow tube well equivalents a year (one deep tube well equals roughly four shallow tube wells) were sold, and foodgrain production expanded at an average rate of 3.6 percent a year. From 198586 to 198788 only about 11,000 shallow tube well equivalents were sold, and the growth in foodgrain production fell to only 0.8 percent a year.

Incremental employment generated by tube well irrigation in Bangladesh was estimated in the National Water Plan as 840 man−days a year per shallow tube well, while field studies in West Bengal reached a figure of 697 man−days. These data imply a loss of employment potential ranging from 12.6 million to 15.1 million man−days a year between 198586 and 198788 because of the decline in shallow tube well sales. Considering that the readily available surface water is fully exploited, continued growth of irrigation from groundwater is essential to increase agricultural employment.

The next section describes how the amount of groundwater available for different types of irrigation wells was determined. This is important because each well type has specific social, technical, and economic advantages and disadvantages.

Hydrogeology

Most of Bangladesh is a gently sloping surface formed by the delta and alluvial plains of the Ganges, Brahmaputra, and Meghna rivers, bordered by hills on the northeast, east, and southeast margins. Floodplains and piedmont plains occupy almost 80 percent of the land area of 143,000 square kilometers (km2), and hills about 12 percent. Half the country is less than 12.5 meters (m) above mean sea level and is underlain by a deep basin that has been filled with sediments during previous geologic periods. Groundwater development and related exploration has been confined largely to the shallow sediments within 150 m of the surface, except in the coastal areas where fresh water aquifers are found only at depths exceeding 400 m.

The upper aquifer sequence functions as a reservoir, generally referred to as the groundwater storage reservoir, in which surface water from the monsoon season is stored for later use in the dry season. The groundwater storage reservoir has three divisions:

An upper silty clay layer, varying from 1 to 50 m in thickness.

A middle composite aquifer of fine to very fine sands averaging about 20 m in thickness.

A bottom aquifer (the main one) of medium, medium−to−fine, to medium−to−coarse sand with layers of clay and silt extending to a depth exceeding 50 m.

The composite aquifer and main aquifer form one hydraulically connected aquifer. Wells placed in either aquifer withdraw water from a common source. Because the upper aquifer is generally unconfined, or locally partially confined, it is recharged vertically from percolating rainfall or flood water during the annual monsoon from June to September.

A lower, saucer−shaped sedimentary artesian sequence of aquifers, which may reach depths of 2,000 m or more, has been identified in central Bangladesh. Similar deep artesian aquifers are believed to be present beneath the Terai alluvial plain of Nepal and India, recharged through the Bhabur zone in Nepal. Insufficient information was available during the formulation of the National Water Plan to make any resource estimate of these lower aquifers except in the coastal belt, and they have not been included as a potential source of irrigation water.

Groundwater hydrology

Under natural conditions the level of water in the groundwater reservoir rises and falls in an annual cycle in response to recharge during the monsoon season. Except in the Chittagong Hill tracts, the Rajshahi High Barind, and the Madhupur tracts north of Dhaka, groundwater levels are at or near ground level during July−October. Levels fall from October to their lowest in April−May, ranging from 3m below surface in the north to more than 15 m in the area of largest groundwater withdrawal northwest of the Dhaka district and in Dhaka city.

During the dry season, most minor rivers are sustained by groundwater outflows, and there is a significant loss of bank storage next to major rivers because of their large change in water level. Pumping groundwater for irrigation starts in January and may continue to June. Groundwater from deep tube wells (shallow tube wells are fielded for the dry season from January) is also used for supplemental irrigation for the aman crop in September−October.

The amount of groundwater available to different types of irrigation wells was established in the National Water Plan by determining potential recharge, how much space is needed in the upper aquifer sequence to store potential recharge, and the amount of groundwater stored within the pumping lift range of various well types.

Using potential recharge as the main development constraint, the mix of feasible well types was determined for each evaluation unit (the upazila, with a typical area of 290 km2) according to accessible storage, and integrated into 160 catchments, the basic National Water Plan planning unit.

Groundwater recharge

The depth of water that annually fills and drains from the groundwater reservoir under natural conditions is referred to in the National Water Plan as actual recharge. Actual recharge varies according to the local relief and drainage and ranges from more than 800 millimeters (mm) in Rangpur district, to less than 100 mm in the southeastern border area. Actual recharge can be increased by creating more groundwater storage space.

Groundwater development potential

The safe seasonal volume of water available for use is highly variable from place to place because of differences in soils, climate, land use, and water quality. The key variables in groundwater resource assessment and development planning—potential, usable, and available recharge, and resource potential—are defined in table 1.2. The groundwater available for future development is the incremental agricultural development resource potential.

Groundwater recharge is derived from horizontal inflow from rivers during the monsoon and deep percolation of rainfall and surface water to groundwater storage. In Bangladesh the contribution from horizontal flow is negligible, except locally, because of very small groundwater gradients under the flat deltaic terrain. Consequently, the vertical recharge is the major source of groundwater recharge.

Under natural conditions the groundwater system is in equilibrium and recharge from rainfall and flood water is lost by drainage to rivers and evapotranspiration in the dry season. Nationally, excluding the Chittagong Hill tracts, natural recharge is estimated at 20,300 million cubic meters (Mm3) a year, equivalent to an average depth of water of 196 mm. If the natural groundwater regime is disturbed by pumping, additional recharge will occur to balance withdrawal until the limit of recharge, potential recharge, is reached. Figure 1.1 illustrates the mechanism to increase capture of recharge.

Potential recharge is the mean annual volume of rainfall and surface water that could reach the groundwater reservoir. It is a theoretical upper limit to the amount of recharge that could occur if it could all be stored. Potential recharge is the sum of actual recharge and rejected recharge. Rejected recharge is the amount of water at the surface that cannot infiltrate and percolate because the water table is at the surface. Rejected recharge becomes surface runoff.

If more groundwater storage is created by lowering the dry season water table, actual recharge will increase and rejected recharge will diminish until the limit set by potential recharge is reached. For this catchment the calculated mean annual potential recharge is 500 mm. Figure 1.2 shows how the balance between actual and rejected recharge changes with lowered dry season groundwater levels.

Annual potential recharge was calculated in the National Water Plan using a simulation model. The major factors affecting the magnitude and timing of groundwater recharge are the availability of water (rain, floods, and rivers) and the infiltration and percolation properties of the soil profile and upper silty clay layer. Potential recharge was calculated from twenty−year and ten−day time series of rainfall and flooding for 430 upazilas, and twenty years of results were integrated into the National Water Plan's 160 catchments. Results show that potential recharge correlates strongly with annual rainfall. Between 15 and 30 percent of annual rainfall can percolate to groundwater storage if storage capacity is not a limitation.

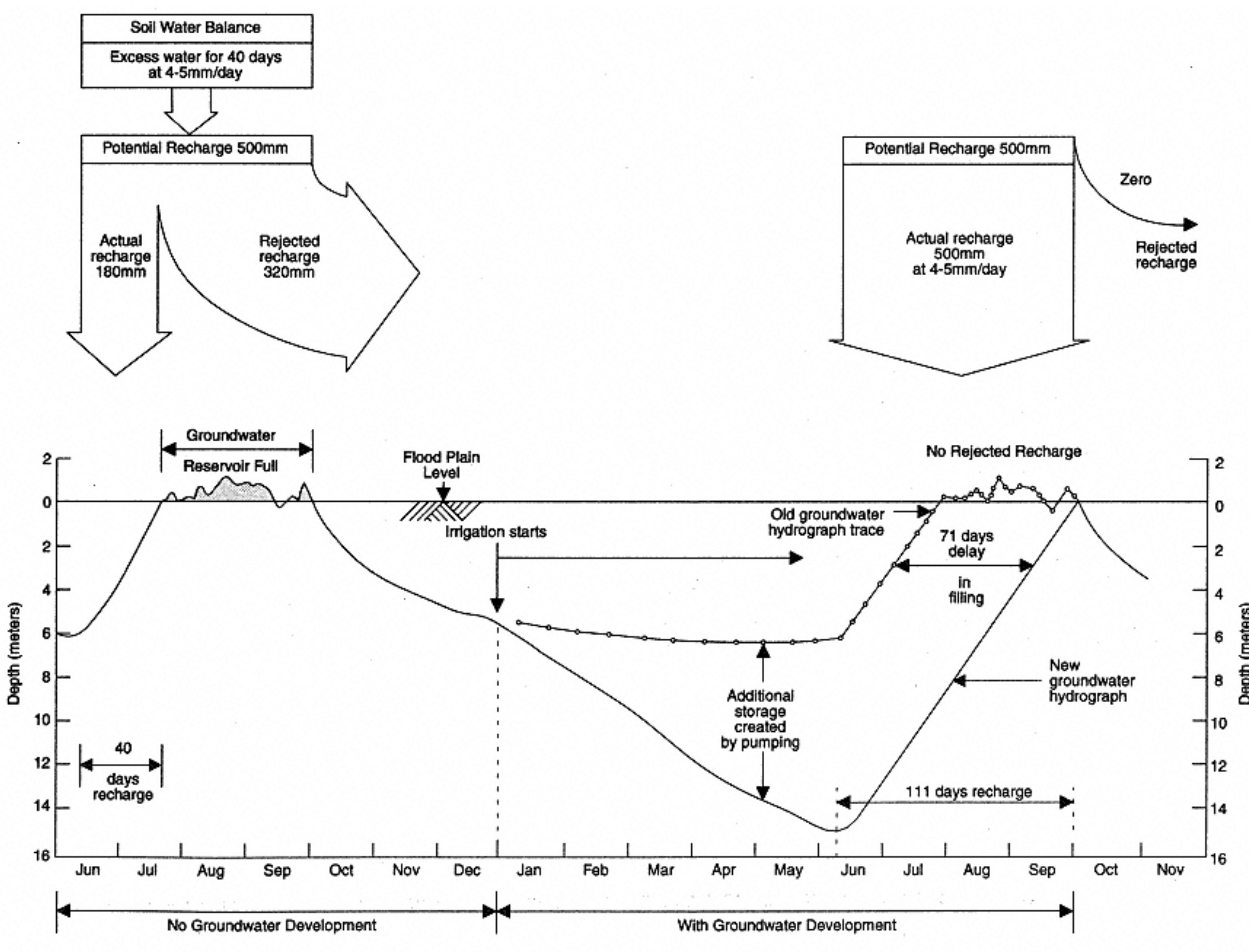

Figure 1.1
Groundwater Storage Creation to Capture Potential Recharge, Bangladesh

	Annual Recharge Balance						
Recharge potential, mm	500	500	500	500	500	500	500
Water table depth, m	6.9	7.3	7.9	9.2	9.9	9.6	11.4
Actual recharge, mm	157	168	183	227	254	242	337
Rejected potential recharge, mm	343	332	317	273	246	258	163

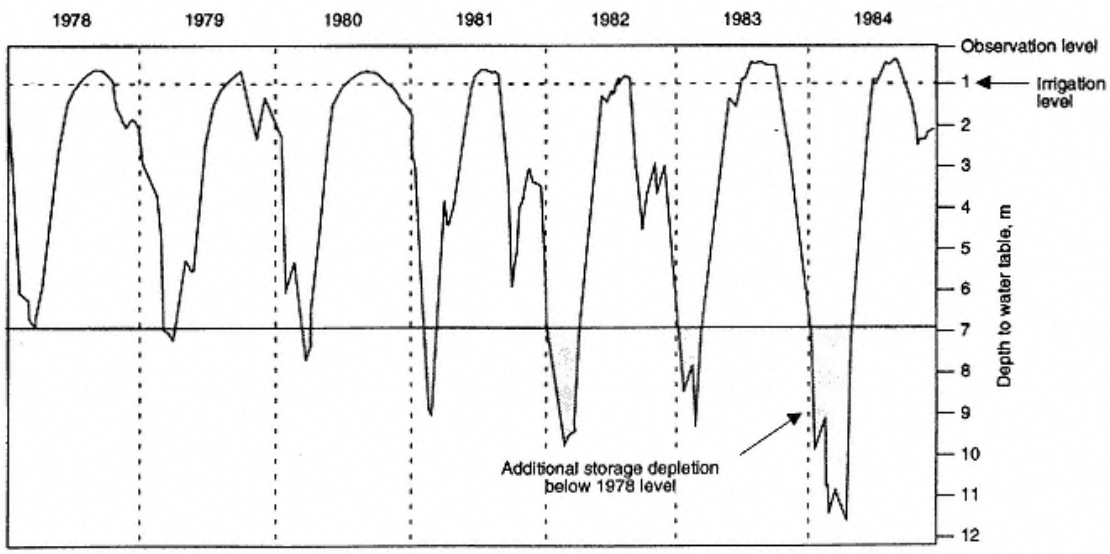

Figure 1.2
Annual Recharge Balance with Groundwater Development (Well Co.− 50 Comilla Kotwali), Bangladesh
Source: Bangladesh Water Development Board.

Table 1.2 National Water Plan groundwater resource assessment and development planning

Level of groundwater assessment	*Process*	*Variable*	*Description*	*Land area considered* a (km2)	*Recharge* b (Mm3)	*Future resource potential (Mm* 3)
1.	Resource assessment	Potential recharge	Assessment of potential recharge using a calibrated water balance model of soil profile and upper groundwater zone. Soil characteristics, such as infiltration and percolation, cropping	134,860	63,620	

			patterns, flooding, and meteorological parameters are included. Results are unconstrained by storage or usage limitations.			
2.	Resource assessment	Usable recharge	Establish reserve to account for uncertainty in estimate of potential recharge, and to account for unplanned groundwater development, cropping pattern changes, and reduction of flooded area. One−quarter of potential recharge is placed in reserve.	134,860	47,720	
3.	Resource assessment	Available recharge	Deduct loss of recharge area due to (i) geographic and physical constraints on groundwater use for agriculture (e.g., salinity, peat soils, terrain), (ii) existing surface water schemes (e.g., Chandpur, GK), and (iii) loss of recharge as outflow to rivers and as capillary evapotranspiration.	71,810	24,410	
4.	Resource development	Future resource	Deduct present use (4,864 Mm3),c allocate sufficient volume to satisfy domestic and industrial demand (838 Mm3) in 2005,d and reduce potential in those planning areas where it exceeds agricultural water demand on	71,810	24,410	17,000

available land (1,686 Mm3).e

km2 Square kilometers.

Mm3 Million cubic meters.

Note: All figures have been rounded.

a. This differs from the resource assessment given in Bangladesh 1986b, Table 10−21, Vol. 2 because it excludes active floodplains as detailed in Table 10−28.

b. Recharge calculated (or estimated) for all catchments excluding active floodplains and Planning Area 59 (Sundarbans).

c. Estimated 1985 groundwater use excluding active floodplains, based on Master Plan Organization (April 1986) estimate of irrigated areas, cropping patterns, and water demands.

d. Calculated for 2005 and put in reserve, excluding active floodplains.

e. Surplus is the difference between available groundwater and maximum crop demand for the water and land resources available under present cropping patterns.

Source: Bangladesh 1986b.

Potential recharge is a variable dependent on future development in each area. Changes in vegetation, land use, and flood control and drainage will modify potential recharge because it is regulated by the water balance of the soil profile. A periodic reassessment will be required, based on updated crop statistics and changes in land use.

The distribution of mean annual potential recharge is summarized in figure 1.3. The annual volume of potential recharge is 68,650 Mm3 over 143,000 km2 , a mean depth of 480 mm. Values over 900 mm occur in the sandy soil areas to the north of Dinajpur and Sherpur. Values less than 200 mm occur west of Jessore and Kushtia where rainfall is low and the upper silty clay layer is thick.

Usable recharge is set at 75 percent of potential recharge leaving 25 percent to account for such variables as future land use and flood control development. Available recharge is determined by reducing usable recharge for geographic and physical limitations on groundwater use; eliminating areas where water needs are already met by surface water development; and deducting outflow to rivers from the start of the monsoon season to the beginning of the irrigation season.[1]

The groundwater resource potential for agriculture, excluding the active floodplain, is equal to mean annual available recharge (24,410 Mm3), less present annual agricultural groundwater use (4,864 Mm3) and domestic and industrial water supply needs (838 Mm3) in 2005. The annual resource potential is thus 18,708 Mm3 , which is 76

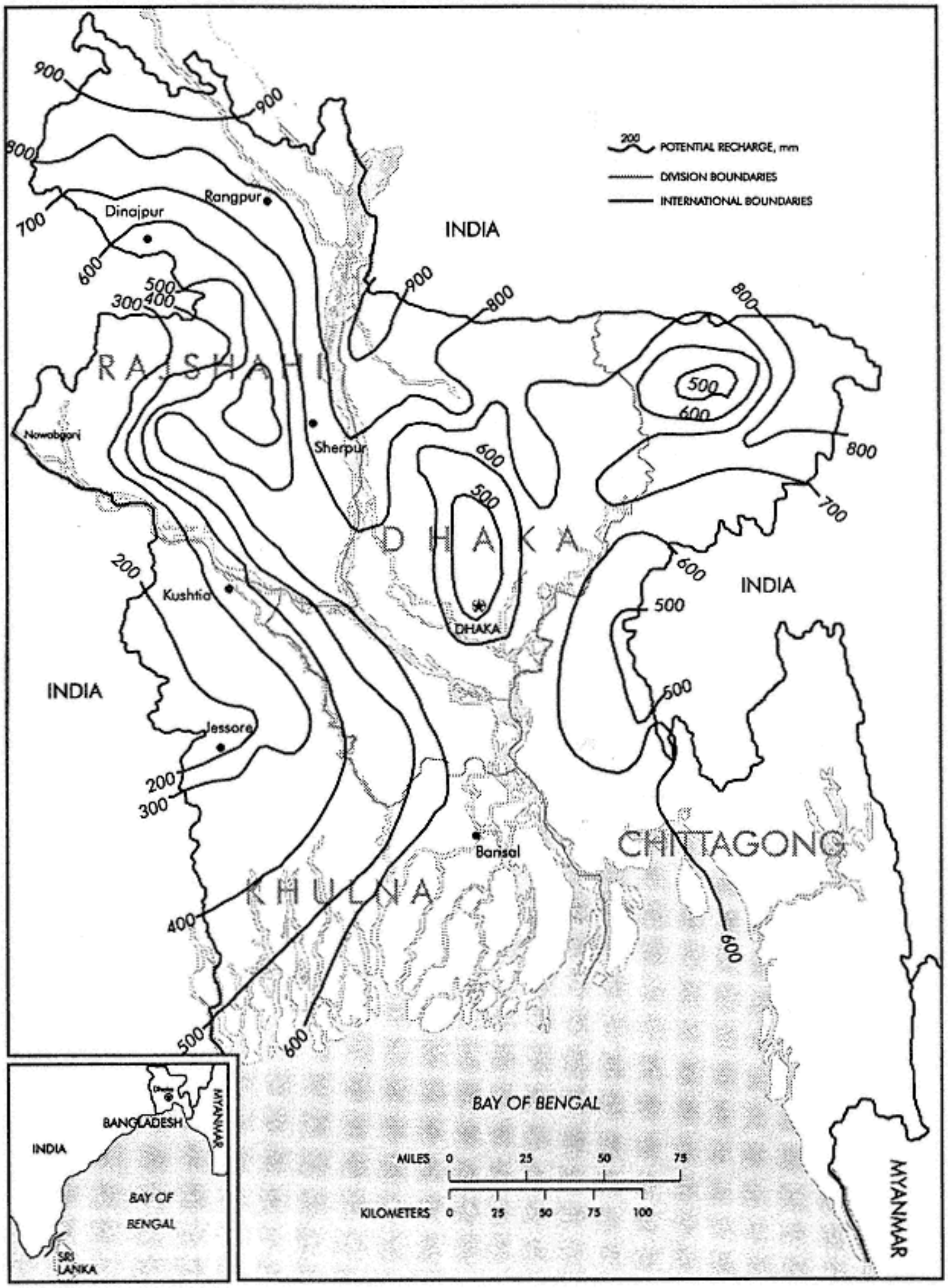

Figure 1.3
Mean Annual Potential Recharge, Bangladesh

percent of available recharge and 29 percent of potential recharge.

This agricultural resource potential cannot be used up where it occurs because in parts of Rangpur, DinajpurJamalpur, Kushtia, and Barisal, there is a surplus of 1,690 Mm3 a year after meeting total dry season agricultural demand. Unless the excess groundwater resource potential is transferred elsewhere for use, the net agricultural resource potential falls to 17,018 Mm3 a year.

Utilization of the groundwater resource potential

To capture all potentially available recharge, National Water Plan policy was to create storage through seasonal drawdown of the groundwater reservoir analogous to a surface water reservoir. In the plan the correlation between volumes of stored groundwater and depth below the surface was established on the basis of lithologic−specific yield analysis of over 16,000 drilling logs.

Nationally, almost 80,000 Mm3 of water can be stored in the top 15 m of the groundwater reservoir, but this water is not evenly distributed among regions (table 1.3). A clearer picture of the variability of groundwater storage is shown in figure 1.4, which maps the depth of reservoir required to store 500 mm. Upazila data show that 500 mm can be stored in only 5 m of sandy groundwater reservoir in Bogra in the northwest, while 17m would be required in the silty day at Khulna in the southeast.

Because tube wells have differing pumping lift capacities, use of a particular tube well type may curtail full development of the groundwater resource by limiting the volume of groundwater that is accessible. The following section describes the

tube well types used in Bangladesh and how groundwater development can be zoned according to the choice of technology.

Groundwater development

In the National Water Plan groundwater was an alternative to surface water development. The criterion for choosing water source was "economic subject to the constraints of water resource availability."

To determine the optimal and most economic means of enhancing agricultural productivity, the cost of developing water resources was determined for a common twenty−five year planning horizon. The costs of groundwater are for installing and operating tube wells, less the disadvantages of groundwater utilization to others (for example, baseflow depletion and disruption of potable water supply hand tube wells). In Bangladesh, both suction mode and force mode tube wells are in use.

Tube well types

Figure 15 illustrates the range of tube well types used in Bangladesh. A suction mode tube well, that is, a shallow tube well, costs around $1,000 and is purchased, installed, and operated by the private sector. A shallow tube well consists of a small−diameter (100 mm) cased well with a 15 liter per second (1/s) capacity pumpset (pump and engine) mounted at the surface. A variation—the deep set shallow tube well—locates the pumpset in a shallow pit. Shallow tube wells and deep set shallow tube wells typically irrigate a command area of 45 ha and serve up to thirty farmers. The significant difference is that shallow tube wells are able to access only the top 6 m of the groundwater reser−

Table 1.3 Groundwater reservior storage volume by region, Bangladesh *(million cubic meters)*

Depth of groundwater a reservior (meters)	*Northwest*	*Northeast*	*Southeast*	*South central*	*Southwest*	*Active floodplain*	*National total*
2	2,015	2,012	437	403	868	526	6,261
4	4,532	4,212	869	823	1,711	1,148	13,295

6	7,976	6,923	1,417	1,322	2,845	1,974	22,457
8	12,232	10,164	2,048	1,880	4,206	2,974	33,504
10	16,891	13,926	2,771	2,493	5,836	3,715	45,632
15	27,979	24,642	4,924	4,380	10,577	7,175	79,677
Percentage of national groundwater reservoir	35	31	6.2	5.5	13.3	9	100

Note: Regional totals exclude districts for which no data were available.

a. Depth below average floodplain level.

Source: Master Plan Organization.

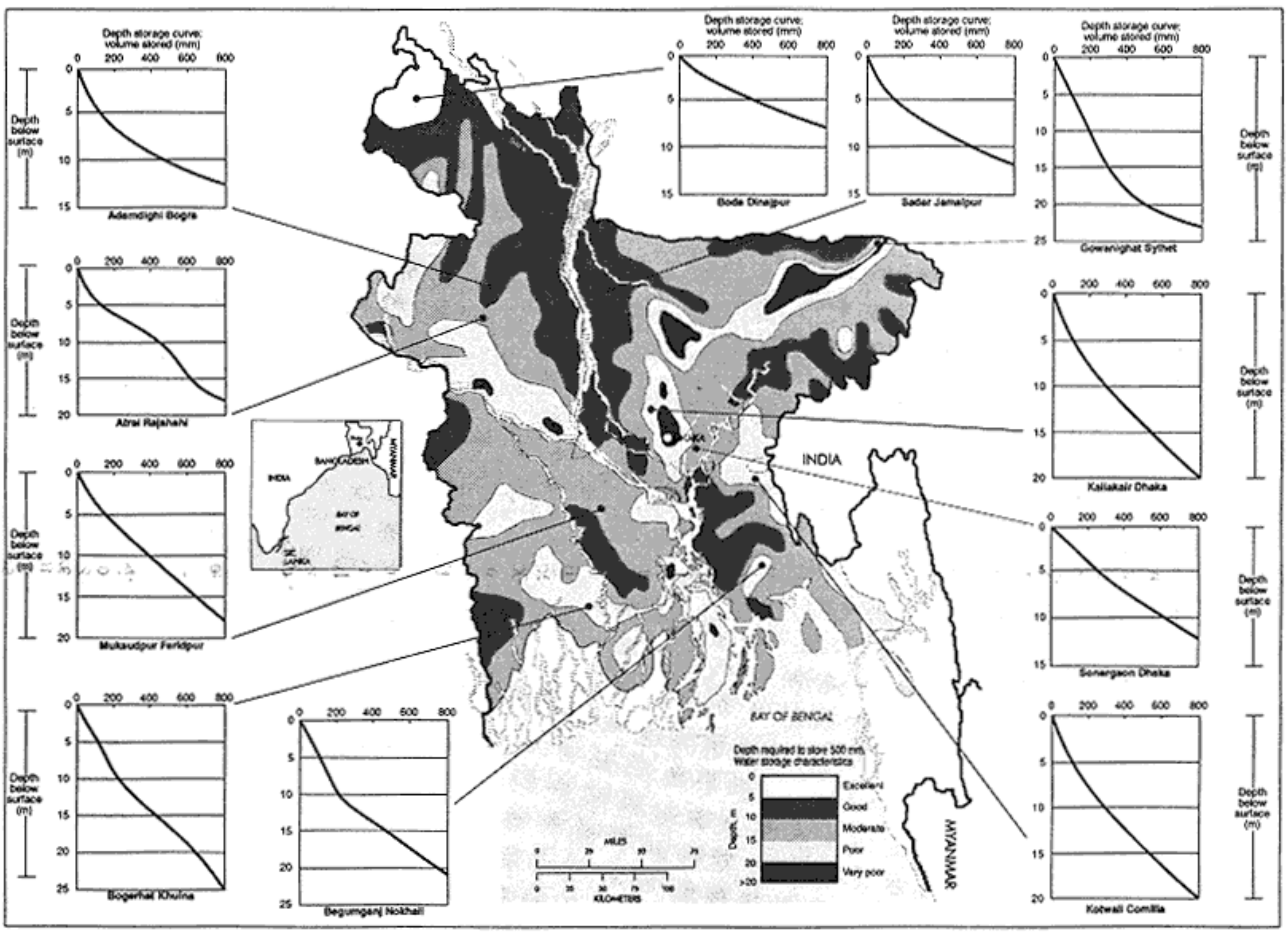

Figure 1.4
storage Potential of the Upper Groundwater Reservoir, Bangladesh
Source: Master Plan Organization.

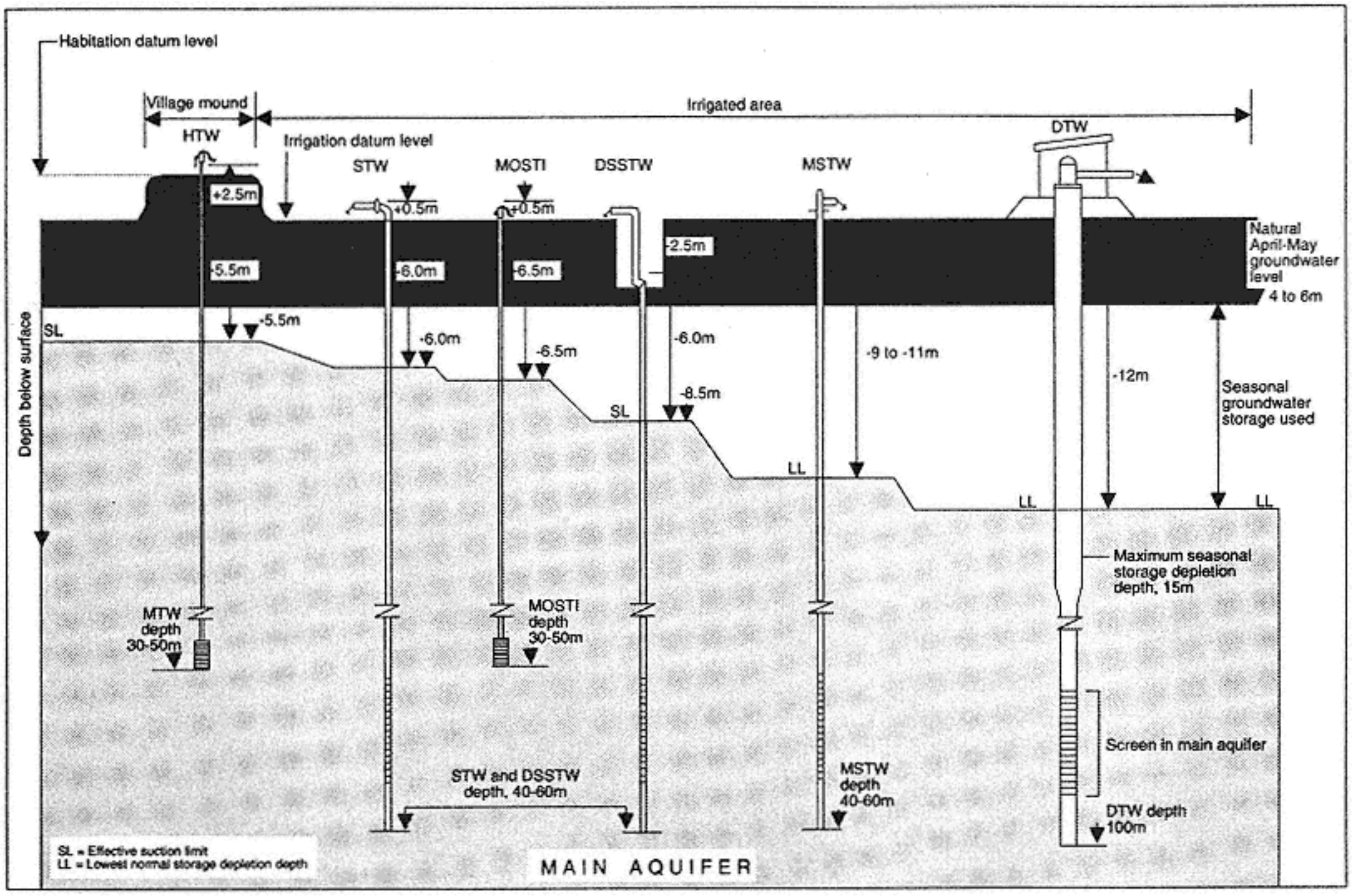

Figure 1.5
Lift Capability of Different Types of Wells, Bangladesh

voir, while deep set shallow tube wells can access the top 8.5 m. The deep set shallow tube well can therefore take advantage of a higher percentage of available recharge over a greater area of Bangladesh than the identical equipment configured as a shallow tube well. Deep set shallow tube wells were advocated by the Master Plan Organization in 1984−85 as a simple way to increase groundwater accessible to suction lift pumps. The concept, a common one in India, was viewed with skepticism by the government of Bangladesh and considered nonviable by the Bangladesh Water Development Board.

Force mode tube wells have been primarily lineshaft turbine pumps driven by a diesel motor mounted at the surface. These wells, called deep tube wells, discharge 601/s and lift groundwater from depths of 1025 m. Deep tube wells can irrigate up to 25 ha of wetland rice, cost $15,000$20,000, and are operated by cooperatives of up to 200 farmers. Deep tube wells are supplied and owned by public sector agencies, generally as part of large donor−funded projects (3,000 units), and are rented or sold to cooperatives at a 70 percent subsidy.

Potable water is supplied by hand tube wells fitted with locally made cast iron suction pumps (no. 6 handpumps). Small−scale manually operated shallow tube wells for irrigation have adapted the no. 6 handpump for irrigation and are normally owned and operated by a single farmer to irrigate tiny plots (100−300 m2). A manually operated shallow tube well can access the top 6.5 m of groundwater reservoir if placed in lower land areas. However, hand tube wells suffer from a severe disadvantage, as they are invariably placed in village compounds and have to raise water 13 m above the irrigated floodplain level. Hand tube wells can access only the top 3.55.5 m of groundwater reservoir.

A new innovation, a modified shallow tube well, uses a force mode pump within the low−cost, small−diameter shallow tube well design. This has recently been renamed the force mode tube well. The force mode tube well is a low−cost substitute for deep tube wells for areas where the water table is deeper or where drawdown is greater because of poor aquifer properties. The forced mode or modified shallow tube well was designed to be affordable by the private sector with no government subsidy. It can irrigate 24 ha with a discharge of 510 1/s and can access 911 m of groundwater storage.

In practice all wells compete for the same groundwater resource according to their water lifting capability. The maximum water lifting capability defines how much groundwater reservoir storage each well can drain. The order of competitiveness is deep tube wells, modified shallow tube wells, deep set shallow tube wells, manually operated shallow tube wells for irrigation, and hand tube wells, with deep tube wells having the greatest lifting capacity and hand tube wells the least. All the pump technologies, except deep tube wells and modified shallow tube wells, are self−regulating at their suction limit and are unable to draw down water levels excessively (except in the coastal areas, where saline incursion is a danger) or to deprive other farmers with the same pump technology of access to groundwater.

Groundwater availability by tube well type

Each tube well type is able to utilize recharge according to the reservoir storage accessible by the pump used, which is constrained by its lifting capacity. The pump lifting capacity of shallow tube wells, deep set shallow tube wells, manually operated shallow tube wells for irrigation, and hand tube wells is fixed by their suction lift capability; deep tube wells and force mode tube wells are not limited by lift, but by economics and the availability of groundwater.

Aquifer transmission properties determine how much of the suction lift capacity is used to make groundwater flow into the well. A standard measure is actual well performance, measured as water yield per unit of drawdown in liters per second per meter (l/s/m), or specific capacity. Specific capacity varies from less than 2 l/s/m in Sylhet, to more than 35 l/s/m along the Brahmaputra flood−plains. Where the specific capacity is small, the balance of suction lift available to withdraw water from groundwater storage is small, development potential is limited, and force mode tube wells or deep tube wells would be required to fully develop the resource.

To maximize groundwater development the National Water Plan adopted a zoning policy to discriminate between suction mode and force mode pumping areas. In several areas of Bangladesh it is possible to fully utilize available recharge with shallow tube wells, deep set shallow tube wells, and manually operated shallow tube wells for irrigation. Installing wells with a greater lifting capacity is unnecessary and uneconomic.

Deep tube wells, if installed in a shallow tube well zone, could withdraw more than the available recharge and cause shallow tube wells to run dry. Conversely, shallow tube wells and deep set shallow tube wells are self−regulating and could not operate in competition with deep tube wells in deep tube well−zoned areas.

For zoning, the deep set shallow tube well was taken as the upper limit of suction lift pumping and the 75 percentile line was used to demarcate the suction mode tube well zone. The deep set shallow tube well pumping capability was the criterion because shallow tube wells can be easily and cheaply converted into deep set shallow tube wells. This zone includes most of the northwest, southeast, and southwest regions, the Old Brahmaputra and Jamuna floodplain west and north of Dhaka, and the low−lying areas of the middle and lower Meghna floodplain. Within the suction mode tube well zone there are areas that require force mode tube wells, modified shallow tube wells, and deep tube wells to fully develop the resource. These areas are in the Barind tract of Dinajpur and the West Dinajpur regions and along both banks of the Ganges east of Rajshahi to its junction with the Brahmaputra. Throughout the suction mode tube well zone, deep tube wells will be needed in some localities because of local relief or poorer aquifer properties. The force mode tube well zone is defined as areas where less than 75 percent of available recharge can be developed by deep set shallow tube wells.

Choice of well technology constrains groundwater development. Table 1.4 shows that available recharge varies by tube well type. In Bangladesh the choice is made more difficult by social and equity considerations attached to particular types of wells and pump technologies. If a policy is followed to promote dependable groundwater supplies and maximize the development of the groundwater resource, then the government must modify its preference for high technology deep tube wells in public sector programs. Deep tube wells may be a less desirable alternative than shallow tube wells: shallow tube wells have extremely favorable benefit/cost ratios, while deep tube wells have very high unit costs, require large command areas, and need more management for efficient utilization. However, shallow tube wells can utilize only 70 percent of the groundwater resource.

Uncertainties, risks, and externalities of groundwater development

The absolute volume of groundwater available to a tube well type is uncertain because of the many hydrogeological assumptions and estimates required to make a resource estimate. In addition the tube well technology adopted may differ from the assumptions about that technology that were used to plan development (table 1.5).

The most uncertain, but critical parameter in resource evaluation is the storage potential of the groundwater reservoir. Reservoir storage depends on the values assigned to specific yield for the evaluation.2 Results of sensitivity tests to differing values of specific yield are shown in table 1.6. Doubling the specific yield increases recharge available to shallow tube wells by 60 percent, but the increase is only 25 percent for deep set shallow tube wells; halving specific yield decreases recharge available to shallow tube wells by 48 percent and that of deep set shallow tube wells by 41 percent. The quantity of recharge available to deep tube wells increases as specific yield decreases because less recharge is stored at the top of the aquifer and therefore less is lost by natural drainage and evapotranspiration.

There are important planning implications if real values of specific yield are significantly different from those assumed in the National Water Plan.

Table 1.4 Available recharge by tube well type, various regions in Bangladesh
(million cubic meters)

Type of well	*Northwest*	*Northeast*	*Southeast*	*South central*	*Southwest*	*Active floodplain*	*National total*
Hand tube well	4,675	2,359	541	735	1,392	501	10,203
Shallow tube well	5,194	2,299	453	659	1,431	674	10,710
Manually operated shallow tube well for irrigation	5,408	3,454	649	933	1,495	669	12,608
Deep set shallow tube well	8,297	4,855	802	1,089	1,900	1,121	18,064
Modified shallow tube wella	9,271	8,466	1,337	1,619	1,967	1,303	23,963
Deep tube well	9,480	9,615	1,538	1,801	1,980	1,335	25,749

Note: Regional data excudes Planning Areas 59 and 60.

a. With 14 meter lift capacity.

Source: Bangladesh 1986b.

Table 1.5 Sensitivity of resource availability assessment by tube well type and data source

Data influencing resource assessment	*Hand tube well*	*Shallow tube well*	*Manually operated shallow tube well for irrigation*	*Deep set shallow tube well*	*Modified shallow tube well*	*Deep tube well*
Available recharge	ns	s	ns	s	vs	vs
Specific yielda	vs	vs	vs	vs	vs	vs
Water level data	vs	vs	vs	vs	ws	ws
Village elevation	vs	vs	vs	vs	ws	ws
Observation well type	vs	vs	vs	vs	ws	ws
Suction lift assumptions	vs	vs	vs	vs	ns	ns
Discharge assumptions	ws	vs	ws	vs	ns	ns
Deep set shallow tube well pit depth	ns	ns	ns	vs	ns	ns

vs Very Sensitive.

s Sensitive.

ws Weakly sensitive.

ns Not sensitive.

a. Specific yield is the volume of water that a cubic meter of fully saturated soil will yield if drained fully by gravity. This is possible in practice by lowering the water table.

Source: Bangladesh 1986b.

If values are higher, say by 200 percent, then almost 90 percent of available groundwater could be used by deep set shallow tube wells. These wells are more economic than deep tube wells and are financed by the private sector. Conversely, if specific yield values are half those assumed, then only about 40 percent of groundwater development potential can be achieved through the private sector. With a limited government budget for public sector irrigation investment, this could severely reduce the success of groundwater irrigation as a means of creating employment.

The other factors contributing to the uncertainty of resource availability were evaluated in the National Water Plan, but these factors are far less critical than specific yield because all indicate that available recharge is unlikely to be 20 percent more or less than the value used for each tube well type in the National Water Plan. Monitoring and feedback is clearly needed to determine the robustness of the groundwater resource evaluation in the National Water Plan. Uncertainty is different from risk. Taking the values of available recharge for each well type, the risk of shallow tube wells and deep set shallow tube wells running dry was evaluated.

Risk of shallow tube wells and deep set shallow tube wells running dry

Suction mode tube wells, unlike force mode deep tube wells, are unable to use the groundwater reservoir's carryover capacity following a dry monsoon because the suction lift limit does not reach very deeply into the reservoir. Thus, in dry years, as the groundwater system nears full development, some shallow tube wells and deep set shallow tube wells will fail before the dry season irrigation requirement is met. Failure to allow for periodic failure in planning shallow tube well and deep set shallow tube well development could lead to an official stop−go policy for groundwater development, which would surely undermine market confidence, as happened from 198387.

The probability that actual annual recharge will be less than the mean annual recharge used in the National Water Plan for deep set shallow tube wells is more than once in five years nationally and once in 3.3 years in the border areas of the southwest region. If shallow tube wells and deep set shallow tube wells are installed according to the available recharge, their risk of failure is less than

Table 1.6 Results of sensitivity tests: Effects of specific yield on available recharge
(*available recharge by tube well type—Mm* 3a)

Specific yield scenario	Hand tube well	*Shallow tube well*	*Manually operated shallow tube well for irrigation*	*Deep set shallow tube well*	*Deep tube well*
Very high yield (200%)	15,720	17,110	19,540	22,560	25,220
High yield (150%)	13,820	14,880	17,760	21,140	25,530
Master Plan Organization (NWP value)	10,200	10,710	12,610	18,260	25,750
Low yield (50%)	5,350	5,520	6,700	10,710	26,840

a. Total available recharge, including active floodplains, but excuding Planning Area 59 (Sundarbans).

Source: Bangladesh 1986b.

once in twenty years for most of the country, except for a small area of the northwest region. Localized overcrowding or local topographic variability will increase the risk of failure. All these factors contributed to the 1983 shallow tube well problems in the northwest region.

In dry years groundwater levels will not fully recover during the monsoon, and stream flow in the postmonsoon (October−April) period will be reduced. Even during average monsoons, local rivers will dry up earlier in the dry season, adversely affecting low lift pumps, fisheries, and navigation. Potable water supplies from suction handpumps will almost always be adversely affected from April to October. This can be mitigated either by changing from the standard suction mode handpump to the Tara force mode handpump or by using irrigation tube wells for domestic water supply. The disadvantages can be quantified as either the incremental cost of replacing suction mode handpumps with force mode handpumps or the additional cost of distributing water from the irrigation well sites to the households.

Table 1.7 shows the quantitative effects on surface water of fully developing the groundwater resource. As baseflow reduction affects low lift pump potential and flood control and drainage schemes, the benefits of additional groundwater development must be traded off against lost surface water development. Nationally, the volume of dry season surface water that may be lost at full development of the constrained groundwater resource is 2,305 Mm3 , equivalent to approximately 370,000 ha of irrigation. Table 1.7 summarizes the calculated regional base flow reduction for the rabi season (January to April) for the planning areas with data subject to planning constraints.

Adverse effects (that is, failure more than once in twenty years) of groundwater development are limited to western Bangladesh. It is only in central border areas of the southwest region that the rate of probable failure is high enough to make low lift pumps or groundwater alternative forms of development. Considering that there is far more groundwater than surface water, this part of the region should be zoned against low lift pump development if groundwater exploitation is economically viable.

It should be noted that changes in cropping pattern and calendar and the introduction of supplemental irrigation would cause these estimates of base flow reduction to change. Additional field data are required to improve the estimates. Additional interactive surface water−groundwater models are essential for realistic trade−off analyses.

Financial and economic viability of tube wells

A comparison of alternative types of irrigation development using wells has been made using the results of the Master Plan Organization's economic analysis. Manual irrigation was examined in some detail and four of the available manually operated shallow tube wells for irrigation (the suction handpumps, no. 6, rower, and treadle, and the force mode handpump, the Tara) were compared.

Alternative types of tube well investment were analyzed according to two criteria, benefit−cost ratio and internal rate of return, over a twenty−four−year period. Benefit−cost ratio was calculated using a discount rate of 15 percent. Internal rate of return is the discount rate at which the present value of benefits minus the present value of costs equals zero.

In calculating the internal rate of return the assumption was that all payments and receipts occur simultaneously each year. This prevents calculating the internal rate of return on tube well investment alternatives where benefits exceed costs in the first year of investment. If the internal rate of return were calculated for these alternatives taking into account monthly cash flows, or arbitrarily lagging benefits one year, it would still be very high. For example, the internal rate of return calculated in that way for low lift pumps would be greater than for shallow tube wells because the costs of low lift pumps are much lower.

Table 1.7 Base flow reduction caused by groundwater development, rabi season
(*million cubic meters)*

Types of tube well	*Northwest*	*Northeast*	*Southeast*	*South central*	*Southwest*	*Active floodplain*	*National total*
Shallow tube well	710	150	45	100	80	105	1,190
Deep set shallow tube well	1,050	410	65	120	125	140	1,910
Deep tube well	1,200	570	85	140	140	170	2,305

Source: Bangladesh 1986b.

Two types of analysis were performed: a financial analysis to determine the viability of the alternative investments at the market prices farmers would have to pay; and an economic analysis to rank these alternative investments in a national perspective, using shadow prices that remove distortions caused by noncompetitive markets, tariffs, and trade barriers.

Table 1.8 presents the results of the financial analysis of alternative types of irrigation, evaluated at market prices. All types of manually operated shallow tube wells for irrigation, except Tara, are profitable from the farmers' point of view. Among alternative manual irrigation pumps, the treadle pump recorded the highest benefit−cost ratios, followed by rower and no. 6 handpumps.

Mechanical irrigation technologies show higher returns compared with manual systems. This is attributed to the much greater operation and maintenance costs of manual systems, particularly the labor cost of operating the manual pumps. However, the returns of manually operated pumps are enhanced appreciably and almost always exceed those of the mechanical pumps in almost all cases when the family labor costs of pump operation are excluded.

Table 1.9 presents the results of an economic analysis, based on shadow prices, of the alternative types of irrigation. The economic analysis shows that:

All irrigation modes have high rates of return and, in absolute terms, are potentially good investments.

The economic returns to mechanical irrigation wells are greater than the returns to manually operated pumps, with treadle pumps coming close to competing with deep tube wells.

The relative ranking of alternative modes remains almost invariant under financial and economic analysis.

Effects of alternative irrigation on income distribution

The effect on income distribution was analyzed for five irrigation pumping technologies: manually operated shallow tube wells for irrigation, shallow tube wells, deep tube wells, low lift pumps, and major irrigation (MPO 1985). Distribution of income, including wages for hired labor, was estimated for four social groups under various land development conditions. The four social groups

Table 1.8 Alternative irrigation technologies, at market prices

Technology	*Benefit−cost ratio*	*Internal rate of return (percent)*	
Manual irrigation			
No. 6 hand tube well	1.2 (4.1)	63.3	(−)
Rower	1.4 (5.1)	946.3	(−)
Treadle	1.9 (7.1)	−	(−)
Tara	1.0 (2.7)	12.9	(194.7)
Mechanical irrigation			
Shallow tube well	3.2 (3.2)	290.0	(290.0)
	2.0 (2.0)	104.0	(104.0)

Deep set shallow tube well			
Deep tube well	2.3 (4.0)	48.5	(232.2)
Low lift pump	4.6 (5.0)	−	(−)

− Not available.

Note: The figures in parentheses for manual irrigation modes represent benefit−cost ratio and internal rate of return when nine−tenths of pump operation is performed by the farm family for which no cost is imputed. The figures in parentheses for mechanical irrigation modes, particularly for deep tube wells and low lift pumps, represent benefit−cost ratio and internal rate of return with a subsidy of 70 percent and 25 percent, respectively.

Source: Master Plan Organization report on alternative manual irrigation wells.

were landless laborers, small farmers (0.04 ha to 0.6 ha), medium farmers (0.61 ha to 2.02 ha), and large farmers (more than 2.02 ha). The assumptions for land ownership patterns, percentages of land irrigated, and total labor hired are shown in table 1.10.

Sharecropping was assumed to be 15 percent (countrywide), and land was assumed to be rented to small farmers by large farmers. The terms of sharecropping leases are that the farmer takes 50 percent of the fertilizer, pesticides, and irrigation costs, provides labor and bullock power, and receives 50 percent of the output. With these assumptions, it was possible to estimate the proportion of income generated by the irrigation mode that ac−

Table 1.9 Alternative irrigation technologies, at shadow prices

Technology	*Benefit−cost ratio*	*Internal rate of return (percent)*
Manual irrigation		
No. 6 hand tube well (0.25 ha)	1.5	526
Rower (0.30 ha)	1.8	−
Treadle (0.40 ha)	2.4	−
Tara (0.25 ha)	1.3	77.2
Mechanical irrigation		
Shallow tube well (5.0 ha)	3.8	617
Deep set shallow tube well	2.7	188
Deep tube well (24.0 ha)	2.5	61

Low lift pump (18.0 ha)	5.4	–

Note: The figures in parentheses indicate the assumed command areas for these irrigation modes.

Source: Master Plan Organization Technical Report No. 22 on economic analysis of agricultural modes of development.

Table 1.10 Assumptions used in Income distribution analysis

	Percentage of land owned			*Percentage of land operated*			
Landowner group	*Shallow tube wells*	*Manually operated shallow tube wells for irrigation*	*Others* a	*Shallow tube wells*	*Manually operated shallow tube wells for irrigation*	*Others*	*Percentage of labor hired*
Small farmers	10	30	15	25	45	30	40
Medium farmers	35	50	35	35	50	35	60
Large farmers	55	20	50	40	5	35	80

Note: Different sets of assumptions were used while carrying out sensitivity analysis. These have been indicated in Master Plan Organization Technical Report No. 23, 1986.

a. Low lift pumps, deep tube wells, and major irrigation projects.

Source: Master Plan Organization.

crues to each of the four social groups. Results are expressed as income concentration ratios (the Gini coefficient) and percentage changes in large/landless and large/small farmer income ratios.

The net return per hectare for each land type (for example, nonflooded land) is calculated by multiplying a cropping pattern vector showing the proportion of the area under each crop by the net return for each crop "without" and "with" irrigation improvement. Once this has been done for each land type, it is possible to estimate the annual value added per hectare for each transition from one land type to another by subtraction. Net return per hectare for each of the transitions is shown in table 1.11.

Table 1.11 shows that net income per hectare increases from Tk 8,100 without irrigation to between Tk 18,800 and Tk 26,100 with different irrigation technologies. The increase is greatest for major (gravity) irrigation and lowest for manually operated shallow tube wells for irrigation. With flood control and drainage, net income increases only from about Tk 7,300 to Tk 10,000.

In estimating the income accruing to each social group, it was assumed that the landless derive income from laboring and from sharecropping; small farmers from laboring, sharecropping, and cultivation of their own land; medium farmers from their own land; and large farm holders from their own land and from land sharecropped by small farmers. Two measures of income distribution are used: the Gini coefficient (index of inequality that varies from zero to one; the higher the index, the greater the inequality) and the percentage of agricultural income accruing to the rural poor (small farmers and landless laborers).

The effects of alternative irrigation technologies on income distribution under existing ownership and tenancy patterns are shown in table 1.12. The conclusions are as follows:

Manually operated shallow tube wells for irrigation have a positive and significant effect on equity. The Gini coefficient drops from 0.19 to 0.17, indicating a significant improvement in income distribution.

The most adverse effect on equity results from major irrigation.

Shallow tube wells perform marginally better than major irrigation projects, but result in an increase in the Gini coefficient from 0.36 to 0.39 and show a slight decline in the average share of agricultural income going to the rural poor (34 percent to 33 percent).

Deep tube wells and low lift pumps also have a regressive effect on income distribution, but result in a lesser inequality compared with shallow tube wells.

Table 1.11 Net return for each transition between land types

Transition number	*Without projects*	*Net return (Tk/ha)*	*With project*	*Net return (Tk/ha)*	*Change (percent)*
1	Nonirrigated	8,100	Low lift pump irrigated	19,700	143
2	Nonirrigated	8,100	Shallow tube well irrigated	20,100	148
3	Nonirrigated	8,100	Deep tube well irrigated	19,000	144
4	Nonirrigated	8,100	Major irrigation	26,000	222
5	Nonirrigated	8,100	Manually operated shallow tube well irrigated	18,800	132
6	Medium flooded	7,500	Shallow flooded	10,000	33
7	Deep flooded	7,500	Shallow flooded	10,000	37

Tk/ha Takes per hectare.

Note: 1983 prices: Take 25/US$

Source: Ahmed and Jones 1991.

Table 1.12 Effects of alternative irrigation technologies on distribution of income
(percent)

		Income distribution, with irrigation				
Social group	*Income distribution, without*	*Manually operated shallow tube*	*Shallow tube wells*	*Deep tube wells*	*Low fit pumps*	*Major irrigation*

	irrigation	*wells for irrigator*				
Landless	17	16	16	14	14	11
Small farms	21	33	18	22	22	22
Medium farms	28	40	26	27	27	31
Large farms	34	11	40	37	37	36
Total	100	100	100	100	100	100
Gini coefficientc	0.33	0.17	0.39	0.36	0.36	0.40
Change of Gini coefficient	n.a.	−12	7	10	10	25
Percentage change of large/landless income	n.a.	−17	21	29	29	68
Percentage change of large/small farm income	n.a.	−5	0	2	2	4

n.a. Not applicable.

Note: Income distribution is under existing land ownership and tenancy patterns.

a. This corresponds to the distribution under deep tube wells, low lift pumps, and major irrigation only. Manually operated shallow tube wells for irrigation and shallow tube wells have special distributions as indicated in Master Plan Organization Technical Report No. 23, 1986.

b. Refers only to manually operated shallow tube wells for irrigation.

c. Rounded to two figures after decimal.

Source: Master Plan Organization 1985.

Among the various irrigation modes analyzed, the manually operated shallow tube well for irrigation was the most equitable and major irrigation and the shallow tube well the least. Deep tube wells and low lift pumps have regressive equity effects but are less inequitable than shallow tube wells. Caution should be exercised in interpreting these results because of the partial nature of the methodology used and the limited availability of data.

Nonetheless, although absolute values of Gini coefficients and income shares going to the poor will change as improved field data become available, it is unlikely that the ranking of these irrigation technologies would change for their effects on income distribution. It should be noted that the analysis is a partial one. The assessment included only the effects on income distribution of different types of transition in crop production activities. The effects of secondary influences on income distribution were not considered.

Note also that the analysis was of the shifts in distribution of the relative shares of income resulting from investment in irrigation. In an absolute sense every group involved in water resource investment is better off in the short term because total income increases, including wages for hired labor. Table 1.13 shows employment increases attributable to the various types of irrigation pumping technologies.

Manually operated shallow tube wells for irrigation are the most equitable type of water sector project and shallow tube wells and major irrigation projects the least. But rank order would change significantly if effects on income distribution were evaluated for their effect on poverty rather than on equity. The rank order for effect on poverty, measured by changes in absolute income accruing to the rural poor, would be: major irrigation, manually operated shallow tube wells for irrigation, shallow tube wells, deep tube wells, low lift pumps, flood control and drainage (medium to shallow), flood control and drainage (deep to shallow), with major irrigation having the greatest, and flood control and drainage the least, effect on poverty.

Thus, although major (gravity) irrigation is most inequitable, it nonetheless has the greatest effect on poverty followed by manually operated shallow tube wells for irrigation, minor irrigation (shallow tube wells, deep tube wells, and low lift pumps), and finally by flood control and drainage schemes. While it is likely that the Gini coefficients

Table 1.13 Incremental employment for different types of irrigation technologies
(person−day per hectare)

Type of irrigation	*Before*	*After*	*Increment*	*Increase (percent)*
Manually operated shallow tube well for irrigation	138	400	262	189
Shallow tube well	138	306	168	122
Deep tube well	138	286	148	107
Low fit pump	138	283	145	105
Major	138	287	149	107

Source: Master Plan Organization.

Table 1.14 Alternative development strategies for groundwater

Objectives	*Option 1: Maintain existing groundwater levels.*	*Option 2: Lower groundwater levels in the dry season to increase recharge and resource potential.*	*Option 3: Lower groundwater levels to enable development of full resource potential and groundwater reserves.*
Protect all existing groundwater investments and water rights.	Status quo: No further groundwater development.	Not consistent.	Not consistent.
Expand groundwater irrigation, but protect suction mode investments and accept limited replacement of potable	Not consistent.	Feasible for a limited area but development of resource potential is limited.	Not consistent.

water supply hand tube wells.			
Expand groundwater irrigation by means of a change in suction mode technology and accept increased replacement of potable water supply hand tube wells.	Not consistent.	Feasible for a large area; but development of resource potential is limited.	Not consistent.
Expand groundwater irrigation to the optimal technical and economic limit and replace, as required, suction mode for irrigation and water supply.	Not consistent.	Feasible strategy but negative effects increase.	Feasible strategy for every limited areas of Bangladesh. Not feasible in major portions of the southwest, south coast, and southeast regions.

Note: Specific projects and programs proposed under a strategy characterized in this table as feasible must still satisfy feasibility and appraisal criteria.

Source: Master Plan Organization.

and income shares going to the poor will change as better field data become available, it is unlikely that the ranking of the different transitions for their effects on equity or poverty would change much (Ahmed and Jones 1991).

These results assume that all types of wells have fixed running costs, constant discharges, and constant command areas. Low−discharge deep tube wells (281/s) are not economically viable at pumping lifts greater than about 17 m, while 581/s deep tube wells are just economically viable at lifts approaching 40 m. It is clear that deep tube wells are not economically viable in some areas of Bangladesh.

The financial and economic analyses indicate a preference for manually operated shallow tube wells for irrigations if equity is important and farm family labor is less costly—not an unreasonable assumption, considering the underemployment and unemployment levels.

Groundwater development in the National Water Plan

Availability of groundwater is not a constraint to its continued rapid development in the next decade. Total groundwater resources are estimated at 63,800 Mm3 . The resource available for development is 24,400 Mm3 , equivalent to an irrigation potential of 3.9 Mha. Allowing for the present (1985) development of about 0.78 Mha and nonagricultural use and reserves, the incremental groundwater development potential is 2.94 Mha.

Options for groundwater development are summarized in table 1.14. Options 1 and 3 have substantial limitations. Option 1 preserves the rights of existing groundwater users but severely limits future irrigation development from groundwater. Option 3 aims at full development of available recharge and groundwater reserves but may have substantial and unforeseen negative effects on surface water users and groundwater users. Option 2 consists of a range of feasible strategies that allow increased development while minimizing local effects.

Four alternative National Water Plan groundwater development strategies under Option 2 are described in table

1.15, and the incremental resource potential under each strategy is shown. These values represent the upper limit on development before economic appraisal. The objective of the first strategy, status quo, is to protect all existing uses and technologies.

This objective is not consistent with National Water Plan objectives, however, because it precludes future development. The remaining three strategies have progressively higher levels of irrigation development using groundwater. Although a mixed strategy is possible, a change from one strategy to another in a specific location would

Table 1.15 Groundwater resource development strategies and limits (under option 2)

Objective	*Strategy*	*Incremental resource potential (Mm 3)*	*Percentage of maximum incremental resource potential*	*Incremental potential area irrigated (hectares)*
Protect all existing groundwater investments and water rights.	*Status quo:* Maintain approximate 1985 groundwater levels to protect present groundwater and surface irrigation investments; minimize replacement of existing village water supply hand tube well suction lift pumps.			
Expand groundwater irrigation, but protect suction mode investments, and accept limited replacement of potable water supply hand tube wells.	*Irrigation suction lift technology:* Lower groundwater levels to the shallow tube well suction lift limit measured at field level.	5,120	30	1,048,000
Expand groundwater irrigation by means of a change in suction mode technology and accept increased replacement of potable water supply hand tube wells.	*Intermediate irrigation pump technologies:* Lower groundwater levels below the suction lift limit of pumps using deepest shallow tube wells. Deep tube wells would continue to function where they are now installed. Shallow tube wells would be lowered in pits wherever possible.	Up to 10,180 (varies with mix of technologies)	up to 60	Up to 1,893,000
Expand groundwater	*Present estimated*	17,000 (varies	100	2,944,000

irrigation to the optimal technical and economic limit and replace, as required, suction mode technologies for irrigation mode and water supply.	*maximum resource:* Lower seasonal groundwater levels below the limit of deep set shallow tube wells by using force lift technologies such as Deep tube wells to fully develop the available resource. Depths rangefrom about 5 m to present maximum observed depths of about 15 m in some locations. Alternative approaches include a mix of technologies and may include zoning.	with mix of technologies)

Mm3 Million cubic meters

Note: Recharge calculated (or estimated) for all catchments excluding active floodplains (AFP) and PA 59 (Sundarbans). All figures have been rounded.

Source: Master Plan Organization.

require a shift to a different technology, commensurate with the strategy being pursued.

The second strategy, irrigation suction lift technology, would allow new shallow tube wells and existing deep tube wells to operate but would severely constrain future groundwater resource development potential. The third strategy, intermediate irrigation pump technologies, limits future development to deep set shallow tube wells. The last strategy, present maximum estimated resource, aims to develop all the resource potential using a mixture of shallow tube wells, deep set shallow tube wells, and deep tube wells, the latter installed only where deep set shallow tube wells cannot utilize 95 percent of the resource.

Present groundwater development programs adopted by the government in the Third Five−Year Plan (198590) are a combination of the second and third strategies and include a significant number of deep tube wells. A key component of each strategy is an expanded groundwater monitoring and assessment program that should be implemented in those catchments and upazilas where permissible groundwater pumping depths are to be extended up to and beyond suction lift (shallow tube well) limits.

Alternative development plans and scenarios

The primary objective of the National Water Plan was foodgrain self−sufficiency. Employment and equity, although considered, did not have a high priority in the plan selection process. Groundwater development was weighed on its economic merits against alternative investment opportunities in minor and major irrigation and flood control and drainage. Land, water, salinity control, and navigation were the primary constraints on development.

The National Water Plan groundwater investment program is driven by the need for quick imple−

mentation to attain foodgrain self−sufficiency early in the plan period 19852005. Shallow tube wells and deep set shallow tube wells are the most attractive investments capable of high rates of implementation. A peak rate of almost 200,000 ha was achieved in 198283, but an average of only 100,000 ha a year was used in the National Water Plan.

Resource availability

Estimated available surface water is based on the 80 percent dependable flow in March, the most critical month. Small amounts of stream flow are currently withdrawn from the main rivers (the Ganges, Brahmaputra, and Meghna), but about 26 percent of the smaller regional river flow is withdrawn for irrigation. However, the primary resource demands for river water are salinity control, fisheries, and navigation. The greatest demand for groundwater is in March—about 29 percent of the total seasonal volume of available recharge of 24,400 Mm3 ; of this 4,850 Mm3 was used for irrigation, domestic, and industrial uses in 1985. Available water resources are not distributed uniformly among the regions of the country.

Gross water requirements consist of the projected use of water for domestic and industrial purposes; the stream flow required for salinity control, navigation, and fisheries; and the water requirement for agriculture. Agricultural water requirements are based on irrigation of the total irrigable area following the present cropping patterns. Nonagricultural water demand is 37 percent of total gross water requirements for 2005, or 25,700 Mm3 .

The National Water Plan analysis shows that, by the turn of the century, all regional surface water and exploitable groundwater resources will have been utilized for foodgrain production, assuming current rates in the use of agricultural inputs. Using water from the major rivers (Ganges, Brahmaputra) will become imperative to meet in creasing demand for food. The National Water Plan urges immediate preinvestment studies of these schemes to ensure timely implementation and to increase the use of nonwater inputs to increase agricultural productivity.

Alternative plans

Four alternative plans were formulated based on strategies identified for all water users. The surface water strategy is the same for each plan: full development of regional surface water, midterm use of the main river, and flood control and drainage development. There are four alternative groundwater strategies, however, ranging from the low level of development associated with shallow tube wells (Plan I), to strategies aimed at full development of the resource potential (Plans III and IV). Two additional plans were considered that are identical to Plan IV in strategy and resources but differ in implementation rate.

Comparison of alternative plans

The overall strategy of complementary and coordinated surface water and groundwater development is the basis for the alternative national water plans. These plans differ only in choice of specific strategy for groundwater development within the overall strategy for water resources development. Each plan's investment priorities and programs to develop resource potentials were determined by optimizing each plan in line with the National Water Plan objective subject to budget and institutional limitations.

The groundwater development strategy had variable water resource limits dependent on the technology used. Conversely, the surface water development strategy had a fixed water resource constrained by the need to maintain navigability, fisheries, and salinity control. These surface water development constraints were determined by a trade−off between unwanted effects and water availability in the critical months of April and May. The four plans have the same surface water development strategy but differ in the strategy adopted for groundwater development, as follows:

Plan I: Shallow tube wells only.

Plan II: Shallow tube wells and deep set shallow tube wells only.

Plan III: Deep set shallow tube wells and deep tube wells as needed, shallow tube wells where feasible.

Plan IV: Zoned approach to groundwater development, deep tube wells limited to areas where shallow tube wells or deep set shallow tube wells fully utilize the resource.

Under Plan III, shallow tube well and deep set shallow tube well development is allowed at the full rate until the resource limit is reached, after which, the use of deep tube wells is initiated. If new deep tube wells are installed to extend the resource

limit, all shallow tube wells and deep set shallow tube wells become hydraulically redundant and have to be replaced by deep tube wells to maintain the irrigated area developed.

Plan IV gives preference to shallow tube wells and deep set shallow tube wells if they can develop at least 95 percent of the resource. Selection of mechanical wells does not preclude development by manually operated shallow tube wells for irrigation. However, manually operated shallow tube wells for irrigation were not considered in the plan because of the large numbers required (millions) and the lack of sufficient production capacity in Bangladesh.

To determine an investment program for each plan, assumptions had to be made concerning budgets, the best match of conditions and inputs for resource development, and institutional capacity to implement the plan. Rates of implementation for groundwater development were based on best sales and installation performance (table 1.1).

Figure 1.6 summarizes the outcomes of each alternate plan in 2005 for incremental land developed, foodgrain production, value added, and employment.

Plans I and II are based on shallow tube well and deep set shallow tube well groundwater development strategies respectively and have growth rates of 3.1 and 3.3 percent each during the Third Five−Year Plan (198590), tapering off to 2.3 and 2.7 percent during the Fifth Five−Year Plan. By comparison the rates are 4.0 and 3.5 percent for Plan IV, which shows the effect of the more restrictive groundwater development strategies under the other plans. Plan IV is a mixed deep set shallow tube well/deep tube well development strategy and has the most desirable overall pattern of growth compared with the other plans.

Production from surface water irrigation without the main river barrages is about the same for all plans. Under Plan IV, for example, the increase in production of 11.4 million metric tons is divided as follows: 7 percent from flood control and drainage, 28 percent from surface water irrigation, and 65 percent from groundwater irrigation.

The change in groundwater strategy that accompanies a shift from Plan I (shallow tube well) to Plan II (deep set shallow tube well) results in a 2.3 million metric ton increase in foodgrain production, while a further shift to Plan IV (mixed deep set shallow tube well/deep tube well) results in a further increase of 1.7 million metric tons in foodgrain production. Production is almost equally distributed between deep set shallow tube well and deep tube well modes in Plan IV.

The recommended National Water Plan

Judged by the four main criteria in figure 1.6, Plan IV was consistently superior. It was presented by the Master Plan Organization to the Bangladesh National Water Council in 1987 and is the recommended National Water Plan.

Under the plan, the area irrigated by surface water will double from 16 to 32 percent. The increase will come mainly from mid−term development of the main rivers and development of regional surface water in the southeast regions by major flood control and drainage infrastructure schemes. Of the 4.42 Mha that have potential for development by flood control and drainage schemes, only about 2.44 Mha, 55 percent, can be economically developed. About 1.8 Mha of this area are recommended for development under the plan.

The area irrigated by groundwater will increase from 10 to 40 percent. About 47 percent of the increase will come from deep set shallow tube well development in the northwest and southwest regions. An additional 36 percent of the increase will come from deep tube well development in the northeast region.

Of the 17,006 Mm3 of groundwater resource available for agricultural use, 12,809 Mm3 will be developed under the National Water Plan. The balance, 4,197 Mm3 , is not economical to develop at present, but is available for future use beyond 2005, should it become economically viable.

Under the recommended plan, the area irrigated by groundwater will increase from 10 to 40 percent of net cropped area. About 47 percent of the increase will come from deep set shallow tube well development in the northwest and southwest regions. An additional 36 percent of the increase will come from deep tube well development in the northeast region. In terms of the National Water Plan objective, 42 percent of the increase in foodgrain production comes from shallow tube wells and deep set shallow tube wells at no public cost.

In the Third Five−Year Plan the required rates of implementation are 19,800 shallow tube wells/deep set shallow tube wells and 3,110 deep tube wells a year. In later plan periods replacement in vestment becomes dominant from 1995 as groundwater becomes fully developed.

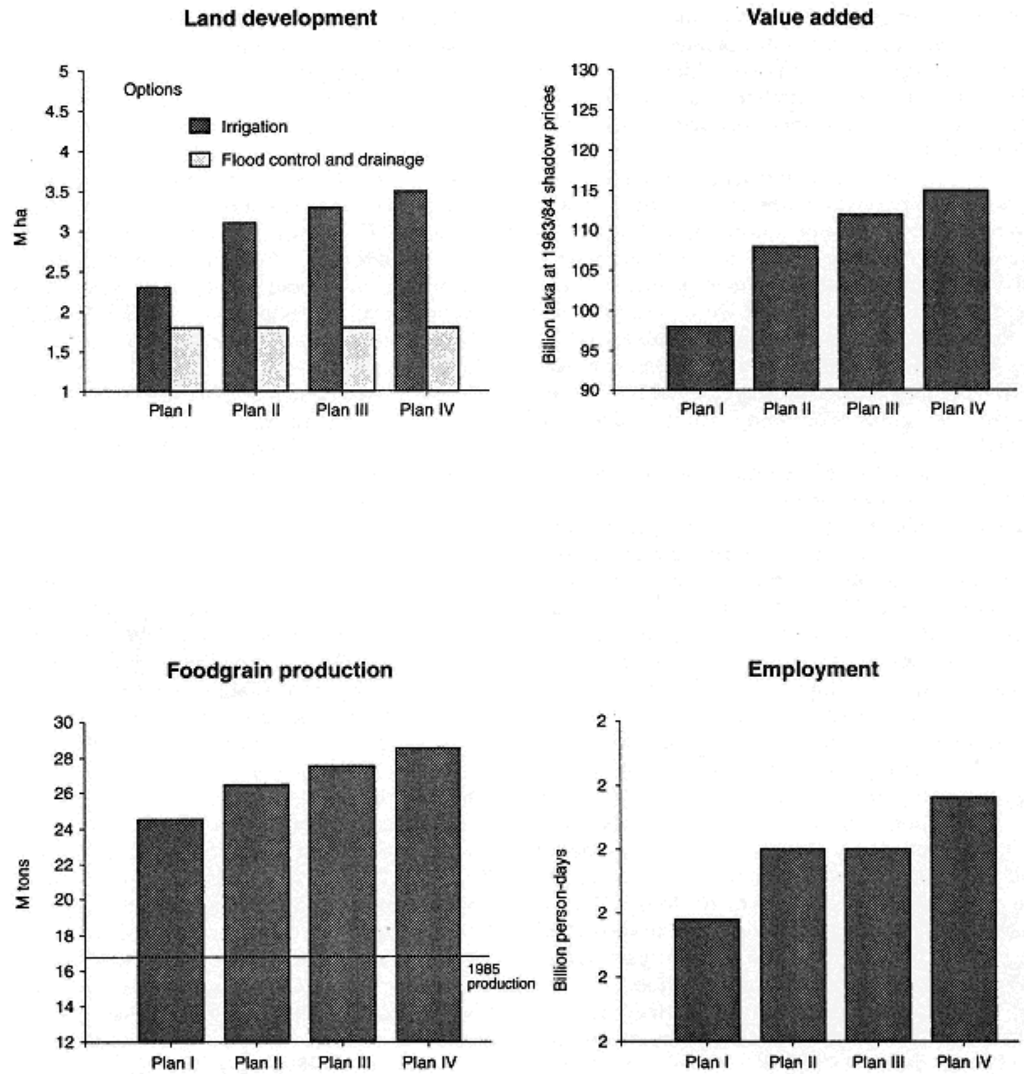

Figure 1.6
Alternative National Water Plan Outputs, Bangladesh, 2005

Table 1.16 National Water Plan: Incremental area irrigated by groundwater

Region	*Present area irrigated by groundwater ('000 ha)*	*Incremental area irrigated with deep set shallow tube wells*		*Incremental area irrigated with deep tube wells*		*Total area irrigated by groundwater ('000 ha)*
		Area ('000 ha)	*Units* a ('000)	*Area ('000 ha)*	*Units* b ('000)	
Northwest	344	823c	165	142	6	1,309
Northeast	254	62	12	813	34	1,129
Southeast	47	36	7	56	2	139
South coast	13	43	9	46	2	102
Southwest	112	244	49	12	<1	368

Bangladesh	770	1,208d	242	1,069	44	3,047

a. Five hectares per unit.

b. Twenty−four hectares per unit.

c. Adjusted downward for the Teesta Project dry season service area of 19,000 ha in Planning Area 7.

d. In deep tube well zones where the net present value is less than zero, the zone is changed to a deep set shallow tube well area and the groundwater development potential is set equal to the deep set shallow tube well.

Source: Master Plan Organization.

The regional areas for groundwater development and numbers of wells are shown in table 1.16. Phasing of groundwater development from 1985 to 2005 is shown in table 1.17.

Incremental employment

The incremental employment generated by increased rabi season cultivation made possible by groundwater development is given in table 1.18. Assuming full−time employment during the five−month rabi season, the total incremental employment from groundwater irrigation is only 0.92 million additional jobs by 1990, and 2.44 million by 2005. Compared with 14.3 billion man−days available in the Bangladesh economy in 2005, the groundwater contribution of 2.6 percent is negligible.

Findings since the National Water Plan

Since finalization of the National Water Plan, two surveys of groundwater irrigation have concluded that a policy based on shallow tube well and deep set shallow tube well development may not be the

Table 1.17 Phasing of groundwater incremental irrigated area in the National Water Plan Five−Year Plans
(millions of hectares)

Well type	*Third (198590)*	*Fourth (199095)*	*Fifth (199500)*	*Sixth (200005)*
Shallow tube well/deep set shallow tube well	0.50	0.92	1.23	1.24
Deep tube well	0.37	0.76	1.01	1.07
Total	0.87	1.68	2.24	2.31

Source: Bangladesh 1986c, chapter 15.

best type of groundwater development for increasing equity and employment.

Ownership

Most deep tube wells in the Master Plan Organization sample were owned by the Bangladesh Agricultural Development Corporation and rented to farmers. A surprisingly large number (26 percent) of the privately owned deep tube wells were privately financed. Conversely, 79 percent of the shallow tube wells were financed by agricultural credit banks (table 1.19). Almost all well owners seemed satisfied by the size of the loan and the time it took to acquire a loan.

Number of farmers served

The small size of landholdings, which typically comprise several scattered plots, means that almost all wells provide water to several farmers in each command area. (Table 1.20 shows the relationship between commanded area and average irrigated land per farmer.) Typically, deep tube wells serve more than forty farmers, while shallow tube wells serve between six and thirty farmers. Only a small number of wells, 14 percent of shallow tube wells and 11 percent of deep tube wells, serve a single farmer. Details of well ownership, water rates, water rotation practices, and so on are available for all well types from the Master Plan Organization survey, but have not yet been analyzed.

Table 1.18 Incremental agricultural employment from groundwater irrigation, Five−Year Plans
(million person−days)

	Third	*Fourth*	*Fifth*	*Sixth*
Well type	*(198590)*	*(199095)*	*(199500)*	*(200005)*
Shallow tube well/deep set shallow tube well	84.0	154.6	206.6	208.3
Deep tube well	54.8	112.8	140.5	158.4
Total	138.8	267.1	356.1	366.7

Source: Master Plan Organization.

A study of the distribution of landholdings among owners of manually operated shallow tube wells for irrigation shows mixed evidence about the socioeconomic status of these pump users (table 1.21). The MCC survey does not provide any information with respect to distribution of pump owners' landholdings and thereby fails to give any definitive picture about the beneficiaries of this technology. However, the average landholding of 1.44 ha recorded in the sample indicates that the beneficiaries are not limited to small farmers or to those owning less than 1 ha, but include many medium farmers and possibly quite a few large farmers.

Information collected in the MAWTS, JCCIP, and IBA surveys gives more conclusive evidence. About two−thirds of the pump owners in the MAWTS sample were small farmers; and in the JCCIP sample, small farmers predominate with a share of 76 percent. In the IBA sample, on the other hand, more than half of hand tube well owners were medium and large farmers with an average landholding of 1.57 ha. Considering that the hand tube well project was specifically for small and marginal farmers, this proportion is high.

Use of wells

Most wells irrigate more than one crop (table 1.22). A higher percentage of deep tube wells irrigate a third crop because they are permanent fixtures, usually sited on flood−free or shallow−flooded lands. Conversely, shallow tube wells and manually operated shallow tube wells for irrigation are generally removed from farmers' fields before the start of the monsoon and reinstalled from November to January, depending on flood levels and land elevation. A surprisingly high percentage of wells inventoried were operating: 85 percent of deep tube wells, 96 percent of shallow tube wells, 89 percent of deep set shallow tube wells, and 99 percent of manually operated shallow tube wells for irrigation.

Table 1.19 Pump ownership

				Source of funds	
Pump type	*Survey sample*	*Rented*	*Purchased*	*Bank*	*Government*
Deep tube well	728a	547	178	36	53
Shallow tube well	1,771a	15	2,006	1,257	149

a. Complete information sometimes not available.

Source: Master Plan Organization.

Table 1.20 Average irrigated area per participating farmer

	Shallow tube wells		*Deep tube wells*	
Land area per farmer (hectares)	*Number of wells*	*Percentage*	*Number of wells*	*Percentage*
0.00.1	1,146	9.2	89	4.7
0.10.2	3,143	25.2	501	26.8
0.20.3	5,239	42.7	1,465	78.4
0.30.4	7,586	60.8	1,550	82.9
0.40.5	7,866	63.0	1,628	87.0
0.51.0	9,674	77.5	1,817	97.2
1.02.0	10,831	86.8	1,820	97.3
> 2.00	12,479	100.0	1,869	100.0

Source: Master Plan Organization.

Table 1.21 Distribution of landholdings of pump owners for manually operated shallow tube wells for irrigation, various surveys

			Distribution of landholding (percent) a		
Origin of survey	*Sample size*	*Average landholding (hectares)*	*Small farmers*	*Medium farmers*	*Large farmers*
MCC	795	1.44	−	−	−
MAWTS	4,660	0.94	64	29	7

JCCIP	98	1.83	76	22	2
IBA (1984)	1,830	n.a.	45	30	25

a. Small farmers−0.41 to 1.01 ha; medium farmers−1.0 to 2.02 ha; large farmers−more than 2.02 ha.

Source: Shahabuddin and Pitman 1987.

Table 1.22 Irrigated cropping intensity and well type
(percentage of total)

Cropping intensity	*Deep tube well*	*Shallow tube well*	*Manually operated shallow tube well*	*Artesian well*	*Dug well*
Single−cropped	57	71	76	100	70
Double−cropped	30	19	5	−	90
Triple−cropped	13	1	1	−	−
Total number of wells	1,867	12,480	450	484	1,010

Source: Master Plan Organization Technical Report No. 7

Regulation of groundwater development

Wells following the Bangladesh government's siting criteria (1985 Groundwater Management Ordinance) are the exception rather than the rule. This finding shows the futility of attempting to regulate groundwater development with rules that cannot be applied across the board, considering the diversity of land ownership and the ridge and basin landscape.

Farm survey data show that, even though quality assurance checks were made when funding or renting, local development pressures soon overrode them (table 1.23). In many instances wells have to be sited near each other on floodplain ridges to ensure adequate distribution of water. The argument for a laissez−faire approach to well siting is further supported by the fact that, despite the general lack of adherence to the official spacing rules, the average actual irrigated command areas for deep tube wells and shallow tube wells are 83 percent and 82 percent of government targets respectively. (How realistic these targets are is questionable, however.)

Conclusion

The National Water Plan is a continuous, interactive, and iterative process. Because of this, it should be reevaluated and, if necessary, reformulated at different stages. Reevaluation should include: continuous data collection, improved assessment of the water resource, monitoring of plan implementation and performance, and assessment of national priorities, the external economic climate, and prevailing socioeconomic conditions within the country.

Neither irrigable land nor groundwater availability are constraints on the continued rapid growth of groundwater irrigation and the production and employment benefits it brings.

Growth of groundwater irrigation between 1983 and 1987 declined to 4,300 units sold in 198687. Factors identified as constraining the rate of groundwater development in that period were:

Reduction in the profitability of irrigation because of a reduction in subsidies on inputs.

Differential rates of tax payable on diesel engines for agricultural sector use, depending on whether the engine is approved by the government or not.

Lack of freedom for farmers to select their own engines when they have to seek agricultural credits.

Bureaucratic fear that a totally free market for shallow tube well sales and installation will get out of control.

A subsidy of 70 percent offered for deep tube wells (the most expensive technology).

Lack of understanding of the groundwater resource also contributed to the slowdown in 198388. During the last year of the National Water Plan formulation process (198485), the growth trend for groundwater development came to an abrupt halt (table 1.1). Because irrigation statistics take about one year to collate, the hiatus was not apparent until 1986—well after the National Water Plan was drafted. To some observers, the 198586 hiatus in sales signaled severe problems with the groundwater resource. But the interruption in sales was a reaction to the failure of a few hundred shallow tube wells in northwest Bangladesh after the dry season monsoon of 1983 (a rare occurrence, perhaps once in twenty to thirty years). The reaction was to ban shallow tube well sales in twenty−two upazilas, which signaled the market that shallow tube wells—and groundwater—were unsafe investments. Compounding this problem was enforced standardization of all shallow tube well pumps and motors, obliging

Table 1.23 Groundwater regulation, well−siting checks

		Well−siting checks			*Actual command area*	
Type of pump	*Sample size*	*From statements of purchases*	*By officer in field*	*Spacing less than rules*	*Less than 24 ha*	*Less than 5 ha*
Deep tube well	728a	144	571	356	417	−
Shallow tube well	1,771a	1,242	529	1,276	−	1,162

a. Complete information not available for every survey.

Source: Gisselquist 1991a.

farmers to buy only government−selected and marketed equipment.

Fortunately, the government recognized the restrictive nature of both the shallow tube well ban and standardization, and these were relaxed in 198687. The government also opened the market to private importers and reduced tariffs on pumps and engines from 50 to 15 percent in 198889. The results were dramatic: shallow tube well sales increased from 193,400 in 198788 to 270,000 in 198990 and deep tube well sales from 20,300 to 25,000 in the same period.

In 1990 the government, assisted by the World Bank and the Asian Development Bank, agreed to the complete removal of subsidies on deep tube wells within five years. The rationale was to create a level playing field for public sector deep tube wells and private sector groundwater development. Other incentives introduced were equalization of import taxes and tariffs on all irrigation equipment.

Groundwater development in Bangladesh has benefited from greater privatization and a relaxation of government controls. Giving the farmer free rein and ensuring a greater degree of pluralism in the marketplace is a sound policy for sustaining agricultural development in Bangladesh.

One of the biggest potential constraints on rapidly delivering private sector groundwater development benefits to smaller and marginal farmers is the Government of Bangladesh Groundwater Management Ordinance (1985). Although it has not yet been applied, all available evidence indicates this ordinance would be almost impossible to implement, except as a means to curtail rather than regulate development.

Specific risks are the wide powers given to the upazila *parishads* (elected bodies with government nominees as advisers) to license tube wells and engage in rent−seeking behavior. The most obvious danger is the protection of vested interests by large landowners, either locally or upazila−wide, leading to monopoly control and pricing of irrigation water in established command areas. This control could be exercised by objecting to new development and would curtail the many benefits of continued groundwater development. Removal of some or all of these constraints would speed implementation rates significantly.

Another incentive that the government could provide would be to curb the Bangladesh Water Development Board's monopoly water development rights in major irrigation and flood control and drainage projects. For example, groundwater development is banned in the Ganges Kobadak command area, even though it provides only supplementary kharif irrigation to 40 percent of the command area.

The National Water Plan gives preference to shallow tube wells and deep set shallow tube wells because of their implementation rates. Manually operated shallow tube wells for irrigation are equally competitive, however, at least with shallow tube wells, and the use of manual modes would create higher levels of employment for the same irrigated area—a potential benefit for farmers. In addition, Ward (1985) has found that sales of manually operated shallow tube wells for irrigation are still taking place in the relatively inelastic range of demand.

In the face of current demand and supply conditions, credit availability will not be sufficient to redirect manually operated shallow tube wells toward small and marginal farmers. The logical solution is to take steps to increase the supply of these wells available to all farmers. Adopting policy measures needed to increase the supply from the private sector would take market pressure off the manually operated shallow tube wells supplied through government projects and nongovernmental organizations, giving smaller farmers better access to them.

When private and nongovernmental organization sales management discover they can no longer sell all manually operated shallow tube wells for cash, they will start selling to smaller farmers on credit. They are not likely to do so before the cash demand is saturated. The most rational approach would be to allow private suppliers to fill this cash demand. Considering that the potential market is almost infinite (at least 500,000 a year), supply and marketing appear to be the major constraints to enhanced installation rates.

Postscript: The Bangladesh establishment and groundwater development

During the formulation of the National Water Plan, there was considerable opposition to further groundwater development, mostly from the Bangladesh Water Development Board (BWDB). The BWDB has the mandate to develop surface and groundwater, but traditionally has focused on large−scale engineering projects for flood control and drainage and for flood control, drainage, and irrigation. The latter projects provide supplemen−

tal irrigation to early and late kharif crops by pumping and diverting surface water from the main rivers. Opposition to groundwater development was rooted in the dispute with India over rights to the waters of the Brahmaputra and the Ganges.

The government has consistently argued that Bangladesh, as the lower riparian of the Ganges and Brahmaputra rivers, has been treated unfairly by India for water rights, particularly since construction of the Farakka barrage. To support the government's argument for a more equitable share of the main rivers, the case was made that all other water resources indigenous to Bangladesh were negligible and that all water−related crises derived from Indian intransigence. Before the National Water Plan all assessments of groundwater potential had been done by the Groundwater Directorate, a planning cell of the BWDB. It is not surprising that estimates showed that groundwater had insignificant development potential and that recommendations for future water resources investment were for additional large−scale schemes for flood control, drainage, and irrigation.

The recommended National Water Plan has never been formally adopted by the government despite eight years (198390) of assistance in institution−building from the World Bank (financed by the United Nations Development Programme). The BWDB still maintains that there is no further potential for groundwater development, despite a growth in groundwater irrigation from almost zero in 1970 to about 2.37 Mha in 198990.

In response to the hostility to groundwater development, the Master Plan Organization thoroughly evaluated the groundwater resource before making recommendations for the National Water Plan. Conservative planning constraints were applied to resource estimates (table 1.2). For example, the planning assumption for available recharge was only 29 percent of the potential resource. The rationale for this approach was that it was prudent to demonstrate that groundwater was sufficient for at least the ten−year period to 1995, rather than to argue that groundwater was so plentiful that little surface water development by large−scale surface irrigation was needed. Nonetheless, the BWDB still maintains that the groundwater resource is seriously overestimated. Ironically, a World Bank review mission in 1988 stated its belief that the groundwater resource had been seriously underestimated in the National Water Plan (Barber and Gisselquist 1985).

Despite arguments among experts and bureaucrats, farmers in Bangladesh have continued to prosper from groundwater development. They install tube wells and respond to the changing annual availability of groundwater by switching from shallow tube wells to deep set shallow tube wells following a dry monsoon and by switching back to shallow tube wells in normal and wet monsoon years.

Farmers not only quickly understand the appropriate response to drought, they also find cheap engineering solutions to changing shallow tube wells into deep set shallow tube wells. In the National Water Plan analysis, a well−engineered deep set shallow tube well was estimated to cost Tk 17,000 more than a shallow tube well, and operating costs were estimated at Tk 4,200 more for a deep set shallow tube well than for a shallow tube well. A recent field survey in Rajshahi, confirmed by other observers (Palmer−Jones 1988, p. 7), found that farmers paid only Tk 400 to convert a shallow tube well to a deep set shallow tube well (Gisselquist 1991a). These findings indicate that deep set shallow tube wells are more economical than assumed in the National Water Plan.

With major advances in groundwater irrigation in the past five years, primarily as a result of deregulation, the question arises as to whether national water planning is worth the effort and expense. The answer is yes, on balance, because the magnitude of the groundwater resource and of its economic development potential revealed in the National Water Plan was so outstanding that policymakers had to take note and free the market. Before the National Water Plan, uncertainty and a near−the−limit approach fostered regulation and a search for public sector solutions that favored large, politically visible projects.

By promoting groundwater development, the 1987 National Water Plan has led to deregulation and the transfer of decisionmaking about irrigation development to the small peasant farmer of Bangladesh. Irrigation development and increased employment opportunities since then have more than vindicated the skepticism about controlled, public sector irrigation development.

Notes

1. Outflow losses to rivers during the irrigation season are taken into account when considering alternate plans for groundwater development.

2. Specific yield is normally expressed as a percentage and will range from 25 percent for coarse sands to less than 1 percent for silty clays.

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2—
Improving the Access of the Rural Poor to Groundwater Irrigation in Bangladesh

M.A. Hamid

Bangladesh is one of the few countries with a large concentration of rural poor. In the past twenty−five years, the number of poor households in this country has been increasing faster than the number of rural households—at a rate of 3 percent compared with 2 percent (Hossain 1986). According to the Census of Agriculture and Livestock of 198384, as many as 80 percent of the 13.8 million rural households fall within the definition of this study's target group—that is, asset−poor farmers and the landless.[1]

The most significant initiative of the government of Bangladesh to change the socioeconomic circumstances of rural people is the introduction of irrigation technology, specifically, seed−fertilizer−irrigation technology. Bangladesh farmers have for centuries used bucket−lift methods, such as dhones,[2] swing baskets, and dug wells, to irrigate a dry season boro crop (January to May) on lands near ponds, rivers, low−lying canals, and depressed water basins. According to the 1960 Agricultural Census of what was then East Pakistan, nearly 7 percent of cultivated land was irrigated by these traditional methods in 195960.

Modern irrigation was initiated with low lift pumps, a surface pump used in the 1960s, and expanded quite rapidly in the 1970s. It was soon realized, however, that excessive withdrawal of surface water during the dry season would not only affect fish culture and navigation but would cause salt water intrusion from the sea. With 58,000 pumps distributed, many believe that Bangladesh has reached the limit of surface water development—a belief supported by the government's recent emphasis on groundwater development (Bangladesh, Planning Commission 1985, chap. 9). One advantage of using groundwater is that it allows extension of irrigation to areas where surface water resources have been exhausted. Another advantage is that tube wells can be sited next to areas to be irrigated and costly distribution systems can be avoided.

Groundwater development began with deep tube wells in 196768 and gained momentum in the mid−1970s with smaller−capacity shallow tube wells. The importance of groundwater as a source of irrigation increased sharply from 198283 to 198485 (table 2.1). In recent years, of 3 million hectares (Mha) of irrigated area, about 60 percent is served by groundwater, and the other 40 percent by other methods. The Fourth Five−Year Plan (199095) proposes to increase the area irrigated by deep tube wells and shallow tube wells from 1.81 Mha in 198990 to

3.02 Mha by 199495. The commitment recently announced by the government of Bangladesh—to make the country self−sufficient in foodgrains by 199192—has led to a planned increase in the number of deep tube wells and shallow tube wells, respectively, from 16,700 and 137,000 in 198485 to 23,000 and 168,000 by 199192 (Bangladesh, Planning Commission 1985).

One of the government's main objectives for irrigation development is "to ensure equitable distribution of benefits" (Bangladesh, Planning Com−

Table 2.1 Groundwater irrigation development, Bangladesh, 1972−87

		Area irrigated by groundwater	
Year	*Total area irrigated (Mha)*	*(Mha)*	*Proportion of total (percent)*
1972−73	1.21	0.04	3
1973−74	1.30	0.05	4
1974−75	1.44	0.09	6
1975−76	1.41	0.10	7
1976−77	1.22	0.09	7
1977−78	1.46	0.13	9
1978−79	1.49	0.16	11
1979−80	1.59	0.18	11
1980−81	1.64	0.22	13
1981−82	1.73	0.27	16
1982−83	1.85	0.41	22
1983−84	1.92	0.67	35
1984−85	2.07	0.88	43
1985−86	2.10	0.96	46
1986−87	2.20	0.98	45

Source: Bangladesh Bureau of Statistics.

mission 1985). The effects of irrigation development on asset performance and the landless are thus the best indicator of its effectiveness. Empirical results show that irrigation technologies have increased agricultural productivity and employment, but these benefits have accrued disproportionately and more rapidly to the relatively rich than to the poor, the target group (Master Plan Organization 1984, chap. 5).

This chapter analyzes the potential effect on poverty of groundwater irrigation to identify feasible policies and institutional and organizational approaches that will improve the access of the rural poor to irrigation. More specifically, this chapter:

Assesses the benefits of groundwater irrigation accruing to the rural poor.

Analyzes the financial and socioeconomic issues in improving the access of the rural poor.

Suggests feasible policies and institutional and organizational approaches that would ensure a more rapid transfer of benefits from groundwater exploitation to the rural poor.

A useful analytical tool is to discuss these objectives in connection with the three principal sources of the benefits of groundwater irrigation. The data for the analysis of these sources come mostly from microlevel studies by the Department of Economics, Rajshahi University, under the leadership of the author, and studies by the Bangladesh Institute of Development Studies (BIDS), the Bangladesh Agricultural University (BAU), the Master Plan Organization (MPO), and others. National statistics are mainly from the Bangladesh Bureau of Statistics (BBS).

Assessing the benefits

What are the benefits of groundwater irrigation? How extensive are these benefits? Most important, who receives more benefits, the rich or the rural poor?

Access to tube well ownership

In Bangladesh a tube well can be owned by an individual or by a group. Empirical studies show that in either case the tube well owners or managers gain a substantial proportion of the total benefits of irrigation.

A 1982 study of shallow tube wells (Hamid and others 1982) shows that, by spending 5,764 taka (Tk) for operation and maintenance, an owner or manager received on average Tk 14,160 from water charges, yielding a benefit−cost ratio of 2.45. A study conducted in 1988 (Hamid 1988, table 3) shows that an owner or manager of a 2−cusec[3] low lift pump received Tk 60,765 against total expenses of Tk 40,840, for a benefit−cost ratio of 1.49. One BIDS study also showed that the excess of charges over cost varies from 10 percent for shallow tube wells to 62 percent for low lift pumps (Osmani and Quasem 1985, p. 165). Other field studies show similar results. It is therefore important to learn the socioeconomic status of the owners or managers of different groundwater irrigation devices.

Until recently, all deep tube wells were distributed either by the Bangladesh Agricultural Development Corporation (BADC) under its rental program to informal groups or by the Bangladesh Rural Development Board (BRDB) to formal Agricultural Cooperative Societies (KSSs). Field results show that in both informal (not surprisingly) and formal (surprisingly) groups, the deep tube wells are owned or controlled by big farmers.

The ownership/management picture is similar for shallow tube wells, including those under BRDB management. For example, the 1982 Hamid study showed that only one of nineteen randomly selected BRDB−managed shallow tube wells was managed as a strict cooperative; the others were managed by individual owners or by managers acting as de facto owners.

To quote from the study: "The persons designated as managers, bearing the land security, have

in fact become the owners of the STWs [shallow tube wells]. The participating farmers, contrary to expectations, have no real basis to feel that the shallow tube wells belong to them. They pay the usual water charges, as given by farmers, of tube wells owned by individuals, without having any chance to see the account of the expenses incurred in running the tubewell " (Hamid and others 1982, p. 191).

The study shows that the average area cultivated by owners or managers (3 ha) is much larger than that cultivated by farmers (1.34 ha). Even shallow tube wells operated under nongovernmental organizations, such as the Christian Commission for Development in Bangladesh, exhibit this pattern of ownership. And now that all deep tube wells and shallow tube wells are sold either for cash or on credit, there is little reason to believe that the rural poor will become the owners.

For traditional technologies such as hand tube wells and dug wells, the pattern of ownership is more or less the opposite. Because these technologies have a small capacity (generally less than 0.05 cusec) and a high demand for hard labor, they are owned and managed mostly by relatively poor farmers. In his village study, Howes (1981) shows that as many as 78 percent of the hand tube well owners are nonrich peasants. Because traditional techniques such as hand tube wells and dug wells account for only a minor fraction of the area irrigated by groundwater devices, it may be concluded that the rural poor receive little of the benefit from access to technology and ownership.

Access to produced benefits

In this analysis produced benefits are those that derive from access to irrigation for land that is within the command area under the tube well, access to a timely and adequate supply of water, access of sharecroppers to a fair share of output, and access to employment opportunities and fair wages.

By definition, people in the target group—asset−poor farmers and the landless—would have little land under any irrigation scheme. But we are asking a different question: Do the poor have equal access to water for their own and shared land—however small it may be—under a given irrigation scheme?

The Hamid (1982) study of shallow tube wells shows that although owners or managers had as much as 37 percent of their cultivated land under the selected irrigation schemes, other participating farmers had only 14 percent of their land covered (Hamid and others 1982, p. 59). Owners or managers try to install the equipment in a location that covers the maximum amount of their own land. Shams (1975) showed that the average size of the landholding of farmers on whose lands the deep tube wells were sited was 3.72 ha compared with 1.21 ha for others.

Access to an adequate supply of water by relatively weak farmers depends on such factors as nearness of the land to the tube well, regularity of the payment of water charges, and, above all, the social relationships of the purchasers with the tube well owners or managers. Field studies show that water goes first to the owners or managers, then to their close relations, then to the regular and timely water−charge payers, and finally to others. This sequence becomes even more pronounced during a crisis, when water output is reduced. Considering the socioeconomic circumstances of the poor, it is probable that they are always last to have their lands irrigated. (An exception might be access for an asset−poor sharecropper who works a portion of an owner's or manager's irrigated land. Out of self−interest, the owner or manager would ensure a fair supply of water to a sharecropper who paid a share of output in kind rather than a fixed amount in taka.)

If benefits are measured in increased yield per hectare, small and marginal farmers do appear to enjoy some premium. The shallow tube well study (Hamid and others 1982) shows that yield per unit of land for small and marginal farmers is 2 to 3 percent higher than average yield (although these differences were not found to be statistically significant).

What about the benefits to sharecroppers? Traditionally sharecroppers bore all the costs of production and received half the produce, with the other half going to the landowners. Irrigation development has led to some changes in this tenancy system. First, primarily because of the heavy cost of cultivation, many shallow tube well owners operate large farms and cannot avoid sharecropping their lands. This has worked to the advantage of sharecroppers in some places. Second, sharing conditions have changed. In most cases, sharecroppers that bear all costs receive two−thirds of output. Empirical results show that sharecroppers get relatively more benefit if they pay the share of output in cash rather than in kind. However, whatever the share of output received by a sharecropper, the

net share may be zero if the costs of family labor are considered (Hamid and others 1984, chap. 7).

Beyond any doubt, irrigation technology has increased employment opportunities and wage rates. Field studies demonstrate that irrigation has created at least 50 percent more employment in rural areas and has led to an increase in wage rates of about 50 percent (Hamid and others 1982; Hossain 1988).

In a village study, White (1989) draws attention to another effect of irrigation technology. White notes that irrigation changed not only the amount of work, but also its structure. Regular work on a fixed−term contract is now less common. The change in the cropping system as a result of irrigation has meant an increased demand for labor during more of the year. And it has also created a much steeper peak period of demand. Sharecutting laborers can now receive about 12.5 percent of output for cutting, carrying, threshing, and putting produce in sacks.

White also points out that irrigation has contributed to a growing shortage of fuel. Wood and bamboo have become scarce as forests have been cut down for fuel and to expand cultivable land, a trend reinforced by the higher profitability of irrigated crop production. Cattle dung, another fuel source, has been less plentiful as cattle numbers have dwindled. Rich households are self−sufficient in fuel or can buy it, but gathering debris for fuel—dry leaves, bark, dung or straw left after harvest in the fields—has become a major burden for the women and children of poorer households.

As for the effect on wages, White points out that wages have risen considerably in regions with little unemployment and an inelastic labor supply. But in−migration of labor from other regions and the availability of labor−saving mechanized technologies have limited such wage increases (White 1989).

Access to ancillary services

New technology and high yielding varieties have given rise to new ancillary services and expansion of existing services. Examples are tube well markets, workshops, mechanical services, input markets, and crop processing.

Tube well markets. The sale of tube wells could offer important benefits. But the mechanisms through which tube wells are now distributed and sold do not allow the rural poor access. Formerly, the tube wells were distributed and sold through the BADC and through other agencies such as commercial banks and appointed dealers, to which the poor have no access. (In an IDA−sponsored shallow tube well project, the IDA shallow tube well 724−BD project, the turnkey contractors received a 20 percent markup over the sale price of the shallow tube wells.)

Workshops. With the introduction of modern irrigation, a number of workshops were established at the district and even at the subdistrict (*upazila)* levels. These workshops belong to the well−to−do people of rural Bangladesh. Still, the development of tube well markets and the establishment of workshops benefit the poor by expanding employment opportunities.

Mechanical services. Mechanical services, formerly provided by the BADC, are now provided by the private sector. Field studies show that both poor and wealthier households engage in mechanical work. White notes, however, that "mostly, [mechanics] are sons of once fairly prosperous parents [and] have used their inheritance as initial capital" (White 1989, pp. 2021).

Input markets. Wealthy farmers have also taken control of the input markets, particularly chemical fertilizers. Again, the poor work as wage laborers in these markets.

Crop processing. The increased agricultural output resulting from irrigation requires processing, transport, storage, and so forth before it is ready for the market place. Field studies demonstrate that these activities have expanded rapidly in intensively irrigated areas.

Ancillary activities. The poor appear to benefit from ancillary activities. Take the case of rough rice processing. Formerly, this processing was done by the traditional method, *dheki*. Rice mills have replaced this method almost entirely, causing unemployment among rural women. But even though it is possible that the rich own all the modern rice mills, this does not mean that the poor do not benefit. Field visits show that in villages with irrigation systems rough rice processing by the poor has intensified rather than slackened. The poor buy rough rice from the local market, process it at home with the help of wives and children, husk it at nearby rice mills, and sell it at the local market.

Analyzing the socioeconomic issues

This section analyzes the socioeconomic and financial issues related to groundwater benefits. The issues are complicated and controversial. What follows are the personal observations of the author.

Tube well ownership

Why is it so difficult for the rural poor to own tube wells? The socioeconomic issues include choice of technology, mode of tube well distribution, credit delivery system, and the nature of subsidies.

Technology. Four types of tube well technologies are found in rural Bangladesh. Although the poor have relatively good access to traditional technologies—hand tube wells and dug wells—they have no access to modern technologies—deep tube wells and shallow tube wells.

Capital costs, operation and maintenance costs, and total costs per hectare meter of water are much lower for hand tube wells than for shallow tube wells, and these are in turn much less costly than deep tube wells (table 2.2). Although each of these technologies has its place, the choice of technology for specific locations and groups of people is not guided by relative costs and produced benefits. For example, although until recently farmers irrigated mostly with hand tube wells, recent findings show that more than half of these tube wells have gone out of operation. The decline in use of hand tube wells is normally attributed to the drudgery of the method and to low returns to labor. To these, however, must be added the installation of shallow tube wells in the command area of hand tube wells and the availability of modern devices with easy credit.

Tube well distribution. For tube well ownership the mode of distribution and sale is crucial. Formerly, nearly all tube wells were rented; now, most of them are purchased. What follows is a discussion of the performance of tube wells under these two programs (discussion drawn from Hamid and others 1984).

One advantage of the rental program is that the BADC takes responsibility for repair and maintenance of tube wells, while under the sales program, owners are responsible for repair and maintenance. The BADC has adequate, efficient, well−trained, and experienced mechanical staff to look after tube well engines. Owners may not have the services of the best mechanics when they are needed.

Another advantage of the rental program is that tube wells are used on a group basis. This increases irrigated area per cusec, reduces unit cost of production, increases income, and ultimately stabilizes food prices. This does not necessarily happen in the sales programs. Under the rental program, tube wells are to be used for irrigation only and thus can claim a greater contribution to the country's self−sufficiency in food. There is no mechanism under the sales program for ensuring that tube wells are used for irrigation only.

Under the rental program, the BADC can make scientifically based choices about the distribution of water. But if the rental program is discontinued, all tube wells will gradually be owned by the rich and the BADC's opportunity to influence water distribution will be lost.

There are several advantages to the sales program, however. First, because individual farmers own the tube wells and so take special care of them, the engines have a longer life. Second, under individual ownership of tube wells managerial problems are less complex, and owners can use the machines more productively than under the rental program.

Table 2.2 Cost of Irrigation water by different types of groundwater technology, Bangladesh, 197677 prices
(takas)

	Deep tube wells		*Shallow tube wells*		*Hand tube wells*	
Costs	*With duty*	*Without duty*	*With duty*	*Without duty*	*With duty*	*Without duty*
Capital cost	240,550	223,000	30,446	24,100	1,835	1,380
Capital cost per hectare meter of water	824	753	353	282	518	388
Operation and maintenance cost per hectare meter of water	659	659	648	648	471	471
Total cost per hectare meter of water	1,483	1,413	1,001	930	989	859

Note: US$1.00 = Tk 14.39.

Source: Government of Bangladesh and the World Bank 1982.

Finally, under the rental program, managing committee members often must make false statements about the number of participating farmers and the area of land to be irrigated. The sales program saves the farmers from these illegal doings.

In measuring the performance of tube wells under the rental and sales programs (table 2.3), four aspects are distinguished: productivity, distribution, net return, and employment. The results show that for coverage and production the rental program substantially outperforms the sales program. For distribution, the number of farmers per cusec is much higher in the rental program (36) than in the sales program (21). Under the sales program, irrigators generally own more land than their counterparts in the rental program; and water rates charged per hectare are higher. Nonetheless, the net return per household is higher in the

Table 2.3 Performance of rental and sales programs for groundwater irrigation, Bangladesh

Variable	*Rental program*	*Sales program*	*Ratio (R/S)*
Productivity			
Area irrigated (ha/cusec)			
Boro	8.51	6.19	1.37
Aman	1.09	1.39	0.78
Total production, boro+aman (MT/cusec)	28.44	25.20	1.13
Distributional aspects			
Number of farmers (per cusec)			
Boro	32	16	2.00
Aman	2	5	0.40
Total	36	21	1.71
Land per household (ha)			
Owned	1.06	1.66	0.64
Cultivated	1.16	1.70	0.68
Water rates (Tk/ha)	1,480	1,657	0.89
Net farm income (Tk/household)	5,696	10,009	0.57
Total family income (Tk)	13,184	16,014	0.82
Net returns			
Net return per hectare (boro HYV/Tk)	2,989	4,031	0.74
Net return per cusec (boro HYV/Tk)	25,422	24,936	1.02
Net return from other crops (Tk/cusec)	5,003	6,667	0.75
Total net return from irrigation	30,425	31,637	0.96
Net return from other activities	–	5,150	–
	30,425	36,787	0.83

Total income (Tk/cusec)			
Employment (man−days/cusec)			
From irrigation activities	1,043	880	1.19
From nonirrigation activities	−	265	−
Total	1,043	1,145	0.91

− Not available.

ha Hectare.

MT Metric ton.

cusec Unit of flow equal to one cubic foot per second.

Tk Taka.

HYV High yielding variety.

Source: Hamid and others 1984, Table 10.2.

sales program than in the rental program. And for employment, levels are higher in the sales program than in the rental program.

Having considered these factors, the Hamid study (1984) concludes that, if the national objectives are to achieve self−sufficiency in food and maximum utilization of irrigation devices by smaller farmers, the rental program should be preferred to the sales program. But if the national objectives are to derive maximum economic and financial benefit per pump unit and to create nonfarm job opportunities, the sales program should be preferred. (Further discussion on privatization is in the subsection to follow, in connection with water markets.)

Credit. Tube well ownership is highly correlated with the availability and mode of distribution of credit. The availability to the poor of credit for irrigation and insights into the credit delivery system are discussed with reference to a World Bank shallow tube well project (1147−BD credit project) evaluated by the Bangladesh Unnayan Parishad under the leadership of the author (Bangladesh Unnayan Parishad 1985).

The project distributed some 27,000 shallow tube wells in northwest Bangladesh. With the Bangladesh Bank as lead agency, partners in the project were turnkey contractors for the sale of tube wells, nationalized commercial banks for the provision of credit, and the Bangladesh Rural Development Board for the formation of cooperative groups. The latter agencies were designated as "participating credit institutions."

The project aimed to sell about 27,000 shallow tube wells within four years. During the first three years, as many as 25,609 shallow tube wells were sold (a 95 percent success rate), which surpassed all previous records. The successful results are attributed to several factors:

Exceptional motivation on the part of the turnkey contractors and participating credit institutions. The incentive for the contractors was clear: the greater the sales of shallow tube wells, the higher the markups received.

Assistance to prospective buyers in obtaining technical feasibility reports from the Upazila Technical Team. Unfortunately, in most cases this was done by paying Tk 200 to Tk 300 extra to the team.

Reduction of the time between application for and receipt of equipment. Previously, buyers had to wait eight weeks. In the privatization scheme,

of fifty−two case studies, 39 percent obtained the equipment within the specified period of fifteen days, another 27 percent within four weeks, and the rest a bit longer. The average time between application and delivery was estimated at five weeks, three weeks less than in the earlier program.

Tacit understanding that the equipment may be used for any purpose the buyer chooses. (Under the BADC program, owners are allowed to use the machine only for irrigation.)

Provision of a grace period of eighteen months for loan repayments. This produced double benefits. During the grace period, borrowers were not required to repay any installment money and were entitled to receive repair and maintenance services from dealers free of charge.

Freedom to carry and sink the equipment according to the borrowers' own arrangements.

The sale of irrigation equipment on credit is just one part of the picture. The other part has to do with the realization of the loans disbursed and the socioeconomic status of the borrowers. During the period of the investigation, the loan operations of some randomly selected participating credit institutions (Bangladesh Krishi Bank, Janata Bank, and Sonali Bank) were scrutinized. The records show that, for the first three years of the project, a sum of Tk 177.01 lakhs[4] was disbursed and Tk 7.52 lakhs was realized, for a loan realization rate of a little more than 4 percent. The study points out that the rate of realization, according to repayment schedules, ought to have been at least 64 percent during this period. (As of the last week of February 1989, the rate of realization of loans did not exceed 50 percent in most cases, even though the final repayment date expired two to three years earlier.)

Various explanations are given for these poor performances on loan repayments. Loans were not disbursed according to normal practices. Bank officials explained that because of government directives to disburse loans for a specified number of shallow tube wells within a specified time period, they had to relax customary lending conditions. This adversely affected loan repayments.

It is alleged that agents for dealers often coached buyers on what to say to the bank and how to say it about the amount of land they owned, the irrigation scheme they had prepared, and so forth. It is also alleged that these agents, by stating that loans were coming from such donors as Saudi Arabia and the World Bank, convinced the borrowers that they would not have to pay more than a few installments on their loan. (The field visit referred to above found evidence of this assertion.)

The government's policy of waiving the interest on or even writing off loans because of natural or other hazards is also responsible for the poor repayment. (Political factors play a role in this.) And the social environment in Bangladesh, where defaulters go unpunished, is also responsible.

A participating credit institution branch is not allowed to sanction further loans until it has realized at least 50 percent of disbursed loans. Field visits show that many branches have lost their power to distribute loans because of their inability to fulfill this condition. This ban on further loans also contributes to the poor repayment. Disbursement of credit by multiple agencies in the same area is another reason for poor repayment as borrowers repay loans to one agency by borrowing from another.

Who received shallow tube wells through the credit system under review here? It might be thought that small and marginal farmers would be assured of receiving the shallow tube wells if they were distributed through the BRDB. In the 724−BD credit program, however, where at least 60 percent of the shallow tube wells distributed through the IDA credit were required to go to BRDB groups, only 39 percent of total sales were made through these cooperatives (Hamid and others 1982). In the 1147−BD credit program, some special provisions were made for the BRDB groups: they would make a down payment of Tk 1,000 compared with Tk 2,900 for non−BRDB buyers and would repay loans in nine installments rather than in the seven required of the non−BRDB buyers.

Empirical results show that these provisions were grossly misused by forming fake Agricultural Cooperative Societies. The result is that credit benefits have accrued mostly to individuals who do not belong to the target group.

Another empirical finding is that the effect of privatization on entrepreneurial development has been negligible. Only a small proportion of the total private investments in irrigation is self−financed, while the surpluses from such investments are invested in purchases of agricultural land, housing, and other businesses.

Subsidies. The current subsidy policy affecting access to technology ownership is that the larger the capacity of the equipment, the higher the rate of subsidy, with zero subsidy in the case of traditional devices.

For example, for BWDB−managed irrigation schemes, the rate of water charges is nominal in relation to costs and the rate of subsidy is 25 percent for low lift pumps and 75 percent for deep tube wells, as estimated by the planners in the Third Five−Year Plan. There is no subsidy for shallow tube wells and hand tube wells. Although more than one−fourth of irrigated land is irrigated by traditional methods, no attempt has been made to subsidize the use of these technologies. This has encouraged farmers to switch from labor−demanding, traditional methods to oil−run, modern technologies.

Produced benefits

The pattern of land distribution is an important issue for the access of Bangladesh's rural poor to the produced benefits of groundwater irrigation. The Census of Agriculture and Livestock of 198384 recorded that the bottom 70 percent of farmers own 29 percent of the land, and the top 5 percent own 26 percent. Empirical results demonstrate that the smaller the size of household holding, the better the productivity. But attempts made to redistribute land resources have not been very successful.

Estimates are that the amount of land available for redistribution would be only 0.2 million ha if the ceiling is set at 10 ha per family. In a country where four−fifths of the rural households are landless or functionally landless, this amount of land would barely meet the demand even for the poorest of the poor (Hamid 1988a).

The nature of the water market is an important factor in the distribution of benefits among farmers because water costs comprise about one−third of cultivation costs. There is confusion in the literature about the nature of the water market in rural Bangladesh. The reality can be explained in the following manner.

First, the rate of water charge depends on ownership of the tube well. If the tube well is owned and managed by individuals, it is likely that the charges will be higher than the rates charged under joint management. Water rates are higher in the private sector by about 12 percent (Hamid and others 1984, p. 205), and Osmani and Quasem (1985, p. 165) have shown that the "excess charges over cost varies from 10 percent for STW [shallow tube wells] to 62 percent for low lift pumps."

Second, the extent of excess charges over actual cost is determined by whether the participating farmers have access to water from other tube wells installed near their land and whether the irrigators can shift their cropping pattern in the next season.

Third, water rates vary from farmer to farmer even within the same irrigation scheme, depending on, among other things, the type of soil, the distance of the land to be irrigated from the tube well and, above all, the social relationships between the owners or managers and the buyers.

Fourth, there are as many as seven different ways of charging for water in irrigated areas (Hamid and others 1984). The most popular are fixed share of output, varying from 22 to 33 percent, and fixed taka per unit of land (plus diesel costs).

Those who pay with a share of output are for the most part the losers. But there are merits and demerits in both systems. In the share−of−output system, the owner or manager generally gets more benefits but must invest a large amount out of his own pocket. He also shares the risk of crop failure.

When sharing output, the owner or manager is careful to give water in the right quantity at the right time. If the water charge is paid in cash, the owner or manager normally collects 50 percent at the beginning and the rest in installments—according to informal agreements—at later stages of irrigation.

Finally, the rates charged for water vary between a diesel−run engine and an electric−run engine. For a diesel−run engine the charge usually is higher by 15 to 20 percent (Hamid and others 1984, p. 66).

Another factor in access to produced benefits is the land tenancy system in the country. Bearing full costs but having an unfair share of land and no security of tenure are important constraints. Other factors include high population growth rate, which puts pressure on employment opportunities and wages; a lack of equal access of women to produced benefits; and so forth.

Irrigation activities, whatever their rate of expansion, will not absorb all the workers entering the labor market. One study shows that the agricultural sector will not be able to absorb more than 30 percent of the expected rural labor force increase of 5 million for the period 1989 to 1995 (UNDP 1988). This is crucial information for those concerned with improving the socioeconomic circumstances of the rural poor through groundwater irrigation alone.

The amount of rural credit obtained from both institutional and noninstitutional sources is also an important determinant in the poor's access to produced benefits. The cost of production for an irrigated crop is much higher than for a nonirrigated crop. Hossain (1988, p. 134) puts the difference at 165 percent.

Although in recent years the number of commercial bank branches and the amount of loans disbursed in rural areas have increased manyfold, "owing to the weaknesses of the credit institutions, credit has remained concentrated in the hands of the medium and large farmers, and complicated loan sanction procedures have led to untimely disbursement, which together with the spread of corruption among bank officials, has promoted laxity in credit disciplines and poor recovery. The small farmers who need credit badly have suffered" (Hossain 1988, p. 24).

Ancillary services

Although in ancillary services the lion's share of benefits accrues to the well−to−do, the poor also derive tangible benefits. Attempts to give the poor more benefits more rapidly would raise the following concerns.

First, transaction costs are high for the various ancillary activities conducted by the target group who, by definition, are poor and deal with small amounts of goods. For instance, in marketing rice or fertilizers, the poor cannot deal with more than a few quintals. Unless the poor can handle commodities in bulk, they cannot hope to gain sizable benefits.

The opportunity to deal in larger quantities hinges, however, on the availability of credit to small farmers or small businessmen. Borrowing from noninstitutional sources—because of their lack of creditworthiness for institutional lenders—entails heavy interest rates, so incentives to expand, or even to stay in business, are lost.

What about the access of women to nontraditional activities? Women still depend on such typical activities as handicrafts, cottage industries, and poultry and livestock raising. But women with proper training could easily take up jobs in mechanical services and in buying and selling spare parts.

Skill−training programs in rural Bangladesh, however, are not in good shape. Sometimes the poor are given proper training, but because of a lack of necessary tools and equipment they cannot use their knowledge. This lack of linkage between training and jobs constrains the expansion of benefits to the poor.

Another constraint is the relatively low prices received by the poor. It is well known that to get cash, poor farmers sell a sizable proportion—about 25 percent—of their rice immediately after harvest, when the market price is low, and buy back later, when the price is high. Government procurement policy mostly is ineffective in helping the poor receive the declared price.

Policy interventions

This section looks at policy interventions required to improve the access of the rural poor to groundwater irrigation. A brief sketch of the implementation mechanism of these interventions then follows.

Tube well ownership

As ownership of tube wells is a source of irrigation benefits, attempts should be made to see that the rural poor can either become the owners of tube wells or participate fully in the decisionmaking process when tube wells are managed jointly. The following interventions are suggested.

Two instruments for promoting access of the poor to tube well ownership are competition and cooperation. Promoting entry and competition is probably the best way to undermine the monopoly that most tube well owners now enjoy. This would imply that all regulations prohibiting farmers from installing shallow tube wells in deep tube well command areas should be abolished. But to do this, two conditions must be stipulated. First, deep tube wells that have been installed under the rental program must be left undisturbed; otherwise they will become economically inoperative, as has happened in many areas of Tanore and Manda Upazilas of Rajshahi district. Second, coastal areas where the aquifer is subject to salinization should be excluded. To promote cooperation, the best way to sell or distribute tube wells would be through group ownership, either formal, as in BRDB−KSS, or informal, as in the BADC rental program.

To ensure competition and to provide a feeling of ownership to the relatively weak irrigators, rental programs and sales programs should be allowed to continue side by side.

As set out by the BADC, the distances between two deep tube wells (600 m), between a deep tube well and an shallow tube well (420 m), and between shallow tube wells (240 m) should be maintained. This would relieve the drawdown problem in many locations, including the Barind region of northwest Bangladesh.

The common wisdom, "small is beautiful," should be borne in mind by both the government and the donor agencies. For exploiting groundwater, hand tube wells should be preferred to shallow tube wells, and shallow tube wells to deep tube wells. This suggestion makes sense for containing costs (as seen in table 2.2) and for simplifying management.

Attempts should be made to develop the locally invented techniques of irrigation, including bamboo tube wells and dug wells. Here, too, the donor agencies have a significant role to play.

The current policy of subsidizing the bigger technologies and neglecting the smaller, traditional technologies should be modified. With access to credit, the smaller technologies can perform creditably in irrigation. And if the smaller, traditional technologies are developed, this may bring revolutionary changes in irrigation, including reduced dependence on foreign countries for the supply of this basic technology.

Poor recovery of tube well loans is due primarily to psychological rather than socioeconomic factors. In most cases, borrowers are failing to repay loans, not because they are unable to do so, but because they believe that the loans, or at least the interest on them, will be written off. Institutional mechanisms for both credit delivery and credit recovery need overhauling.

Produced benefits

To increase the access of the poor to produced benefits, the following interventions are needed.

Redistribution of the most important asset, land, generally is regarded as a precondition for fair distribution of irrigation benefits. In view of current sociopolitical circumstances, land redistribution does not appear realistic. A better idea might be insisting on full utilization of all cultivable lands—a measure that could be implemented by introducing a fallow land tax or underutilization tax. Another incentive to full utilization would be permitting the acquisition of land that has remained fallow for several years.

The three−tiered tenurial system as envisaged by recent land reforms should be fully implemented. Security of tenure and provision of minimum wages, as suggested by the Land Reform Committee, should be implemented to the letter.

To break the monopoly in the water market, in addition to policy interventions to promote entry and competition it is essential to form and maintain water users associations, either formal or informal. With formal BRDB−KSS groups, a difficulty is that such cooperatives are people−based, but irrigation requires land−based cooperation.

In forming a management committee for a water users group, proportional representation of irrigators from among the rural poor must be ensured. Fair access of the rural poor to groundwater exploitation requires systems designed to favor them.

In addition to equal access to water, the water users group might be given the right to raise a water tax; be given preferential treatment in access to irrigation equipment; and be given access to lands belonging to such organizations as the BADC, the BWDB, the IWTA, and even educational institutions. (These measures would require legal backing.)

All Khas land, that is, land belonging to the government, must be identified and distributed among landless and nearly landless farmers. And cooperative use of this land should be ensured. Attempts made in this regard are encouraging but need more stimulation.

The rural poor should be given needed credit without collateral. The Grameen Bank has proved that providing credit to the poor without collateral, if special management systems are used, is not risky but beneficial to both the borrowers and the lenders. As suggested above, the entire credit system should be overhauled. Among other credit programs, the Special Agricultural Credit Program (SACP), introduced in the mid−1970s, should be discontinued and merged with the normal program.

Because of the poor's ever increasing numbers, they cannot benefit from the expanded employment opportunities and increased wages from irrigation. A solution would be the creation of nonfarm job opportunities as explained below.

Ancillary services

To ensure the rural poor receive further benefits from ancillary services arising from groundwater development, the following interventions are suggested.

The poor should be extended adequate and timely credit under easy terms and conditions.

Nonfarm job opportunities need to be created, preferably for jobs having to do with high yielding variety technology development. Self−employment is better than wage employment. So creation of self−employment opportunities in such areas as rough rice processing, poultry and livestock rearing, vegetable production, and fish culture must be ensured. The Grameen Bank's experiences may become the basis for expanding these types of activities.

Women's entry into nontraditional types of employment must be encouraged and facilitated. Such jobs pay better than do the traditional tasks village women perform.

Small farmers sell a substantial proportion of their produce—about 25 percent (UNDP 1988, p. 24)—immediately after harvest, when the price is low; they then buy produce at a later date, when the price is high. To alleviate this problem, the retaining power of the poor should be increased. One way to do this is to take cooperative action through institutional credit. Cooperative marketing efforts with institutional support can help small businessmen reduce the high transaction costs of dealing in small quantities and ultimately can enable small businessmen to expand their business operations.

Practical training should be provided to prepare the rural poor for employment in mechanical services. Training must be accompanied by financial support for tools and equipment. Training should center on management, organization, and good business practices and on health and nutrition.

Implementation mechanism

The foregoing policy interventions require an appropriate implementation mechanism. Several such mechanisms are currently in use in Bangladesh. Experience suggests, however, that none of the mechanisms will be able to provide the rural poor with adequate access to groundwater irrigation.

The one exception is the operation of the Grameen Bank. But this operation is an exclusive one, limited to a special group of people for special types of activities. The present venture will require the involvement of not only the poor, but the rich, that is, of all who are involved directly or indirectly in the chain of activities connected to irrigation development. Nonetheless, the experiences of the Grameen Bank will be useful.

There is an important organizational issue that affects the security and continuity of programs. In the past, almost all programs and mechanisms were person−or personality−based. When the program head left, the program went with him. Comilla Model has lost its credibility because Akhtar Hameed Khan has been away. The Swanirvar Bangladesh movement has come to a standstill because its initiator has passed away. The Swanirvar Gram Sarker and Khal Kata Karmasuchi (canal digging programs) have been discontinued because the Zia government is no longer in power.

Similarly, critics are saying that the Grameen Bank will do well only as long as Muhammad Yunus remains. Many people, particularly in the Muslim world, believe that for local institutions to achieve sustainability, they must be built on a stable foundation and not be dependent on an individual or particular government.

One possibility is to build local institutions around village mosques. There are about 0.2 million mosques in Bangladesh. The government recognizes their importance in local communities and has already started training the leaders, about 0.4 million people. About one−tenth of the leaders have had basic training in various socioeconomic activities. So there is a basis for evaluating whether effective rural institutions could be built around village mosques.

A field test should be conducted, with the following objectives:

To exploit the unused and underused water and other resources in the area.

To organize the local people into a cohesive group to foster a cooperative spirit.

To use existing infrastructural facilities to benefit the local people, including the poor.

To encourage the participation of all irrigators, including the rural poor, in the many activities connected with irrigation, including decisionmaking.

To provide the information and experience needed to build a comprehensive rural−development model that would be based on high yielding variety technology and would ensure that a fair share of the benefits goes to the rural poor.

Notes

1. The target group includes farmers who have up to one hectare of land; these farmers are often called "functionally landless."

2. A long canoe−shaped wooden conduit that is tipped to convey water from its source to the land to be irrigated.

3. Cusec is a volumetric unit of flow equal to a cubic foot per second.

4. A lakh is one hundred thousand.

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3—
Groundwater Irrigation in Bangladesh:
Access, Competition, and Performance

M.A.S. Mandal

A quarter century ago, a well−known Pakistani economist, Ghulam Mohammed, applied the results of his survey of the size of farm holdings in what were then West and East Pakistan. He calculated that a total of 26,000 private tube wells, singly and jointly owned, could be installed in East Pakistan if the size of holdings was the sole criterion. He refuted the arguments of East Pakistani government officials that the small size of holdings made private tube well development inappropriate in East Pakistan (Mohammed 1966).

The average size of holding in Bangladesh has declined rapidly since then, but there has been considerable development of tube well irrigation both in number of wells and area covered. There were about 22,000 deep tube wells, 160,000 shallow tube wells, and 200,000 hand tube wells in operation in 198687, far more than Mohammed calculated. These wells, and such other groundwater technologies as treadle pumps and dug wells, probably cover about two−thirds of the irrigated area—some 2.1 million hectares (Mha) in 198586.

These irrigation technologies are used mainly to grow high yielding varieties of boro rice and wheat in the dry winter months, although the growing season of boro rice under tube well irrigation has almost replaced that of broadcast aus or broadcast aus−aman in many areas of the country in recent years.

The spread of irrigation in number of tube wells and area irrigated has been less than expected in the Third Five−Year Plan. The implication is that the government's avowed objectives of attaining foodgrain self−sufficiency and eliminating poverty are unlikely to be achieved within the stipulated period.

Many supply−side problems have contributed to the poor performance of irrigation, including:

Deficient technical support services.

Poor management of equipment by farmers.

Restrictive agrarian structure.

Unequal access to government institutions for credit and inputs.

Large−scale privatization of irrigation equipment and withdrawal of subsidies.

But demand−side constraints on the profitability of irrigation, poor performance of mainstream irrigation management institutions, and imperfect competition in the water market have also affected performance. This chapter discusses access and competition in the groundwater market and the performance of tube well irrigation.

Access to groundwater irrigation

Small farmers

Who has access to irrigation technologies and on what scale? What are the benefits? Early evaluations showed that deep tube wells, which were heavily subsidized, were controlled mostly by rich, landed farmers who gained considerable income

from the sale of water as well as from their own cultivation.

The farmers using irrigation also profited from high yielding varieties of rice, although small farmers gained relatively less than rich farmers, because of unequal access to land (Hamid and others 1978; BIDS 1980).[1] Large farmers also gained income by not repaying rental charges or bank loans for tube wells.

Recent evidence on relative access of different size farms to mechanized irrigation needs careful consideration. Parthasarathy (1988) looked at percentage changes in number of holdings reporting irrigation and in irrigated area to cultivated area between 1977 and 198384, as given in the Agricultural Census Report of 1986. He concluded that large farmers had greater access than small farmers and that "the small farmers appear to be losing their differential advantage with progress in tube well irrigation" (Parthasarathy 1988, p. 19). But rearrangement of the Census Report statistics (BBS 1986, p. 49) shows that the number of small, medium, and large farmers using irrigation increased by 200, 67, and 49 percent respectively from 1977 to 198384 (table 3.1).

The irrigated area increased by 148 percent for small farms, 72 percent for medium farms, and 51 percent for large farms. From 1977 to 1984, the number of small farms increased by 127 percent, while the number of large farms decreased by 16 percent. The operated area for small farms increased by 60 percent, but for large farms it decreased by 17 percent. This might imply that small farmers, an ever expanding group, are gaining access as irrigation is expanded.

A 1987 countrywide inventory of shallow tube wells by the Agricultural Sector Team sponsored by the Canadian International Development Agency (CIDA) mentions that the average size of the shallow tube well owner's or operator's landholding has been falling steadily in recent years, indicating that the proportion of larger landowners among shallow tube well owners is slowly declining as small farmers gain access to institutional loans and enter the product market for irrigated crops (Bangladesh and CIDA 1987, chap. 14).

This is corroborated by Mandal (1988) in a study of an intensely competitive area of the Tangail district, which shows that most shallow tube well owners had an average area of about one hectare (ha), the national average farm size. Five of twenty−nine shallow tube well owners owned less than 1 ha and three owned only 0.150.2 ha. Furthermore, five of twenty−nine shallow tube well owners did not own or cultivate any land under their tube wells and took up water selling. Many of these tube wells were bought by more than one owner, who shared not only capital and operation and maintenance costs, risks, and profits, but also management responsibilities.

Shallow tube wells are small, easily moved from one site to another, and usually can be repaired by local mechanics, sometimes with cheap materials. So shallow tube wells tend to be owned and operated by small and medium farmers.

These owners are not necessarily "landlordscum−waterlords" and may not operate their tube wells as monopolists, but they are entrepreneurs who appear to have earned "normal profits" considering the high costs and risk of operating tube wells.

Table 3.1 Distribution of farms, operated area, and Irrigated area, by farm size group, between 1977 and 198384 census periods, Bangladesh

Distribution of farms and farms reporting irrigation:

	Share of total farms (percent)		*Farms reporting irrigation use (percent)*	
Farm size	*1977*	*198384*	*1977*	*198384*
Small	49.7	70.3	48.1	62.9
Medium	40.9	24.7	41.8	30.5

Large	9.4	5.0	10.1	6.6
Total	100.0	100.0	100.0	100.0

Distribution of operated area and irrigated area:

	Share of total farms (percent)		*Farms reporting irrigation use (percent)*	
Farm size	*1977*	*198384*	*1977*	*198384*
Small	18.7	29.0	24.7	33.2
Medium	48.9	45.1	46.6	43.0
Large	32.4	25.9	28.7	23.8
Total	100.0	100.0	100.0	100.0

Change in number of farms, operated area, and irrigated area between 1977 and 198384: *(percent)*

Farm size	*Change in number of total farms*	*Change in operated area*	*Change in number of farms*	*Change in irrigated*
Small	127	60	200	148
Medium	−3	−5	67	72
Large	−16	−17	49	51
Total	60	3	131	84

(−) signs Indicate negative changes.

Small farm = cultivating 0.02−1.00 ha.

Medium farm = cultivating 1.01−3.03 ha.

Large farm = cultivating 3.04 ha and above.

Source: Calculated from Bangladesh Bureau of Statistics (1986), Tables 5 and 16.

The Mandal study shows that tube well owners' land irrigated by their own tube wells constituted as little as 17 percent of deep tube well command areas and 29 percent of shallow tube well command areas. Considering the land fragmentation, this may mean that the owner or managers, as well as the cultivators, have their plots irrigated in several command areas. This runs counter to the argument that tube well owners have the most land to irrigate in their command areas and hence give preference to their own land and deny other farmers irrigation water.

The status of sharecroppers with irrigated boro rice seems to have worsened in several ways:

Sharecroppers were given land to cultivate irrigated high yielding variety boro rice, with high costs for inputs and labor, but they were evicted seasonally by landowners and denied the cultivation of low−cost, rainfed, secure aman crops (Chisholm 1984).

In shallow tube well irrigated areas, tenancies for lower−risk, higher−yield boro cultivation on relatively high and medium land went to wealthier households, while the lowest land for higher−risk, lower−yield aman crops went to the poorer households (Glaser 1988).

Sharecroppers were affected by "reverse−tenancy," in which land previously sharecropped by poor farmers was contracted by shallow tube well owners on fixed in−kind renting (Quasem 1987).

Sharecroppers' returns from irrigated boro cultivation have declined over the years, and with declining yields and rising costs of production, sharecroppers are left with small or negative returns after costs (Mandal 1987, 1988; Quasem 1987).

Landless groups

In the early 1980s organizational and financial support was provided to landless groups to procure and operate tube wells and low lift pumps and to sell water to landowning farmers on a one−third to one−fourth crop−share basis. The Bangladesh nongovernmental organization PROSHIKA pioneered the program, but later the Bangladesh Rural Advancement Committee (BRAC), the Grameen Bank, and the Bangladesh Rural Development Board (BRDB) sponsored landless irrigation programs. And CARE launched a collaborative program with PROSHIKA, BRAC, and the Grameen Bank under the name "Landless Owned Tube Well Users Support."

Early evaluations suggested greater financial success for PROSHIKA landless irrigation groups in the initial years than for private water sellers (Wood 1984). But in subsequent years, tube wells owned by landless groups had no significant comparative advantages over private tube wells with respect to yield, employment, or small farmers' access to irrigation (Wood 1988). Nonetheless, considering the unequal access of the poor to irrigation equipment credit, support services, and political power, landless pump groups performed at least as well as private water sellers, and significantly better than the state−supported cooperative (KSS) groups.

There are gaps, however, in landless pump group development. First, many participants drop out of landless irrigation schemes because of mechanical problems, financial losses, and conflicts among group members. Second, at least in the case of the Grameen Bank, there was a gradual concentration of tube well ownership, which meant that a few took advantage of "joint−liability loans" to buy tube wells and then diverted this productive resource from collective benefits to private interests. Third, landless groups need continued institutional support to build and strengthen their management capabilities. When such support is reduced or withdrawn, the groups cannot cope with social, technical, and natural problems. With this in mind the Grameen Bank has taken on an ambitious program to buy new and derelict deep tube wells and to sell water against a one−fourth share of the crop. But it is suspected that the landless will benefit only indirectly through wage employment and dividends on their share of capital (Mandal 1989).

Handpump irrigation and the poor

Development programs focused on poverty have recognized the importance of handpumps and the latest version of treadle pumps as appropriate technologies for irrigation (Hannah 1976; Howes 1985; Biggs and Griffith 1987). But questions about handpump irrigation arise:

Is handpump irrigation for high yielding variety boro rice profitable?

If profitable, is it more profitable than using deep tube wells and shallow tube wells?

If more profitable than deep tube wells and shallow tube wells, at what scarcity price is the pumping labor valued?

Considering the drudgery of pumping labor, is the huge employment that is generated feasible, desirable, and productive?

Are handpump laborers free from exploitation by the rich?

With the withdrawal of subsidies, has there been expansion of handpump irrigation?

The empirical basis for verifying these issues is flimsy, and further studies are needed. Nonetheless, we will address the issues with what evidence is available.

First, a field survey of fifty−four handpumps conducted by Hussain (1982) in Sharishabari, Jamalpur, showed that the net return over the total cost of high yielding variety boro rice was negative, implying that family labor could not be paid for. Second, high yielding variety rice yields under handpumps were higher than under deep tube wells and shallow tube wells. Still, high yielding variety boro production with handpumps was reported profitable only when the opportunity cost of labor was considered zero (Jaim and Rahman 1978).

Third, although the opportunity cost of pumping labor is claimed to be very low, a calculation shows that the equilibrium between total cost and gross returns of high yielding variety boro production occurred when labor was valued at 55 percent scarcity prices (Hussain 1982). In recent years, with the dry season employment created by earth work, local transport, and petty trades, one might expect that labor for pumping should be valued at more than 55 percent scarcity prices in many areas of the country.

Fourth, manual pumping requires both family and hired labor, with hired labor constituting about 22 percent of the pumping labor force. It is not only shortage of family labor that leads to hiring pumping labor. The drudgery and stress of physical labor, especially in the hottest months of March and April, often causes sickness in pump operators. To save crops, even in a normal year, hand tube well owners must hire extra laborers. And the drudgery cost is higher to family labor than to hired labor, because hired help usually pump during the day, whereas the family (including children and women) has to work day and night (Mandal 1978).

Fifth, the level of exploitation with handpump irrigation is not necessarily low because 50 percent of handpump users cultivated either sharecropped land or a combination of sharecropped and owned land. Moreover, more than half of the shallow tube wells were rented at a charge equivalent to 16 percent of gross output. Furthermore, 66 percent of gross output produced by a handpump went to land and capital owners—50 percent for land plus 16 percent for the hand tube well—and sharecroppers were left with little for family labor.

Finally, handpump irrigation has not expanded but declined in recent years, despite the withdrawal of direct subsidies for shallow tube wells and deep tube wells. Field experience shows that hand tube well irrigation is appropriate for small patches of land that cannot conveniently receive water. Handpump irrigation technology is suitable for crops such as vegetables, which require irrigation, or for irrigation through furrows and strips, which requires a reliable, independent water supply.

In any case, handpump irrigation is likely to be limited to areas characterized by:

A good aquifer with a very high water table.

Good quality soils.

Nonavailability of wage employment.

High foodgrain prices, requiring rice production for survival.

Nonexistence of mechanized irrigation facilities.

Competition in the groundwater market

Large−scale privatization of irrigation equipment has created a market for groundwater irrigation that involves social, economic, and political competition for access to tube wells, tube well sites, and command area plots. In areas with a high water table, where intensive tube well development programs have been pursued, the market for water has become somewhat competitive, although the playing field is scarcely even for heavily subsidized deep tube wells and almost unsubsidized shallow tube wells.

In the upland areas, this competition does not exist because only deep tube wells are technically feasible, except in some low−lying pockets where deep set shallow tube wells may offer some competition. In such a natural monopoly environment, other forms of competition can be promoted, including competitive bidding for deep tube well management by different institutions; currently only BRDB cooperatives can manage deep tube wells (Palmer−Jones and Mandal 1988). The Grameen Bank is already competing to manage derelict deep tube wells in these areas.

The main features of the groundwater market are discussed below. The market for groundwater

technologies is imperfect because of discrimination between technologies on acquisition prices and subsidies.

Deep tube wells, which mostly go to large farmers, have been heavily subsidized, and they are sold with subsidized bank credit. There have been little or no direct subsidies for shallow tube wells and hand tube wells, most of which are bought by small and medium farmers, and the proportion of cash purchases for shallow tube wells is higher than it is for deep tube wells.

There are many hidden subsidies for all types of technologies from loan defaults, but this reflects credit market failure, bureaucratic inefficiency, and politics. There is also discrimination between groups of farmers, in that landless groups do not have access to mainstream lending institutions to purchase irrigation equipment.

After a rapid increase in tube well irrigation in the early 1980s, a slowdown in tube well sales, especially shallow tube wells, has occurred in recent years. Supply−side reasons for the downturn include the restriction on shallow tube well imports and sales, bank caution in the face of credit sanctions, panic about drawdown externalities, and unnecessary spacing regulations (Palmer−Jones 1988). Demand−side problems are the credit squeeze, the declining profitability of irrigated boro rice cultivation, and large−farmer bias in tube well sanction.

Concurrently with the slower sales of deep tube wells and shallow tube wells by government agencies, a market for secondhand shallow tube wells has developed. The small and medium farmers buy this equipment, along with low−cost innovations, for cash. In response to inadequate technical support services from mainstream irrigation−related agencies, indigenous private workshops and private mechanics have sprung up.

The emerging water market has created growing demand for electrical connections and electricity supplies—and tube well owners often pay more than the official price. This is one reason that the costs to owners/managers and cultivators of electrified tube wells are not lower than for diesel tube wells.

Interregional discrimination in the supply of electricity has meant that poor farmers in areas with electricity supplies have gained more from groundwater irrigation than those in areas with no electricity installations. For example, the districts of Tangail and Bogra, which have high water tables and low energy requirements for pumping, have received electricity. But tube wells in the districts of Faridpur, Jessore, Rangpur, and Dinajpur, where irrigation has expanded very slowly, have not received electricity connections.

With increasing awareness of the need to improve irrigation efficiency for boro rice production, "screening of plots" by the suppliers and users of irrigation water is under way in intensively developed areas. Screening is influenced by the social, economic, and political relationships between water suppliers and water users and by the agronomic and soil characteristics of the irrigable plots.

For example, water suppliers try to reduce conveyance and seepage losses by avoiding plots that are distant or have poor soils and topography. Water users also choose among water suppliers, depending on the distance of plots to water sources, contract terms and payment requirements, and other social and economic reasons.

Such market signals lead to the continual adjustment of command areas. One implication of such adjustments and negotiations is that inefficient tube well command areas are being squeezed by the more efficient ones and, in many competitive areas, less efficient and derelict deep tube wells are losing plots to newly installed shallow tube wells that disregard government spacing regulations.

The problem of drawdown externality has arisen in some districts. In years of insufficient rainfall, the problem becomes so acute that shallow tube wells and hand tube wells give low discharge and often run dry, although for only a short time (Gill 1983).

In areas such as Manda in Rajshahi, installation of deep tube wells in recent years has worsened the drawdown, hitting the shallow tube wells first. Shallow tube well owners were the ones to suffer economic losses because of increased pumping costs, the cost of digging pits, rapid depreciation of machinery, reduced discharges, and low command areas. In 1988 shallow tube well owners in Manda and Khanpur (Bogra) responded to the drawdown by deep−setting their tube wells a few feet.

Finally, competition in many areas has pushed down prices for water from one−third crop share a few years ago, to one−fourth or even one−fifth crop share in recent years (BAU 1986). The threat of encroachment or forces of competition caused water suppliers to revert to a cash payment system from a share payment system or to resist a shift from the cash payment system to the share payment system.

The competition has encouraged water suppliers to ensure adequate water supplies to command area plots. In recent years, tube well owners in such competitive areas as Tangail have given bonuses of supplementary irrigations for transplanted aman as an incentive for cultivators to continue to use irrigation water from these tube wells for boro production.

Performance of tube well irrigation

Private versus rented tube wells

In this section, tube well performance is discussed for command area per installation and output per command area. A comparison of private and rented deep tube wells in different areas shows no significant differences in command area (table 3.2). This means that the objective of improving capacity utilization of tube wells through privatization has not been achieved.

There are no a priori reasons for differences in performance because deep tube wells, private or public, have to operate under similar physical, technical, and farm structural constraints. Managers of private and public deep tube wells face similar negotiation and transaction costs in bringing widely scattered or fragmented plots into their command areas. (Discussion of other potential benefits of privatization of deep tube wells, such as improvement of owner/manager performance or savings on recurring administrative costs of irrigation agencies, is beyond the scope of this chapter.)

Irrigation performance by management and payment systems

Differences in the management approaches and support services of management institutions did not contribute to significant differences in command area, yield, or gross output of tube wells—except that KSS−managed deep tube wells and shal−

Table 3.2 High yielding variety boro rice command area of private and rented public deep tube wells and shallow tube wells in different areas of Bangladesh a

			Deep tube well command area		*Shallow tube well command area*
Source	*Year of Study*	*Location*	*Private*	*Rented*	
Quasem	198283	Basail, Damurhuda, Dhunot,	14.8b	19.7	5.3b
1985		Gabtoli, Gopalpur, Meherpur,	(27)	(37)	(15)
		Monohordi, and Sarail	18.7c	n.a.	4.3c
			(24)	n.a.	(40)
Quasem	1985−86	Bhanga, Bogra, Chandina,	n.a.	n.a.	3.9b
1987		and Nogarpur			(79)
Mandal	1983−84	Fulbaria	19.0d	19.1d	n.a.
1984			(32)	(25)	
			27.7e	30.9e	n.a.
Mandal	1987−88	Ghatail	n.a.	n.a.	4.1
1988					(29)
Shikder	1983−84	Fulbaria	25.8e	26.8e	n.a.
1986			(10)	(10)	
BAU	1984−85	Ghatail, Kalihati	19.5	19.4	4.6
1985			(9)	(9)	(37)
Mujibullah	1985−86	Gazipur	19.4d	20.3d	n.a.
1987			(9)	(6)	
			18.2e	21.0e	n.a.
		(3)	(6)		
Bashar	1986−87	Muktagacha, Phulpur, and Trishal	21.9	18.8	4.4
1987			(22)	(22)	(19)

n.a. Not applicable.

Note: Figures in parentheses are the number of tube wells.

a. For deep tube wells, Mandal (1984) showed significant differences in command areas between diesel−operated and electrically operated wells but no difference between private and rental wells. In other studies, statistical tests confirmed that there were no significant differences in command areas between private and rented deep tube wells.

b. Cooperatively owned.

c. Individual group owned.

d. Diesel−operated.

e. Electrically operated.

Source: Author's compilation from various studies (see table).

low tube wells did less well than others (Mandal 1987; Palmer−Jones and Mandal 1987).

The initial success of deep tube wells under specialized programs, such as the Irrigation Management Programme and CARE, could not be sustained because of high dropout when supports were withdrawn (Biswas 1988). The deep tube wells and shallow tube wells operated by the Grameen Bank landless groups performed on a par with tube wells under other institutions, and the bank's shallow tube wells significantly outperformed KSS−managed shallow tube wells, despite restricted access of the landless groups to institutional credit.

The payment system for water profoundly affects the performance of irrigation equipment. In the Tangail district, for example, all deep tube wells operated under the one−fourth crop share system had lower command area, yield, and gross output than deep tube wells operated under a fixed payment system. One explanation is that the inefficiency of sharecropping with land and water does not offer adequate incentive to water suppliers or water users. In areas where there is a high risk of crop failure and where most farmers have cash−flow constraints during planting time, inefficiency is attributed to the risky environment and imperfect institutions for credit and support services.

Profitability of irrigated boro rice

The expansion of groundwater irrigation has been limited by the declining profitability of irrigated boro rice production in recent years. This reduced profitability has resulted from a decline in yields for high yielding variety boro in intensively cultivated areas, an increase in production costs, and a modest increase in harvest prices of rice.

For deep tubewells under one−fourth crop share for water, for example, yields declined 25 percent between 1985 and 1988, prices increased 13 percent, the cost of production, excluding water charges paid with a share of the crop, increased 31 percent, and net returns declined by about 50 percent (table 3.3).

This trend of declining profitability for high yielding variety boro rice cultivation is corroborated by nationwide cost−and−return surveys (Bangladesh 1987). Returns to sharecroppers are still lower, and even negative, meaning that they have been forced to sell family−supplied human and animal labor at less than the going market wage rates.

Returns to tube well owners have declined mainly because of shrinking command areas per tube well and an increase in owner/manager costs per hectare. A comparative analysis shows that deep tube wells, operated under one−fourth crop share for water, generated 64 percent lower net returns per hectare in 1988 than in 1985. For shallow tube wells, returns to management per hectare of tube well command area were 36 percent lower in 1988 than in 1985 (table 3.4).

Conclusion

The expanding group of small farmers are gaining access to groundwater irrigation technologies, although medium and large farmers have a larger share of operated area and irrigated area. Small farmers likely will gain additional access as irrigation expands to new areas.

But the expansion of irrigation has been hindered by a decline in the profitability of irrigated high yielding variety rice, which has caused low demand for irrigation.

Action should be taken to intensify crop production with improved agronomic practices and soil management. But this will require strengthening

Table 3.3 Changes in costs and returns per hectare of high yielding variety boro rice in Ghatail, Tangail, between 1985 and 1988

	Share payment, deep tube wells		*Share payment, shallow tube wells*		*Fixed payment, deep tube well*	
Variables	*Own land*	*Share−cropped*	*Own land*	*Share−cropped*	*Own land*	*Share−cropped*
Yield (kg/ha)						
1985	5,476	4,591	5,690	5,173	5,885	5,780
1988	4,126	3,572	4,678	4,951	4,324	−
Total cost (Tk/ha)						
1985	16,064	11,566	16,687	12,533	12,502	11,791
1988	17,905	14,747	18,706	15,979	14,343	−
Net increase (Tk/ha)						
1985	7,482	−1,694	7,780	−1,413	1,2801	−11
1988	1,864	−6,154	3,445	−4,042	6,485	−

− Not available.

Source: BAU, 1985; Farm survey, 1988, government of Bangladesh.

Table 3.4 Comparative indicators of tube well performance in Ghatail, Tangail, between 1985 and 1988

	Deep tube wells		*Shallow tube wells*	
Variables	*1985*	*1988*	*1985*	*1988*
Boro command area (ha)	19.44	14.33	4.63	4.11
Aman command area (ha)	−	4.98	−	1.36
Boro yield (kg/ha)	5,120	4,044	5,569	4,721
Owner/manager costs (Tk)	38,445	35,718	11,831	10,340
Owner/manager costs per hectare (Tk)	1,979	2,489	2,555	2,571
Return to "management"				
Per hectare (Tk)	3,244	1,157	3,108	1,985
Per scheme (Tk)	59,284	16,787	15,885	8,231

− Not available.

Note: Only the tube wells under the one−fourth crop−sharing system are considered here. 1988 calculations are based on field experience and it is assumed that 5 percent of water charges could not be collected. Costs of harvesting and threshing, at one−fourth share of the rice from fields, were deducted from the gross value of collected rice.

Source: Farm survey, 1988, government of Bangladesh.

the domestic foodgrain procurement program to offer incentive prices, a measure that will require creation of sufficient storage facilities. In recent years, postharvest prices of irrigated rice have risen to offer some incentives; but action must be taken to ensure these prices, or at least the declared procurement prices, during the boro harvest when most small farmers have to sell.

One intervention would be expanding rural electrification on easy terms. In addition to reducing operation and maintenance costs of tube wells, and the cost of water to farmers, this might encourage diversified uses of electricity in developing rural industries—a development that could increase the uptake of Green Revolution technologies in less developed areas.

For choice of technology, returns from high yielding variety boro rice production with handpump irrigation are not high enough to encourage rapid expansion. The drudgery and high cost of pumping labor reduces job satisfaction and diminishes the appeal of hand tube wells, even to poor, small farmers.

The expansion of hand tube wells seems limited to areas with a high water table without any drawdown externalities. Hand tube wells may be suitable for irrigating hard−to−reach land between deep tube wells and shallow tube wells and for cultivating high value vegetables or crops that require reliable plant−to−plant irrigation.

The expansion of irrigation under the privatization program has spawned a competitive market for water in areas with a high water table. But competition has been imperfect because the market is inefficient and because the poor have unequal access to government institutions for irrigation equipment, credit, input supplies, electricity supplies and connections, and repair and maintenance services.

To promote efficiency and equity in the water market, institutional discrimination in granting access to credit and equipment markets and to management control of irrigation technologies should be eliminated. For example, the Bangladesh Rural Development Board KSS−managed deep tube wells did not show significant comparative advantage over other deep tube wells for productivity or equity, yet KSS is the only official means to acquire deep tube wells. To improve efficiency, other formal and informal institutions should be allowed to compete to manage deep tube wells.

Irrigation by landless pump groups appeared no less effective than irrigation under other management, suggesting that institutional incentives to landless groups to procure and operate tube wells may promote productivity and equity. The BRDB−Bityaheen Samoboy Samity, which has experience in landless irrigation, should pursue the program on a larger scale.

This chapter is based on limited, location−specific evidence. More detailed studies are needed on groundwater irrigation under diverse physical, social, and economic conditions. Candidates for immediate research are such issues as the effect of the groundwater market on employment, production, women and poverty, irrigation management for diversified cropping, the access of the poor to groundwater irrigation, and the economics of irrigated crop production under changing ecological conditions.

Notes

1. Small, medium, and large farms are defined as those cultivating 0.02−1 ha, 1.013.03 ha, and 3.04 ha and above, respectively.

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4—
Socialization of Minor Irrigation:
A Strategy for Growth with Equity

Qazi Faruque Ahmed

Proshika, a Bangladesh nongovernmental organization, began an action−research project in 1980 called the "Socialisation of Minor Irrigation." The main premise of the project was that, if groups of landless laborers or land−poor peasants were helped to acquire mechanized irrigation equipment, such as shallow tube wells, deep tube wells, and low lift pumps, they would be able to establish irrigation services for landowning farmers, rich and poor, and thus be in a position to share in the resulting increased productivity. It was assumed that such irrigation projects would be efficient, socially and economically, compared with irrigation projects controlled by large landowners and private entrepreneurs.

Research for the project was complemented by immediate implementation of the first projects in 1980. The research was to measure the economic and social performance of the projects and to analyze the potential of such intervention in agrarian reform. So far, some 300 projects are in operation, implemented by about as many groups of landless and marginal peasants, covering almost all regions of Bangladesh and providing irrigation services for more than 2,400 hectares (ha).

Mainstream agricultural development strategy relies on farmers, especially large landowners, for expansion of irrigation and, therefore, increased agricultural production. But studies show such reliance is not only misplaced, it has adversely affected both production and equity. An evaluation by the Swedish International Development Agency (SIDA) (Stroberg 1977) shows that most subsidized irrigation equipment is monopolized by well−to−do farmers. Another study by Rajshahi University (Hamid 1978) shows that deep tube wells controlled by rich farmers irrigate about 45 percent of their potential command area. And some village studies (Khan 1979a, 1979b; Siddiqui 1980; Hartman and Boyce n.d.) show that small peasants are almost always either excluded or charged exorbitant fees and are losing land at a fast pace.

The action−research project, by reversing the usual thought process that goes into policymaking, has benefited the rural poor, both socially and economically. And it has shown that, given the opportunity, the poor can be efficient managers of irrigation resources and can even be the key to overcoming stagnant agricultural production.

The project in context

Bangladesh has a large agrarian sector, with about 80 percent of its 100 million people living in teeming villages and eking out a living from agriculture and related activities. Although the average landholding is 1.01 ha per household, this statistic hides glaring inequalities in land ownership and resulting class stratifications. About 10 percent of households own 56 percent of cultivable land, while 51 percent of households are effectively landless.

Production in the agricultural sector is stagnating because of high input costs, low prices for ag−

ricultural commodities, skewed land ownership patterns, weak effective demand for food (because of the high incidence of landlessness), and periodic natural calamities. These factors have prevented intensive cultivation with an adequate outlay of capital, labor, and technology. With returns relatively low, landowners find it more profitable to engage in moneylending, mortgaging, hoarding, trading, and a host of other unproductive lines, rather than make optimal investments in production.

Although small farmers and sharecroppers have the strongest motivation to produce, they are crippled by high input costs and lack of access to institutional credit. The landless, with only their labor to sell in periods of stagnating productivity and weak absorption capacity of urban industrial sectors, find only seasonal employment and suffer long lean periods of unemployment or underemployment and negligible income.

Huge numbers of new laborers enter the market each year, further depressing the wages and income of the rural poor. This further reduces the effective demand for food and thus completes the vicious circle: unequal access to resources results in low prices, and low prices act as a disincentive for optimal outlay of capital and technology. The net result is that growth in production falters. Thus, anyone interested in promoting growth should look not only to capital and technology for solutions, but also to equity in access to productive resources.

The government, however, has remained myopic and, in the Second Five−Year Plan and Medium−Term Food Production Plan, has diagnosed agricultural production problems as the result of:

Scarcity of cultivable land

Limited yield potential

Climatic hazards

Underdeveloped dry−season irrigation

Weakness in agriculture support services

Inadequate input supply.

The government's strategy for liberating the rural economy from bureaucratic management and control is to encourage open−market systems of food and input distribution. The assumption is that a combination of support prices and open−market dealing of agricultural inputs would encourage landholders to raise the productivity of their lands, thus increasing their marketable surplus and ability to pay full market price for inputs.

As mentioned earlier, rich landowners traditionally have opted for higher rates of return on investment capital in nonproductive economic activities. However, if the incentive assumption behind the Second Five−Year Plan is valid, we would expect sharecroppers to be disposed of at a faster rate and small owners/cultivators to become more dependent on credit, usurious or institutional, to compete successfully for inputs. When small peasant farmers fail to obtain cheap sources of credit at the right time, the productivity of their land stagnates or declines. And in consequence, the rural landless population increases. These outcomes are a threat to production and equity as landlessness and indebtedness increase, unemployment or underemployment rises, and effective demand for agricultural products further declines.

Thus PROSHIKA, concerned with these risks to the rural poor and interested in demonstrating that equity issues can be integrated with a supply−side growth strategy, embarked on this action−research project.

The action−research project in operation

Work began in 1980 in two areas where PROSHIKA had years of experience mobilizing and organizing the rural poor. Sixteen groups of landless farmers acquired sixteen shallow tube wells and ten groups acquired ten low lift pumps with bank loans provided by the Bangladesh Krishi Bank, guaranteed by PROSHIKA.

In 1987, 163 groups were operating 108 shallow tube wells, 35 low lift pumps, and 20 deep tube wells in seventeen areas. A shallow tube well can irrigate about 5.3 ha, and a low lift pump and deep tube well about 20.2 ha each. In 1988, nearly seventy irrigation projects were added, bringing the area under the project to about 2,430 ha.

Several steps are required to establish the group irrigation service. Group selection is of critical importance. Groups associated with PROSHIKA are selected by mutual consent of the groups and PROSHIKA's field animators. Selection is based on a group's previous experience generating income and on evidence of its solidarity under pressure (from other classes in the area or from such climatic difficulties as flood or drought). Once a group has been selected to participate in the program, group members negotiate with the landowners and sharecropping farmers who cultivate land in a potential command area, and, if agreement is reached, a formal contract is drawn up.

Agreements specify the duration of the scheme (usually five years), siting of equipment, rates for water delivery, form and rates of payment (usually 25 to 30 percent crop share), and division of responsibility between farmers and the group for building and maintaining the main channels or drains and the feeder channels to the plots.

Next, the group must arrange credit to meet capital equipment and operating costs. In the first years, the Bangladesh Krishi Bank provided credit on condition that PROSHIKA acted as guarantor. As years went by, groups had problems obtaining loans on time, thus risking the entire project. Since 1985, PROSHIKA has provided the required loans.

After securing credit, the group arranges to buy equipment from either the Bangladesh Agricultural Development Corporation or open−market dealers. Diesel and engine oils are obtained from local markets, and most spare parts can be obtained from nearby towns. The equipment is installed at the agreed site with the help of local technicians, and the group constructs the main channels with voluntary labor. Each command area is divided almost equally with three main channels, and water delivery is systematic with the last plot getting water first.

Research starts immediately after installation and is carried out by groups and PROSHIKA's field animators and program coordinators. Dr. Geof Wood, University of Bath, Dr. S. Mandal of Bangladesh Agriculture University, and Dr. Richard Palmer−Jones, University of Oxford, participate in the research at different levels.

Dr. Wood designed the research methodology in consultation with landless groups and PROSHIKA staff. Dr. Palmer−Jones developed a computer program to systematize and analyze the data, especially to measure economic and employment performance. Assisted by PROSHIKA's field animators, groups kept accounts of income and expenditure, a pumping log book, and information on command area size and characteristics. Field animators periodically gathered data on groups' socioeconomic performance based on questionnaires developed by Dr. Wood. Dr. Mandal conducted research on small farmers' access and employment with the assistance of field researchers he employed.

The purpose of this research was to assist PROSHIKA internally in improving its strategy for increasing the opportunities for the landless to control productive assets in Bangladesh. And, to contribute to wider policy debate on strategies for the rural poor, the research explored the principle of agrarian reform and social action—whose relevance extends beyond Bangladesh.

Research results

Economic and technical variables determining performance

One objective of the research was to find out which factors were key to successful performance of irrigation groups, so that the strategy and management of this program can be further improved.

Data analysis has shown that the economic viability of an irrigation project depends on command area, fuel use, irrigation intensity, and yield. Command areas depend partly on ecological circumstances and partly on economic circumstances—for example, the price of rice and rough rice, in the context of bargaining between water selling groups and client farmers. On average, command areas for landless groups were considerably better than for cooperatively or privately owned irrigation projects although, during the period 198284, command area size decreased because of high input costs relative to the price of rice. Command area size rose again after 1985 when fertilizer and fuel prices remained stable.

By improving the irrigation groups' technical skills and managerial abilities through training, it was possible to keep operating costs down. On average, 70 percent of the groups were successful. Causes for failure varied and could not be applied across the board. Small command areas, sandy soil, early floods, and poor management were some of the reasons for failure.

Financial performance

PROSHIKA has closely monitored groups' financial and economic performance. Landless groups have repaid 77 percent of Bangladesh Krishi Bank's loans and 74 percent of PROSHIKA loans. (Outstanding loans are overdue.) Of the Tk 20 million disbursed to the groups, 23 percent was overdue by 1988. Landless groups have outperformed their competitors in the financial arena.

Employment

Project research sought a better understanding of the opportunities for employment—and thus survival strategies—for landless workers and marginal peasants. How were they affected by the irrigation services program? Did employment generation vary significantly according to the social organization used to provide water services?

Assumptions tested by this research were, first, that employment opportunities are indirectly enhanced by the group schemes because landless groups have larger command areas and, second, that water contract systems encourage farmers to deploy full cultivation practices because they ensure that small farmers receive more equal and timely water service.

Research was in two parts. Dr. Mandal conducted one study with farmers of three landless−managed schemes and three privately managed schemes as respondents in three areas in Bangladesh. In the other study by PROSHIKA Research and Development, Dr. Palmer−Jones analyzed data collected by group member respondents in irrigated and nonirrigated areas.

In Dr. Mandal's study, no difference in employment per 0.4 ha was found in one area under privately owned and landless schemes; but in the other two areas, employment per 0.4 ha under landless schemes was about 18 percent higher than employment under privately owned schemes. The landless schemes also performed better in aggregate employment enhancement because the landless schemes had larger command areas.

In Dr. Palmer−Jones' study using group members as respondents, group members were selected and interviewed weekly to gather data on their employment during the previous week. Interviews continued for a year and group members from two areas were selected from three categories: own irrigated area, irrigated area, and nonirrigated area.

Analysis of interview results revealed that agricultural laborers had higher average wages and more employment days in irrigated areas than in nonirrigated areas. And agricultural wages were higher in own than in other irrigated areas. In Saturia, wages were Tk 28 in own irrigated areas, Tk 22 in irrigated areas, and Tk 21 in nonirrigated areas. In Gheor, wages were Tk 24, Tk 23, and Tk 21, respectively. Total income for landless group members from agricultural and nonagricultural work in irrigated areas was higher than in nonirrigated areas.

Because income from cultivation of owned small plots was not accounted for in the research design, research results could not be confirmed as group members in nonirrigated areas had more operational landholdings than members in irrigated areas, that is, in Saturia 0.31 ha against 0.11 ha, and in Gheor 0.42 ha against 0.15 ha.

Access of small farmers

Dr. Mandal's study of small−farmer access to irrigation drew its sample from the bottom 50 percent of farmers in two types of command areas: landless−controlled irrigation schemes and privately owned irrigation schemes. The study looked at farmers in three localities and found that:

Small farmers and sharecroppers had greater control over water distribution in landless schemes than in private schemes.

Water distribution on small farmer plots in landless schemes appeared more efficient than distribution in private schemes as measured in above−average water supplies, increased hours of pumping per unit of land, and more timely application of water.

In irrigation schemes with improved water supply, a significant number of sharecroppers were evicted by landowners who then either cultivated the land themselves or rented it to others.

Relations with other classes

This portion of the research focused on whether ownership of a productive resource reduced vulnerability (thereby reducing dependence on other classes), improved social status, and facilitated access to other institutions.

Because this study dealt with qualitative rather than quantitative information, case study methods were used. The case studies showed, first, that group members' social status improved as they were able to own and manage efficiently a productive asset; second, that group members' ability to negotiate with institutions outside the village was enhanced; and, third, that group members were able in some cases to establish rights on government land and waters and to secure justice from village courts.

The effect of ownership of irrigation assets on group structure and operations could not be confirmed as the groups chosen for this research had shown cohesion and solidarity before owning the irrigation assets.

Conclusion

The strategy of setting up irrigation services with the rural poor has been found to be socially and economically efficient. An equity objective is not necessarily antagonistic to an economic growth objective, and, on many occasions, the objectives complement each other. With the right kind of assistance, the rural poor can manage efficiently a technologically and socially difficult project.

Although this strategy will benefit from an appropriate government policy, the main responsibility for wider dissemination rests with those nongovernmental organizations whose task is organizing the rural poor.

Similar principles of organization and management will apply if this strategy is broadened to include other agricultural services, such as fertilizer dealerships, equipment repair and servicing, and so forth, and common property resources, such as open waters, barren forest land, and common land. In the absence of genuine land reform, this approach has the potential for agrarian reform, in which agricultural resources other than land can be redistributed, promoting growth with equity.

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PART 2— NEPAL

Both chapters in this part focus on groundwater issues in the southern part of Nepal, the Terai. It is here that groundwater irrigation potential exists and that past developments have taken place. The chapters differ sharply in their assessment of groundwater potential. Chapter 5 assesses it at little more than 350,000 ha, while chapter 6 estimates it at about 1 million ha. This large difference highlights how little solid information is available.

Chapter 5 starts by recording the unimpressive performance of irrigation in general and the short−falls in cost recovery in Nepal. It then examines the technical basis for groundwater irrigation, the technologies available for its development, and the technological improvements that can be introduced. This is followed by a presentation of the impact of irrigation on incomes, based on three major studies completed by different institutions, including the Agricultural Development Bank of Nepal (ADB/N). After a description of groundwater development programs in Nepal, the author discusses the changes in loan procedures introduced by the ADB/N and the other initiatives the bank has taken to promote groundwater development, such as bulk purchase of equipment and help in procuring drilling services. Finally, the author reflects on the importance of forming farmers' groups and offering appropriate incentives if groundwater is to become more accessible to small farmers.

Chapter 6 emphasizes the importance of farmer participation in system management, both in terms of management requirements and opportunities. The chapter examines the interaction between land ownership, tenure and leasing systems, and the development of groundwater irrigation.

5— Use of Groundwater Resources to Alleviate Poverty in Nepal: Policy Issues

S.K. Upadhyay

The kingdom of Nepal, a landlocked nation between China and India, covers about 147,500 square kilometers (km2). Its varied geographic features make up five physiographic zones: Terai, Siwaliks, middle mountain, high mountain, and high Himalayas. Land elevation varies from less than 200 meters (m) in the Terai in the south to more than 8,000 m in the high Himalayas.

Nepal's per capita gross domestic product of US$180 in 1989 places it among the poorest countries in the world. With accelerating population growth and low, stagnating economic growth, poverty has been a continuing feature in the country. About 43 percent of the population has been estimated to be below officially defined, absolute poverty lines. The literacy rate has reached only about 30 percent.

Nepal's underdevelopment can be explained partly by its landlocked location and rugged terrain and partly by historical factors. When Nepal emerged from self−imposed isolation in 1950, modern transport and communication facilities were virtually absent. There were fewer than 200 hospital beds, and the literacy rate was less than 4 percent. Above all, it lacked an institutional framework to carry out development.

Performance of crop agriculture

The economy of Nepal is based almost totally on agriculture. More than 90 percent of the population derives its livelihood from land, and most industries draw raw materials from agriculture.

The performance of agriculture relative to population growth has remained dismal. Between 197475 and 198586, grain production increased by only 1.5 percent annually, while population growth exceeded 2.5 percent a year. Consequently, during this period, per capita food production fell from 92 percent of the requirement to between 80 and 85 percent.

Nepal's agriculture is largely rainfed and of a subsistence nature. Crop production contributes about 60 percent of total agricultural output, and foodgrains account for about 84 percent of gross cropped area with rice accounting for almost half of this. The resource base for crop production is severely limited by the rugged terrain as only about 20 percent of the land is cultivated. Most of the cultivated land (54 percent) is located in the humid, tropical lowland of the Terai.

Foodgrain yields are low: 2 tons per hectare (t/ha) for rice, 1.2 t/ha for wheat, and 1.4 t/ha for maize. More important, yields have been declining or, at best, stagnating.

The low rate of agricultural growth can be attributed to a number of factors, including inadequate transport infrastructure, absentee land ownership, small and fragmented holdings, poorly fed livestock with low genetic potential, and an inadequate and declining forest base. These factors are reinforced by a failure to develop yield−raising technologies, weak extension coverage, inadequate levels of modern inputs and services, increased cultivation of marginal lands (particularly in the hills), and, above all, unimpressive performance in the development of the irrigation sector.

Irrigation achievements and potential

Estimates of irrigation potential in Nepal vary significantly. Estimates suggest that public irrigation schemes cover about 140,000 ha or about 5 percent of cultivated land. But the area receiving reliable irrigation during the winter season is much smaller.

Private irrigation schemes account for about 400,000 ha and, because they have to depend on temporary structures, these schemes suffer from reduced reliability and a low utilization rate. About 100,000 ha are estimated to be irrigated with groundwater, and the rest with surface water.

Lack of irrigation facilities is not related to irrigation potential. Nepal has abundant water resources with annual river discharges averaging about 150 billion cubic meters (Bm3). Of total cultivable land, about 1.3 million hectares (Mha) are suitably located for command by gravity, and at least 0.4 Mha can be irrigated with groundwater resources.

Constraints on surface irrigation development

The large gap between potential and achievement in surface water irrigation is explained by a number of factors. In part it is a technical problem related to heavy sediment loads and resulting high maintenance costs. But it is primarily a financial and managerial problem.

The financial problem arises because reliable, perennial water supplies are provided by eight major or medium−size rivers, which require large investments in headworks relative to the small areas that can be commanded. The heavy investment required is constrained by the difficult budgetary position of the government. Donor agencies are hesitant to finance these projects because of the riparian issue, which perhaps is the most important constraint now facing the government.

The unimpressive performance in the irrigation sector can be attributed to management problems that arise from slow execution of projects, followed by irregular operation and maintenance. The resulting unreliable supply of water for irrigation hinders the collection of irrigation fees. Most of Nepal's public irrigation systems have failed to recover costs, which may remain a major concern for years to come.

Prospects for groundwater development and type of technology applied

The potential for groundwater development in the Terai and river valleys is considerable. It is estimated that about 72,000 shallow tube wells commanding 288,000 ha and 1,500 deep tube wells commanding 65,000 ha can be installed in the kingdom.

Except in the districts of Kapilvastu and Nawalparasi, Nepal Terai has a good shallow aquifer. In those two districts, drillers hired by the Agricultural Development Bank of Nepal (ADB/N) have encountered a thin aquifer to no aquifer at all. However, possibilities for deep tube wells cannot be ignored. In areas where aquifers are thin, multiple screens can be used, but they require highly skilled manpower and inflate the cost of drilling.

In the southern Terai, drilling is easier and done manually at present. In almost all the districts, an unconfined aquifer is available. groundwater characteristics vary from region to region though not remarkably. The average discharge of a shallow tube well is about 12 liters per second (lps).

In the northern belt, only manual percussion drilling methods (hammering) are used to exploit groundwater. This method, however, is limited by the experience and patience of drilling contractors. In some places almost a month is required to install a 15.2 m (about 50 foot) shallow tube well. This is because drillers frequently encounter boulders. This problem can be eliminated by the manual rotary system. The shallow tube wells installed in those areas have good discharges ranging from 18 to 30 lps.

In certain districts, the static water level is too deep for shallow tube wells, and thus the installation method differs from other areas. A pit is constructed depending on the static water level, and a sinking method is used from the static water level until the desired aquifer is reached. In cases where the static water level is 6.118.3 m (2060 feet) from the ground surface, a check valve is used for easy priming. Pump units with a fast and loose pulley are installed at the bottom and are driven by a diesel engine with a flat belt.

There has never been a report of poor quality groundwater in Nepal. Nonetheless, attention to

adequate drainage facilities should be maintained. Nepal is rich in recharge potential, and the annual groundwater withdrawal at current levels does not warrant artificial recharge. The most important and difficult task ahead is the spacing of tube wells to check any possibility of depleting the aquifer.

About 98 percent of shallow tube wells are powered by diesel engines; the remaining 2 percent run on electric motor−driven centrifugal pumpsets, where power is available in urban or suburban areas. Farmers generally tend to acquire high horsepower (hp) engines to drive pumpsets. For example, an average shallow tube well requires 3hp pumpsets, but farmers use 510 hp engines. The only valid justification is that these can also be used for threshing and other agricultural purposes.

In recent years the ADB/N has encouraged the use of manually driven devices for small farmers with a holding size of up to 0.5 ha. The first in the series is the rower pump, which is an improved version of the conventional reciprocating hand pump. It is simple, low−cost, long−lived, and able to discharge relatively more water than the conventional hand pump. The size and type of the casing and screen used is 406 millimeter (mm) polyvinyl chloride pipe. A Y−piece is fixed to the top of the casing. At one end of the Y−piece a surge chamber made of polyvinyl chloride or aluminum is attached, and at the other side of the Y−piece a polyvinyl chloride pump cylinder is connected. The limiting factor of the pump is that it can be used only to lift surface water using flexible suction pipe at the bottom end of the Y−piece.

The treadle pump, introduced only recently, is a foot−operated, reciprocating pump for extracting groundwater. It has twin cylinders made of mildsteel sheet metal or appropriate sizes of mild−steel pipes. The cylinders are joined together at the bottom by a junction box to which the suction pipe, made of bamboo or polyvinyl chloride, is connected. Foot valves are placed at the bottom of each cylinder. The upward and downward motions are actuated by the twin bamboo treadles. The bamboo treadles are connected by a rope that passes over a wooden pulley. The front end of the treadles will nest on the long pin and short pin at the rear.

During the upward motion, one valve of the cylinder opens while the other closes, and, on the downward motion, the open valve closes forcing water up through the cylinders. The flow of water is almost even because of the twin cylinders. Normally a treadle pump can discharge 1.25 lps. The treadle pump is most suitable where the static water level is up to 4 m from ground surface.

Use of groundwater resources

Historically, the use of groundwater in the Nepal Terai was confined to human and animal consumption or, to a limited extent, used for irrigating kitchen gardens. The principal devices were dug wells and hand tube wells.

When the ADB/N began an aggressive program for utilizing groundwater resources in 198081, primarily by promoting shallow tube wells and diesel pumping sets, farmers were initially hesitant to install them and only 240 shallow tube wells were installed. But substantial increases in the number of installations were noted in the second year, when 904 shallow tube wells were installed. By the third year, the shallow tube well program of the ADB/N started showing significant results.

In areas where farmers preferred dug wells, the ADB/N continued to provide financial assistance. Beginning in 198687 the ADB/N introduced the rower pump, which gained instant popularity in Nepal Terai and is expected to contribute substantially to using water resources in Nepal.

Since 198283 the annual installation through the ADB/N program by device is as follows:

	198283	*198384*	*198485*	*198586*
Shallow tube wells	2,575	1,944	2,319	2,334
Dug wells	134	248	339	392
Rower pumps	−	−	−	−
	198687	*198788*	*198889*	*198990*
Shallow tube wells	2,222	2,621	3,860	1,368
Dug wells	263	372	429	268
Rower pumps	254	1,865	2,271	989

− Not available.

The devices mentioned above required both the technical and financial assistance of the ADB/N. Technical assistance involved identification and training of entrepreneurs, offering drilling services, and maintaining quality control for shallow tube wells. The ADB/N also provided financial assistance to borrowers who received technical services from other government agencies.

The three government agencies involved are the Groundwater Resources Development Board (GWRDB), the Shallow Tube Well Division under the Sagarmatha Integrated Rural Development Project (SIRDP), and the Tube Well Irrigation and Agricultural Service Project (TIASP). The number of devices installed by 198788, with technical assistance from the various agencies, were:

	Shallow tube wells	*Dug wells*	*Rower pumps*
ADB/N	15,159	1,847	2,119
TIASP	2,295	−	−
SIRDP	2,318	−	−
GWRDB	359	−	−
Total	20,131	1,847	2,119

− Not available.

Of devices installed through the technical assistance of government agencies, all but a few have received financial assistance from the ADB/N. Because Nepal does not have a licensing system for groundwater tapping devices, it is hard to get information on privately installed devices. But because substantial subsidies are available for the devices—administered by the ADB/N exclusively through its credit program—it would be rare for farmers to install the devices privately.

Almost all the shallow tube wells and dug wells use 5hp diesel engines as lifting devices. The large number of installations thus accounts for the over−whelming importance of the 5 hp diesel pump (operating a 10.16−centimeter [4−inch] shallow tube well) in tapping groundwater resources, although a smaller device might be more appropriate for the size of holdings in Nepal. That 5 hp diesel pumps can be used for other purposes (for example, hulling, threshing) offers only a partial explanation. The unavailability of lower horsepower pumps among popular brands in India (a major source country), the decreasing economies of scale with lower horsepower pumps, the unavailability of electricity for farm purposes, and the prevalence of fragmented holdings make electric pumps unsuitable.

Impact of shallow tube wells on irrigation availability, input use, production, productivity, and income

Substantial increases in irrigated cropped area were reported by three major studies conducted in Nepal.[1] Whereas the Agricultural Projects Services Centre (APROSC) study reported an average increase of area under pump irrigation from zero to 2.6 ha, the GWRDB study showed an increase from 0.7 to 3.9 ha. And the ADB/N study showed an average increase from 0.9 to 3.2 ha. The improvement in cropping intensity reported by GWRDB was 127 to 143 percent, the APROSC study reported an increase from 139 to 152 percent, and the ADB/N study an increase from 137 to 156 percent. The ADB/N study reported the number of farmers cultivating wheat increased from 71 percent to 95 percent after the installation of a shallow tube well. The study also reported that the average area under improved varieties increased from 0.9 to 2.2 ha for rice, and from 0.5 to 1.5 ha for wheat.

Impressive increases in the use of fertilizer application accompanying the installation of a shallow tube well were also reported. The ADB/N study reported an increase in the nitrogen fertilizer application from 17 kg/ha to 32 kg/ha for rice, 35 kg/ha to 48 kg/ha for wheat, and 8 kg/ha to 15 kg/ha for maize. These increases have been confirmed by the GWRDB study.

Some increments in labor use in major cereal crops have also been found. Man−days per hectare, which were found to be 120 for rice, 69 for wheat, and 68 for maize, increased to 127, 79, and 74, respectively, on newly irrigated land.

As a combined effect of availability of water and application of more inputs, the productivity of major cereal grains was found to have increased impressively after the installation of a shallow tube well. In newly irrigated areas, rice yields per hectare were reported to have increased from 1.9 tons to 2.5 tons by the ADB/N study, and from 1.5 tons to 2.3 tons by the GWRDB study. Yields for wheat had increased from 1.7 tons per hectare (t/ha) to 2.1 t/ha as reported in the ADB/N study and from 1.0 t/ha to 1.7 t/ha in the GWRDB study. The ADB/N study also reported an increase in the yield of maize, from 1.4 t/ha to 1.7 t/ha.

With the increases in availability of water, cropping intensity, and input application, net income from crops per farm family was reported to increase from Nepal rupees (NRs) 13,900 to NRs 21,300. The highest increase in net income, 77 percent, was reported for rice, followed by other, minor crops (17 percent).

Impact of shallow tube wells on poverty alleviation: Empirical evidence

Size of landholding of individual households and its effect

The appropriateness of a technological option in a particular economic context is largely decided by whether the technology is scale−neutral. If a technology is scale−neutral, it can be adopted by smallholders to their benefit. If the technology is not scale−neutral, its benefit can be shared by small farmers through some sort of institutional mechanism for sharing the cost and benefit of the technology. Benefit can also be shared by small farmers, although only partially, if neighboring

medium and big farmers rent the facility to the small farmers.

Within this framework, it is pertinent to compare the holding size required for the economical operation of a shallow tube well and the nature of land distribution in the country, to find out the usefulness of shallow tube well technology for the alleviation of poverty.

The average size of cultivated land per household is very small in Nepal, that is, 0.85 ha in the hills and mountains, 1.47 ha in the Terai, and 1.12 ha overall (table 5.1). This is further complicated by the highly skewed distribution of land among farm families. In 1981, the bottom 51 percent of households, with average landholdings of 0.15 ha, shared less than 7 percent of the cultivated land, and the top 9 percent owned more than 47 percent of the cultivated land. Overall, the concentration ratio (Gini coefficient) of landholdings was estimated to be 0.7.

In the Terai, where the development of ground−water sources is technically feasible, the concentration of holdings is even more evident. In 1981, the bottom 46 percent of the population shared less than 3 percent of the land and on average owned only 0.09 ha. In the same year, the top 14 percent shared 59 percent of the land with an average holding size of more than 6 ha.

Another factor that determines the effectiveness of a shallow tube well is the number of parcels into which the holding is divided. Nepalese farms suffer in this respect also. The GWRDB study showed that, on average, 4.7 ha of land were divided into seven different parcels.

As stated earlier, the average shallow tube well with a diesel pump yields 1214 lps, which is adequate to irrigate 4.5 ha of any crop when fully and optimally utilized, and costs about NRs 19,000. Thus, it is difficult to expect that this technology will be able to cater to the needs of small farmers.

Empirical evidence also suggests that shallow tube wells have been installed mostly by medium and large farmers. The APROSC study reported that shallow tube well nonowners cultivated about 3.5 ha, whereas shallow tube well owners cultivated 6.6 ha. The GWRDB study derived the same result.

Shallow tube well owners had average landholdings of 6.9 ha. The top 38 percent had a landholding greater than 6.8 ha, the middle 51 percent owned 2.05 to 6.8 ha, and the bottom 10 percent had less than 2.05 ha. The bottom 10 percent and middle 51 percent had an average holding size of 1.3 and 3.7 ha, respectively.

The ADB/N study reported an average holding size of 3.8 ha among nonowners and 5.3 ha among owners. Landholdings of about 5 ha were reported in almost 39 percent of the cases, but landholdings of less than 2 ha were also reported in more than 20 percent of cases, that is, higher than in the GWRDB study. More than 41 percent of the holdings were reported to be from 2 to 5 ha.

Table 5.1 Farm size and distribution of cultivated landholdings in Nepal, 1981

Region/size of landholding (hectares)	*Number of households*	*Percentage of households*	*Total cultivated land (hectares)*	*Share of cultivated land (percent)*	*Average size of cultivated holding (hectares)*
Nepal					
Less than 0.5	1,107,902	50.5	161,987	6.6	0.15
0.51.0	355,420	16.2	264,522	10.8	0.74
1.03.0	535,964	24.4	868,201	35.3	1.62
More than 3.0	194,623	8.9	1,160,628	47.3	5.96
Total	2,193,909	100.0	2,455,338	100.0	1.12

Terai					
Less than 0.5	434,210	45.6	38,705	2.8	0.09
0.51.0	123,250	13.0	91,367	6.5	0.74
1.03.0	262,336	27.6	463,521	33.1	1.77
More than 3.0	131,312	13.8	807,833	57.6	6.15
Total	951,108	100.0	1,401,526	100.0	1.47
Hills and mountains					
Less than 0.5	673,692	54.2	123,282	11.7	0.18
0.51.0	232,170	18.7	173,155	16.4	0.75
1.03.0	273,628	22.0	404,680	38.4	1.48
More than 3.0	63,311	5.1	352,795	33.5	5.57
Total	1,242,801	100.0	1,053,912	100.0	0.85

Source: Central Bureau of Statistics, Sample Census of Agriculture, Katmandu, 1981.

Joint ownership of shallow tube wells

Neither statistics compiled by ADB/N nor figures collected through surveys showed wide−spread joint ownership. However, study results are contradictory. For example, in a subsample selected for detailed investigation, there were multiple but related owners in 67 percent of the cases with pumpsets and borings, usually a father and son or a group of brothers.

But the survey with a full sample and fewer details found joint ownership to be uncommon. The study attributed the result of the full sample to less detailed questions and concluded that even though "official" (in the sense of legal) joint ownership does not appear common, de facto joint ownership often occurs. The study also found that, with few exceptions, joint ownership is confined to people who are related.

Buying and selling water

Small farmers who are unable to install their own shallow tube wells can derive indirect benefits from wells through buying water from neighboring, better−off farmers. The APROSC study showed that the number of water sellers, both those selling water from their wells and those renting out pumpsets, had reached 39 percent.

In the GWRDB study, one−third of the subsample respondents reported selling water to others. Water was most often sold for NRs 20 to 25 per hour pumped. All those selling water also rented out pumpsets, usually for NRs 30 to 35 per hour, including the cost of engine oil, gear oil, and diesel fuel. A similar proportion of respondents were sharing water with others, usually neighbors with adjoining plots. In these cases, it was usual to buy diesel fuel without paying any other costs. Even then, poorer farmers were said to find the charges too high, and therefore would not buy water.

The parceling of land also seems to play a role in restricting water sales. Unless a water buyer had several adjacent plots, he could not take advantage of passing water from field to field, thus getting more for the money paid. In many areas with shallow tube wells, prospective water buyers were said to have their own borings and pumpsets already.

The study further reported that, in all cases of water selling or sharing, the owner of the well and the pumpset decided who received water and at what time. Usually, this was done on a first−come, first−served basis unless someone could make a case for special need. Usually there was no such competition for priority delivery. No situation was found where the demand for water, at the usual rates, was greater than the owner could supply.

The average farm size of the water buyers interviewed was 2.63 ha, of which about 0.25 ha was under irrigation before water buying began. This increased to 0.41 ha after water buying, resulting in a slight increase in planting of wheat and early rice, but no increase in monsoon rice.

Distributional equity

The effects of the shallow tube well program on distributional equity—for better or worse—may be indirect. For example, the program may encourage tractorization and reduce labor requirements, worsening the condition of agricultural laborers by lengthening the period of unemployment and reducing the generally elastic agricultural wages. The program's effects may be even more indirect, with affluent farmers purchasing land and other productive assets from poorer farmers, leading to increased marginalization and pauperization of small farmers.

Empirical studies conducted in Nepal did not show any adverse effect on distributional justice. As stated earlier, shallow tube wells led to increased cropping intensity and higher labor requirements. Similarly, the ADB/N study showed no change in landholding size among shallow tube well owners after the installation of shallow tube wells, a result also confirmed by the GWRDB study.

Improving access of the poor to groundwater: Recommended policies

Promotion of technologies suitable for small farmers

In Nepal the choice of appropriate technology for using groundwater is crucial, considering the size and fragmentation of landholdings. The use of 5 hp diesel pumps with shallow tube wells is rarely suitable, and alternative methods must be identified and disseminated.

Electric motors with small−bore shallow tube wells can be a good alternative, but the availability of electricity for farm purposes likely will remain low for years to come, considering the high investment required for its distribution. Nepal's

current hydropower sources, which are basically "peak−load" types, and the large number of land parcels per individual farmer also restrict the use of electricity.

Changing lending policies and procedures

The factor that has contributed most to the success of the ADB/N−managed shallow tube well program has been the change in lending procedures. Revisions in these procedures have aimed at reducing the transaction cost to borrowers. Such revisions include a simplified loan analysis procedure, reduced delays in the branches, a liberalized collateral policy and, above all, on−the−spot sanctioning of loans by the bank's field assistants.

The ADB/N has also trained and developed entrepreneurs who offer drilling services. The ADB/N field office accredits those entrepreneurs, and borrowers usually do not have to spend time looking for appropriate services. The ADB/N also procures and supplies pumping sets and pipes for shallow tube wells and rower pumps, which are not only cheaper (because of bulk purchases from international markets) but also of assured quality. Because these inputs are used at the village level, transaction costs to borrowers are less, especially for small farmers.

Demand for irrigation devices using groundwater begins in early November in Nepal and increases steadily until the end of June. But in some years, when the monsoon is delayed, demand surges unexpectedly in late June or early July. If such demand is met, significant progress can be made within a limited period. But meeting demand will require that financial institutions be geared up to handle lending requirements.

Encouraging joint ownership

Although groundwater tapping devices that are designed to cater to farmers with various farm sizes are increasingly available, an effective, scaleneutral technology is still a distant dream. This is especially true of power−driven devices for small farmers in Nepal. This situation would best be tackled by organizing neighboring farmers into groups. Such groups could not only share the costs and benefits of a larger scheme, but could also share information.

Certain conditions have to be met before an operational group can be formed. First, members' landholdings need to be contiguous, or at least close to each other. Second, because a "patron−client" relationship exists between big and small farmers, it would be desirable to have members with similar farm sizes. Third, because Nepal Terai has a highly stratified society with numerous caste and ethnic groups, homogeneity would be helpful in maintaining group cohesion.

Because of these requirements, joint ownership of irrigation devices was not found to be very popular in Nepal. But this does not mean that the joint ownership concept is alien and impossible to implement. What it means is that an added incentive is required to encourage joint ownership. This has been proved in the first seven months of the current fiscal year, when the number of jointly owned shallow tube wells increased impressively with a change in subsidization policy that increased the subsidy for jointly owned wells.2

It should be remembered, however, that the differential rate of subsidy, if administered indiscriminately, may eventually benefit big farmers rather than the intended small farmers. The ADB/N has tackled this problem by incorporating some provisions in its lending policy.

The Small Farmers Development Program (SFDP), which seeks to raise the income level of households that are below the absolute poverty line, identifies poor farmers through household surveys conducted in the initial stage of the project. The differential rate of subsidy is offered only to those identified as poor. In operations outside SFDP, the ADB/N requires at least five families to form a group before they can avail themselves of higher subsidy rates.

Subsidization policy

Shallow tube wells in Nepal Terai have been found to be attractive investment opportunities for farmers.3 But, because surface−water irrigation schemes heavily subsidize water, farmers perceive the government as the provider of water for irrigation. This is even truer among small farmers who rarely have enough surplus, or the potential to generate surplus, to think of investment opportunities. In this situation, subsidies from the government would act as a major incentive and would encourage farmers to act.

The effect of increased subsidies on the demand for shallow tube wells was clearly visible in Nepal in 198889. During the first seven months of fiscal year 198788, when the effective subsidy on a shallow tube well and a 5 hp diesel pumping set amounted to NRs 2,000 and covered only the labor cost for drilling, installations numbered 853. During the same period in 198889, when the subsidy on the same scheme amounted to NRs 9,000 and covered 40 percent of the total cost of shallow tube well and pumping sets, installations jumped to 1,560.

Whether an increase in subsidies for groundwater−based, farmer−run irrigation schemes is justified, either by economic efficiency or distributional equity, depends on many factors and requires in−depth study and analysis.

Considering the high initial costs of surface irrigation schemes, their low rate of use,4 and their high maintenance costs,5 surface irrigation schemes, which are mostly run by the government, are likely to show low economic efficiency. Additionally, because shallow tube wells are under their control, farmers with access to them feel more secure in adopting risky improved farming practices that could yield higher production.

The issue of distribution would be complex, but if there is a mechanism to identify subsidy recipients, as in the SFDP, and if loans are made accordingly, groundwater−based projects become easier to administer to achieve distributional equity.

Financing water purchase by small farmers

Hiring a shallow tube well and pumping set requires cash input by`small farmers. Because the agricultural economy until now has been predominantly of a subsistence nature, small farmers often do not have this cash. Realizing this, the ADB/N's credit policy explicitly arranges financing for hiring shallow tube well and pumping sets, while sanctioning the loan for production credit.

This approach to helping small farmers and thus alleviating rural poverty is not optimal because the small farmers may not get the required service when most needed. And it may perpetuate the unproductive patron−client relationship. But it should be taken as an option when other options are not available.

Conclusion

The low and stagnating level of agricultural productivity that has resulted in rural poverty in Nepal Terai is partly explained by the overwhelming dependence on the vagaries of the monsoons. This has not only led to deprivation among small and marginal farmers during drought years but has also discouraged improved farming practices that are closely related to the availability of irrigation water.

Because surface−water development is costly and time−consuming, development of groundwater resources appears to be an attractive policy option in Nepal Terai.

Assisted by the technical and financial support from the ADB/N and relying on private initiative encouraged by incentives provided by the government, the shallow tube well program has become highly successful. Empirical studies have shown the program is effective in achieving economic efficiency and improving production and productivity. But its role in alleviating rural poverty has been found to be rather limited.

Some policy changes have been made to achieve distributional equity. These policies must be complemented by administrative efforts to encourage joint ownership of irrigation devices among small farmers. Similarly, technological innovations that suit the needs of small farmers must be introduced along with the propagation of conventional technologies designed for medium and large farmers.

Notes

1. Three major empirical studies have been conducted in Nepal principally to measure the impact of groundwater resources on agricultural production, productivity, and employment. The first in the series, commissioned by the ADB/N, was conducted in 198283 by the Agricultural Projects Services Centre (APROSC). The second study was conducted in 1987 by Ground Water Development Consultants (International) Ltd. on behalf of the Ground Water Resource Development Board (Government of Nepal) and is referred to as the GWRDB study. This study took

248 samples, which represented all the development regions. It also took nineteen subsamples for detailed investigation. The third study was conducted by ADB/N. Samples for this study were selected on a stratified random basis, representing all districts in the Terai and all field offices of ADB/N. Altogether, 423 respondents, owning 554 shallow tube wells, were selected for final analysis.

2. The subsidization policy until the past fiscal year did not differentiate between individually or jointly owned shallow tube wells. But beginning in the current fiscal year, jointly owned schemes were provided subsidies amounting to 75 percent of total costs as against 40 percent for individually owned shallow tube wells.

3. The GWRDB study found that a shallow tube well scheme would break even at 0.7 to 1 ha of irrigated land

(depending on geographical area). It would generate a 25 percent return if the area irrigated exceeded 2.22.4 ha (as against its rated capacity of 45 ha).

4. The Master Plan for Irrigation Development in Nepal reported the effective use of existing projects of the Department of Irrigation to be 62 percent during summer and 29 percent during winter.

5. In one lift irrigation project (Chitawan), the annual maintenance cost was estimated to be as high as NRs 2,000 per ha.

6—
Improving Access of the Poor to Groundwater in Nepal: Sociopolitical and Managerial Issues

R.N. Deo

Nepal is a small, poor, landlocked, and predominantly agricultural country, in which the Himalayan mountains give way to rolling hills and eventually to the plains of the Terai. Of an estimated 2.5 million hectares (Mha) of agricultural land, about 5 percent lie in the mountains, 40 percent in the hills, and the remainder in the Terai. Following that continuum, landholdings increase in size from roughly 0.6 to 0.9 to 1.5 hectares (ha), with an overall average of 1.1 ha.

Nepal's population of 17.3 million is growing at 2.6 percent annually. More than 90 percent of the population is engaged in agriculture, which contributes 60 percent of gross domestic product and a similar percentage of exports. Agricultural production, however, has been unable to keep pace with the growing population.

Lack of irrigation and continued reliance on the monsoons are two major constraints to agricultural production. Although more than four−fifths of the cultivable land could be irrigated with ground and surface supplies, less than 25 percent (584,000 ha) actually receives some form of irrigation.

Scope for groundwater development

The potential for groundwater development of some 1 million ha, the focus of this chapter, lies in the Terai, an area roughly 700 kilometers (km) long and 2045 km wide. Ground elevations vary from 60 to 150 meters (m) above sea level.

Although Nepal has huge potential for surface irrigation, the high cost of investments and the long period necessary for construction of dams and irrigation systems preclude achieving this potential in the near future. By contrast, groundwater resources developed through tube well irrigation have low capital costs, short gestation periods, deliveries close to the field, and are available year−round on demand. With an effective mechanism for year−round operation and maintenance, tube well irrigation will play an important role in increasing agricultural production in the Terai.

Groundwater irrigation in Nepal is at an early stage of development and only a small fraction of its potential has been exploited. Aquifer conditions restrict development options to shallow tube wells in some cases and deep tube wells in others. However, much of the Terai could be developed by both shallow tube wells and deep tube wells. Conservative estimates foresee the development of 50,000 shallow and 1,000 deep tube wells.

Agencies involved in groundwater development

The Groundwater Resources Development Board (GWRDB), under the Department of Irrigation, is the primary government agency responsible for groundwater development in Nepal. The agency's Terai activities were consolidated in 1969 with the start of a United States Agency for International Development (USAID)−sponsored study of the hydrology of the western half of the Terai. The re−

search was performed in association with the United States Geological Survey (USGS). GWRDB's activities include construction of exploration and production wells, and the agency's work has been mainly concerned with the deep aquifers and the installation of deep tube wells to a depth of about 150 m.

Groundwater irrigation development in the Terai has progressed in the following stages:

Field exploration by the USGS and the government of Nepal in the west and far west region totaling about 185 bores between 1969 and 1974.

Project−oriented irrigation development at Bhairahwa Lumbini totaling ninety−eight large−capacity deep tube wells by March 1989 (International Development Agency [IDA]−assisted).

Exploration/production wells in Jhapa, Kailali, Kanchanpur, Kapilvastu, Mohottari, Morang, Rupandehi, Saptari, Siraha, and Sunsari districts; 220 were bored by 1987.

Shallow tube wells purchased with Agricultural Development Bank of Nepal (ADB/N) loans or with funds of the Sagar−Matha Integrated Rural Development Project (SIRDP); 2,314 shallow tube wells and 372 deep tube wells had been constructed with local funds in various districts by mid−1987.

Three other agencies are involved in Terai groundwater irrigation: the Narayani Zone Irrigation Project (NZIP), the Janakpur Agricultural Development Project (JADP), and the Farm Irrigation and Water Utilisation Division (FIWUD) under the Department of Irrigation. The NZIP has drilled thirty−one production deep tube wells and sixty−three community shallow tube wells. The ADB/N is involved in shallow tube well development in the Terai and disburses credit for farmers to purchase wells through the Agricultural Credit Project, assisted by the Asian Development Bank. By mid−1988,15,259 shallow tube wells had been installed under direct ADB/N credits, and an additional 4,613 through ADB/N in the JADP and SIRDP.

Tube well performance in providing equitable access to water

Shallow tube wells

At high utilization levels, shallow tube well development is vastly profitable. Private shallow tube well development, once shown to be profitable, is more rapid than public development. Pearse has described the major part played by private tube wells and pumpset owners in the Green Revolution in India and Pakistan (Carruthers and Stoner 1981). Private well owners maintain their equipment in good order and, at an individual−well level, the private operator is much more efficient. However, rapid installation of individual private wells with low technology can lead to excessive levels of investment per unit area, with small farmers being excluded from access to the resource. But increased well density in an area will stabilize the water market once shallow tube well owners start selling water.

Where groundwater resources for private development are scarce, they are likely to be monopolized by the few richer and more influential farmers or overexploited by the many. But where groundwater is plentiful, as in most parts of the Terai, policy can be shaped to maximize access to this resource and to spread the benefits of its use among poorer farmers.

Because landholdings in the Terai are generally small and fragmented into even smaller parcels, most small farmers can afford neither to construct a shallow tube well, nor to operate and maintain it, particularly when collateral in the form of land is needed for an institutional loan.

Private initiatives in tube well irrigation have produced a wide range of labor−intensive, low−technology, low−cost innovations. Bamboo tube wells and various types of hand pumps, including rower pumps provided by the ADB/N, are examples. This type of irrigation may gain popularity for some time, particularly among those with very little land. But the highly labor−intensive technology involved in pumping and the very low discharge would inevitably limit its use for irrigation on a wider scale.

Small shallow tube wells with centrifugal and suction pumps at the well head can also have low−cost, local−technology advantages in unconsolidated, shallow, sandy aquifer conditions and are most commonly employed by larger, private farmers.

The advantages of this type of installation are relatively low capital cost and mechanical simplicity. Small diesel engines or electric motors used in such tube wells do not present operation and maintenance problems to the farmer. Gravel or boulder aquifers would require power drilling for shallow tube wells and increase the cost. Small tube wells

with submerged pumps are technically possible where lift is beyond suction head, but economies of scale demand larger wells for irrigation.

Farmers value the independence provided by a private tube well. When they are certain that shallow tube wells are profitable and are given subsidized institutional loans, private farmer development of shallow tube wells is much more rapid than is public sector development.

Deep tube wells

Deep tube wells are publicly developed and managed. In Nepal, initial constraints on their development include:

Lack of farmer involvement in selecting the well site and in designing the distribution system.

Consequent low identification of farmers with the wells and their water distribution systems, and the attitude that the wells belong to the government, which should therefore operate and maintain them.

Long delays between drilling and commissioning.

Difficulties with managing command areas greater than 60 ha with open channels.

Inadequate distribution systems in many cases, with large losses in unlined channels and low−lying areas subject to waterlogging.

Unwillingness to pay for using pumps on deep tube wells.

Difficulties with project−appointed operators.

Irregular electricity supplies.

Lack of coordination and cooperation among users.

One publicly developed and managed deep tube well system, the Bhairahwa Lumbini Groundwater Project (BLGWP), reflects deep tube well performance under current operating conditions. The BLGWP is situated in Rupandehi, the southern district of the Lumbini Zone in the midwestern Terai region. To improve the status of the people through better agricultural production, the International Development Association and the government of Nepal jointly initiated the project in 1976. In addition to providing irrigation, the project integrates other support services related to agriculture under one umbrella. These support services include building a network of gravel roads for transportation services, setting up electrical transmission lines for operating the pumps and for rural electrification, and imparting advanced agricultural techniques and agricultural input uses through extension services.

The BLGWP extends irrigation services to 7,680 ha of cultivable land and has deep tube wells with 226 km of open canal systems, 96 km of gravel roads, and 96 km of electrical transmission lines in its Stage I area. Each deep tube well comprises 4.3 km of open canals that irrigate 120 ha on average.

Every user, large or small, has the right to irrigate by paying water charges, presently Rs 200/ ha/year. Fragmentation of land has no significant effect on distribution of water as project staff, together with water users groups, have developed a demand−based, rotational system dividing the area into just six parcels. Every farmer knows when he is supposed to receive water and plans cultivation accordingly. No disputes have arisen so far. Operation and maintenance of the system is the joint responsibility of users and project staff.

Tube well distribution systems need to be as efficient as possible to minimize water management problems and operating cost. To overcome the conveyance losses due to leakage from earthen canals, BLGWP, in its Stage II area, has constructed thirty−eight deep tube well units with buried polyvinyl chloride systems, which appear less expensive than brick−lined, open conveyance systems.

Large−capacity deep wells are cheaper per unit of water pumped, but they require higher initial investment and are necessarily designed and constructed by the government. Electric power, when available, is very convenient and financially attractive to farmers. The cost of an electrical connection for larger tube wells is usually a small part of the total cost of the system, whereas the cost of an electrical connection could be very high for the smaller shallow tube wells.

In electrified tube wells, the routine attention required by even a large capacity motor is relatively minor. The maintenance requirements of diesel−operated wells, however, are substantial. Thus, the choice of small or large tube wells and of electric or diesel power, depends on the amount of government support required for the maintenance of pumps.

Private tube well group approach

Group ownership of shallow tube wells is an option that would result in more effective use of shallow tube wells, increasing the utilization level and the irrigated area. Farmer groups might prefer

shallow tube wells to deep tube wells because they can be managed by smaller and, therefore, more cohesive groups, often with family or ethnic links.

Government support could be in the form of policies and strategies oriented toward promotion of such group−owned tube wells. For example, government support to farmer groups for construction of shallow tube wells could be through a loan with a higher subsidy and repayable on favorable terms. In addition, such promotional activities as publicity campaigns, fielding group organizers, and the like might be required. A project−oriented approach, aiming at clusters of group−owned shallow tube wells for intensive shallow tube well development, could eventually enjoy the advantages of institutional support services. However, government initiatives will be required to promote such an approach. The ADB/N could play a pioneer role by initiating the clusters approach on a pilot basis through some of the small farmer development projects in the Terai.

Another option that could make shallow tube wells more attractive to the small, private farmer would be the introduction of low−technology, labor−intensive hand pumps or taxi pumps provided by a contractor or a shallow tube well pump owner. Increased water−selling or joint ownership of pumps by groups of private farmers are other options.

Public tube well group approach

The Bhairahwa Lumbini Groundwater Project illustrates the group approach to water supply with deep tube wells—an approach that seems to be more effective for operation and maintenance of the system and for water distribution to users. All sixty−four water users groups are functioning in the Stage I project area of BLGWP and consist of 1,575 turnout (or "outlet") representatives. In the Stage II area, fifteen water users groups have been established recently.

A water users group's membership starts at the grass−roots level. Every farmer is served by a turnout and is a member of the group. According to the design of the water distribution system, each pump unit provides several turnouts, serving up to 5 ha each. At each turnout, one farmer is elected to represent the farmers served by that turnout. The turnout representatives of each pump unit area form a general assembly. The General Assembly elects one chairman and six members from the assembly members to form an executive committee. The chairman, the members of the General Assembly, and the Executive Committee generally serve for one year.

The water users group formulates rules for water distribution schedules and implements water distribution and canal protection activities. The group takes action against those who damage canals, say, by letting loose cattle trample over them, and formulates rules and regulations for collecting water taxes. Water users groups are also involved in minor maintenance of the system, quality control of work done by contractors, periodic cleaning of the distribution system, and field channel construction by farmers.

The Executive Committee has been very effective in operation and maintenance of the irrigation system. About 375 km of field channels have been constructed with farmer participation mobilized by the Executive Committee. Similarly, the routine water supply at different turnouts, governed by the Agricultural Division of the project, has been monitored by water users groups. Thus, there is equity in water distribution.

The formation of water users groups is in line with the principle of development administration. It encourages the participation of the users, seeks equal distribution of water, and leaves project management to local managers. However, attempts to turn over the full responsibility of operating pumps to the water users groups have not been successful.

Clearly, a unified approach is lacking in the development, operation, and management of deep tube well irrigation systems. In most systems water users groups have been organized, but their authority, responsibility, and effectiveness vary widely, depending on the approaches taken by the project. Greater effort is needed to develop existing water users groups into stronger, better−run organizations to ensure their effective participation in the management of deep tube well irrigation systems. Recruitment and fielding of group organizers has recently been initiated for this purpose.

There has not been much support for landless owners of pumpsets because ADB/N loan procedures require mortgages to ensure repayment, a guarantee not available from landless farmers. The ADB/N now provides loans to groups of farmers, with those owning property providing collateral for a mortgage so that small farmers, together with the landless, can own pumpsets.

Farmer participation

The main objective of an irrigation system is to increase agricultural production. This objective can only be achieved if the system is operated and maintained effectively, ensuring a timely and reliable supply of water. If the farmers in the system do not receive enough water or receive it only at random intervals—if they cannot count on receiving an adequate water supply when it is most needed—they will be unwilling to adopt more productive cultural practices.

Farmers must make managerial decisions on allocation of resources for production and are naturally cautious to protect their investment. However, with an adequate, timely, and reliable supply of water, farmers will quickly adopt improved practices leading to intensive irrigated agriculture. And, with the interest that comes from a sense of ownership, farmers will strive for effective operation and maintenance of the system.

Need for farmer participation

In most of the irrigation projects, institutional and social aspects have received inadequate attention and implementing agencies have usually followed a construction−oriented approach with the assumption that once a physical system is constructed to capture and transport water, the farmers will take over at the field level and construction of field channels and water management will follow automatically.

Experience has shown, however, that this does not happen so easily. In such systems, the local farmers, ignored during planning and construction, are not motivated to organize themselves for operation and maintenance of the systems. Attempts to organize farmers into water users groups after physical systems have been completed have generally resulted in hastily created, ineffective paper organizations.

Farmers view such systems as government−designed, government−constructed, and government−imposed, and, therefore, the government's responsibility. But the government, overburdened by the necessity of creating more physical systems for the expansion of irrigated areas, cannot effectively operate and maintain the systems.

Therefore, with the creation of a physical system, a feeling of ownership and shared commitment for managing and maintaining the system must be created by involving local farmers in planning and construction. Ensuring their effective participation will help develop more functional and more sustainable physical systems. And farmer participation in planning, design, and construction is key to developing effective water users groups willing to participate in the operation and maintenance of the irrigation system.

Policy and operational requirements of the participatory approach

Government policies have supported the mobilization of human resources through increased local participation in development activities. The participatory approach in irrigation development has recently gained much acceptance and is reflected in the government's new working policies on irrigation development for its basic needs fulfillment program. The new working policies have made the participation and consent of the beneficiaries compulsory for the selection, planning, design, construction, operation, and maintenance of irrigation projects. However, considerable effort will be needed at the departmental level for the implementation of this participatory approach.

Experience from the Philippines has shown that the participatory approach requires fundamental shifts in the policies, procedures, norms, attitudes, and expectations in the implementing agency. Implementation of the participatory approach will require simultaneous development of the physical system and the local capability to operate, maintain, and manage the system on a sustainable basis. This requires mechanisms for building the implementing agency's capacity to implement the participatory approach and to develop strong water users groups.

Opportunities for farmer participation

Various development options and technology choices are available for developing ground water irrigation in the Terai. Social, financial, and technical aspects of the options govern the degree of farmer participation in tube well irrigation systems.

Technological opportunities, such as economies of scale, exist in the choice of tube well irrigation systems. One option is low−capital, high operation−and−maintenance cost, shallow wells with smaller, more cohesive user groups, and therefore greater

farmer participation. The other option is a high−capital, low operation−and−maintenance cost, deep tube well system with larger pumps, larger users groups, and related organizational and management problems. Choosing which option to pursue is the dilemma faced by those involved in the development of tube well irrigation systems.

Constructing irrigation tube wells based on farmer requests, whether from individuals or groups, will result in motivated and willing farmers participating in the development and operation and maintenance of the system. For private shallow tube wells, this is usually the preferred route. But for deep tube wells, the situation is different.

Constructing deep tube wells based purely on farmer requests is a practice vulnerable to abuse, particularly by richer, more influential farmers. This could lead to isolated and widely distributed tube well sites, inevitably with diesel−operated pumps. A few tube wells might be electrified, by coincidence rather than design, because of their location near an electrical supply system. The cost of electrification of an individual or a few isolated tube wells could be very high. In some cases, inaccessibility of the tube well sites could result in severe operation and maintenance problems.

Building deep tube wells in clusters based on technical criteria will benefit from a minimized unit cost for electrification and for building service roads when necessary. This would also facilitate project backup services required for organizing and developing water users groups, water management training, maintenance of pumps and motors, and agricultural extension and support services for farmers.

Influence of landownership and leasing tenure arrangements on groundwater development

Present land tenure system

Reliable irrigation and proper water management, assuring increased production, may influence landownership and leasing/tenure arrangements. The ownership of agricultural land in Nepal is highly skewed, with 55 percent of the farmers owning less than 12 percent of the land. The average farm size for this 55 percent is 0.21 ha. The 6 percent of the farmers with the largest holdings own almost 44 percent of the land, with an average holding of 6.8 ha. The farmers with larger holdings are mostly absentee landlords who organize production on the basis of sharecropping arrangements, under which the sharecroppers have neither the motivation nor the resources to increase production.

In Nepal, several leasing/tenure arrangements exist, including:

Share of produce

Fixed quantity of produce

Fixed amount of money

Owned/rented holding.

Of these arrangements, fixed quantity of produce is the most popular in the Terai region.

Influencing leasing arrangements with irrigation development

Increased production due to irrigation may influence leasing arrangements. For the share of produce arrangement, because more inputs and labor are used with irrigation for increased production and because the additional product is shared with the landowner, the tenant farmer receives fewer net benefits. Thus, tenant farmers will try to rearrange the system.

In the fixed amount of produce or money arrangement, even with increased production the tenant farmer pays the same amount to the landowner. Thus, the landowner might try to increase the amount to be paid.

In the case of owned or rented holdings, with increased production the landowner might try to free his land from the tenant. An accepted procedure for this is to give one−fourth of the land to the tenant farmer. In this case, landownership patterns will also be influenced.

In the BLGWP area, because of the infrastructure available to farmers—such as irrigation facilities, approach roads, rural electrification, and intensive agricultural support services—land prices have soared to as much as ten times their level before the project.

As the potential for raising one's standard of living is greater in these areas, many people are migrating there and land prices are soaring. Landlords are happy to sell their land, and if the land is leased at the time of sale, the arrangement of giving one−fourth of the land to the tenant farmer can be used.

The ADB/N study of October 1988 of the impact of a shallow tube well program in the Terai shows there is some difference in landownership

and leasing/tenure arrangements before and after introduction of shallow tube well irrigation.

Conclusion

Tube well irrigation will play an important role in increasing agricultural production in the Terai. It permits intensive irrigated agriculture and is highly profitable, although it involves relatively higher operating expenditures.

Government operation and maintenance of tube well irrigation systems requires large, recurring budgetary allocations, which usually are not available. And operation and maintenance costs in agency−managed tube well irrigation systems might prove difficult to recover because of operational and management problems, although operation and maintenance costs usually are a very small part of the net incremental tube well−irrigated farm income. Moreover, the government is overburdened by increasing numbers of tube well irrigation systems. Therefore, there is a growing consensus that increased and more effective farmer participation is needed in the development, operation, and maintenance of tube well irrigation systems.

The shallow tube well development option is available for some parts of the Terai and, because of its low capital cost and local−technology advantages, this option provides greater opportunity for farmer participation in its development, operation, and maintenance.

Surface−mounted centrifugal pumps, commonly used in electrical or diesel−driven shallow tube wells, are simple to operate and maintain. Obviously, shallow tube wells provide the easier route for private sector development of tube well irrigation systems.

Private development of shallow tube wells by innovative, rich farmers will encourage smaller farmers to own, operate, and maintain shallow tube wells. Institutional loans on favorable terms will help make shallow tube wells accessible to smaller farmers.

Increasing water−selling by providing loans to buyers may also spread the benefits of tube well irrigation and increase utilization levels of shallow tube wells. But excessive fragmentation of landholdings and lack of adequate distribution systems restrict water sales. Under such conditions, numerous shallow tube wells with overlapping command areas will be required to promote an effective and competitive water market, assuring a reasonable price for water. Thinly distributed shallow tube wells will preserve the monopoly power of the richer shallow tube well owners.

Group ownership and operation will bring shallow tube wells within the reach of small farmers. Therefore, strong government support should be provided to promote group−owned shallow tube wells by assisting in group organization and by providing higher subsidies to group−owned shallow tube wells. Government support in promoting clusters of group−owned shallow tube wells through a project−oriented approach could minimize the cost of electrification. Electrification will make shallow tube wells much more attractive to farmers because of the financial and operational advantages of electricity−driven shallow tube wells. An electricity tariff structure based on fixed, flat rates with minimum pro rata charges could increase water sales tremendously.

Although some farmers have constructed canals for distributing water from deep tube wells, such farmer−constructed canals are inevitably earthen channels with high water losses that result in operational and management problems. Tube well distribution systems need to be as efficient as possible to minimize water management problems and operating cost. This requires an eventual commitment to buried polyvinyl chloride pipe distribution systems for tube wells. These distribution systems, though cheaper than brick−lined canals, are nonetheless capital−intensive and provide limited opportunity for farmer participation in construction. However, farmers can participate in excavating and filling trenches during the laying of polyvinyl chloride pipe distribution systems.

Most important to the success of an irrigation system is effective farmer participation in operation and maintenance. This requires building strong, well−structured farmer organizations and involving them as much as possible in preconstruction and construction activities, so that by the time a physical system is completed, a water users group has also developed with clear expectations about and a willingness to participate in the operation and maintenance of the system.

Farmer group participation is needed at each turnout for water allocation and distribution to individual farmers, construction and maintenance of field channels, collection and payment of water charges, and other management tasks within the turnout command area. Water users groups are also needed at the tube well level for the operation and maintenance of the pump and main distribu−

tion system and for the assessment, collection, and payment of water charges.

Farmers need training in water management at both the tube well and field levels. They need government support for the maintenance of pumps. And they need support in preparing bylaws and rules and regulations for system management. Such government support in the operation and management of the system should be limited to tasks that the farmers cannot handle themselves and should be aimed at developing local management capacity.

Deep tube wells should be planned mainly on the basis of technical criteria that permit maximum well density, under a project−oriented approach to minimize electrification costs and to ensure effective project support services.

Social need and level of demand should be strongly considered when selecting project areas. Planned deep tube wells should be allocated on the basis of requests from potential beneficiary farmers, but care must be taken that distribution is not skewed based on requests from richer, more influential farmers. Group organizers should be fielded to promote the proposed tube wells, collect farmer requests, and organize and develop farmer groups.

Construction of deep tube wells should be initiated only after a formal agreement is reached with the water users group on the participatory requirements for construction, operation, and management of the system. Water users groups should be involved in planning and construction as this will help them develop strong organizations capable of smoothly operating and managing the system.

The ultimate objective should be to develop a self−sustaining farmer organization that functions like a private water company, paying rent on tube wells to the government, if applicable, and operating and managing the irrigation system. As reliable irrigation and proper water management leads to increased production, landownership and leasing/tenure arrangements will likely be affected.

References

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PART 3—
INDIA

The chapters in part 3 are concerned with eastern India, although most of them have wider significance. Any one of the states in this region has a much larger population than Nepal, with the population of the smallest, Orissa, almost double that of Nepal at 31.5 million (1991 census). The largest, Uttar Pradesh, has nearly 139 million people, more than the population of Bangladesh. However, only the eastern part of Uttar Pradesh is part of the study area.

Chapter 7 begins with the history and the natural resource endowment of the lower Ganges Basin and then focuses on a case study of North Bihar, which the author considers representative of the basin. The chapter examines groundwater availability, its past and present utilization, and prospects for development in relation to surface irrigation, droughts, and flood control and drainage. While the author expects water control to lead to substantial increases in agricultural production, changes in cropping patterns, increases in employment, and so forth, he also feels that flood control, irrigation and drainage have to be treated as an integral package if success is to be achieved. Finally, the chapter looks at key areas in which policies will have to be formulated and implemented, for example, pumping energy, ownership and management of tube wells, and access to groundwater for small and marginal farmers.

Chapters 8 and 9 look at the performance of a new generation of tube wells designed to remedy the shortcomings of the earlier generation of public tube wells. These tube wells were first supported by the World Bank and are thus called "World Bank tube wells" in this volume, even though other financing agencies have subsequently supported their installation as well. Both chapters describe the new design of these tube wells, with the minor differences that reflect local adaptations of the basic design.

Chapter 8 is based primarily on a sample survey of tube well operators and farmers in the tube well command areas of three districts in eastern Uttar Pradesh. The author examines the performance of these wells compared with the previous generation of state tube wells with respect to area irrigated, access of the poor to irrigation water, methods of water distribution, and user involvement in distribution and management. The author complements his survey results with official data from the State Irrigation Department. The chapter concludes with a report on earlier studies of the water market in the study area, in particular the proportion of farmers buying water in the market, the installation of private irrigation facilities in the command areas of World Bank tube wells, and the likely reasons for this development.

Chapter 9 follows the case study method; it is grounded in a detailed examination of the water distribution system and rotational water allocation procedures in World Bank tube wells in eastern Uttar Pradesh. The authors describe innovations in these wells, examine the reasons for their introduction, and compare technical and socioeconomic performance with what was expected to be achieved and with the performance of older state tube wells. Comparisons are made for each innovation and, in order to capture synergistic effects, for the whole package of innovations.

Chapter 10 comprehensively reviews water markets. The author first describes patterns of groundwater appropriation. Drawing on a variety of evidence in addition to his own field work, he develops a typology of water markets related to the abundance or scarcity of the resource, the present degree of its utilization, the degree of competition between water sellers, and so on. An examination of water pricing and its determinants leads to an investigation of factors that influence the market power of water sellers. Having identified power pricing as one important factor, the author reviews different ways of pricing power and traces their impact on the supply and pricing of water, as well as their social costs and benefits. Finally, the author reflects on how subsidies can be targeted better to reach the poor and what effects water markets have on public tube wells and on irrigation groups.

In chapter 11 access to irrigation water forms the basis of an examination of the role of credit delivery to small and marginal farmers and the landless. The author focuses on credit delivery under a variety of organizational approaches for exploitation of groundwater. He presents two case studies of cooperative societies, describes the experience with small farmer associations modelled after the Vaishali Area Small Farmers Association, outlines the experience of the Ramakrishna mission with the Youth Clubs it has sponsored, and reports on the experience of the West Bengal Comprehensive Area Development Corporation with farmer groups. The chapter traces the experience of banks with credit delivery to poor farmers and emphasizes the importance of user groups to the credit system.

A word of caution on our understanding of the group approach, including cooperatives and farmer associations, may be in order. A thorough analysis of the monetary and manpower costs of setting up and nurturing these groups has yet to be done. Such an analysis is necessary, not only for an evaluation of group performance, but for deciding on the replicability of the group approach. Many groups have failed, for reasons that need to be more thoroughly investigated. The widespread attention given to these failures and, even more so, to the success stories may give a misleading impression of the scale on which the group approach has been adopted. To date, it seems such groups cover only a tiny portion of lift irrigation in the Ganges Basin, even though precise statistics are not readily available.

7— Ground−water Development for Economic Emancipation in the Lower Ganges Basin: Problems, Prospects, and Strategies

T. Prasad

The lower Ganges Basin of the Indian subcontinent has been a region of affluence and prosperity for long periods in history. Several flourishing empires of ancient India such as the Maurya Empire, established around 320 B.C., and the Gupta Empire, founded around 320 A.D., had their capitals and their centers of prosperity there. The region appears to have enjoyed almost uninterrupted progress until about 1200 A.D. when a slow and gradual decline in prosperity seems to have set in, manifesting itself in administrative and political upheavals, stress in daily life, and associated phenomena from the late 16th century onward. The decline of this region has influenced the course of history in the Indian subcontinent, figuring significantly in the downfall of the Moghul Empire, the advent of British rule, and the mass struggle for independence.

The past prosperity and ensuing decline in the region are attributable to its agricultural performance and productivity. The region has excellent agropotential because of its natural endowments, such as a congenial agroclimate, fertile lands, and ample water. These natural endowments have not gone through or recorded any systematic or cataclysmic changes. Yet the decline of this region resulted primarily from the increasing incapacitation of agriculture. What can explain the region's decline and what lessons might there be for its return to prosperity?

Favorable agroclimate and land are not liable to lose their significance or suitability for agriculture nor is there evidence that they have done so in the past. And with existing techno−economic techniques, these endowments cannot be significantly manipulated.

Water, however, is a renewable, dynamic resource, whose occurrence and distribution over time and three−dimensional space are governed by laws that depend on hydrologic, hydraulic, topographic, and other factors. Thus, the need for water in agriculture is at the mercy of laws that depend on agronomic, climatic, soil, and crop factors. Because of these divergent sets of laws, the availability of water is not in step with the requirements of agriculture.

Moreover, the natural distribution of water in this region is governed by distinct seasonality, considerable variability, and extreme occurrences, such as recurrent floods and frequent droughts. Thus, human intervention in the natural regime of water resources is imperative to bring about conformity between water availability and the agricultural requirement, to manage the resource to best advantage, and to avoid, where possible, the damage and devastation of flood and drought.

Human intervention in the water resource regime, like intervention in all natural systems, is not an unmixed blessing. It is apt to cause adverse side effects or be counterproductive in the long run. Circumspection and care are called for.

It is this aspect that explains the gradual decline of agricultural productivity and the progressive impoverishment of this region. And it is this as−

pect that holds the promise of economic emancipation and prosperity through increases in agricultural productivity commensurate with the region's natural endowments. India's hope of increasing food production to meet its growing requirements lies in this promise.

Water resource management with a view to ensuring its optimal utilization for agriculture will be the key to realizing this promise. Because of considerable hydrologic interaction between surface and groundwater, high groundwater potential, and other relevant factors, groundwater development will have to play a major role. It is in this context that the prospects, the problems, and the strategies related to groundwater development in this region have to be viewed.

North Bihar. A case study

The hypothesis examined in this chapter is based on the physical and socioeconomic conditions in North Bihar, a subregion situated almost centrally in the lower Ganges Basin. These conditions are largely typical of the whole region, and hence the hypothesis established for North Bihar would be valid for the lower Ganges Basin with minor variations arising from location−specific features.

North Bihar comprises 52,442 square kilometers (km2)—30 percent the area of Bihar. It lies in the lower Gangetic plains, bordered by Nepal to the north, the Ganges river to the south, eastern Uttar Pradesh to the west, and northern West Bengal to the east.

It is traversed by seven major rivers—Bagmati, Burhi Gandak, Gandak, Ghagra, Kamla, Kosi, and Mahananda—all flowing from the sub−Himalayan zone in the north. They originate mostly in Nepal and meet their master drainage channel, the Ganges river, in the south. Inhabited by 45 percent of the population of Bihar, the area has a population density of 604 persons/km2 , compared with 402 persons/km2 for Bihar and 221 persons/km2 for India.

The per capita annual income in North Bihar—about Rs 1,900 in 198889—is little more than half the national average. With more than 50 percent of its people living below the poverty line, it lies in one of the two "poverty belts" of the world, as identified in the Brandt Commission Report.

Agriculture is the dominant economic activity of the region, contributing more than 60 percent of gross national product and engaging 85 percent of the work force, more than 90 percent of which is rural. Low income from the agricultural sector, which reduces farmers' ability to hire labor at prescribed wage levels, is the reason for the endemic poverty of this region. As pointed out by the Sen Committee (Sen 1984), this is explained only by poor agricultural productivity.

The poor agricultural productivity of North Bihar is paradoxical considering that it has the most favorable agriculture−related natural resource endowments in the region. Almost 80 percent of the geographical area of North Bihar is cultivable with highly fertile tracts of land. Agroclimate is congenial for year−round cropping. With an average annual rainfall of 130 centimeters (cm), it has ample water resources, both surface and underground, to meet all present and potential water requirements for crops. Its huge labor force is steeped in the ways of agriculture.

An analysis of the problems that have hindered the harnessing of the natural resource endowments to achieve commensurate agricultural productivity clearly points to certain physical and socioeconomic factors. Because of monsoon hydrometeorology, where 85 percent of annual rainfall occurs in less than four months of the year, and topographical features, with steep gradients in the upper high−rainfall catchment areas joining the flat plains of North Bihar, the region suffers from recurrent threats of flood. This not only causes direct damage, mostly to crops, constituting 40 percent of damage nationwide, it also keeps agricultural operations in perpetually low gear.

Paradoxically, the region frequently suffers from drought because of considerable variability in the amount and timing of rainfall. Another problem is waterlogging, which is fairly extensive in this region and which adversely affects agricultural yields as well as environmental conditions. And on the socioeconomic front, the preponderance of marginal and small farmers, a tradition of inequitable land tenancy arrangements, and low levels of farm income have trapped the population in the vicious circle of poverty and low agricultural productivity.

Clearly, the prospects for economic emancipation and the development of the region hinge on enhancing agricultural productivity. While examining the techno−socioeconomic feasibility of optimum increases in agricultural productivity, two hypotheses can be proposed. One is that flood control and irrigation are imperative for gaining stable and reliable control of water in order to realize the high agropotential of this region. The other is that

irrigation by surface water is not entirely suitable for the alluvial region of North Bihar.

The latter hypothesis is corroborated by the experience of two surface irrigation projects, Kosi and Gandak, implemented in this region in the 1960s. The projects are based on diversion of river flows through a network of canals. The experience with irrigation by these exclusively surface−water projects over more than two decades has revealed their adverse and counterproductive features. In the Kosi project, large−scale waterlogging of cultivable land because of seepage from canals and the obliteration of minor and field channels resulting from years of siltation have considerably reduced the effectiveness and usefulness of the project. Similarly, the Gandak project not only fails to serve reliably and adequately the irrigation requirements in the lower half of the canal command, it is also having a harmful effect because of the rapid rise of the water table.

It is in this context that the role of groundwater for agricultural development in North Bihar has attracted attention and assumed vital significance.

Groundwater availability

There is a large body of groundwater underlying the alluvial plains, where there are several layers of mostly high−yielding aquifers of varying thickness, extending up to depths of 1,000 to 3,000 meters (m). In these aquifers, groundwater occurs under unconfined, semiconfined, or confined conditions. There is also evidence that groundwater exists under artesian conditions in very deep aquifers (1,500 m or deeper) in an extensive area in the Gangetic alluvial plains of eastern India. The technical feasibility and economic viability of tapping these aquifers are being investigated.

Water tables exist at shallow depths, varying from 1 to 4 m in postmonsoon periods to about 3 to 8 m in premonsoon periods. Annual recharge to groundwater from various sources such as infiltration of rainwater, seepage from canals and other water bodies, percolation of irrigation water, and the like is estimated to amount to 50 to 75 cm.

Apart from this vertical recharge, considerable recharge to aquifers takes place horizontally through percolation of water through a highly pervious zone, called the Bhabar Zone, which consists of boulders and cobbles deposited at the sub−Himalayan foothills in a width ranging from 10 to 20 km. All the rivers that drain the Himalayan range must cross this zone, thereby recharging groundwater supplies in aquifers and deposits that underlie the plains. A year−round water table gradient of 1/2 m per km from north to south corroborates this substantial horizontal recharge.

The quality of groundwater throughout the North Bihar plains is good to excellent, except in a few isolated areas where some investigation is needed to ascertain the quality before planning large−scale use of groundwater for irrigation. In any case, quality will not be a constraint in extensive and intensive utilization of groundwater for irrigation development in North Bihar.

Prospects for groundwater use

As water tables exist at shallow depths in the Gangetic alluvial plains, tube wells exploiting unconfined aquifers will have low lifts. Even the tube wells exploiting deeper aquifers, mostly under confined conditions, will have as low or even lower lifts than those of shallow tube wells because of the high piezometric, or "free water," surface. Thus, exploitation of groundwater in the alluvial plains of North Bihar, in particular, and in eastern India, in general, will be economically viable, and the danger of groundwater mining leading to excessive lifts and other adverse effects is remote.

Groundwater is also an attractive source for irrigation because it can be used as an exclusive source or as an alternative, complemental, or supplemental source, in space as well as in time, to surface water sources. Moreover, groundwater irrigation is imperative in North Bihar for several reasons:

There is substantial hydrologic interaction between surface water and groundwater in the alluvial plains. Because of a relatively high water table in these plains, occurrence and distribution of both surface water and groundwater are inter−dependent as well as sensitive to any measure of utilization and management of the water resource. Thus, irrigation exclusively by surface water resources is bound to result in the gradual rise of the water table in the alluvial plains. This may lead to encroachment of the root zones, salinization, and waterlogging. This will cause agricultural productivity to deteriorate over the years. Thus, exclusive surface water irrigation in the alluvial plains will not be sustainable over a long period and may prove counterproductive. The only effective antidote is conjunctive use of surface water and groundwater.

Because of the seasonality of river flows, diversion schemes for surface irrigation are unable to meet the full irrigation requirements or realize the full agricultural potential of this region.

Typically, a diversion scheme for surface irrigation without the support of upstream storage can hardly achieve an irrigation intensity of more than 120 percent, whereas irrigation intensity commensurate with agroclimate, soil fertility, and water availability in the region can be as high as 250 percent on average. This can be achieved only by large storage schemes or conjunctive groundwater use or both.

Drainage is an important and sometimes constraining consideration in irrigation development in the alluvial plains. Without ensuring efficient drainage, irrigation will not be fully effective or optimally productive. Groundwater utilization promotes subsoil drainage.

Groundwater development and its current status

Use of groundwater from percolation wells and ponds for domestic purposes has been common from historical times. Use of groundwater for agriculture was resorted to during times of particular stress. But planned and regular use of open wells and ponds for irrigation was uncommon in North Bihar. A prime reason was that there was normally adequate rainfall for crops in the kharif season, the most dominant cropping season of the region. Cultivation of crops in other seasons, when moisture deficiency was more common, was considered incidental.

At the beginning of the planning era in India, development of surface irrigation was emphasized with the objective of flood control where feasible and needed, such as in the Kosi project.

For several reasons, such as Indian experience in canal irrigation, uncertain assessment of groundwater potential, lack of pumping equipment, constraints on energy required for pumping, and so on, groundwater development did not receive adequate attention, either in the public or in the private sector. From the Third Plan on, the situation seems to have changed in favor of groundwater irrigation, as evidenced by expenditures in successive plan periods. In the wake of the severe drought in eastern India in 196667, particularly in Bihar, the advantages of groundwater irrigation over surface irrigation were poignantly realized by the people, the government, and other concerned organizations.

This boosted the development and expansion of groundwater irrigation in the country in general, and in eastern India in particular. In North Bihar, a perceptible move toward expansion of private and public tube wells for irrigation seems to have occurred after a later drought in 197273. Even in areas served by canal irrigation, such as the Kosi command, private tube wells have come to supplement or complement it. Where canal irrigation has not been introduced, whatever irrigation is practiced employs tube wells.

The present status of groundwater utilization for agriculture in North Bihar, in spite of the expansion of the past fifteen years, is substantially below the potential, both in terms of safe yield of groundwater and area provided with irrigation.

It is estimated that at present, less than 25 percent of safe yield is being utilized for agriculture by way of private and public tube wells, covering less than 20 percent of cultivated area. Although a number of public tube wells, which are invariably deep units that tap aquifers at depths greater than 80 m, were installed in the region in the 1970s and early 1980s, most of them have become non−operational because of an erratic and inadequate supply of electricity and the lack of repair and maintenance.

Thus, groundwater utilization for agricultural purposes in the region is predominantly through private tube wells, typically shallow tube wells, which tap aquifers at depths less than 80 m or quite often less than 15 m, use diesel−operated 5 horsepower (hp)−capacity pumps, and have a pipe diameter of 10 cm.

Although the majority of landholdings in the area belong to small and marginal farmers, most of the tube wells are owned by farmers other than the small and marginal. To some extent, the small and marginal farmers have access to groundwater through the market, but in the socioeconomic and agroclimatic environment prevailing in this area, there are limits to the growth of the groundwater market. The improvement in agricultural and hence economic performance of tube well−owning farmers is quite visible and is in obvious contrast to the performance of those without this facility in the same village.

There are several reasons for the low utilization of groundwater. A prime factor is the preponderance of marginal and small farmers, with holdings exceeding 50 percent of the total cultivated area, who simply cannot afford to provide themselves with tube wells. Added to this is a lack of incentive or a positive disincentive arising from envi−

ronmental and hydrological factors. Fertile lands and normally adequate rainfall in the monsoon season ensure these farmers a subsistence level from kharif crops.

Residual soil moisture and the winter rains are also generally suitable for rabi crops. Under these normally congenial conditions farmers are not motivated to construct tube wells. This is corroborated by the fact that more than 70 percent of existing tube wells in this area were installed in the wake of the severe drought of 197273. But even this adversity and the evidence that tube well irrigation leads to substantial improvement in returns from agriculture have not stirred the small and marginal farmers to sink tube wells. There is a circular cause−and−effect relationship between economic status and private initiative in groundwater use for irrigation. Another disincentive for these farmers to invest in tube wells is the recurrence of floods and the consequent damage to crops in this region.

An important inhibitor to tube well irrigation in this area is the paucity of adequate, reliable sources of energy required to operate tube wells. Electrical energy is either nonexistent, inadequate, or erratic, and hence is not relied upon for the purpose. This has been a major cause of the nonperformance or poor performance of public tube wells. Diesel−operated tube wells are more common. But the inconvenience, the uncertainty of diesel supply, and the cost involved have deterred widespread adoption of diesel pumps for tube well irrigation.

Agricultural development using groundwater

Considering the prevailing hydrometeorological conditions in the lower Ganges Basin, the region's high agropotential can be realized only by providing the farmer with complete control of water in his field. It is up to the farmer to ensure a supply of water to crops according to requirements for maximum yields and to guard against undue disturbance of the salt−moisture regime in the root zone to ensure long−term sustainability of productive irrigation.

To be effective, control of water resources must be optimally consistent with the growing seasons for different types of crops, with attention to specific needs for water and fertilizers at various agronomic stages of growth. Considering hydrological, topographical, and other relevant factors in North Bihar, this control cannot be achieved by surface irrigation alone. This has been demonstrated by the two canal irrigation projects (Kosi and Gandak) in this region. It is only through the dominant use of groundwater, either alone or in conjunction with surface water, that the farmer can gain this control. Once this control is effectively secured, the following consequences are bound to result:

Increase in productivity. Agricultural productivity per hectare of land per crop will increase severalfold, commensurate with the congeniality of agroclimate and fertility of land. Present low productivity is primarily attributable to poor control of the water resource.

Almost 100 percent irrigation command. With extensive availability of good quality groundwater throughout the North Bihar plains and with surface water in the numerous streams criss−crossing them, almost 100 percent of the cultivable area can be brought under irrigation compared with the current figure of about 35 percent.

An average of 250 percent cropping intensity. Figuring in agroclimatic features, the cropping season, and emerging crop varieties, cropping intensities of up to 300 percent are clearly within the realm of possibility in this region. Accounting for local variations, an average of 250 percent cropping intensity for the entire North Bihar is feasible.

New cropping patterns. With more effective farmer control of water for agriculture, cropping patterns will change. With the ability to satisfy crop−specific demands for water, farmers will plant more remunerative and superior crops. Absent the critical constraint of water, cropping patterns will be more responsive to agronomic and agroeconomic factors.

Employment generation. More extensive and intensive agricultural operations will raise the demand for labor severalfold. And the new cropping intensities and patterns will give rise to more regular and year−round, rather than ad hoc and seasonal, employment. Consequently, employment will be more productive for farmers and more remunerative for laborers.

Linkages in economic development. Because agriculture is the main source of livelihood for most of the population (almost 80 percent) and is the backbone of the economy, the importance of agricultural development in any program of economic regeneration for this region cannot be overemphasized. Such development will result from effective farmer control of water for agriculture using groundwater as the dominant source. This will lead to a high level of income generation in the agricultural sector—estimated at ten to fifteen times current levels—and equitable distribution of the additional wealth produced. The grass−roots economy will be strengthened directly, rather than through a trickle−down effect. Through complex linkages to secondary, tertiary, and other sectors of the economy, this strengthening will lift the region from its downward spiral and stimulate its rapid economic transformation.

Strategies and policy implications

Effective farmer control of water for agriculture is essential for the above prospects to be realized. In North Bihar this means control over three related tasks—flood control, irrigation, and drainage. Because of the inevitable hydrologic and hydraulic interaction and the interdependence of these three water−related phenomena, it is necessary that they be dealt with in an integrated way—dealing with them separately is not optimally beneficial and may even be counterproductive. This calls for adoption of a package of coordinated measures, optimally effective for all three tasks, rather than a series of measures that are effective only for individual tasks.

Various measures in the package may have different time frames and different requirements for adoption and implementation. This may necessitate developing consistent plans of action for the short term (five to ten years), the medium term (ten to twenty years), and the long term (more than twenty years). In this perspective, conjunctive use of surface and ground waters, with groundwater use predominating, will be the most suitable strategy for irrigation development in North Bihar.

To implement this program, certain issues will have to be resolved at the policy level:

Energy alternatives. Lack of adequate, reliable sources of energy has been one of the major constraints to expansion of groundwater irrigation. It has also been learned that of the two alternatives, electricity and diesel, electricity is by far the preferred energy source for tube well pumps. Hence, a reliable and adequate supply of electrical energy is an essential condition for this program.

Ownership and management of tube wells. Tube wells can be owned and managed by the government, the community, or individual farmers. All three options have limitations as well as advantages for installation, operation, maintenance, and management. This issue will have to be considered and resolved in the light of both past experience and future prospects.

Access to groundwater by small and marginal farmers. This issue is vitally important in a region such as Bihar where almost 90 percent of landholdings and 50 percent of cultivated area belong to small and marginal farmers. Because of severe handicaps imposed by the size of their holdings and because of their inability to invest, these farmers have largely been deprived of irrigation benefits. Appropriate measures and interventions must be formulated to provide them with access to groundwater.

These are the policy issues that must be resolved to boost development of groundwater utilization for agriculture and to ensure that resulting benefits accrue commensurately to the poor.

But there are wider policy issues that must be resolved so that this program will fit within the framework of both optimum water resource development and related developments that have to be carried out in the medium and long terms. Although it is prudent not to lose sight of these vitally important intermediate planning initiatives, the suggested program of massive groundwater development must be taken up immediately to alleviate poverty and to realize, partially if not fully, the growth potential of this region. This, in turn, will help raise food production in India.

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8— Performance of the World Bank Tube Wells in India

Niranjan Pant

This chapter is based on a larger study conducted by the author between June and December 1988 (Pant 1988). The study, which was conducted in three districts of eastern Uttar Pradesh, set three main objectives: first, to examine the existing pattern of water distribution and management in the World Bank tube wells; second, to study the nature and extent of user involvement in these tube wells; and third, to make relevant recommendations on water distribution and management with increased user involvement. This chapter reports on some of the findings concerning the first two objectives.

A survey of the tube well operators and the command area farmers was carried out in the three districts of Faizabad, Basti, and Deoria during September and October 1988 (*kharif*, or wet, season). A two−stage sampling was done to select the tube wells and the command area farmers from the three districts.

In the first stage, 20 percent of the World Bank tube wells were selected from each district. In making the selection, the tube wells were chosen so that they were proportionately drawn from Phases I and II wells1 (in the case of Faizabad) and from different clusters and different sizes. Our sample from the three districts contained 57 tube wells, of which 11 were of Phase I and 46 were of Phase II. In terms of capacity, the sample contained 48 tube wells of 150 cubic meters per hour (m3 /hr), 7 tube wells of 300 m3 /hr, and 2 tube wells of 225 m3 /hr. Further, the sample consisted of 52 new tube wells, 3 modernized tube wells, and 2 dedicated tube wells.2

In the second stage, five farmers from each tube well command were selected. Because small and marginal farm holdings constituted about 90 percent of total holdings, in all districts the selection of the farmers was designed accordingly. Therefore, from each tube well command, two farmers were selected with less than 0.4 hectares (ha) of land, two farmers with 0.4 to 1 ha of land, and one farmer with more than 1 ha of land. This sampling procedure was adopted to give adequate representation to small and marginal farmers. Of the total sampled tube wells, 21 were drawn from Faizabad, 20 from Basti, and 16 from Deoria. This enabled us to interview 105 farmers from Faizabad, 100 from Basti, and 80 from Deoria, totaling 285 farmers.

Although the selection of farmers from different landholding categories was done on the basis of their land in the surveyed tube well command area only, we also inquired about the total land owned by each respondent. Data on landholdings of respondents are presented in table 8.1.3

Irrigation—de jure

According to the design framework of the World Bank tube wells, the operation criteria for irrigation are such that water is allocated by holding areas within a tube well command area, with service to farmers in given areas on a predetermined day of the week. The design practice is to divide the command area of a buried pipe distribution loop into seven equal parts of about 7 ha. Each 7−

Table 8.1 Data on landholdings of study respondents, Faizabad, Basti, and Deoria, 1988
(percent)

Landholding size (ha)	*Size of landholding in command area*			*Size of total landholding*		
	Faizabad	*Basti*	*Deoria*	*Faizabad*	*Basti*	*Deoria*
<0.4 ha	38.1	40.0	43.7	27.6	35.0	33.7
0.4 to 1 ha	48.6	42.0	45.0	40.0	43.0	40.0
>1 to 2 ha	7.6	14.0	8.8	18.1	13.0	16.3

>2 ha	5.7	4.0	2.5	14.3	9.0	10.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

ha Hectares.

hh Household.

ha unit, known as an "area day command," is entitled to water supplies from the tube well on a fixed day of the week at a stream flow of about 75 m3 /h.

The water right of each farmer in the area day command is set by the Irrigation Department in proportion to his holding area with the water right expressed in hours of tube well operating time. An area day command is the unit by which water deliveries are scheduled and quantities delivered to each command area based on a rotational allocation designed by Irrigation Department staff. Only one outlet on a loop distribution system is to be opened at a time, thus fixing the rate of water delivery and allowing the quantity delivered to be measured on a time basis.

Assisted by the Junior Engineer and the Agricultural Supervisor, farmers within each area day command would form a committee to organize a schedule for water distribution within their area. Leaders chosen by each area day committee would in turn select, from their ranks, five representatives to sit on the Tube Well Management Committee. The committee would be responsible for coordination and cooperation among area day committees, adjudication of disputes, oversight, and adjustment, in concert with the Junior Engineer in charge of the cluster. The president of each Tube Well Management Committee would be consulted by the staff of the Irrigation and Agricultural Departments on issues affecting the entire cluster.

Irrigation—de facto

The water deliveries and irrigation practices prevalent in the tube well commands differ vastly from what was conceived and designed. The main problem arises from the uncertainty regarding the availability of electricity, compounded by electric, mechanical, and civil defects that occur frequently. Consequently, the *osrabandi* (water rotation schedule), the day committees, and the tube well committees remain on paper, and the water delivery principles, such as "only one outlet on a loop distribution system would be opened at a time," are rarely practiced. However, before making such generalizations it would be worthwhile to examine the findings of our survey with respect to various aspects of water distribution and management.

Need for and provision of tube well water

In table 8.2, survey data has been arranged in terms of respondents' need for water from the World Bank tube wells and the portion of their land being irrigated. The table clearly shows that an over−whelming majority of respondents need water from the World Bank tube wells and that a very small portion of farmers do not need water, usually those who own their own irrigation sources. This does not mean that all those who own private means of irrigation do not want or need water. An important point that emerges from the table is that a significant portion (18.6 percent) of sample respondents report that they need water, but do not get it. However, this does not appear so significant if we

Table 8.2 Need for tube well water and portion of command area receiving Irrigation, Faizabad, Basti, and Deoria, 1988
(percent)

Categories	*Faizabad*	*Basti*	*Deoria*	*Overall*
Need	81.9	70.0	86.3	78.9

Need but do not get	18.1	25.0	11.2	18.6
Do not need	0.0	5.0	2.5	2.5
Total	100.0	100.0	100.0	100.0
All of the land in CA receiving irrigation	34.3	36.0	25.0	32.3
3/4 of the land in CA receiving irrigation	5.7	9.0	16.3	9.8
1/2 of the land in CA receiving irrigation	25.7	14.0	30.0	22.8
1/4 of the land in CA receiving irrigation	16.2	14.0	13.7	14.7
No portion of the land receiving irrigation	18.1	27.0	15.0	20.4
Total	100.0	100.0	100.0	100.0

CA Command area.

compare it with conventional state tube wells, studied earlier, where 47.5 percent of the command farmers did not get any water.4

With regard to the portion of landholdings in a command area receiving irrigation, about 32 percent of farmers mention that all their land gets irrigated. About 48 percent report that part of their land gets irrigated, while 20 percent mention that no portion of their land gets irrigated. Thus, whereas about 19 percent complain that they do not get water, about 20 percent mention that none of their land in the command area receives water from the tube well. This means that the later cross−check reinforces the former response of the farmers ("need water but do not get") and authenticates the view that about one−fifth of the command area does not get any water.

Use of other means of irrigation

We also asked our respondents whether they ever used any other means of irrigation in the tube well command area; those who replied in the affirmative were asked about the means. Our data show that 33.7 percent of the farmers do not use any other means of irrigation in the command area and 66.3 percent either use their own diesel pumpsets or electric tube wells or purchase water from those who own them.

The performance of the World Bank tube wells is much better than that of conventional state tube wells we studied earlier, where we found that only 10.5 percent of gross irrigated area in state tube well commands was irrigated by those wells (Pant 1984, p. 173). Among the main reasons for the use of other sources, the uncertainty of power—because of low voltage or power failure—appears to be the most important and was mentioned by thirty−six of the respondents. That is followed by wrong placement of outlets, broken outlets, and absence of field channels (14.8 percent), followed by defects in the tube well because of electrical, mechanical, or civil reasons (13.7 percent). However, there are interdistrict variations in this respect. In Faizabad and Basti the uncertainty of power is the most important reason, while in Deoria the wrong placement of outlets stands out.

There appears to be near uniformity among the users of other means with respect to the ownership of electric tube wells, which are owned by about 14 percent of them in all three districts. However, a lot of variation is present in the case of diesel pumpsets. These are owned by about 7 percent of the users of other means in Faizabad, 13 percent in Basti, and 20 percent in Deoria, with the average for the three districts being 12.7 percent.

Access of the poor to tube well water

The one dimension under which the performance of the World Bank tube wells needs to be examined is equity in water distribution. Hence, in table 8.3, we have examined this aspect of irrigation in relation to landholding size. It should be noted that the landholding categories have been drawn from the respondents' land in the tube well command.

The data on land receiving irrigation indicates that farmers in the smallest and the next to the smallest landholding categories are the biggest beneficiaries of the World Bank scheme. A high proportion of these farmers get all their land irrigated. The biggest losers seem to be the largest farmers, those holding more than 2 ha, as about 53 percent of their land does not receive any irrigation. From the point of view of equity, this is positive. However, what is disturbing is that 25 percent of farmers in the smallest and 21 percent of those in the next smallest category receive no irrigation from the World Bank tube wells. For those who use other means of irrigation, 53 percent of the small−

Table 8.3 World Bank tube wells irrigation and use of other irrigation sources by landholding size, Faizabad, Basti, and Deoria, 1988

Landholding category	*Sample size (number of farmers)*	*Land Sample in command area (ha)*	*All of land irrigated by World Bank tube wells (percent)*		*None of land irrigated by World Bank tube wells (percent)*		*Percentage of sample size using other sources of irrigation*
			Farmers	*Land*	*Farmers*	*Land*	
< 0.4 ha	96	26.9	49.0	40.1	25.0	21.3	53.1
0.4 to 1 ha	117	85.4	30.8	25.8	19.7	19.1	65.8
1 to 2 ha	40	43.9	15.0	19.3	12.5	17.0	72.5
2 ha	32	32.3	9.4	23.5	18.7	52.8	87.5
Total	285	188.5	n.a.	n.a.	n.a.	n.a.	n.a.

ha Hectares.

n.a. Not applicable.

est farmers are in this position, but this percentage rises as with the larger landholding categories.

It is interesting to examine the question of equity with regard to state tube well irrigation. Table 8.4 presents data from an earlier study of the author. Although the sample in that study did not have many smallest category farmers, this does not vitiate the findings. The average area irrigated per household came to 0.08 ha for small farmers and it goes up to 0.34 ha per household for farmers having more than 2 ha of land. (This might not hold if we took into consideration the proportion of total command area land getting irrigated by state tube wells—but these data are not readily available.)

The data in table 8.4 nonetheless indicates that the biggest gainers from state tube well irrigation are the largest farmers, those holding more than 2 ha, and the biggest losers are farmers having 0.4 to 1 ha of land.

We have also examined the question of poor farmers' access to tube well water in the context of community tube wells.5 One important objective of the study was to examine the performance of community or group tube wells in terms of percolation of irrigation benefits to small and marginal farmers in two districts, Deoria and Vaishali.

Study data presented in table 8.5 show that, among group members, 97.1 percent of users in Deoria are marginal and small farmers and irrigate 91.2 percent of members' land. In Vaishali, 88.3 percent of members are marginal and small farmers, with tube well commands covering 79.3 percent of members' land.

Big farmers account for 2.9 percent of membership and 8.8 percent of irrigated land in Deoria and 11.8 percent of membership and 20.7 percent of irrigated land in Vaishali. Thus, among members in both districts, the major users of the program are small and marginal farmers.

Table 8.4 Landholding area irrigated by conventional state tube wells

Landholding category	*Percentage of respondents in state tube well commands*	*Percentage of area irrigated by state tube wells*	*Average area irrigated by state tube wells (per hectare)*
< 0.4 ha	11.4	13.5	0.26
0.4 to 1 ha	36.4	13.1	0.08
1 to 2 ha	27.2	36.8	0.31
2 ha	25.0	36.6	0.34
Total	100.0	100.0	n.a.

ha Hectare.

n.a. Not applicable.

Note: Sample size is 280 farmers, 63.3 hectares of land.

Source: Adapted from Pant 1984, pp. 165, 195.

Method of water distribution

The survey respondents in three districts were also asked, "How is water distributed from the World Bank tube well?" Five alternative answers were suggested to them. The first thing to be noted is that only 13 percent of farmers reported that water is distributed on the basis of "particular outlets on particular days," although according to design norms, all farmers are supposed to get water on this basis. Thirty−seven and a half percent of farmers mentioned, "Operator decides after discussing with farmers." This is closely followed by 34.7 percent of the respondents who stated, "Operator decides arbitrarily or by wrong means." Twelve (12.3) percent said that what mattered in water distribution was "might is right" and 2.8 percent mentioned other modes of water distribution.

User involvement in water distribution and management

The technical design of the World Bank tube wells was so devised that it required hardly any role for the Irrigation Department in the day−to−day management of the tube well. The water rights of each farmer were predetermined on the basis of osrabandi, which ensured availability of water to each farmer on a particular day, at a particular time, from a particular outlet.

The idea was to create equity, which was managed by the user farmers through their two committees and a village−based, part−time operator. The basic difference between the conventional state tube well and the World Bank tube well is the role user farmers are expected to play through their committees. In the World Bank tube well, they are expected to play a very active role in the distribution of water and the maintenance of tube well structures, as well as in the resolution of conflicts arising from these tasks.

The findings of our survey, however, do not show any positive points in these respects, and the blame has to be placed squarely on government functionaries. Our survey revealed that command area farmers were by and large ignored in tube well preinstallation discussions, which is obvious from the fact that only 11.9 percent of respondents reported that a cross−section of future users was consulted. The little importance the irrigation bureaucracy attached to these committees can be judged by the fact that, in a large number of sample tube wells, the committees did not exist. There is a pro−

Table 8.5 Irrigation from group tube wells, Deoria and Vaishali districts, 1983

Farmers and land receiving irrigation	*Deoria district*		*Vaishali district*	
	Group members	*Nonmembers*	*Group members*	*Nonmembers*
Number of farmers				
Marginal: up to 1 ha	148.0	98.0	304.0	69.0
	(71.8)	(33.2)	(74.2)	(32.9)
Small: >1 up to 2 ha	52.0	189.0	58.0	128.0
	(25.2)	(64.1)	(14.2)	(61.0)
Big: >2 ha	6.0	8.0	48.0	13.0
	(2.9)	(2.7)	(11.7)	(6.2)
Total	206.0	295.0	410.0	210.0
	(100.0)	(100.0)	(100.0)	(100.0)
Irrigated area (ha) cultivated by:				
Marginal farmers	150.2	104.0	220.9	78.2
	(52.7)	(21.8)	(54.0)	(17.5)

Small farmers	109.5	330.5	103.8	291.6
	(38.4)	(69.2)	(25.4)	(65.3)
Big farmers	25.2	43.5	84.7	76.8
	(8.8)	(9.1)	(20.7)	(17.2)
Total area irrigated	284.8	478.2	409.3	446.5
	(100.0)	(100.0)	(100.0)	(100.0)

Note: Figures in parentheses indicate percentages. Categorization of farmers is based on the government of India's definition.

Source: Adapted from Pant and Rai 1985, pp.6061.

vision for fourteen to twenty−eight area day committees, depending on the size of the tube well, and for one tube well management committee for each World Bank tube well. In practice, of fifty−seven tube wells studied, seventeen tube wells (about 30 percent) had no committee.

Even where these committees were formed, this was done just to meet paper requirements, which can be judged by the manner of their constitution and the role they have played in water distribution. The survey shows that in a majority of cases, committees have been constituted by surveyors acting alone (25.2 percent) or after consulting with local people of influence (61.5 percent), who were not necessarily farmers. Only in about 9 percent of cases did the surveyor call a meeting and form committees after consulting a cross−section of the people. In several cases, we found that the so−called members did not know they were members of such committees.

The meeting register, which is necessary for recording the minutes of the meetings, was nonexistent in a large number of cases. Of fifty−seven tube wells studied, only sixteen meeting registers existed and meetings were recorded in only four registers. Meetings recorded in these registers numbered seven, with three meetings in one register, two meetings in another register, and one meeting in each of the other two. Thus, it can be safely concluded that the concept of user−managed tube wells has remained confined to World Bank Staff Appraisal Reports. It is not that user farmers take no interest, which is the usual official explanation, but that the irrigation bureaucracy has made little serious effort in this respect. In a few stray cases where an irrigation officer has shown some interest, farmers do not lag behind in efforts to fulfill their role.

Net and gross irrigated area

On the preceding pages we discussed the existing state of affairs of the World Bank tube wells based on our farmer and tube well surveys. Here we intend to examine the performance of these tube wells on the basis of official data collected from the Irrigation Department offices in the three districts.

The performance evaluation was based on secondary data for the two cropping seasons, *kharif* (wet) and *rabi* (dry), relating to net and gross irrigated area and the running and the closure hours of the World Bank tube wells. The data were made available to us for every World Bank tube well working in a district. We have, however, presented the data by computing averages for all tube wells on an annual basis and by cropping seasons and have presented these by phase, cluster, and district in tables 8.6 (Faizabad), 8.7 (Basti), and 8.8 (Deoria). We have not followed a uniform pattern in the tables. Because Faizabad was the only district in our sample with Phase I tube wells, the data are presented by phase. Data for Basti and Deoria are presented by cluster.

Table 8.6 Irrigated area, number of waterings, and running hours of tube wells, Faizabad

	Kharif season						*Rabi season*			
Year	*Number of tube wells*	*Net irrigated area per tube well*	*Gross irrigated area per tube well*	*Number of waterings per tube well*	*Running hours per tube well*	*Number of hours per hectare*	*Number of tube wells*	*Net irrigated area per tube well*	*Gross irrigated area per tube well*	*Number of waterings per tube well*
Phase I										
198384	37	22.2	39.6	1.8	2.8	12.7	37	41.0	84.9	2.1
198485	36	24.6	43.7	1.8	3.0	12.6	37	45.1	113.1	2.5
198586	37	21.0	38.7	1.8	3.3	15.4	37	42.2	90.2	2.1
198687	36	31.4	43.9	1.4	3.8	16.0	37	38.9	79.2	2.0
198788	37	24.5	37.2	1.5	3.1	15.3	37	34.4	51.0	1.5
198889	36	17.0	25.4	1.5	2.5	18.1	−	−	−	−
Phase I avg.a		23.4	38.1	1.6	3.1	14.8		40.3	83.6	2.1
198586	−	−	−	−	−	−	20	59.0	116.5	2.0
198687	21	25.6	45.6	1.8	3.0	11.9	23	58.1	113.4	2.0
198788	32	24.9	46.1	1.8	3.8	14.9	45	35.8	61.1	1.7
198889	49	22.3	37.1	1.7	3.5	15.9	−	−	−	−
Phase II avg.		23.8	41.7	1.8	3.4	14.6		46.9	87.4	1.9
Overall district avg.		23.5	39.2	1.7	3.2	14.7		42.4	84.9	1.9

− Not available.

a. Up to 15 September.

Tube well performance is evaluated in relation to expected performance. According to an internal World Bank report of February 1983, a World Bank tube well in the eastern region of Uttar Pradesh is expected to provide a rabi and kharif irrigation intensity of 91 percent, with 33 percent for kharif, 55 percent for rabi, and 3 percent perennial (sugarcane). If we divide the perennial in two equal parts and merge these with rabi and kharif, it would give us a kharif irrigation intensity of 34.5 percent and rabi irrigation intensity of 56.5 percent. However, it should be clear that 91 percent irrigation intensity was set on the basis of a crop water requirement of four to five waterings during rabi and two to three waterings during kharif. Based on these norms, a 150 m3 /h (1.5 cusecs[6]) tube well with a 100−ha command area is expected to irrigate a net area of 56.5 ha during rabi and 34.5 ha during kharif.

Based on these performance criteria, tables 8.6, 8.7, and 8.8 show that tube well performance for net irrigated area, gross irrigated area, and number of waterings falls short of expected performance in all three districts. Nonetheless, it is worthwhile to look at the performance of these tube wells by district.

Data for Faizabad district (table 8.6) are confined to 1.5 cusec tube wells and do not include the two tube wells with 2.25 cusec capacity and the eleven tube wells with 3 cusec capacity that also operate in the district. The data show that although net irrigated area per tube well, in rabi as well as in kharif, falls short of the envisaged area, the actual performance is better during rabi than during kharif. If we merge the Phase I and Phase II tube wells, we find 23.5 ha net irrigated area per tube well during kharif compared with 42.4 ha during rabi. Thus, during rabi about 75 percent and during kharif about 72 percent of expected net area is irrigated. The same relationship, however, does not hold in the case of the number of waterings. Even though two waterings during rabi are better than 1.7 waterings during kharif, the rabi waterings fall far shorter of their expected mark—four to five waterings—than do the rabi waterings, with two to three waterings expected.

The average time required to irrigate one hectare of land in the district is 10.5 hours in rabi and 14.7 hours in kharif. A striking feature, which applies equally to Phase I and Phase II tube wells, is that the hours of pumping required has gone up consistently over the years.

Basti district, unlike Faizabad, has only Phase II tube wells, and most of them are of recent origin, irrigating for the past two years only. The data show the same pattern found in Faizabad, with rabi performance better than that of kharif (table 8.7). In fact, the improvement over kharif is far greater as the net irrigated area is more than three times as large in rabi as in kharif. However, the number of waterings during kharif at 1.4 is slightly higher than that of rabi at 1.3.

Among the clusters, Basti appears to be doing best, but this is not the case. About half of the tube wells in the cluster are 300 m3 /h (3 cusecs) tube

Table 8.7 Irrigated area, number of waterings, and available electricity, Basti

		Kharif					*Rabi*		
Name of cluster	*Year*	*Number of tube wells/cusecs*	*Net irrigated area per tube well*	*Gross irrigated area per tube well*	*Number of waterings per tube well*	*Number of hours per hectare*	*Number of tube wells/cusecs*	*Net irrigated area per tube well*	*Gross irrigated area per tube well*
Ramnagar	198687	11/1.5	9.8	10.8	1.1	8.8	27/1.5	50.2	78.6
	198788	27/1.5	19.8	32.1	1.6	14.0	27/1.5	44.9	60.5
	198889	37/1.5	7.9	9.6	1.2	14.7	−	−	−
Up to 15 September, cluster average			12.5	18.1	1.4	13.6		47.5	69.6
Bansi	198687	19/1.5	14.6	19.0	1.3	13.4	23/1.5	27.8	32.3
	198788	25/1.5	6.1	11.2	1.8	17.6	28/1.5	41.8	46.4
	198889	29/1.5	6.7	9.6	1.4	18.0	−	−	−
Up to 15 August, cluster average			8.6	12.6	1.5	16.1		35.5	40.0
Basti	198788	−	−	−	−	−	18/1.5	30.2	40.3
	198788	−	−	−	−	−	15/3.0	33.6	40.3

Net and gross irrigated area

	198789	18/1.5	12.4	14.8	1.2	16.2	−	−	−
		15/3.0	15.8	19.8	1.2	11.6	−	−	−
Up to 31 August, cluster average			14.2	17.1	1.2	13.8		31.8	40.3
District average			11.2	15.7	1.4	14.5		39.3	51.7
				Kharif (hours per day)				*Rabi (hours per day)*	
	Period			*Available electricity*	*Running hours*		*No demand*	*Available electricity*	*Running h*
Ramnagar average	198689 up to 15 Aug			7.3	1.5		4.4	13.4	4.2
Bansi average	198688 up to 15 Aug			11.9	1.2		10.1	15.6	2.8
Basti average	198788 up to 15 Aug			6.6	1.5		2.8	7.8	2.2
District average				8.6	1.4		5.8	12.3	3.2

− Not available.

cusec Unit of flow equal to one cubic foot per second.

wells and are expected to irrigate double the area irrigated by a 150 m3 /h (1.5 cusecs) tube well. With this in mind, the Ram Nagar cluster performance is best, followed by the Basti cluster.

However, the performance of all the clusters is poor when compared with expected performance. Even with a low number of waterings, none of the clusters covers nearly the expected irrigated area of 56.5 ha during rabi and 34.5 ha during kharif for 150 m3 /h (1.5 cusecs) tube wells and 113 ha during rabi and 69 ha during kharif for 300 m3 /h (3 cusecs) tube wells. The best performance is 12.5 ha for kharif and 47.5 ha for rabi by the Ram Nagar cluster. An important point that emerges from the table is the extremely poor performance of 300 m3 /h (3 cusecs) tube wells. The actual net irrigated area from such tube wells in the Basti cluster is only 20.6 percent of expected net irrigated area during kharif and 28.3 percent during rabi and this, too, with very low waterings of 1.2 times for both kharif and rabi.

The data for Deoria (table 8.8) show that rabi performance, in terms of net irrigated area, is better than kharif performance at the district as well as at the cluster level. But, surprisingly, the number of waterings during rabi is smaller than in kharif at the cluster as well as at the district level. At the district level, th number of waterings in kharif is 1.5 compared with 1.4 in rabi. However, the performance during both kharif and rabi is quite low compared with expected performance. In this respect, 300 m3 /h (3 cusecs) tube wells have fared the worst. In Bhatpar cluster, where we have used only data for 300 m3 /h (3 cusecs) tube wells, the kharif net irrigation with 1.1 waterings is 16.1 ha per tube well, which comes to 23.3 percent of the expected area. During rabi, with 1.2 waterings, 36 ha net area is irrigated, which comes to 32 percent of the expected area.

The preceding examination shows that performance in all three districts is quite poor compared with planned performance. Of the three districts, the performance of Faizabad is by far the best in terms of both net irrigated area and number of waterings during rabi as well as kharif. This is despite the fact that Faizabad does not include any larger size tube wells.

Table 8.8 Irrigated area, number of waterings, and available electricity, Deoria

Name of cluster	*Year*	*Number of tube wells/cusecs*	*Net irrigated area per tube well*	*Gross irrigated area per tube well*	*Number of waterings per tube well*	*Number of hours per hectare*	*Number of tube wells/cusecs*	*Net irrigated area per tube well*	*Gross irrigated area per tube well*	*Nu we pe we*
Bhatpar	8586	−	−	−	−	−	10/3.0	40.0	44.1	
	8687	14/3.0	11.1	11.3	1.0	9.7	19/3.0	32.7	38.2	1.
	8788	18/3.0	20.0	23.3	1.2	12.5	17/3.0	43.1	51.1	1.
Cluster average			16.1	18.0	1.1	11.8		36.0	44.4	1.
Khukhundu	8687	−	−	−	−	−	21/1.5	32.1	50.7	1.
	8788	24/1.5	14.6	27.3	1.9	15.4	24/1.5	39.1	58.5	1.
Cluster average			14.6	27.3	1.9	15.4		35.8	54.8	1.
Deoria	8687	−	−	−	−	−	21/1.5	26.1	36.3	1.
	8788	27/1.5	12.3	21.0	1.7	18.3	26/1.5	37.8	55.8	1.
Cluster average			12.3	21.0	1.7	18.3		32.6	47.1	1.
District average			14.4	21.7	1.5	15.1		34.8	48.7	1.

		Kharif (hours per day)			*Rabi (hours per day)*	
Cluster	*Period*	*Available electricity*	*Running hours*	*No demand*	*Available electricity*	*Ru ho*
Ramnagar average	198689 up to 15 Aug	7.3	1.5	4.4	13.4	
Bansi average	198688 up to 15 Aug	11.9	1.2	10.1	15.6	2.
Basti average	198788 up to 15 Aug	6.6	1.5	2.8	7.8	2.
District average		8.6	1.4	5.8	12.3	3.

− Not available.

cusec Unit of flow equal to one cubic foot per second.

Running and no demand hours

Data on power availability and its use in the three districts is also presented in tables 8.6, 8.7, and 8.8. Because we did not have power availability and "no demand"7 data for Faizabad, only running hours are presented in table 8.6, on an annual basis. The power data for Basti and Deoria are not presented by year; rather, averages for the whole periods for which the data were available have been computed and are presented in tables 8.7 and 8.8.

The performance of the tube wells in terms of operating hours also falls far short of the expected 16 hours per day. The average operating hours per tube well per day come to 3.2 for kharif and 4.9 for rabi in Faizabad, 1.4 for kharif and 3.2 for rabi in Basti, and 1.8 for kharif and 2.4 for rabi in Deoria. Thus, the performance of all the districts in this respect is quite dismal. To simplify the comparison, we will merge the kharif and rabi figures and talk in terms of averages. This shows performance is best in Faizabad, where tube wells have run 4.1 hours a day compared with Basti's 2.3 hours a day and Deoria's 2.1 hours.

With regard to availability of electricity and no demand period, we have data only for Basti and Deoria. The availability of electricity is slightly better in Basti, where it is available 10.5 hours a day—about 66 percent of expected availability. In Deoria, it is available 9.9 hours per day—about 62 percent of expected availability. The no demand period is 7.3 hours a day for Basti and 6.5 hours a day for Deoria. Thus, no demand constitutes about 70 percent of available electricity time in Basti and 66 percent of available electricity time in Deoria.

No demand is high not only during kharif, but also during rabi. In Basti, it is 8.8 hours a day and in Deoria 6.2 hours. This comes to 72 percent of available electricity in Basti and 61 percent in Deoria. The high proportion of no demand during rabi is a puzzle. During kharif it is understandable to some extent as irrigation is supplemental to rain and rainfall is high in the eastern region.

During field work in the three districts, we found three main reasons for the high proportion of no demand during rabi. The first reason, low and high voltage, was a common phenomenon. In several cases it was found that, although electricity was available, voltage was so low that even a 12.5 horsepower (hp) motor would not run. This was a chronic problem in the Bhiti cluster of Faizabad district. In contrast, high voltage marred the running of tube wells in the Basti cluster of Basti district. Because there was no column for high/low voltage in the official forms, the tube well operators entered all such cases as no demand in official records.

The second reason was that operators generally recorded no demand whenever the tube well was not running. In several cases operators filling in several days' records at the time of a field visit were observed marking "no demand" whenever there was no irrigation recorded. In one case, there was no electricity at the time of a field visit and project staff were informed that the electricity line had not been in working order for the previous ten days, but the operator had marked all those days as "no demand." When asked why he had done so, the operator replied that, because there were heavy rains for the past several days, there was no question of any demand for water.

The third reason for the high proportion of no demand was that operators were dissatisfied with their meager salary, and it appeared to project staff that they compensated for their paltry salary by making extra money through unfair means and not recording all running hours. This task was further simplified because a large proportion of the meters installed in the pump houses were either not working or not working properly. The author suspects that the operators themselves destroyed the meters in several cases.

That aside, the fact remains that a large number of meters were not working. Our data reveal that in Basti, of twenty tube wells surveyed, fifteen meters were either not working or not working properly and in one case the meter had not been installed. In Deoria, of fifteen tube wells for which information was available, meters were out of order in five cases and in one case the meter had not been installed. In Faizabad, of twenty tube wells for which information was available, meters were out of order in six cases. Thus, in the three districts taken together, the meters were not functioning in about 51 percent of the tube wells.

Impact on groundwater market

It seems Shah is right in saying that localized, fragmented, village−based groundwater markets are more pervasive and important in terms of size, role, and implications than most studies show or policymakers imagine (Shah and Raju 1988, pp. A23A28). We will not review the literature on groundwater markets, as this was done by Shah in a recent paper (1989), but we would like to mention the findings of our earlier studies in this respect.

One such study, for which surveys were conducted during June and September 1981, found a lot of sales and purchases of groundwater from electric tube wells and diesel pumpsets. The study showed that, although a small proportion of households (14 percent) own tube wells or pumpsets in eastern Uttar Pradesh, a very high proportion of households (86 percent) purchase water.

On the other hand, in central and western Uttar Pradesh, a much larger number (35 percent) of farmers own tube wells and pumpsets, but relatively fewer households (about 65 percent) purchase water. What is significant, however, is that 72 percent of households from a sample drawn from three regions of the Indo−Gangetic Plains purchase water. In terms of area irrigated, the eastern region tops the list. Area irrigated per private tube well or private pumpset for the eastern region comes to 11 ha, followed by 6.5 ha for the western region, and 2.8 ha for the central region (Pant 1984, p. 198).

Another study, for which surveys were carried out in June 1983, found sales of large proportions of water from group tube wells owned and operated by very poor farmers. In Deoria (eastern Uttar Pradesh) and Vaishali (North Bihar), owners of group tube wells sold water to outsiders; our study revealed that more water was sold than was used by group members in Deoria as well as in Vaishali. In Deoria, twenty−five group tube wells irrigated 309 ha of land, of which 37 percent was held by members and 63 percent by nonmembers who purchased water. In Vaishali, twenty−five group tube wells irrigated a total of 346 ha, which contained 48 percent members' land and 52 percent outsiders' land.

A differential water rate was charged to nonmembers. In Deoria, members paid about 2 rupees (Rs) per hour, while nonmembers were charged Rs 6 per hour. In Vaishali, members paid Rs 2.20 per hour, while nonmembers were charged about Rs 10.20 per hour. This wide variation in water rates between Deoria and Vaishali may be due to the fact that, although all tube wells in Deoria were electric, 52 percent of tube wells in Vaishali were diesel−operated (Pant and Rai 1988, p. 65).

During field visits to the states of Orissa, West Bengal, Assam, and Bihar in January and February 1988, the sale and purchase of groundwater was routinely observed. The water was generally sold by affluent farmers to less affluent ones. At times, however, very small scheduled caste farmers, who obtained subsidies of up to 75 percent for the installation of pumps and tube wells, were seen selling water to their more affluent neighbors, who preferred to buy water rather than have their own pumps and tube wells.

A common feature found in all the eastern region states was the sale and purchase of water on an hourly basis. The rates varied from state to state and situation to situation and ranged between Rs 8 and Rs 25 per hour from a 5 hp pump or tube well (Pant 1991b, p. 276).

In the three districts that are the focus of this chapter, the water market is linked to the inability of World Bank tube wells to meet the demand of command farmers. Our survey revealed the existence of a tremendous water market in the command areas of the World Bank tube wells. About two−thirds of command farmers used other means of irrigation; only about one−fourth of these owned tube wells or pumpsets, while three−fourths purchased water from private tube wells and pumpsets. About 40 percent of users of other means purchased water from electric tube wells and about 34 percent from diesel pumpsets. In the purchase of water, whether from tube wells or pumpsets, Faizabad users of other means top the list; more than 55 percent of them purchase water from tube wells. The reason for this high percentage may be the perpetual problem of low voltage. Because of low voltage, the public tube wells with heavy horse−power cannot run, but low−horsepower private tube wells face no problems on this account.

The existence of such a big water market in the command areas of World Bank tube wells raises the question of the impact of World Bank tube wells on that market. We examined this question in our study of World Bank tube wells by comparing the number of private tube wells and pumpsets in the command areas at the time of World Bank tube well installation and their number at the time of the survey (September−October 1988). Data were available for only fifty−one tube wells of the fifty−seven studied and are presented in table 8.9.

Overall, there has been an increase in the number of tube wells (21.4 percent) and the number of pumpsets (28.1 percent) after the installation of the World Bank tube wells. Among the districts, the greatest growth has been in Faizabad, where pumpsets show a phenomenal rise of 80 percent, while tube wells increased by 36.5 percent. In contrast, Basti shows a negative growth, particularly for tube wells, whose numbers declined by 8.2 percent. The negative growth in Basti may stem from two factors. First, the World Bank tube wells in Basti are of recent origin with little irrigation experience—about one to two years in the area. Second, as mentioned above, 80 percent of the tube wells in the district are unmetered, which allows private water marketing from the World Bank tube wells, and hence a less obvious need for private tube wells and pumpsets.

In terms of the number of private tube wells and pumpsets per World Bank tube well command, Deoria has the largest number, about sixteen per command, followed by about twelve in Faizabad and eleven in Basti. Tube wells outnumber pumpsets per World Bank tube well command in Faizabad, while in the two other districts, pumps are well ahead of tube wells. The reason for the enhanced number of tube wells in Faizabad may be low voltage electricity, which, as previously mentioned, hampers the operation of high−powered public tube wells but not that of less powerful pri−

Table 8.9 Private tube wells and pumpsets at World Bank tube well installation, 1988 survey

District	*Number of World Bank tube wells*	*At installation*			*At present*			*Percentage increase or decrease*		
		Private tube wells	*Private pumpsets*	*Both*	*Private tube wells*	*Private pumpsets*	*Both*	*Private tube wells*	*Private pumpsets*	*Both*
Faizabad	20	93	65	158	127	117	224	+36.5	+80.0	+54.4
Per World Bank tube well	n.a.	4.6	3.3	7.9	6.4	5.9	12.2	n.a.	n.a.	n.a.
Basti	18	61	147	208	56	148	204	−8.2	+0.1	−1.9
Per World Bank tube well	n.a.	3.4	8.2	11.5	3.1	8.2	11.3	n.a.	n.a.	n.a.
Deoria	13	38	122	160	50	163	213	+31.6	+33.6	
	n.a.	2.9	9.4	12.3	3.8	12.5	16.4	n.a.	n.a.	n.a.

Per World Bank tube well										
Overall	51	192	334	526	233	428	661	+21.4	+28.1	+25.7
Per World Bank tube well	n.a.	3.8	6.5	10.3	4.6	8.4	13.0	n.a.	n.a.	n.a.

n.a. Not applicable

Note: Private tube wells are electricity−based; privat pumpsets are diesel−based.

vate tube wells. In the other two districts, farmers opted for pumpsets because of unreliable power supply.

The preceding examination points out clearly the tremendous development of private groundwater within the commands of the World Bank−assisted tube wells. The question is whether or not this development helps make groundwater accessible to the poorest of the poor farmers. The findings of our latest study, in the Bahraich and Faizabad districts of eastern Uttar Pradesh, indicate that the smallest farmers—those with landholdings of up to 0.4 ha—are the biggest beneficiaries of water markets and that they gain the least from the World Bank−assisted tube wells. Data show that, among these farmers, 64 percent in Faizabad and 53 percent in Bahraich irrigate their wheat crop with water purchased from owners of private irrigation facilities. Only 8 percent in Faizabad and 6 percent in Bahraich irrigate their wheat with water obtained from the World Bank−assisted tube wells (Pant 1991a, p. 52).

This means the inequity perpetuated by the World Bank tube wells is offset by the water markets. While public tube wells increase inequity, water markets reduce it by making water accessible to the poor. However, the question remains, "At what cost?"

Conclusion

The analysis shows the performance of the World Bank tube wells has been far below expectations. The poor performance has been on both technical and organizational grounds. On technical grounds, power availability and quality have been the principal problems, followed by infrastructural shortcoming and mechanical defects.

On the organizational side, the committees have not been functioning as hoped by the planners and designers of the tube wells. The problem has been worsened by the lack of concern of irrigation engineers with the operation and maintenance of the tube wells. The irrigation engineers, including the junior ones, lose interest in the tube well the moment its construction is complete. In most cases we found command farmers very hostile toward irrigation engineers.

Moreover, the agriculture extension wing has not played the desired liaison role in connection with the tube well program. Nowhere did we find coordination between the field staff of agriculture extension wings and the junior engineers of irrigation departments. Consequently, the coordination of these staff, envisaged in the program as a way of strengthening farmer organization in tube well commands, has remained in the blue print−stage in World Bank and state government documents and reports. The crux of the problem is that the World Bank program sees technical deficiencies as the main obstacle to the success of public tube wells. Consequently, the strategy it offers is heavily loaded with technical refinements. The preoccupation with technical improvements is so great that crucial management and institutional factors recede into the background.

Notes

1. Phase I refers to the pilot World Bank−supported scheme that initially comprised 500 new−design public tube wells and was started in April 1980 in twelve districts of the state. In the course of project execution, the number of tube wells installed was raised to 570. The supposed success of this pilot scheme led to its extension to forty−seven nonhilly districts in Uttar Pradesh under Phase II, which started in April 1983. Phase II involved constructing 2,200 new and upgrading 750 existing public tube wells. The tube wells were to be clustered in groups of twenty−five on dedicated power lines to ensure reliable power supply to the users.

2. "New" tube well refers to one constructed under the project with all new components. A "modernized" tube well is a renovated state tube well that was either an old well with a dilapidated distribution system or a new well without a distribution system, and that was part of a World Bank tube well cluster. A "dedicated" tube well refers to an old state tube well that falls within a World Bank cluster, receives only minor repairs, and is connected to a dedicated feeder line.

3. Other data on landholdings of study respondents:

	Faizabad	*Basti*	*Deoria*	*Overall*
Average size of landholding (ha)	1.0	0.9	0.8	0.9
Average number of				
Chaks in landholding per hh	2.3	2.2	2.4	2.3
Fields in landholding per hh	9.0	7.7	5.0	7.4
Chaks per ha in landholding	2.3	2.5	2.7	2.5
Fields per ha in landholding	8.7	8.5	5.9	7.9
Chaks in command area per hh	1.7	1.8	1.8	1.7
Fields in command area per hh	6.2	6.5	4.0	5.7
Chaks per ha in command area	2.5	2.5	3.0	2.6
Fields per ha in command area	9.4	9.1	6.6	8.0

4. The study (reported on in Pant 1984) examined three major canal irrigation systems and conventional state tube wells in the districts of Meerut (west), Lucknow (central), and Deoria (east). The total sample consisted of 868 farmers, of which 588 belonged to canal commands and 280 to the state tube well command. The survey for the study in the three districts was carried out during June − September, 1981.

5. The survey for the study (Pant and Rai 1985) was

carried out in June 1983 in the districts of Deoria (eastern Uttar Pradesh) and Vaishali (North Bihar) covering twenty−five community or group tube wells from each district

6. Cusec is a volumetric unit of flow equal to a cubic foot per second.

7. No demand refers to times when electricity is available but not requested.

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Management of Public Tube Wells in Uttar Pradesh

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State ownership and management of deep tube wells has been one way of extending the benefits of groundwater irrigation to small and marginal farmers who cannot own a well. The state of Uttar Pradesh has been a pioneer in investing in state tube wells to utilize abundant groundwater resources. These wells have been used to augment canal water supplies and to provide irrigation where surface irrigation is not feasible. The construction of state tube wells in Uttar Pradesh began as early as 193132 with a few hundred wells. The number increased to as many as 2,305 by 1950, 8,385 by 196667, and nearly 20,000 by 198384 (GOUP 1985, p. 4).

Deep tube wells capable of pumping 150 cubic meters of water per hour (m3 /h) and irrigating nearly 100 hectares (ha) were initially installed in the drier western region of the state, characterized by progressive farmers who ushered in the Green Revolution. In subsequent stages of the program, the installation of wells was extended to other parts of the state that were agriculturally backward with good aquifers but no likelihood of having substantial private investment in groundwater development.

The performance of state tube wells has been less than acceptable. In fact, their performance has deteriorated over time. The average number of hours of well operation during the year, a criterion used for assessing performance, fell from 2,304 in 197677 to 780 in 198384 (GOUP 1985, p. 2). The area irrigated per tube well, a related criterion, fell from 77 ha to 35 ha during the same period. This is against a planned level of operation of 2,500 hours a year and irrigation of about 100 ha per tube well. Largely as a result of low utilization, state tube wells have been a burden on the exchequer. In 198384, for example, the net loss from these wells was 678.72 million rupees (Rs) (GOUP 1985, p. 5).

The reasons for underutilization of state tube wells were found to be related to both supply and demand for well water for irrigation (Dhawan 1990, pp. 19293). The demand factors that influenced utilization were output prices and natural precipitation. Dhawan attributed higher utilization of the wells in the initial stages of the program to a greater proportion of them being located in the drier western region of the state. The supply of water from the tube wells was influenced by both internal and external factors. The internal factors that had a bearing on utilization were the proportion of wells that were not completely developed, that is, without proper distribution systems, the decline over time in the water output of wells, and the lack of timely maintenance and repair. External factors that impinged on the ability to supply water were erratic supply of electric power and absence of law and order that led to frequent theft of equipment and the inability to enforce rotational water distribution.

The state has undertaken to improve the performance of public tube wells by alleviating problems associated with water supply. An internal World Bank report found that inadequate and erratic power supply was the most limiting factor in im−

proving the utilization of wells. Other factors that contributed to poor utilization were poorly built and maintained conveyance systems, frequent absence of operators, inability to repair mechanical and electrical defects within a reasonable time, and the absence of a workable water allocation procedure.

The state initiated a program to construct state−of−the−art tube wells in the early 1980s with the assistance of the World Bank. The design and operating procedures of these tube wells incorporated innovations aimed at overcoming the limitations of older state tube wells. The essential features of the new wells were guaranteed power supply, well laid out and tamper−proof conveyance systems, automatic well operation, an improved water allocation system, and a siting of the wells that facilitates timely maintenance and repair.

The construction of these wells, generally referred to as "World Bank tube wells," was done in two phases. In Phase 1,570 tube wells with capacities of 150, 225, and 300 m3 /h were built in twelve districts of Uttar Pradesh, four each in the western, central, and eastern regions. After testing the innovations in the first phase. Phase II of the program, which is complete now, was initiated. It involved construction of 2,000 tube wells with a capacity of 150 m3 /h, 200 wells with a capacity of 300 m3 /h, thorough modernization of about 100 old state tube wells, and repairs and connection to dedicated power lines of another 650 old state tube wells.

The World Bank tube wells have been operating for a sufficiently long time to examine whether the innovations introduced in their design and operations have been beneficial. This study was undertaken with the primary purpose of understanding how these technical and operational innovations have influenced the day−to−day management of public tube wells. Specifically, the objective is to investigate how each innovation has contributed to overcoming the problem it was designed to alleviate, and to assess the impact of the package of innovations on the overall performance of World Bank tube wells.

The approach was to analyze the working of a few wells using me methodology of case studies. The Campierganj and Pharinda tube well clusters in the Gorakhpur division of Uttar Pradesh were chosen for the study, which was conducted in December 1988 and January 1989 during the *rabi* (dry) season, when much of the irrigation takes place in this part of the state. Within these two clusters, distribution systems of four tube wells (nos. 211 and 212 in Pharinda and nos. 244 and 245 in Campierganj) were examined, and the rotational water allocation records of two of them (nos. 212 and 244) were scrutinized.

Innovations in World Bank tube wells

The World Bank tube wells are distinctly different from the older state tube wells because of their technological superiority. Significant modifications made in the design and operations of state tube wells were incorporated in the World Bank tube wells with the aim of reducing water losses, facilitating automatic operation of wells, improving water allocation procedures, providing facilities for better maintenance and repair, and facilitating speedy construction of tube wells. A World Bank tube well built in Phase II with tested technology is referred to as an improved standard tube well system in the plan documents.

A World Bank tube well system is composed of a deep tube well, mostly of a 150 m3 /h capacity, a pump of less than 30 horsepower (hp), an elevated tank from which water is fed into two or four loops depending on the well capacity, sensors in the tank that enable an electronic system to operate the pump automatically to maintain operating head, buried pipelines, tamper−proof outlets that serve 3 to 5 ha each, and dedicated power supply from a feeder line. The features of a World Bank tube well that distinguish it from the older state tube wells and the reasons for incorporating these features are presented below.

Dedicated power supply

Inadequate and unreliable power supply combined with voltage fluctuations was considered the major constraint to improving state tube well utilization. Although the number of wells increased over the years, the number of hours of power made available to state tube wells went down from 319,000 in 197677 to 154,000 in 198384 (GOUP 1985, p. 6). While the hours of availability put a ceiling on the hours of operation, fluctuations in voltage affected proper functioning of pumps and contributed to frequent motor burnouts. Uncertain power supply also made the implementation of a rotational water distribution system difficult.

A World Bank tube well is connected to an 11 kilovolt (kv) feeder line. The Electricity Board has undertaken to supply power in these lines for at least sixteen hours a day. The additional investment

in dedicated power supply was found to be economically viable, even if reliable supplies of electricity were increased by only one hour a day.

Buried pipelines and tamper−proof outlets

Inadequate and poorly maintained distribution systems in state tube wells result in high conveyance losses and inability to distribute water equitably over the whole command. The average total length of lined and unlined channels per state tube well is 3.2 kilometers (km) against a requirement of 5 to 6 km (GOUP 1985, p. 11). Water from state tube wells is distributed through lined channels over commands sometimes as large as 150 to 200 ha. As a result, the time required to irrigate a hectare of land was almost twenty−three hours for a well of 150 m3 /h capacity in 198384 (GOUP 1985, p. 4).

An elevated tank in the World Bank tube well system divides the water supply into two or four streams depending on the design discharge of the well. In systems of 150 m3 /h capacity, two loops take off from the tank to cover approximately 50 ha each. Each loop is an underground polyvinyl chloride pipeline with eight to twelve outlets, each serving approximately 5 ha. The outlet is an alfalfa valve set in brickwork. It is designed to be tamperproof as it requires a key for opening and closing.

Automatic operation of the tube well

The state tube well operators are frequently absent from the tube well site, which makes full utilization of limited power supply difficult. The problem is acute, particularly as most of the operators do not live in the vicinity of the wells. The control they exercise over well operation also permits them to collect bribes from users.

The elevated tank in the World Bank tube well system, which maintains the operating head in the piped distribution system, enables automatic operation of the wells. Operating head is maintained by sensors in the tank that activate the power supply to the pump in response to changes in water level. The automatic operation of the tube well is intended to overcome the problems of unsatisfactory synchronization of the operators' presence at well sites, the availability of power, and demand for irrigation. In a World Bank tube well command, users can irrigate their fields even in the absence of the operator if power is available.

The World Bank tube well operator works part−time and is resident of one of the villages served by the tube well. He is paid nearly Rs 300 a month for his services.[1] His duties include reporting any breakdowns, making certain that the rotational system is observed, maintaining records of daily operations, billing users, and acting as depository for the outlet key.

Equitable water allocation

In a state tube well, a rotational schedule is prepared by the revenue officer and irrigation is rotated among farmers belonging to an area known as *thok.* The leader of the thok committee is responsible for making sure that rotation is followed. But there are problems. The groups are formed without consideration of the command of an outlet. The rotational system is generally not implemented; the leaders allocate water arbitrarily or the operators themselves play a strong role in deciding who receives water.

A rotational system known as *osrabandi* is used for allocating water among users of a World Bank tube well. The well command is divided into smaller units to be irrigated by rotation. The command of each loop is divided into seven parts, each to be irrigated on a given day of the week. Water rights of farmers in each area, expressed in hours of water supply, are set by the Irrigation Department in proportion to farmers' landholdings in the command.

The rotation within a day area is decided by a day area committee, composed of three farmers who have land in the day area. The day area committee is considered superior to the thok committees of the state tube wells because membership is limited to those who have land in the day area, thereby reducing the chances of power groups controlling the committee. Representatives from the day area committees form a *kshetra din* committee, which oversees the overall functioning of the tube well.

Siting tube wells in clusters

State tube wells break down frequently, and there is undue delay in repairing them. Although the norm set by the Irrigation Department states that maximum times to be taken for repairing burned−out motors, pump defects, and starter defects are three, seven, and one day, actual times taken are much longer (GOUP 1985, p.9). Besides the usual laxity of the staff, the lack of sufficient maintenance funds also contributes to poor performance.

The World Bank tube wells are sited in clusters of twenty−five, each cluster serving approximately 2,500 ha. The siting of tube wells in clusters serves two functions: dedicated supply of power and easier access for maintenance. Each cluster has a facility to house the staff and to provide meeting rooms for farmers and the Irrigation Department staff. A Junior Engineer is supposed to reside at the cluster to be able to reach the systems quickly for maintenance and repair.

The innovations incorporated in the design and operation of the World Bank tube wells can be classified as technical or operational in nature. Technical innovations are those in which an improved technology is used to alleviate a problem, whereas operational innovations are management measures that seek to improve the situation through better organization. Technical innovations are built into the design of the physical system and their implementation often involves construction; operational innovations involve better organization of users and managers. Automatic well operation and buried pipelines belong to the first category, and improved water allocation procedures belong to the second. The two categories often complement each other; before we discuss how they do, we examine the overall performance of World Bank tube wells.

Performance of World Bank tube wells

The World Bank tube wells that were constructed in Phase I to test innovations also suffered from underutilization (UPDESCO 1985, pp. 11922). The UPDESCO study of tube wells in seven districts revealed that in all the districts the share of land in the command irrigated by the tube wells was low, even during the rabi season when much of the irrigation takes place. Highest coverage in terms of the percentage of cultivable command area irrigated was 88 percent in Aligarh district. Except for Lucknow district, where the coverage was 59 percent, coverage of the cultivable command area remained less than 50 percent in all other districts.

The low coverage of the cultivable command area was the result of only a small percentage of the command farmers making use of tube well water; this percentage ranged from 25.7 percent to 70.2 percent in the various districts during the rabi season. The reasons given by farmers for not using the tube wells were location of their fields above the outlets, defective outlets, power failures during their turns, and no need for irrigation because of waterlogging during the *kharif* (wet) season (UPDESCO 1985, p. 123).

Another study of World Bank tube wells in Lucknow, Aligarh, and Varanasi districts also showed that well utilization was far below capacity and performance was falling over time (Singh and Satish 1988, p. 25). Between 1981 and 1987, the average number of hours of operation per well in these districts was 1,440, 1,880, and 2,031 respectively. There was a decline in the discharge of wells ranging from 1 percent to 2 percent a year between 1981 and 1987. And the time required for irrigating a unit of land was found to be increasing at the rate of 7 percent a year during the same period.

The two clusters of World Bank tube wells in the Gorakhpur division were found to be performing satisfactorily when the criterion was area irrigated, but performance was unsatisfactory when hours of pumping was the criterion. The wells in Pharinda cluster irrigated on average between 55 and 64 ha during the rabi season and between 19 and 27 ha during kharif from 1985 to 1988 (table 9.1). The average area irrigated by the wells in

Campierganj cluster, which were more recently commissioned, was much less. The wells are expected to irrigate 60 percent of the net area of 100 ha during rabi, 28 percent in kharif, and 6 percent of perennial crops and to be operational sixteen hours a day during the peak season. Sensitivity analysis showed that pumping for eight hours a day would be required during the peak for the project to be viable.

The average number of hours of pumping in both clusters has not exceeded seven hours a day (table 9.2). The wells pumped water for longer hours during rabi than kharif during all the years. A consequence of low pumping hours and fairly high net irrigated areas is inadequate provision of water. On average, the tube wells have provided between one and two waterings to all crops. It would be difficult for any farmer in the commands of World Bank tube wells to cultivate crops, particularly during the rabi season, without access to an additional irrigation source.

Farmers seem to be using sources other than World Bank tube wells even for planting crops. The net area irrigated by World Bank tube wells during the rice and wheat planting periods is far below the net area irrigated during the season. Most farmers plant rice between July 15 and August 15 and wheat between November 1 and December 15.

Table 9.1 Hours of operations and area irrigated in two clusters of World Bank tube wells, Gorakhpur division

	Campierganj			*Pharinda*		
Month/year	*Total hours of operation*	*Area irrigated (hectare)*	*Number of hours per hectare*	*Total hours of operation*	*Area irrigated (hectares)*	*Number of hours per hectare*
1985						
NovDec	–	–	–	301	37.86	7.95
1986						
JanMar	–	–	–	445	46.76	9.52
AprJun	–	–	–	277	20.27	13.67
JulSep	–	–	–	230	17.95	12.81
OctDec	–	–	–	385	33.60	11.46
Total	–	–	–	1,337	118.59	11.27
1987						
JanMar	212	16.74	12.67	518	25.92	16.90
AprJun	281	19.70	14.27	438	25.92	16.90
JulSep	56	4.11	13.62	247	14.93	16.55
OctDec	434	31.67	13.70	476	37.50	12.69
Total	983	72.21	13.61	1,679	120.81	13.99
1988						
JanMar	546	39.06	13.98	671	46.05	14.57
AprJun	308	19.22	16.02	315	18.83	16.73

JulSep	73	12.96	5.63	109	5.62	19.40
OctDec	462	33.82	13.66	493	39.01	12.64
Total	1,389	105.86	13.22	1,588	109.51	14.50
Average (198688)	1,186	88.64	13.42	1,535	116.04	13.26

− Not available.

Source: Fortnightly reports, World Bank tube wells, Gorakhpur Division, Uttar Pradesh.

Table 9.2 Power availability, hours of operation, and reasons for closure of wells in two clusters of World Bank tube wells, Gorakhpur division

	Campierganj (hours/day)				*Pharinda (hours/day)*			
Month/year	*Power available*	*Operation*	*Civil fault*	*No demand*	*Power available*	*Operation*	*Civil fault*	*No demand*
1985 NovDec	−	−	−	−	16.91	6.54	2.20	8.17
1986								
JanMar	−	−	−	−	12.82	4.94	1.01	6.87
AprJun	−	−	−	−	10.14	3.04	0.52	6.58
JulSep	−	−	−	−	6.37	2.50	0.30	3.57
OctDec	−	−	−	−	12.38	4.18	1.21	6.99
1987								
JanMar	7.83	3.59	1.27	2.97	12.27	5.76	0.78	5.73
AprJun	7.55	3.09	0.74	3.73	9.27	4.81	0.54	3.92
JulSep	5.79	0.61	0.33	4.86	8.84	2.68	0.47	4.89
OctDec	10.11	4.72	0.50	4.89	9.86	5.17	0.54	4.14
1988								
JanMar	11.45	5.93	1.26	4.25	13.86	7.37	0.26	6.22
AprJun	10.32	3.38	1.15	5.78	11.21	3.42	0.40	7.38
JulSep	8.49	0.79	1.66	6.03	5.77	1.18	0.38	4.21
OctDec	11.47	5.02	1.32	5.13	10.03	5.36	0.67	4.00

− Not available

Source: Fortnightly reports, World Bank tube wells, Gorakhpur Division, Uttar Pradesh

In Pharinda cluster, for example, the net area irrigated during wheat planting in 1987 was only about 23 ha. Similarly, during rice planting, only 6.9 ha were irrigated. Other areas either did not require irrigation or were irrigated from other sources. Although one or two waterings are available from the World Bank tube wells, the wells are far from being certain sources of water.

But how does the performance of World Bank tube wells compare with that of state tube wells? Available information seems to indicate that World Bank tube wells perform better. Comparing the extent of irrigation in terms of the coverage of cultivable command areas by state and World Bank tube wells shows that the coverage by World Bank tube wells was distinctly higher during both rabi and kharif (UPDESCO 1985, p. 118, Table 8.1). A comparison of area irrigated by all state tube wells with that of a few World Bank tube wells in Lucknow district shows that, during 198283 and 198384, the area irrigated by the World Bank tube wells during kharif was nearly double that irrigated by the state tube wells. As expected, the extent of irrigation was higher in the rabi season.

Although the World Bank tube wells operate at a higher level of capacity utilization compared with the older state tube wells, they have failed to produce the expected benefits and also to meet the irrigation needs of users. Significantly higher levels of capital investments seem to have brought about less than expected improvement in performance.

Innovations and World Bank tube well performance

The development of World Bank tube wells involved identification of bottlenecks in the older systems, development of innovations to overcome these bottlenecks, and incorporation of these innovations in the design and operation of the wells. But the shortcomings in the process were overemphasis on technical solutions, failure to look at the innovations as a system, and excessive faith in the ability of users to organize themselves for managing water distribution. In the haste to find technical solutions to each problem, more basic but less apparent reasons for the poor performance of state tube wells were ignored.

Three principal reasons can be identified for the poor performance of state tube wells in Uttar Pradesh. First, the design and construction of the tube wells constrained performance. Wells were prone to breakdowns and the distribution systems were inadequate to supply water equitably throughout the command. Performance targets were also unrealistic. Second, there is lack of accountability. The operator is not accountable to superiors or to users. He exercises considerable discretionary power in allocating water that is priced at less than the value it yields through irrigation. Nor is the Irrigation Department accountable to users, with the result that there was little reason for them to strive for improved performance. Third, users failed to organize themselves to make demands on the managers or to distribute water equitably among themselves. A related problem is that law and order are not enforced effectively to protect public property or to make individuals respect regulations. And social pressure for individuals to conform to acceptable norms of behavior are not strong enough.

Measures to remedy these different problems may differ in the degree to which they contribute to better overall performance, but it is essential that all problems be taken care of to improve performance. Although the system cannot be improved by eliminating any single problem, a measure introduced to rectify one problem may reduce the intensity of another. For example, organizing users can lead to improved performance of older tube wells without major improvements in physical structure. But there are limits. Percolation losses, for example, can only be reduced so far without technical solutions. Similarly, a technically superior system, such as the World Bank tube well, which reduces the need for an operator or requires only small groups of users to work together, reduces the effort required for farmers to organize themselves, thereby facilitating evolution of user organizations. Therefore, technology/capital and organization are, to a limited extent, substitutes in improving performance of tube wells.

The innovations in World Bank tube wells were geared toward meeting deficiencies in the physical structures of state tube wells. The result is a system that is technologically far superior to its forerunner. A technically superior system with strong linkages between different components facilitates better management, but it is also more predisposed to breakdowns; failure of any one component has far more impact on the whole system. The weakness or failure of system components resulted in less than the potential benefits being produced by World Bank tube well innovations.

Automatic well operation

Automatic well operation makes World Bank tube wells less dependent on operators but more vulnerable to the misconduct of users. It is a beneficial innovation when allocation rules are adhered to and the distribution system is without leakages, but it encourages anarchy when users are not disciplined—they need only open the outlets to turn on the pump. The operator of well no. 212 told us that outlets 5, 6, and 10 were always kept open by the farmers who have land in the command of these outlets. He could exercise little control over them.

Though designed to work automatically, the tube wells do not always do so because of lack of timely repair (table 9.3). The automatic operation is based on an electronic mechanism that is fairly simple and cheap to repair but that nonetheless requires a trained electronics mechanic. There was only one mechanic capable of doing these repairs in the Gorakhpur division. The mechanism had not

Table 9.3 Information on commands of four public tube wells

Item	*Well no.211*	*Well no. 212*	*Well no. 244*	*Well no. 245*
Cluster	Pharinda	Pharinda	Campierganj	Campierganj
Automatic Operation	Not Working	Not working	Working	Working
Loop inspected	A	A	A	A
Number of outlets	9	10	13	9
Number in working condition	9	4	13	3a
Discharge	−	−	−	28,378 gallons per hour
Number of tube/open wellsb	2/2	5/0	26/16	28/16
Crops and their condition	Banana, wheat; poor condition	Wheat, mustard, banana, vegetables; fairly good condition	Wheat, sugarcane, mustard, vegetables; fairly good condition	Banana, potato, berseem, vegetables; fairly good condition

−Not available

a.The operator said that six of eight outlets in the other loop were not in working condition; three could not be closed and the other three could not be opened.

b.Not very accurate; based on information provided by the operator and farmers met during the study.

Source: January 1989 survey of public tube wells.

been working in wells no. 211 and 212 for two to three months. It was repaired in well no. 245 on the day of our visit, after being inoperative for about a month. Operation of many World Bank tube wells thus continues to be at the mercy of the operators.

Buried pipelines and tamper−proof outlets

Underground pipelines reduce water losses and convey water even to the fringes of the command area. But the outlets are not tamper−proof as they are designed to be.2 The key is actually a wrench. Farmers can have their own key fabricated to open the outlets without breaking them. And many are broken. One of the outlets in well no. 211 was completely broken and the pipe in the loop was plugged with a banana stump. Barring superior technology or higher investments, only a strong farmer organization or strict regulation enforcement can keep users from tampering with the outlets.

There was considerable evidence that outlets were being tampered with frequently. They were in poor condition in two of the four wells examined, wells no. 212 and 245. The condition of outlets is not a result of aging—one of these wells had been operating less than two years. The majority of the outlets of these two wells were not in working condition. Some of them could not be closed at all.

Dedicated power supply

This feature, which is beyond the control of the Irrigation Department, has the potential of severely constraining capacity utilization. Dedicated power supply to the two clusters has been less than the planned sixteen hours a day, but the supply for World Bank tube wells is far better than the electricity supply for state tube wells. The average duration of electricity supply was 8.87 and 10.36 hours a day in Campierganj and Pharinda clusters respectively (see table 9.2). However, in none of the wells were the hours operated close to the hours of power availability. Based on similar data, it was found that power supply was also not a constraint for operation of Phase I tube wells in most of the districts (UPDESCO 1985, p.125).

Although, in the aggregate, power availability does not seem to be a constraint to well operation, data on daily power supply show something different. Daily operation records of wells no. 212 and 244 showed that there were many days on which

electricity was not available or the pump was shut down because of hydroelectric defects (table 9.4). In well no. 244 for example, electricity was not available for nineteen and twenty days during October and November 1987. The same well was shut down because of lack of electricity for twentyfive days in September and all of August in 1988. Although the fortnightly average for the clusters might show power being available for a certain number of hours daily, there can be interruptions in power supply to individual wells that last for several days.3 Such interruptions make the system unreliable for users.

Osrabandi

Of all World Bank tube well innovations, osrabandi is perhaps the most difficult to implement. Implementation involves organizing users—a step that should be taken in the planning stage. The key to successful implementation is the establishment of day area and kshetra din committees that work.

The Irrigation Department has so far focused only on the preparation of osrabandi records. The preparation of the record involves identification of beneficiaries and their landholding in the command, measurement of all plots, and division of the command into day areas to be irrigated on a particular day of the week. The day area committees are then set up by the Junior Engineer in charge of the cluster. That an Assistant Engineer on the project observed that establishing committees in the command of a well takes only one Junior Engineer day reflects the low importance given to the organizations that are to manage the system.

Although the design of World Bank tube wells facilitates farmer organization, the Irrigation Department, through its lack of effort to organize the farmers, has squandered the potential benefits.4 Osrabandi records, which are a prerequisite for implementation of the rotational system, were prepared for tube wells only in Pharinda cluster. Day area committees had also been set up in that cluster. None of this had been initiated in the other cluster, even although the wells had been operating for two years. The Irrigation Department is willing to give water on particular days to groups of "like−minded people," but no groups have come forward to take the responsibility of distributing water.

There is ample evidence to indicate that osrabandi was not being followed in the four wells studied. Day area committees only existed for wells no. 211 and 212. An examination of daily water deliveries and osrabandi records of tube well no. 212 indicated that plots were not irrigated on designated days. Table 9.5 shows days of irrigation for areas designated to receive water on Monday, Friday, and Saturday in the command of this well. The number of irrigations given to different plots also varies widely.

Osrabandi has its own limitations; it works best when there is excess demand, unless water rights can be traded. The system breaks down when there is lack of demand in an area that is supposed to receive water on a particular day. The dilemma is

Table 9.4 Causes and duration of closure of wells, 198788
(*number of days closed*)

	Well no. 212, Pharinda cluster				*Well no. 244, Campierganj cluster*			
Month	*No power*	*No demand*	*Civil fault*	*Hydroelectric defect*	*No power*	*No demand*	*Civil fault*	*Hydroelectric defect*
Oct 87	3	23	0	2	19	11	0	0
Nov 87	11	6	0	1	20	7	0	0
Dec 87	9	0	0	0	1	6	0	0
Jan 88	0	13	0	0	4	0	0	0
Feb 88	0	7	0	0	8	0	0	0
Mar 88	0	11	0	13	16	0	0	0
Apr 88	−	−	−	−	21	0	0	0
May 88	−	−	−	−	22	0	0	0
June 88	−	−	−	−	0	0	0	0
July 88	−	−	−	−	0	12	19	0
Aug 88	−	−	−	−	31	0	0	0
Sept 88	−	−	−	−	25	3	0	2
Oct 88	4	11	0	2	−	−	−	−
Nov 88	7	2	0	0	−	−	−	−
Dec 88	0	6	0	1	−	−	−	−

−Not available

Source: Daily records of irrigation of wells no. 212 and 244

Table 9.5 Water allocation in well no. 212 of Pharinda cluster

Plot number	*Number of irrigations provided*		Irrigations provided each day of week							
	From October 1, 1987 to March 31, 1988	From October 1, 1987 to December 31, 1988	Monday	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*	*Sunday*	Area irrigated (ha)
Outlet 1, Loop A, Monday area										
860	1	2	−	1	−	−	−	2	−	0.45
861	2	−	−	1	−	−	−	−	1	0.21
862	1	−	−	−	−	1	−	−	−	0.44
865	−	−	−	−	−	−	−	−	−	0.05
867	5	3	1	3	−	3	−	−	1	1.09
869	2	1	−	1	−	−	−	1	1	0.51
870	10	6	2	1	2	4	1	3	3	2.23
874	2	2	−	−	−	1	1	2	1	0.29
876	6	5	1	2	−	1	2	2	3	0.70
877	2	1	−	1	−	−	−	1	1	0.50
878	−	−	−	−	−	−	−	−	−	0.06
880	7	7	2	3	2	1	1	1	4	2.83
881	−	−	−	−	−	−	−	−	−	0.06
892	2	8	−	1	1	2	−	3	3	0.48
893	5	3	1	1	1	2	1	−	2	0.98
912	6	1	1	−	3	1	2	−	−	0.72
916	1	3	3	−	−	1	−	−	−	0.88
917	2	2	−	1	−	1	−	1	1	0.97
918	1	1	1	−	−	−	−	−	1	0.33
919	−	2	−	1	1	−	−	−	−	0.72
920	5	−	3	−	−	−	−	1	1	0.09
914	2	3	2	2	1	−	−	−	−	0.58
932	2	5	−	1	1	2	1	2	−	0.65

934	1	−	−	−	−	−	−	−	1	0.10
935	−	1	−	−	−	−	1	−	−	0.17
936	1	−	1	−	−	−	−	−	−	0.33
Outlet 5, Friday area										
835	1	−	−	1	−	−	−	−	−	1.11
Outlet 6, Saturday area										
843	2	1	1	−	−	−	1	1	−	0.84
829	1	−	−	−	−	−	−	1	−	1.32
834	1	1	−	−	−	−	1	2	−	1.94
842	4	2	−	1	−	1	−	−	1	1.14

−No irrigation provided.

Source: Daily records of irrigation of tube well no. 212.

whether to close the well or to supply water to others who may be demanding it. If the latter course is chosen, a list needs to be maintained so that irrigation can be given based on some other criteria, perhaps on a first−come, first−served basis.

Full utilization of well capacity requires that the operator revert back and forth between two allocation procedures depending on the extent of demand in the area to be irrigated on a particular day. Ideally, when there is demand in the designated area, osrabandi should be followed; when there is none, water should be allocated on a first−come, first−served basis to those who demand it. It appears that the Irrigation Department has instructed operators that water should not be released to anyone else when there is no demand in the designated area. As osrabandi is not followed, water distribution seems arbitrary.

Part−time operators

The part−time operator is probably the weakest link in the system. A complex mix of factors makes the operator's role in the system precarious. The work expected from the part−time operator is a lot more than he is compensated for; his duties take more than the three hours that he is expected to work daily. But at the same time, his role in well operation is being decreased through automatic well operation.

Changes in tube well technology have affected the part time operator's role. One technical feature of the tube well has made him more accountable to the Irrigation Department. A meter records hours of pumping, and the operator must account for all these hours. However, many meters do not work. Some are alleged to have been damaged deliber−

ately. The operator thus has the opportunity to use the tube wells for his own benefit.

The operator must be able to exercise enough control to ensure that only designated areas are irrigated and that discipline is enforced, but this control must not be strong enough to permit the operator to make water allocations to his benefit. But because farmer committees have not taken charge of water distribution or overall management of tube wells, the operators continue to exercise control over how water is distributed in the command.5 There is circumstantial evidence that operators can and do use tube wells for their own benefit. They can favor friends by not reporting, or under−reporting, the area irrigated by them and by levying those charges on others. They can account for all the hours operated to the satisfaction of the Irrigation Department and yet indulge in malpractice.6

The strongest indication that operators may be engaged in illegal earnings is that, despite the fact the job is tedious, calls for long hours, and pays poorly, there is considerable demand for it.7

Socioeconomic performance of tube wells

The socioeconomic concerns in tube well performance are of two types. The first has to do strictly with performance, that is, how effective tube wells are as sources of irrigation and whether the benefits of irrigation are extended to different groups of farmers in an acceptable manner. The second concern is for how the World Bank tube wells affect alternative institutions of groundwater development—institutions that could yield more desirable socioeconomic performance.

Concerns about equity

Although public ownership and management of deep tube wells may provide access to water for those not able to benefit through private investment, there is considerable scope for inequity in how water is distributed and priced in the design and operation of World Bank tube wells. Inequity could arise because of nonobservance of rotational water distribution, procedures used in charging for irrigation, and inadequate maintenance of distribution systems.

That osrabandi is not observed and water is distributed in a seemingly arbitrary manner has already been established. One can only presume that the socioeconomic standing of users matters in how water is distributed.8

The procedure followed for water charges, in addition to causing inequality in pricing, rewards inefficient use and provides the operator an opportunity to exploit the system for profit. Users pay different charges per unit of water depending on how they have irrigated their fields in relation to others on the same day. The procedure encourages inefficient use of water; a user who spreads water over a larger area pays a higher price per unit of water than one who applies the same quantity of water to a smaller area. This would be the case unless the hours of supply to each farmer are in proportion to the land irrigated.

Leaks in the distribution system result in wastage of water and inequity in irrigation charges. The user is billed on the premise that 75 m3 /hr is delivered at the outlet. When there are leakages or illegal opening of outlets, the user who has contracted for water receives less than he is paying for.9

The charges paid by farmers vary widely. The charges paid in well no. 244 for irrigating wheat averaged Rs 58.6 per hectare but ranged from Rs 7.4 to Rs 178.8 per hectare. The user can never be certain of the charges for irrigation on any particular day. The charge depends on who else is irrigating on the same day and the quantity of water they apply to a unit area. Uncertainty about water charges may be one of the factors contributing to lack of demand for water from World Bank tube wells.10

Concerns about efficiency

Efficiency concerns include the adequacy of water control of World Bank tube wells, the effect of the wells on private investment, and the choice of power source in private wells.

Benefits from investment in deep tube wells accrue in the form of increased production resulting from irrigation. Although hours of pumping or area irrigated are apparent measures of performance, the true indicator of performance is the degree of water control the tube wells can offer users. Water control determines the extent to which agricultural production can be increased. Tube wells must deliver the required degree of water control to be productive.

If the control offered by the wells falls below a threshold level, even without the uncertainty associated with price, farmers prefer to invest in their own wells or purchase irrigation services from other wells, albeit at a higher cost. Farmers invest in their own wells to develop ancillary sources of supply when the supply of water from public wells is not reliable. As public tube well performance in water control deteriorates, private investment begins to take place, demand on public tube wells is reduced, and public investment is rendered unproductive.

Low water control continues to prevail in the commands of World Bank tube wells, necessitating private investment. A number of private wells were functioning in the commands of the tube wells we studied (see table 9.3), including some that were not there before the public tube wells were installed. A new private well was being installed about 100 meters from well no. 244. Sales of irrigation services from private wells were prevalent, and water from these wells was being priced at Rs 10 to 12 an hour for the discharge from a 5 hp unit. Yet the private wells were not fully utilized because users prefer the cheaper public tube well water when available. Informal inquiries indicated that the wells are used as little as ten hours a month during the rabi season. Thus, both public and private investments remain underutilized.

Apart from poor management, one reason for low water control by the World Bank tube wells may be that commands are too large. A command area is planned based on the assumption of irrigating one hectare from an outlet in fifteen hours and pumping for sixteen hours a day. The economic optimum command could be less than what is technically feasible as the complexity of managing a larger area and greater number of users increases with an expanded command. This is illustrated by the fact that tube wells of 225 and 300 m3 /h capacity have barely irrigated more land than tube wells of the lower capacity (Pant 1989). Doubling the well capacity to 300 m3 /h resulted in less than double the area irrigated (Datye and Patil 1987, p. 224, Tables 8.4 and 8.5). The command is also planned assuming a requirement of 3,000 m3 /ha during rabi. But the existing practice is to apply as much as 2,000 m3 in a single irrigation, assuming a discharge of approximately 135 m3 /h.

The irrigation provided by World Bank tube wells so far appears to be no better than in surface irrigation projects. The degree of water control offered does not appear high enough to increase productivity significantly. A World Bank Staff Appraisal report estimates the anticipated incremental income in eastern Uttar Pradesh at Rs 1,500/ha. Limited evidence indicates that the actual returns may be far less. The estimated incremental income in the commands of two wells amounted to less than Rs 1,000/ha in one and only Rs 450/ha in the other (Satish 1989, p. 3). Productivity gains from irrigation may be traded off by attempting to increase the coverage of public tube wells.

World Bank tube wells, depending on the water control they offer, influence the operation of private wells. Irrigation using water purchased from private wells declined in the commands of Phase I tube wells. In some districts, nearly two−thirds of the irrigation by World Bank tube wells merely replaced other sources of irrigation (UPDESCO 1985, p. 32, Tables 3.7a and 3.7b). Public tube wells may benefit poorer farmers who used to buy from private wells by placing a limit on how much private well owners can charge for their service. But when they are sited in areas served by a significant number of private wells, they merely replace one source of irrigation with another.

World Bank tube wells also influence the choice of energy for lifting water in private wells. Well owners in the tube well commands generally switch from electricity to diesel after installation of World Bank tube wells, as the charge for electricity in Uttar Pradesh is fixed based on the horsepower of the motor. With low anticipated capacity utilization as private wells become only an ancillary source of irrigation, well owners opt for a source of fuel whose cost is variable rather than fixed. Electricity is not economical if operating hours are not long enough to reduce the average cost below that of diesel−driven pumps. This increases the irrigation costs for farmers although, from the social point of view, use of diesel may be desirable because the true cost of irrigation using electric power is considered to be higher than with diesel (Bhatia 1988, pp. 3137).

Despite apparent inadequacies in water supply from the tube wells, the major reason for their low operation is lack of demand. The period of no demand often exceeded the hours of operation in the two clusters (table 9.2).

Several explanations can be offered for lack of demand. One, farmers may feel that irrigation is not remunerative at prevailing prices. Two, the supply of water from public tube wells is so unreliable that farmers rely on their own well or buy from a neighbor. The continued operation of private wells in public tube well commands supports this hypothesis. Three, the uncertainty about the price of water discourages farmers from buying it. As private investments continue to be made in the commands of public tube wells, the most plausible reason for lack of demand for public tube well water is the uncertainty associated with both supply and price. But low demand for irrigation in general in this region should not be overlooked as a reason for low demand for water from World Bank tube wells.

Conclusions and issues for further research

Although World Bank tube wells perform better, in area irrigated and hours of pumping, than state tube wells, their performance is far below their potential. Their superior performance is attributable primarily to their technical features and newness. But their full potential has not been realized because there have been no significant improvements in their management by the Irrigation Department in coordination with users.

A World Bank tube well, despite its superior design and a capital investment that is significantly higher than for a state tube well, fails to provide sufficient water control to the users. The features incorporated into these tube wells do not address all the constraints faced in the management of public tube wells. Technical fixes have been applied to the more visible problems, but more basic constraints have been ignored. Sufficient latitude has been provided to the users to participate in the management, as they should, but undue faith has been placed in user organizations. Implementation has focused on features that can be constructed rather than on organization.[11] Most important of all, the accountability of the Irrigation Department to World Bank tube well users is not any greater than it was with state tube wells. Once construction is finished, there is little concern for the wells.

World Bank tube wells are most appropriately compared with private wells, which offer a clear alternative for groundwater utilization. Private wells offer better water control both to the owner and to those who buy irrigation services. The only major argument for public investment in tube wells then is equity in access to groundwater. There is evidence that in regions with shallow aquifers and fairly low cost per well, as in eastern Uttar Pradesh, private wells and the market for irrigation services can offer fairly equitable access to water to everyone (Kolavalli and Atheeq 1990). This can be facilitated by making credit and subsidies accessible to farmers with small landholdings. Unless World Bank tube wells make ground water available more equitably than private wells, there would be little justification for state involvement in the management of tube wells. However, the features of the World Bank tube well program that are meant to ensure equitable supply, such as osrabandi and farmer participation in day area committees, rarely succeed.

Public tube wells do offer the potential for efficient utilization of groundwater with equitable benefit distribution. They have an important role to play in expanding groundwater use in regions that have abundant groundwater and farmers with small holdings. But what needs to be recognized is that returns from irrigation are not high enough to make it economical for farmers to build systems that can deliver water to individual fields. Nor do we have the technology to design public tube wells that can be managed without user participation. The organization of users is as resource−demanding as are technical fixes. Unless we are willing to commit the resources required to organize users, we should refrain from investing in tube wells that need to be publicly managed.

Many questions about the operation of public tube wells remain unanswered, chief among them, why users behave as they do. Future research should focus on understanding the demand side of irrigation. Detailed study of a few wells representing diverse conditions would be better than studies of the "with and without" kind that cover large areas. Some important issues would be:

Poor demand. Examine the extent of and reasons for lack of demand for water from public tube wells, particularly in the context of continued operation of private wells, existence of a private water market, and increasing private investment in the commands of public tube wells. As a first step, determine to what extent the period of no demand is reported accurately.

Supply uncertainly. Examine the nature of and reasons for uncertain water supply from public tube wells, including power supply, engineering failures, and failure of the rotational allocation system.

Command size. Are the commands too big? By spreading irrigation extensively over a large area, is water control diminished inside the command, encouraging farmers to seek alternative sources of irrigation? Can water control be improved by diminishing the command area and will productivity gains compensate for the loss of command?

What is the optimum command size that will offer a level of water control sufficient to encourage adoption of intensive cultivation practices?

Alternative institutions. What are feasible alternative arrangements for management of wells? Would private water companies be suitable? How about dedicated power supply to private wells rather than construction of public wells?

Irrigation practices and water requirements. Planning is often based on what farmers ought to be doing, not on what they do. Crop water requirements assumed in planning differ markedly from what farmers believe those requirements to be. It would be useful to study farmers' irrigation practices.

User participation and management. Variables that must be understood to initiate and sustain user participation in public well management are tube well design to facilitate user participation; mechanisms to ensure legitimate representation of users on committees; appropriate roles for users, well operators, and the Irrigation Department; mechanisms for swift conflict resolution; processes for integrating construction and the development of user organizations; and measures for establishing ownership rights for users. Research on user participation should begin with studying how water is actually allocated in state tube wells in order to understand the economic, political, and social factors to be dealt with in introducing equitable processes for management of public wells.

Notes

1. An unskilled agricultural laborer in this region earns about Rs 12 a day.

2. There are serious flaws in the design of the outlets besides the fact that they are not tamper−proof. Foremost, the outlets require considerable masonry work. Construction of outlets is unattractive to contractors as the materials needed have to be carried over long distances for minimal work. Masonry needs to be taken out for repairs, and many repaired outlets are left without masonry work, making them more vulnerable to tampering.

3. Charges based on the horsepower of the motor rather than on usage diminish the incentives for the Electricity Board to make timely repairs. One engineer felt that electrical repairs are often done only after much prodding by the users, who sometimes take the trouble of providing transport and other facilities to the repairmen. The Irrigation Department may not be able to provide this support, with the result that there may be some delay in restoration of service. The extent of closure because of hydroelectric defects suggests there may be some truth in this statement.

4. The blame for this cannot be placed on engineers alone. Few of them have the necessary skills or the training required to organize the farmers. Nor do they have the time. Although Campierganj cluster had been in operation for two years, the maintenance wing had not taken over from the construction wing. The only maintenance wing in the division was being converted into a construction wing for a tube well program supported by the Dutch government. Why worry about maintenance when there is a lot of construction to be done!

5. The day area committees are not likely to work properly as they also face an "above the outlet" problem similar to that of a surface irrigation system, that is, deficiencies in system management that result in failure to make regular water deliveries at the outlet. Only the *kshetra din* committee, comprising representatives of day area committees, can ensure uninterrupted delivery at the designated outlets by making sure that day areas are irrigated only on assigned days.

6. The total amount billed to users should correspond to the number of hours the tube well is operated. The Irrigation Department cares little about how the charges are distributed among users.

7. The Irrigation Department screens a large number of applicants with a written test. The job is valued so much that it is difficult to dismiss an operator. When we visited these tube wells, one operator had been dismissed because he had failed to keep records for months. But there was considerable pressure on the Executive Engineer from the local politicians to keep the operator on the job.

8. Although the operator of well no. 212 complained to us that farmers in the commands of a few outlets always kept them open, including outlet no. 5, the irrigation record shows that only one irrigation was given from outlet no. 5 over a period of six months (see table 9.5). Something, either a threat or a bribe, dissuaded the operator from charging the farmers for the water they were using.

9. When the operator of well no. 245 was asked how he made an accounting for water leaking through outlets, he said "Somebody has to pay for it." That "somebody" is generally whoever demands water.

10. We collected data from farmers in the commands of Campierganj tube wells for a different study throughout kharif and rabi in 1989. The farmers told us at the end of rabi that they had not yet been billed for the irrigation in kharif.

11. In both planning and implementation of World Bank tube wells, the emphasis has been on technical fixes rather than on building user organizations. None of the main activities of the research and development program funded by the World Bank is related to user organizations, although experience in India has shown that they cannot be built easily.

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10—
Efficiency and Equity Impacts of Groundwater Markets: A Review of Issues, Evidence, and Policies

Tushaar Shah

Patterns of appropriation of groundwater resources

This chapter analyzes the equity issues involved in appropriation of groundwater in India and examines the potential of village−level water markets to improve the access of the rural poor to the benefits of groundwater development.

Confusion prevails about ownership rights for groundwater. It is often treated as a common property resource, but in view of its fungibility, most researchers recognize that it is privatized as soon as it is captured. Therefore, until it is exploited, it is managed as an open access resource.

Jacob (1989) recently argued that, under British colonial rule and Indian law, a farmer has a private property right over all water percolating through his land and a landowner has the right to sink a borehole on his land and to prevent water that percolates through his land from going to another man's property.

Whatever the legal status, the reality is that as the demand for irrigation has increased with the spread of modern crop production technology, the owners of lift irrigation systems have enjoyed unchallenged de facto ownership rights on the community's groundwater resources. Thus, a water pumper can sell his neighbor water underlying the neighbor's land and still extract a monopoly premium from the transaction. In effect, ownership rights for water are given or denied through the rights to establish modern lift irrigation systems.

Siting and licensing norms adopted by groundwater departments, banks, and electricity boards to contain well interference and excessive withdrawals from the aquifers determine who is denied the right to establish modern lift irrigation systems. These norms, established only in the past twenty years and seriously enforced only recently, do not affect existing modern lift irrigation system owners. Thus, they impose a virtual allocation of ownership rights over groundwater that favors early exploiters and that penalizes late ones, a majority of whom are likely to be resource−poor.

Moreover, although siting norms seek to protect an existing, modern lift irrigation system from a potential modern lift irrigation system, they do not provide any protection to existing *traditional* lift irrigation system owners from new modern lift irrigation systems. And, in many cases, modern systems have wiped out traditional ones (Dhawan 1982).

Spacing and licensing norms are difficult to enforce through the regular policing system. Therefore, in most states, credit support by public sector banks and the issuance of electrical connections are contingent upon compliance with the norms. Those who can self−finance lift irrigation system investment (usually the resource−rich) and can use diesel engines or bribe their way to an electricity connection are thus unaffected by the norms. Moreover, preventing the establishment of new lift irrigation systems in the neighborhood of an existing one usually strengthens the power of the system's

owner in his water transactions with his neighbors; such monopoly power usually takes the form of exploitative prices and arbitrary behavior on the seller's part.

In spite of these inequities, poor people are better off with the development of lift irrigation system capacity, even if it is controlled by the rich, than they would be without it. Moreover, in a community in which few members own lift irrigation systems with the technical capacity to irrigate the bulk of all the members' land, everyone—notably the poor—would be substantially better off with the emergence of water markets.

Four major benefits of water markets can be noted:

Higher and more risk−free income flows from farming for non−lift irrigation system owners who, with a water market, have access to modern farming technologies.

Appreciation of market value of non−lift irrigation system owners' land.

Opportunities for smallholder lift irrigation system owners to extend system utilization beyond their own land, which would spread their overhead over a larger command area.

Improved wages; increased and more seasonally balanced employment opportunities for the landless (Shah 1988b).

Public tube wells, community lift irrigation systems, and water markets

Of the 475,000 million cubic meters (Mm3) of India's known groundwater potential (Padmanabhan 1988), some 180,000 Mm3 are currently used to irrigate about 28 million hectares (ha). At a rate of 0.60.65 meters per hectare (m/ha), the ultimate irrigation potential with groundwater may be around 7080 million ha, nearly twice the current official estimate (Sanghal 1987).

Considering the current expansion rate of groundwater use, much of the remaining potential will be developed in the next twenty years. A crucial question is: Who will benefit from this remaining potential?

Public tube wells that are established and run by state machinery and community lift irrigation systems, owned and operated by groups of or including the poor, and supported by nongovernmental organizations, are often proposed as institutional mechanisms to enable the poor to secure command over groundwater. Although there is much merit in this, in view of the scale and speed necessary to produce a sizable impact, the best bet is to work with the water markets.

The logic of the argument is simple. Of more than 11 million lift irrigation systems currently in use, fewer than 50,000 are state tube wells and, very likely, even fewer are nongovernmental organization group lift irrigation systems. The performance of state tube wells, judged by the most basic indicators of efficiency, viability, and equity, has been found uniformly disappointing in all states (Ballabh and Shah 1989).

With the exception of experimental initiatives in states such as West Bengal, where users are being involved in management (Sen and Das 1987), and a World Bank−supported program in Uttar Pradesh, where technologically superior pumping plants and distribution systems are being tried out, no major initiative can be foreseen that would reverse the current disappointment with public tube well programs. Nongovernmental organizationsponsored lift irrigation systems, though small, operate with a level and quality of nongovernmental organization involvement that makes their replication on a large scale difficult.

More than 95 percent of the area served by groundwater in India is irrigated by some 10.7 million privately−owned lift irrigation systems. This proportion is unlikely tochange drastically. Besides individual lift irrigation system owners, this figure also includes spontaneous lift irrigation system groups such as the water companies of Gujarat (Patel 1988;Shah 1989a)and the small family groups of the type studied by Kripa Shankar (1986 and 1989) in Uttar Pradesh, which behave and operate much like individual lift irrigation system owners.

Although the ownership of lift irrigation system capacity by private famers is highly skewed, access to groundwater and the benefits produced by lift irrigation are not quite as bad, especially in areas where water markets have developed and worked well. As shown later, there are ways to influence the development and working of these markets, which in turn can generate big payoffs for the poor.

Importance of water markets

In much of the recent literature, the term "water market" has been used to describe localized, village−level, informal sales to other members of the community. But the term is a euphemism, because in reality it is a lease market for irrigation equip−

ment. Water can be lifted from open wells or tube wells, deep or shallow wells, or from canals, tanks, rivers, drains, or other surface sources.

Water can be transported to the buyer's field either through unlined or lined field channels, as in some parts of Uttar Pradesh, or through underground pipeline networks as in many parts of Gujarat. Where landholdings are fragmented, most water sellers are also buyers because most farmers sink wells in one or two of their largest and best parcels and use purchased water for irrigating others.

Selling groundwater appears to have been prevalent in many parts of India even under traditional water extraction technology. Studies in Gujarat indicate that well−developed water markets have existed in many parts of Gujarat for seventy to eighty years (Shah 1989a). Since the 1960s, with the capacity to pump water at considerably higher rates per unit of time than required by most lift irrigation system owners, water markets have become more pervasive and refined and have taken on increased importance in the rural, social, and economic life of many regions.

Recent studies indicate that one half or more of the gross area irrigated by private modern lift irrigation systems in many parts of India belongs to water purchasers. But the proportion of total pumpage sold varies across regions. In water scarce areas, pumpage sold tends to be small (Prahladachar 1987; Swaminathan and Kandaswami 1989). In some areas, where water is abundant, for example in parts of Gujarat, pumpage sold is nil. And in still other water abundant areas, pumpage sold reaches as high as 80 percent or more.

In the Kheda district of Gujarat, for instance, selling water, not meeting one's own irrigation needs, is the prime motive behind lift irrigation system investments. A recent survey in Navli village in this district indicated that ten smallholder water sellers, who enjoyed a 45 percent share in the village's booming water market, used less than 5 percent of the total pumping hours for their own irrigation needs. They sold the remainder to other farmers (Shah 1989a).

Because the area irrigated by purchased lift irrigation system service is not fully reported in the gross area irrigated by lift irrigation systems, official estimates are likely to understate the total area irrigated by privately owned and operated minor irrigation sources. For example, recent official estimates show that more than 10 million private lift irrigation systems serve a gross irrigated area of 28 million hectares (Mha) at an average of around 2.8 ha per lift irrigation system. Field studies indicate that the actual gross area, that is, own plus buyers', irrigated by private lift irrigation systems is usually greater than this average by a multiple of two or three and often much more, espedally in water abundant areas (Jairath 1985; Shah 1989a Shah and Raju 1987; and Shankar 1986 and 1989).

In areas irrigated using water markets, the intensity of irrigation might vary greatly. However, because the buyers can get water when they need it, the productivity of water is high.Where opportunities arise to buy small quantities of water at crucial periods of moisture stress, enabling smallholders to take an additional crop, water selling by private lift irrigation system owners can have dramatic beneficial impacts on the incomes of water buyers and on the economy of the community.

In the Midnapur district of West Bengal, this author interviewed the owners of 5 horsepower (hp) diesel lift irrigation systems, each of whom supplied small amounts of irrigation, usually eight to fifteen hours per crop per hectare, to thirty to forty tribal farmers for an additional *rabi* (dry season) potato crop. Each such seller made possible an additional crop over a total of 20.232.4 ha of the buyers' land. The water sellers made a profit of some 3,000 rupees (Rs) per year each, but the tribal water buyers gained much more (Shah 1988a).

Many of the smallholder water sellers from Assam, Bihar, Orissa, West Bengal, and eastern Uttar Pradesh that Pant (1988) randomly met, sell small quantities of water, mostly to other smallholders to save a crop or to make an additional one possible. For many of these sellers, the lift irrigation system investment would not be viable without the opportunity to recover part of their overhead costs through water sales.

Development of water markets

Although in such areas as the Kheda district of Gujarat there has been a long history of water markets, in many other regions of India water selling has begun only recently and only on a small scale. Major differences in the workings and the nature and scale of social impacts of water markets in these two types of regions can best be explained by different degrees of water market development (table 10.1).

In the Karimnagar district of Andhra Pradesh (Telangana region), three contracts were found to be in use in an evolving water market (Shah 1986):

Table 10.1 Comparison of more− and less−developed water markets, India

Features	*More−developed water markets*	*Less−developed water markets*
Transactions	Cash transactions and sale of water per hour of pumping more common; lease contracts standardized to a few types	In−kind transactions dominate a wide variety of lease contracts used; absence of standardization
Proportion of water output sold by lift irrigation system owners	Quite high, ranging from 4090 percent	Low, 1025 percent
Differences in cropping pattern, input use, and technology between lift irrigation system owners and others	Small	Large
Percentage of non−lift irrigation system owners using purchased water	Large	Small
Objective function of lift irrigation system owners	To meet own irrigation needs plus maximize returns from sale of watera	To meet own irrigation needs

a. In a highly advanced stage of water market development, the return from sale of water may become the primary objective of lift irrigation system owners.

Source: The author.

Labor contract, in which the buyer provides labor and draft power to the seller in return for water.

Crop−sharing contract, in which the seller provides only water while the buyer provides land, labor, manure, and other inputs.

Crop− and input−sharing contract, in which the buyer provides land and labor, the seller provides water, and both share other input costs and the output.

In early stages of water market development, the terms of sharing output can vary across transactions depending primarily on the nature of relationship between the buyer and the seller. In the second type of contract, for instance, the sellers' share in output ranged between 33 and 50 percent and in the third type, between 50 percent and 66 percent. As the water transactions increase, the multiplicity of in−kind contracts apparently gives way to one or two standard and widely used contracts, and outright cash payments for water gain precedence over crop−sharing contracts.

Moreover, even in water−based, crop−sharing contracts, depending on the intensity of competition and the economics of lift irrigation systems, the share of water can change substantially across space and time. In many parts of India and Bangladesh, for example, a one−third crop share for water is quite common. Contrast that with Gujarat, where water sellers claim 50 percent and in some cases up to 66 percent of the crop, as recorded by researchers (Asopa and Dholakia 1983; Shah 1985).

Two water−based tenancy contracts used widely in the Kheda district of Gujarat are:

Two−party contract, in which a water seller supplies water and shares half of the cash costs of fertilizer, seeds and, in some cases, hired labor, and claims half the output.

Three−party contract, in which a water seller, a landowner, and a laborer (typically a tribal family from the neighboring district of Panchmahals) share equally all the cash costs as well as the output.

When water is sold for cash, it may be priced on the basis of hectares irrigated for a particular crop or on the basis of pumping hours. Price per hectare of crop is more common in some southern regions, especially with electrified lift irrigation systems, although price per watering is often encountered, too. In Gujarat, price per hour of pumping is more widely practiced. Here, owners of electrified lift irrigation systems often charge per kilowatt hour (kwh) of power used by taking meter readings. For diesel lift irrigation systems, a full price per hour may be charged, in which case the seller procures diesel; or the seller might just charge a fixed sum per hectare as "rent" for the use of the lift irrigation system. In the latter practice, which is widely used in many parts of southern India and Bangladesh, the buyer has to arrange for diesel and oil.

Not enough is known about the factors that facilitate or hinder the emergence of water markets. The availability of water resources in an area is certainly important in explaining the development of mature groundwater markets. More important, however, are the scale and quality of adoption of irrigated farming technologies which, in turn, are

influenced by water markets where these have evolved into mature institutions.

Four profiles for water markets can be discerned:

Low lift irrigation potential, low utilization. In many hardrock areas, where well yields are low, a variety of inhibitions and taboos prevent lift irrigation system owners from sharing water with others. These inhibitions are slow to disappear (Prahladachar 1987). In the Karimnagar district of Andhra Pradesh, where many 5 hp pumps could not operate for more than three or four hours a day, deep−rooted misgivings about selling water influenced even those who had surplus water to share with neighbors.

Low lift irrigation potential, high utilization. In low−potential areas where modern crop production technologies are widely practiced and the economic potential of irrigated farming is recognized, water markets tend to develop rapidly—in some cases into highly mature institutions. The Mehsana, Sabarkantha, Banaskantha, and several other water scarce areas of the Saurashtra region of Gujarat and the Madurai district in Tamil Nadu are such areas. Here, water markets offer major social trade−offs; they intensify overexploitation of groundwater resources, but at the same time, they diffuse access to and benefits from this precious resource to all sections of rural people, including the resource−poor.

High potential, low utilization. Bihar, Orissa, and West Bengal, in contrast to the areas discussed above, have large and easily accessible groundwater reserves, but highly underdeveloped groundwater markets. The constraints here are from supply as well as demand restrictions. In most areas of these states, the resource itself has not been adequately developed, the pace of rural electrification is slow, and traditional water extracting technologies are still widely in use. The slow spread of high yielding variety fertilizer technology and the protective, as distinct from productive, use of irrigation have meant fewer opportunities to sell water to neighboring farmers. Demand factors are also important in explaining the slow development of water markets in areas inhabited by tribal populations, many of which are new to settled, let alone irrigated, modern agriculture.

There are also areas where irrigated farming is advanced but most farmers are so self−sufficient in their irrigation needs that water transactions are very limited. This happens typically in the head reaches of canal commands (Shah 1989b) or where the cost of installing lift irrigation systems is so low that almost every one in the village has his own. A recent study (Chawla, Kumar, and Raghuvanshi 1989) compared the extent of water selling by private lift irrigation system owners in three canal commands in Uttar Pradesh (that is, Tansipur, Salawa in the Meerut district, and Solani in the Saharanpur district) and found water selling to be least prevalent in the Tansipur area, where canal water availability was the most reliable and ample.

High potential, high utilization. Water markets tend to be more developed as moves west. They are more pervasive and important in the Punjab, Haryana, and western Uttar Pradesh than in central and eastern Uttar Pradesh, Orissa, Bihar, and West Bengal. Also, cash sales of water are most common in the Punjab (Jairath 1985), Haryana, and western Uttar Pradesh (Shah 1985); prices tend to be uniform and are normally charged per hour of pumping rather than per hectare of crop. Not owning a lift irrigation system is not a great disadvantage in these areas because of ample opportunities to purchase water. In a study of Naglakaboolpur village in the Meerut district of Uttar Pradesh in 1984, Katar Singh found the cropping intensity of the entire village to be close to 200 percent, although the village had only twelve privately owned tube wells, which supplied water to the rest of the farmers at Rs 56/hr (Prasad and others 1984).

Potential role of water markets

The nature and scale of the social effects of water markets depend on:

The extent to which water markets have developed and are used by lift irrigation system owners and nonowners.

The efficiency of market transactions and the resulting narrowing of the margins between effective water prices and the average economic cost of pumping.

The fit between the ground water endowment of a region and the system of appropriation implied by water markets. Using the water market profiles of the previous section, table 10.2 outlines the social role of water markets.

Eastern India offers a major opportunity for water market development that can produce vast benefits for the poor. Demand factors, such as the slow spread of modern seed−fertilizer technology, an absence of intensive land use, and a semifeudal

Table 10.2 Role of water markets in equitable development of the groundwater resource, India

Area category	*Key problem*	*Potential role of water markets*	*Key goal of public policy*
Low potential, low utilization	Equitable development of unused potential	Positive. Can diffuse access	Stimulate water markets
Low potential, high utilization	Equitable control of withdrawal of water	Potentially harmful as in Mahsana and Saurashtra but can still broaden access	Establish equitable mechanisms to control over−exploitation

High potential, low utilization	Saturation of potential and access to all at low cost: Eastern India	Powerful and positive: can ensure poor people's access regardless of who owns the lift irrigation systems; large employment increases	Stimulate rapid development of water market by removing supply side constraints
High potential, high utilization	Market may become instrument of exploitation of poor by lift irrigation systems	Very positive provided it is efficient; can delink access to water from ownership of lift irrigation systems	Make water market more efficient

Source: The author.

social structure with underdeveloped market relations, and supply−side factors, such as an inadequate and highly unreliable power supply and growing dieselization of lift irrigation systems, inhibit the growth of water markets in many of these regions.

A high degree of land fragmentation, whose negative effects on productivity have been nullified in Gujarat because of hyperactive water markets, is suggested as a major factor that inhibits the development of water markets in eastern Uttar Pradesh (V. Ballabh 1989b). Furthermore, in many water abundant areas, especially in the head reaches of canal commands, water tables are so high that even sugarcane can grow with just one irrigation. Demand for purchased groundwater tends to be weak here. The question then is how to accelerate the development of water markets and make use of the available potential.

In areas where water markets already flourish, ensuring their economic efficiency is a major concern. Where water sellers enjoy a high degree of monopoly power, they can skim off the bulk of the marginal value product generated by irrigation services on the buyer's field. In contrast, a seller operating in an efficient water market will be under pressure to sell more water to more buyers and, in the process, to cut the price to a level close to his average economic cost of pumping. This scenario will generate a larger irrigation surplus and more jobs for the resource−poor and the landless, and it is possible that sellers will not earn less total profit than in the monopoly situation (Shah 1988b).1

Pumping costs, monopoly power, and water prices

Table 10.3, based on field studies conducted by various scholars during 198387, reports prices per hour of pumping charged by owners of diesel lift irrigation systems in ten regions in India.

One important question addressed in recent research on water pricing is: What explains the threefold difference in prices, especially when the cost of diesel and oil, which accounts for over 80 percent of incremental pumping costs, is largely the same in all regions?

Lest it be argued that price differences across regions would be legitimate if, because of differing aquifer conditions, diesel lift irrigation system owners in different regions have to use different capacity engines, we note in table 10.4 that water prices per unit of horsepower per hour (hp/hr) also display sizable differences. The only way these differences can be explained is in terms of differing degrees of monopoly power of water sellers in different regions.

In an oligopoly, sellers earn profits through highmargin, low−volume businessstrategies. But in competitive water markets, sellers are obliged to follow low−margin, high−volume strategies. Whereas the farmer may earn greater profits, the latter system always produces a larger total irrigation surplus, more employment, and better livelihoods.

In oligopolistic water markets, price variations across regions reflect differences in incremental pumping costs as well as differing degrees of monopoly power enjoye by sellers. Since the average pumping costs/hp/hour show remarkable uniformity, one can infer that the differences in prices charged by water sellers in different regions reveal the variations in monopoly power enjoyed by water sellers in those different regions. This makes the ratio of prices charged to incremental pumping costs a good indicator of monopoly power (Lerner 1970).

Such power implies not only more costly irrigation, but usually also inadequate and unreliable

Table 10.3 Water prices, pumping costs, and monopoly power: Dlesel lift Irrigation systems

Source	*Site*	*Water price to buyers (Rs/hour)*	*Ratio of price to incremental pumping costs*
Shah and Raju (1987)	West Godavari district, Andhra Pradesha	7.257.8	1.231.32
Singh, B. (1985, personal communication)	Hoshiarpur district, Punjab	8.09.0	1.31.6
Prasad and others (1984)	Meerut district in western Uttar Pradesh	8.010.0	1.31.7
Kripa Shankar (1986)	Allahabad district	1012	1.72.0
Chawla and others (1989)	Meerut and Saharanpur districts, Uttar Pradesh	814	1.32.2
Shah and Raju (1987)	Northern Khedab (head of a canal in Gujarat)	15	1.9
Shah (1988a)	Midnapur district in West Bengal	14	2.3
Shah (1985)	Panchmahal district in Gujarat	1618	2.73.0
Shah (1986)	Karimnagar district in Andhra Pradesh	1621	2.63.4
Copestake (1986)	Madurai district in Tamil Nadu	1621	2.63.4

a For 5 hp diesel lift irrigation systems, incremental pumping cost used is Rs 6/hr; this includes diesel and all costs (Rs 4.2) labor costs (Rs 1.0), and repair and maintenance costs (Rs 0.8/hr). This cost figure has been applied for all sites except West Godavari and northern Kheda where diesel lift Irrigation systems have higher horsepower. In West Godavari, diesel engines used were of 6 hp and, therefore, diesel cost was estimated by Shah and Raju to be higher Rs. 4.70. In this area, however, the buyer was supposed to provide all the labor. The seller's incremental cost of pumping was estimated to be Rs 5.85/hr without labor cost.

b. Engines used in northern Kheda are 10 hp. Diesel cost was estimated at Rs 6.75/hr and total incremental cost at Rs 7.95/hr by Shah and Raju.

Source: Author's compllation from various studies (see table).

irrigation sold by an indifferent seller. Conversely, studies show that efficient markets with low water prices relative to incremental pumping costs generally imply a more balanced relationship of mutuality between buyers and sellers.2

Understanding the sources of the monopoly power of water sellers tells us a great deal about public policies that can promote equitable groundwater development. Table 10.4 lists a number of factors that affect the degree of monopoly power enjoyed by water sellers in a given regional setting. These may be physical, climatic, institutional, or economic, and may enhance or reduce the degree of competition. All these factors operate through their effect on the intensity and criticality of the dependence on private water sellers of users without their own irrigation sources.

The market structure theory in such a situation would suggest making water markets more competitive to increase their efficiency. But this is difficult to put into practice because (as seen in table 10.4) groundwater markets, even when highly developed, operate as natural oligopolies.

The density of lift irrigation systems (measured as installed hp/100 ha) tends never to be so high as to make an individual water seller completely powerless, as is the case with atomistic competition. Topographical barriers, losses through unlined field channels, and the like, also enable lift irrigation system owners to enjoy limited monopoly power in their command areas.

The high capital intensity of modern water extraction technology often acts as a major barrier to the entry of new competitors. As noted earlier, stringent enforcement of spacing norms through financial institutions and electricity boards strengthens these barriers. All these factors contribute to the oligopolistic interaction among sellers, and between buyers and sellers in village−level water markets.

The main question then is: Is it possible to create a situation where oligopolists behave as if they operate under competitive conditions? In this particular case, it is.

Efficient oligopolies: The role of power pricing

The economics of electric and diesel lift irrigation systems are significantly different because the methods of charging for power adopted by different state electricity boards have different effects on incremental pumping costs. Three important methods of charging for lift irrigation system power consumption are:

Table 10.4 Determinants of monopoly power enjoyed by water sellers

	Low monopoly power	*High monopoly power*
Physical and climatic factors	High and stable rainfall	Low and erratic rainfall
	Abudant aquifer close to surface	High depth to the water table
	Cropping patterns dominated by crops using small quantity of water	Cropping patterns dominated by crops using large quantities of water

	Flat topography	Undulating topography
Institutional economic factors	Low cost of lift irrigation system installation	High cost of lift irrigation system installation
	No spacing or licensing norms	Stringent spacing or licensing norms, or both
	High lift irrigation system density (installed hp/100 hectares of cultivated land)	Low lift irrigation system density
	High degree of rural electrification	Poor progress in rural electrification
Factors enhancing competition	Use of lined conveyance to supply water	Use of unlined field channels by water sellers
	Operation of efficient state tube wells charging low water prices	Inefficient state tube wells charging by high water prices
	Access to canal or other irrigation sources	No canal or other irrigation sources

Source: The author.

Flat rates, in which a lift irrigation system is charged a flat monthly rate per horsepower regardless of actual power used.

Pro rata rates, in which a lift irrigation system is charged per kilowatt of power consumed, based on meter readings.

Flat−cum−pro rata charges, in which there is a fixed charge linked to the horsepower of the lift irrigation system and there is a pro rata charge linked to the actual metered power consumption.3

The choice of a power pricing method has a dramatic effect on water prices charged by the owners of electric lift irrigation systems in different regions. This is illustrated in table 10.5, which reports these prices and other relevant details for the ten sites discussed in table 10.3, except for Midnapur (West Bengal) and Panchmahals (Gujarat), where the villages studied had no electric lift irrigation systems.

In an extreme case, the range of prices charged by water sellers in the Mehsana and Sabarkantha districts in Gujarat are fourteen to fifteen times higher than in West Godavari. While regional differences in lift irrigation system capacity are substantial, even when we adjust for capacity differences by calculating the price/hp/hour, a threefold or fourfold difference in price still remains to be explained. Irrigation cost per hectare also corresponds closely to the differences in water prices and has little to do with the abundance or scarcity of groundwater.

The imposition of flat rates affects the behavior of water sellers in two ways: first, it renders incremental pumping costs virtually zero, and second, it immediately reduces the monopoly power enjoyed by sellers. Both of these occur because, under the flat rate system, sellers have a powerful incentive to expand utilization of their lift irrigation system because the bulk of additional revenue earned constitutes net profit. This stimulus intensifies competition among oligopolistic sellers and forces a lowering of the water price. Table 10.6 illustrates the substantial and immediate increase in average hours of pumping per electric lift irrigation system as reflected in power consumption soon after the change from pro rata to the flat rate system in Andhra Pradesh, Uttar Pradesh, and Maharashtra.

There is some evidence to suggest that in water abundant areas, where physical factors do not support high degrees of monopoly power and where electric and diesel lift irrigation systems coexist, flat rates reduce the water prices charged by diesel lift irrigation system owners as well. An example of this is seen in the large differences in water prices charged by 5 hp diesel lift irrigation systems in the water abundant West Godavari district in Andhra Pradesh (Rs 7Rs 8 per hour) and in the water scarce Madurai district (Rs 16Rs 21 per hour).

Pumping costs per hour could not differ enough to fully explain this large difference. Indeed, in West Godavari, diesel lift irrigation system prices, which were never quite as high as in Madurai, fell after flat rates were introduced in 1983 (Shah and Raju 1987). In Madurai, however, the diesel prices did

Table 10.5 Regional variations In water prices charged by owners of electric systems

Source	*Site*	*Water price charged by owner of electric system (Rs/hour)*	*Average horsepower*	*Water price (Rs/hp)*	*Cost for buyer per acre of irrigation (Rs/acre)*	*Method of pricing power*
Shah and Raju (1987)	West Godavari district, Andhra Pradesh	3.0	8.6	0.35	sugarcane 398 banana 578 tobacco 241 rice (rabi) 266 g'nut (summer) 250	Flat rate Rs 4/hp/month Flat rate
Singh (1984) personal communications	Hoshiarpur district, Punjab	5.0	7.5	0.67	wheat 145	
Prasad and others (1984)	Meerut district, Uttar Pradesh	4.5	7.5	0.530.67	wheat 132 Rs 21.5/hp	Flat rate
K. Shankar (1986)	Allahabad district central Uttar Pradesh	4.5	5.0	0.801.0	Wheat 150160 RS 21.5/hp	Flat rate
Shah and Raju (1987)	Northern Kheda district (head of a canal), Gujarat	15.0	14.0	1.07	tobacco 650 sugarcane 2,380 banana cotton g'nut (summer) 900	Pro rata rate Rs 0.70/kwh

Shah (1988a)	Midnapur district, West Bengal	n.a.	n.a.	n.a.	n.a.	n.a.
Shah (1985)	Panchmahal district, Gujarat	n.a.	n.a.	n.a.	n.a.	n.a.
Shah (1986)	Karimnagar district, Andhra Pradesh	4.55.0	5.0	0.9	rice 450550 ragi 200	Flat rate Rs 4/hp/month
Copestake (1986)	Madurai district, Tamil Nadu	4.06.0	5.0	0.91.0	rice (high yielding) 932 ragi 213 sorghum 252 g'nut (summer) 329	Flate rate Rs 6/hp/month
Shah and Raju (1987)	Charutar tract, Kheda district	2528	21.2	1.7−1.3	cotton 660 sugarcane 3,714	Pro rata rate Rs 0.70/kwh
Shah (1985)	Gujarat				banana wheat 600 summer bajri 632	
Shah (1985)	Mehsana and Sabarkantha districts, Gujarat	4245	30.0	1.41.6	rice 1,2001500 wheat 9001200 g'nut 8501100	Pro rata rate Rs 0.70/kwh

n.a. Not applicable.

Note: 1 acre = 1 hectare; in 1988, 1 US$ = Rs 7.66.

Source: Author's compilation from various studies (see table).

not fall when flat rates were introduced in Tamil Nadu (Copestake 1986).

To be sure, low water prices in electric lift irrigation systems are produced by flat tariffs and not subsidized power tariffs as is generally believed. The level at which the flat rate is pegged has little effect on water prices. This is clear from Table 10.7 where water prices recorded in Uttar Pradesh are comparable to those in Andhra Pradesh and Tamil Nadu, although the flat rate in Uttar Pradesh is five times higher. Many politicians and civil servants in Andhra Pradesh and Tamil Nadu believe that the government is helping poor people through power subsidies. It is not. To enable poor people to gain access to irrigation water, it is enough to switch to flat rates; keeping the flat rates as low as in Andhra Pradesh and Tamil Nadu is neither necessary nor desirable.

Alternatively, raising the flat rate three or four times higher than its current level will have little effect on water prices and on water buyers; it will only help the electricity board mop up some of the profits made by the water sellers and become that much more viable.

The best system seems to be a progressive flat rate such as that introduced by Gujarat recently. In

Table 10.6 Effects of flat rates on hours of lift irrigation system operation
(average power consumption per lift irrigation system)

	Before the switch to flat rates		*After the switch to flat rates*	
State	*Year*	kwh/lift irrigation systeme	*Year*	*kwh/lift irrigation system*
Andhra Pradesh	198182	2,232	198283	3,294
Uttar Pradesh	197374	2,065	197980	6,724
Maharashtra	197576	2,191	197980	3,142

this, the rate/hp rises as the capacity of the lift irrigation system increases. Progressive flat rates not only encourage smallholders to own lift irrigation systems, they also enable small lift irrigation systems to assume a leadership role in the market because they have distinct cost advantages. Additionally, in water scarce areas, these rates discourage large−capacity motors.[4]

Social costs and benefits of flat rates

The flat rate system has the major disadvantage that it makes lift irrigation system owners behave as if the marginal social cost of generating electricity is zero, thus leading them to a somewhat profligate use of power and water. Indeed, the flat rate's salutary effects on water markets are a direct outcome of this changed attitude.

Ideally, the optimal pricing of power requires that lift irrigation system owners, as well as buyers, expand the use of water or power (whichever is more costly to the society on the margin) to the level where its marginal value productivity equals its marginal social costs. This can be achieved only in the limited conditions depicted in figure 10.1.

In this figure, we assume that the bulk of the incremental pumping cost, *S* 0 S, is the social opportunity cost of power, whereas *OS* 0 is the nonpower component of the resource cost of pumping. If power is charged for under the pro rata system and the rate is set at *OS* per hour, the lift irrigation system owner would use *OC* 1 amount of water on his own farm and earn an irrigation surplus of *ASY* 1 . But he will charge the water buyer a water price of *OP* 1 , which will restrict water use on the buyer's land to *OB* 1 and the irrigation surplus on the buyers' land to *AP* 1 X1 ; optimality considerations require that the buyer expand water use to *OB* 2 and generate irrigation surplus of *ASX* 2 , which can be done only by setting the pro rata rate at *OS* 1 and collecting the balance of the power supply cost by a flat rate in a flat−cum−pro rata scheme of power charge. In this case, the lift irrigation system owner will expand water use on his own farm to *OC* 2 , beyond the socially optimal rates; and this "wasteful" power use can be contained only by rationing the power supply per lift irrigation system to *OB* 2 + OC1 .

In contrast, under the flat rate system, incremental power costs are reduced to zero and the incremental pumping cost to *OS* 0 , and the new reduced water price *OP* 3 stimulates water use on the buyer's land to *OB* 3 and on own land to *OC* 3 , both beyond the social optimum levels of *OB* 2 and *OC* 1 , respectively. It is noted that flat rates save resources used in metering power use. Furthermore, to the extent that pilfered power is wastefully used, it reduces such waste by eliminating the incentive to pilfer. As a result of both of these factors, the social opportunity cost of pumping will be less and the optimal water use under the flat rate system will be greater—say, *OB'* 2 + OC'1 —than under the pro rata system.

Table 10.7 Levels of flat rates and water prices charged by electric lift irrigation systems

State	Flat rate (Rs/hp/year)	Region	Water abundant (WA)/ Water scarce (WS)	Water price
Andhra Pradesh	48	West Godavari	WA	Rs 3/hour for 7.5 hp
		Karimnagar	WS	Rs 5/hour for 5.0 hp
Tamil Nadu	75	Madurai	WS	Rs 5/hour for 5.0 hp
Maharashtra	150	Nasik	WS	Rs 67/hour for 7.5 hp
Uttar Pradesh	260	Western and Central Uttar Pradesh	WA	Rs 56/hour for 5 hp
		Eastern Uttar Pradesh	WA	Rs 46/hour for 5 hp
Gujarata	192 (for more than 7.5 hp)	Kheda district	WA	Rs 1416/hour for 20 hp
	to 500 (for more than 10 hp)	Mehsana district	WS	Rs 1820/hour for 30 hp

a. In Gujarat, the progressive flat rates introduced in 1987 levied Rs 192/hp/year for lift irrigation systems of 7.5 hp or less and Rs 500/hp/year for lift irrigation systems of 10 hp or more.

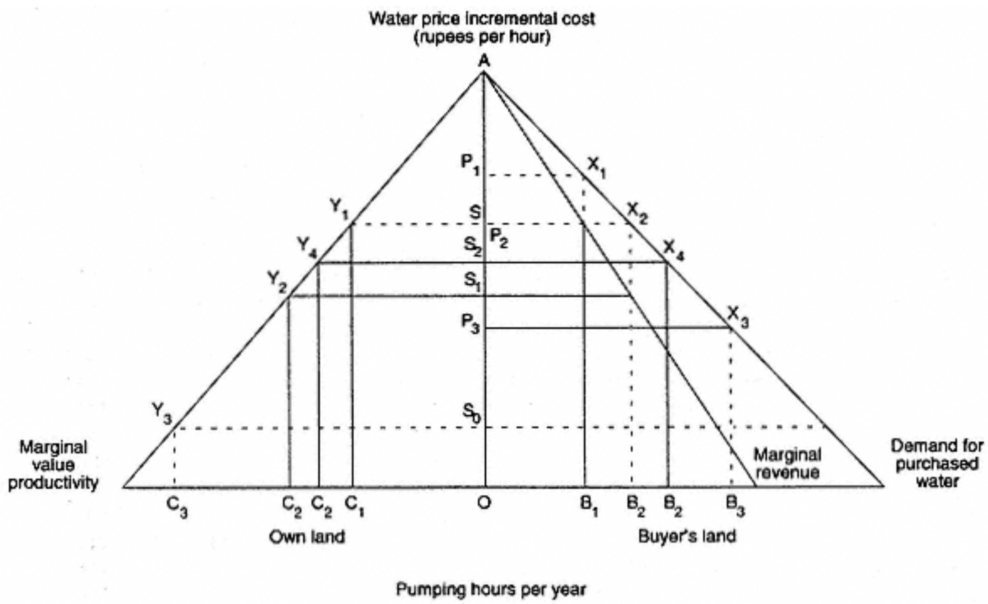

Figure 10.1
Optimal Pricing of Electricity for Lift Irrigation Systems, India

The actual power use can be contained to the optimal levels under flat rates by rationing the total power available per lift irrigation system to *OB* 2 ' + OC1 '. Under such a scheme, irrigation surpluses generated will be *As* 2 Y4 on the seller's land and *AS* 2 *X* 4 on the buyer's land.

This is as far as the theory goes. The optimal productivity and equity effects claimed for the policy mix presume that:

The efficiency of power use is more important than the efficiency of water use, although the same logic would hold if water use efficiency were more important than power use efficiency.

The quality of the "restricted" power supply is good.

The electricity board managers understand the logic of the policy and support it.

If the third condition is not fulfilled, electricity board managers can make things worse by letting the quality of the power supply, that is, its reliability, timing, convenience, predictability, and the like, deteriorate. Moreover, if the flat rate is pegged so high as to result in average pumping costs higher than the value of irrigation at the margin or the water price, then disinvestment in electric lift irrigation systems will cause a reduction in lift irrigation system density and, in the long run, will lead to increased water prices. The recent trend in Uttar Pradesh toward replacement of electric lift irrigation systems by diesel engines in the face of increased flat rates and extremely unreliable and inadequate power supplies is suggestive of this process (Pant 1988; Sharma 1989; Singh 1989).

Although the flat rate system is generally condemned on efficiency grounds, the pro rata system also breeds inefficiency in water use by not penalizing oversized motors used as a hedge against an erratic power supply. A systematic comparison of the efficiency effects of flat rates versus pro rata rates can be complex and much less conclusive than is commonly thought (table 10.8). Furthermore, for the electricity boards, the flat rate system may become attractive for its administrative simplicity, elimination of metering costs5 and reduction in the incentive to pilfer power.

A Rural Electrification Corporation (REC) study of the switch from pro rata rates to flat rates in Uttar Pradesh and Maharashtra showed that, in spite of the 40 to 60 percent increase in power consumption per lift irrigation system following the switch

Table 10.8 Merits and demerits: Pro rata rate versus flat rate power pricing systems

	Flat rate	*Pro rata rate*
Water market		
Water Price	Low	High
Premia charged by diesel lift irrigation systems	Low	High
Dependability	High	Low
Adequacy	Higha	Low
Overall productivity and equity effects	Very positive	Negative
Viability of electricity boards		
Power demand	Sharp increasea,b	Decrease
Metering cost	Zero	Substantial
Collection cost	Very low	Very high
Incentive to pilfer power	Disappears	Very strong
Efficiency of power use		
Incentive for power−saving investment	Low or nil	High
Use of over−capacity motors	Strongly discouragedb	Encouraged
Efficiency of water use		
Danger of over−exploitation	Highb,c	Low
Incentive to invest in pipelines	Lowc	High
Difference in water use efficiency of buyers and sellers	Highc	High

a. Subject to the availability of water.

b. Progressive flat rate tariff will have further positive impact on these.

c. These undesirable effects of flat rates can be minimized through judicious restrictions on "high quality" power supply to irrigation. But low incentive for power−saving investment will remain a drawback of flat rate tariffs just as the encouragement of over−capacity motors will remain a drawback of pro rata tariffs.

to flat rates, the electricity boards could break even on agricultural operations by marginally reducing power subsidies (REC 1985).

The social benefits of flat rates appear large and they accrue mostly to resource−poor water buyers. Flat rates increase lift irrigation system owners' stake in buyers and encourages them to serve buyers better. Moderately high flat rates do this even better than very low flat rates. However, a flat rate that is too high and that is not accompanied by an improvement in the quality of power supply will result in dieselization of the private lift irrigation system sector on a large scale.

A comparison of the Anklav village in Gujarat under the pro rata system with Pandalparru village in Andhra Pradesh under the flat rate system (Shah and Raju 1987) found the water buyers in the latter village were getting a much better deal than in the former by way of substantially lower irrigation costs, better and more reliable irrigation service, and cropping patterns similar to those used by lift irrigation system owners. In Gujarat itself, as the Government Electricity Board switched from the pro rata to the flat rate system in June 1986, there was a 25 to 60 percent decline in water prices in different parts of the state, and it was estimated that, through the price decline alone, a transfer of some Rs 100 crore6 would occur every year from lift irrigation system owners to water buyers (Shah 1989a).

Targeting subsidies

How can subsidies for groundwater development be targeted to generate maximum gains for the poor? At present, public resources are used to subsidize the losses of public tube well and other lift irrigation programs, to subsidize low flat rates, and to provide direct assistance to the resource−poor for investments in lift irrigation systems. One way to evaluate these uses is to examine how each would affect water markets. Such an analysis suggests that, although subsidies certainly have a role, targeting resources to improving the management of public systems can produce salutary effects.

The best examples are power pricing and supply policies. In most eastern states, it can be argued that water market performance can be substantially improved not by subsidizing power, but by raising the level of the flat rate and, at the same time, improving the quantity and quality of power supplied to lift irrigation systems. The first step would increase the pressure on lift irrigation system owners to sell more water; the second would enable them to do so.

If only the first measure is taken—raising the flat rate—farmers will switch wholesale to diesel engines as has happened in Uttar Pradesh in the past five years; and if the second is implemented without the first, that is, improving delivery of power, the electricity boards will go deeper in debt. Improving the quality of power supply would mean providing more power in summer and rabi, targeting power to peak irrigation periods, supplying more power during the day, and announcing and sticking to schedules of power supply.

Similar logic applies to public tube wells. Selling water cheaply, as most tube well programs in the eastern states try to do, seems less important to farmers than selling more dependable and adequate irrigation services. Running state tube well programs better, for example, would make water markets more competitive. Improving canal system performance near the tail would also improve the efficiency of water markets.

Direct subsidies to farmers to invest in lift irrigation systems can increase the density of the systems in a village and thereby make the water market more competitive. This is what happened in the Gonda district of eastern Uttar Pradesh, where the density of private lift irrigation systems increased rapidly with the help of credit from public sector banks and the Deen Dayal Research Institute, a private nongovernmental organization working as a broker between the farmers and the banks. As a result, between 1978 and 1980, through two graduate workers posted in each block of the Gonda district, some 30,000 inexpensive bamboo tube wells and 16,000 pumpsets, mostly diesel, were installed in the region.

As a result of the high lift irrigation system density achieved, a highly competitive water market emerged. Chambers and Joshi (1983) noted the major effects of the emerging water market in Gonda:

A sharp increase in land productivity and total output.

Better access to irrigation for small and marginal farmers.

A rise in real wages, especially where all or part of the wages were paid in kind and set as a proportion of yield.

The free−boring scheme, which also provides a 50 percent subsidy to small and marginal farmers for the purchase of pumpsets in Uttar Pradesh, can aid such saturation in water abundant areas, especially if the hassle involved in using such schemes can be reduced.

In Gujarat, another way of making water markets more competitive has emerged: the underground pipeline system. In most areas of the country, unlined field channels are used to convey water, resulting not only in wastage of power and water, often amounting to 30 to 40 percent or more, but also in reduced competitiveness of water markets. Where water is charged for on an hourly basis, seepage losses are translated into higher water prices for buyers. The greater the distance between the lift irrigation system and the buyer's field, the higher the effective water price. Buyers thus have strong incentive to deal with the closest lift irrigation system owner, who, as a consequence, enjoys a considerable degree of monopoly power (Shah 1987).

For the seller, unlined field channels dictate a market limited to his immediate neighborhood; for the buyer, they mean being tied down to one or two lift irrigation system owners and having to accept whatever terms they offer or revert to rainfed farming. In undulating terrain, unlined field channels imply a high degree of fragmentation of the water market—lift irrigation system owners can only serve segments lower than their own fields by gravity flow and are thus partly insulated from each other. Lining surface channels can help reduce seepage losses and irrigation costs, but it will still restrict competition, especially in undulating terrains, because lift irrigation systems cannot supply water to up−lying terrains, even with lined channels.

The water markets in many parts of Gujarat are different from those in most other areas of the country in that farmers invest in modern lift irrigation systems not so much to meet their own irrigation needs but to sell water. Water selling has become a specialized subsidiary occupation, and substantial private investments made in underground pipeline networks generate a high degree of competition in an otherwise oligopolistic market.

Field studies suggest that this complex, marketdriven irrigation organization could offer efficiency and equity effects that would be difficult to match (Kolavalli and Chicoine 1987; Shah 1989a). The largest component, usually 30 to 50 percent of the cost of establishing a lift irrigation system in these areas and estimated at Rs 90,000Rs 110,000 in 1987, is the cost of pipelines. Early sellers were motivated mainly by the desire to establish a monopoly position in the emerging new business by overcoming topographical constraints in supplying water to a large command.

As it turned out, they drove out several other sellers who used unlined field channels. Because seepage rates can be as high as 25 to 30 percent depending on the distance (Gupta and others 1986), buyers often end up paying as much as one−third more per hectare of irrigation to a well owner without a pipeline than if they purchased water from a professional seller with an elaborate pipeline network—even though both sellers might quote the same price per hour of pumping. Over time, many sellers have been obliged to invest in pipeline systems or to quit as sellers and become buyers.

The evolution of "irrigation grids" is by no means uniform in different parts of Gujarat. The factors that explain the sophisticated development in certain parts of Gujarat are not clear. It is obvious, however, that agriculturally advanced areas

have better−developed grids. And, once one or two lift irrigation system owners begin using pipeline networks, others seem to follow suit. If this is the case, then subsidizing such investments, perhaps starting with just a few lift irrigation system owners in a new area, could have large multiplier effects, especially in water scarce areas. In addition to making water markets more competitive, investments in underground pipelines would increase the efficiency of water and power use.

Private water market effects on irrigation groups and state tube wells

State tube well programs throughout the country have fared poorly compared with private lift irrigation systems and water markets. In many states, the average command area served by state tube wells has declined steadily as users have depended increasingly on private water sellers. Most studies of state tube well performance, regardless of the locale, have blamed state tube wells for several or all of the following: unreliability, poor maintenance, frequent breakdowns and long waits for repairs, power cuts, domination by local bigwigs, indifference on the part of operators, "right−of way" difficulties, and inadequate provision and maintenance of the conveyance system (Datye and Patil 1987; Singh 1989). A direct consequence has been that private water markets have made deep inroads everywhere in the territories of state tube wells.

This is not necessarily a step backward. Empirical evidence in India, Pakistan, and Bangladesh is by no means clear on the superior output and equity effects of even well−run state tube wells when compared with private water markets. A study of irrigation sources in Pakistan found wheat and rice yields of 133 wheat and 35 rice growers using private lift irrigation system water to be 6 percent and 11 percent higher, respectively, than the yields obtained by 33 wheat farmers and 13 rice farmers who used state tube well irrigation (Lowdermilk and others 1978).

In Gujarat, where state tube wells are believed to be doing better than elsewhere in India, an important study (Pathak, Patel, and Patel 1985) found private lift irrigation system irrigation more productive than state tube wells. Asopa and Dholakia (1983, p. 23), in trying to explain the shrinking commands of the state tube wells in Gujarat, wrote: "Discussions with farmers using private sources of irrigation indicate that private supplies are generally more efficient and highly reliable. There are no bureaucratic procedures and payments can be deferred easily. Agreements to provide water are made well in advance and invariably kept."

The World Bank−sponsored tube wells in eastern Uttar Pradesh offer perhaps the only example of a situation in which private water markets have shrunk because of stiff competition from state tube wells. However, a field visit in the Deoria district by R. N. Chambers, N. Pant, and T. Shah raised the question of whether these World Bank tube wells, with advantages of superior technology (see Datye and Patil 1987, pp. 21718), dedicated power supplies, and highly subsidized water rates, were really leaving their patrons better off.

The tube wells inspected on the field visit had induced massive disinvestment in lift irrigation systems owned by private sellers and several lift irrigation groups of smallholders and had resulted in a more or less complete dismantling of water markets. In a few cases, the World Bank tube wells themselves had failed, thus leaving their users in a bind (Chambers 1988). Singh (1989) records similar observations for the village of Majhwalia in eastern Uttar Pradesh. On a more general note, Singh concludes from his case studies of eleven villages that: "In villages saturated with private tube wells or pumpsets, such as Pichari, Mundera, Buzurg, or Bishunpur, and experiencing difficulty of farm labor, marginal and small farmers having command over the labor pool have a decisive role in influencing water allocation. In the villages served primarily by state or World Bank tube wells, the big or high caste farmers that make up the water allocation committees or who work as Thok leaders, hold sway" (p. 29).

On the other hand, small−farmer lift irrigation groups, especially the large groups, tend to break up or shrink when faced with competition from water markets. That small groups survive competition and adversity more easily is evident in Shankar's study (1986) in Allahabad and Nagabrahmam's studies (1989) of lift irrigation groups in eight locations.

Chisholm (1984), who studied four lift irrigation groups in Bangladesh over five years, noted a tendency of members to leave the group. Ballabh's recent case study (1989a) of the Indo−Norvegian Agricultural Development Program (INADP) community tube wells, first written about by Pant in 1984, showed that seven of the original forty−two groups had disintegrated, three had been privatized, and many of the groups still operating had

lost members, especially those with more than ten members.

Singh also notes that the INADP groups have worked well only when members belonged to one or two families. Most successful groups depended heavily on the sale of water at higher prices to nonmembers to subsidize irrigation supplied to members. Over the years, new private lift irrigation systems have been formed and have cut into the nonmember market. Deteriorating power supply also has impaired the capacity of the groups to capture the market surplus. Ballabh notes that, as a result, the expansion of the water market has reduced the utility of group tube wells. And, in Bangladesh, Palmer−Jones and Mandal (1987) reported a similar tendency for groups to shrink or for one of the members to take over as owner/operator.

The only significant evidence that militates against this thesis comes from Gujarat where groups of users, organized as "water companies," have not only withstood competition from individual sellers, but have grown in strength and, in regions such as north Gujarat, have become the backbone of water markets (Patel 1988).

The main difference between these water companies and the other lift irrigation groups appears to lie in the ground rules: in the companies, the members' stake is distributed in proportion to their contribution to capital, whereas in other groups it is the same for all members. The water companies of Gujarat are also far more professionally managed. They keep meticulous accounts—most of them issue printed receipts and have a regular annual profit distribution. In Gujarat, only the water companies show such a high standard of operation. By contrast, there are numerous examples of lift irrigation cooperatives and community lift irrigation schemes that have failed. Why the water companies are better managed and more successful than lift irrigation cooperatives and groups is an issue that has yet to be fully explored.

Notes

1. Inefficient water markets redistribute irrigation surplus from buyers to sellers. If resource−poor farmers are given monopoly rights to lift and sell groundwater to the resource−rich, as with the landless irrigation groups of Bangladesh, substantial transfers of wealth in the form of monopoly profits from water sales can be secured from the resource−rich to poor water sellers through inefficient water markets. However, even in this situation, resource−poor families as a class might be worse off than with efficient water markets when the elasticity of labor demand and wage rate with respect to irrigation use is high, as many field studies show. High water prices will

constrain irrigation expansion to suboptimal levels especially in water abundant areas. It is therefore certain that from output as well as distributional viewpoints, ensuring efficient water markets should be an important goal for public policy for irrigation development.

2. A standard result from the theory of competition applied to our fragmented water markets would explain the relationship between water prices charged by the sellers per hour of pumping (w), incremental pumping cost/hr (c), and the monopoly power enjoyed by water sellers (reflected in e, the elasticity of the water demand function facing each) as: $W = e/(e-1)c$.

When e is small, as in an oligopoly, $e/(e-1)$ will take a large value, and the price charged will be a large multiple of the incremental pumping costs; the markets will be highly inefficient and also inequitable when most buyers are resource−poor. Only in competitive water markets with large numbers of water sellers competing with each other will the value of e increase and of $e/(e-1)$ decline to make water markets efficient.

3. The flat−cum−pro rata system was widely used by northern states and in states such as Gujarat until the early 1970s. For administrative simplicity, many states in the north, notably Uttar Pradesh and Haryana, have switched to flat rate systems since the mid−1970s. Some southern states followed suit in the early 1980s, such as Andhra Pradesh in 1982 and Tamil Nadu in 1983. By 1986 all but a few states—Gujarat, Assam, West Bengal, and one or two others—had switched to the flat rate system. Gujarat and West Bengal had abandoned the flat−cumpro rata system, turning to pro rata rates.

4. For large lift irrigation groups of the resource−poor (such as those established by the Sadguru Sewa Sangh in Dahod and the Agakhan Rural Support Program in Bharuch) using large motors to irrigate their land, the new progressive flat rate system proved highly inequitable because it treated them at par with large farmers. In a recent modification, a separate policy has been announced for such lift irrigation cooperatives. Under this, the total installed horsepower of the lift irrigation system would be divided by the number of members, and the rate levied would be that applicable to twice the installed horsepower per member. In short, all lift irrigation cooperatives would be subject to the minimum charge per horsepower. There is a major move now for the water companies of Kheda and Mehsana to register as lift irrigation cooperatives to take advantage of this concessional policy.

5. Tentative estimates by the Gujarat Electricity Board suggest a major decrease in transmission losses in rural feeders since the introduction of flat rates. The transmission losses, which ran as high as 30 percent in recent years, are now estimated at around 21 to 22 percent. The basis of this estimate, however, is not clear.

6. Crore is a unit of value equal to ten million rupees.

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11—
Delivery of Credit to Poor Farmers for Groundwater Irrigation: Eastern Indian Experience

Shibasankar Chakraborty

Since independence in 1947, Indian agriculture has been largely successful, achieving a 3 percent sustained growth rate without a large physical expansion of the net cultivated area. This has been possible through the intensive use of such inputs as irrigation, chemicals, and improved crop varieties. However, this trend has not been uniform throughout the country. Eastern India, in particular, has lagged behind other states despite its relatively strong position immediately before and after independence and its abundance of natural resources. The region's agricultural growth in foodgrain yields actually slowed after 1960 (table 11.1).

Table 11.1 Trend in foodgrain yield in eastern India
(kilograms per hectare)

	Triennial average			
State/region	*195051*	*196061*	*197071*	*198081*
West Bengal	916	949	1170	1290
Orrisa	540	758	839	779
Bihar	513	714	820	914
East Uttar Pradesh	673a	694	822	914
Eastern regionb	644c	765	897	970
Western regiond	390	524	551	649
Southern regione	554	731	897	1149
Northern regionf	608g	788	1150	1493
All India	541	671	820	975

a. For Uttar Pradesh as a whole.

b. Includes West Bengal, Orissa, Bihar, and east Uttar Pradesh.

c. All Uttar Pradesh; separate data for east Uttar Pradesh is unavailable.

d. Includes Maharastra, Gujarat, Madhya Pradesh, and Rajasthan.

e. Includes Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala.

f. Includes Punjab, Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala.

g. Excludes Uttar Pradesh.

Public investment in infrastructure improvements and supporting services has also lagged far behind other regions. For example, between 1969 and 1985 public investment in irrigation and rural electrification in Haryana was almost eight times the amount of investment in Bihar (table 11.2).

One major limitation in the region is water management—or the lack of it. The area suffers alternating calamities of flood and drought, often in the same year. Between June and September, the seven rivers of the Himalayas generate flow rates as much as 500 times the non−monsoon rates. River flow is further increased by heavy rains, often as much as 130 centimeters (cm) in four months in some areas. Widespread flooding and waterlogging result. For the rest of the year, rainfall is sparse and drought is common.

Because of the proven importance of irrigation to agricultural development in other regions, many observers believe better management of eastern India's water resources could lead to similar gains

Table 11.2 Public Investment in irrigation and rural electrification for agriculture, per agriculture worker
(rupees)

State	*Investment*
Bihar	645
West Bengal	1,730
Uttar Pradesh	1,870
Orissa	2,000
Gujarat	3,980
Kerala and Punjab	More than 4,000
Haryana	More than 5,000

Table 11.3 Groundwater resources of eastern India, 1982
(*1,000 hectares per meter)*

	Gross recharge	*Net recharge*	*Net draft*	*New ground−water balance*	*Stage of development (%)*
West Bengal	2,257	1,581	384	1,197	24
Orissa	2,946	2,062	128	1,934	6
Bihar	3,898	2,729	677	2,052	25
East Uttar Pradesh	3,751	2,624	831	1,793	32

Source: Government of India.

in that region. In particular, considerable improvement could occur through the development of a proper drainage system to avoid waterlogging and through extensive exploitation of the area's abundant groundwater resources. As of 1982, regional utilization of groundwater was, on average, only 25 percent of the potential (table 11.3).

This chapter examines the availability of credit for small and marginal farmers to exploit groundwater and the delivery system that has emerged for that purpose. Several case histories provide examples of different approaches to reaching the target group in this area.

Organizational approaches for groundwater exploitation

Privately operated tube wells

Many farmers install shallow tube wells, either with the help of a bank loan or by investing their own resources. In Murshidabad district in West Bengal, there are 37,260 such private tube wells, irrigating 72,420 hectares (ha) of land in *kharif* (wet) season and 64,000 ha in *rabi* (dry) season, involving nearly 400,000 small and marginal farmers. In fact, Murshidabad is among the districts in West Bengal with the largest numbers of shallow tube wells.

However, because of the small size of landholdings in the district, banks are reluctant to extend credit to farmers. Despite government efforts to encourage resource−poor farmers to sink shallow tube wells through subsidies of as much as 33.3 percent of the cost, progress has been less than satisfactory.

Regulation of private owners is another problem. Tube wells constructed by individuals in certain areas have resulted in slow discharge of water, and at times wells run dry. In the absence of suitable groundwater laws in the region, the government has little control over the construction of shallow tube wells using private financing, which makes it difficult to maintain minimum distances between wells. As a result, shallow tube wells have been constructed indiscriminately, which in turn has lowered the water levels in some areas below the suction limit of centrifugal pumpsets. This is common to many wells in the districts of Madnapore, Hooghly, and Burdwan in West Bengal, particularly between late February and May.

In one effort at regulation, a committee of experts recommended the distribution of loans for shallow tube wells to farmers for irrigating 0.8 ha, or as little as 0.4 ha of compact land, under different situations. In doing so, the committee determined the cost of servicing a bank loan for capital investment in shallow tube wells at different depths as well as the net repayable surplus possible on these two farm sizes. Different agroclimatic zones with different soil textures were also taken into account.

When a farm size of 0.8 ha was considered, shallow tube wells using electric or diesel pumpsets in medium textured soils under conditions of multiple cropping was not viable except where filter points with 80−foot depths using coir filters were used. Similarly, shallow tube wells in the red lateritic zone were not found to be viable. In all other cases, investments in shallow tube wells with electric or diesel pumpsets on a 0.8−hectare farm were viable.

In no case was the investment financially viable with a 0.4−hectare farm size in West Bengal or in lowlands with heavily textured soils, regardless of the agroclimatic zone. In alluvial zones, on the other hand, investment was viable with multiple−cropping on highlands and light textured soils, and also on medium land with textured soil.

However, in this region compact land of 0.4 ha or 0.8 ha is rarely available for small or marginal farmers. Thus, individually exploited tube wells are not financially viable.

Group tube wells

To overcome the problem of nonviability of irrigation investments on small landholdings, the government and commercial banks created the Group Scheme. This scheme involved disbursing loans to groups of farmers who could then sink a well in a convenient place to irrigate land in a command area. But the banks' experience has been less than satisfactory because such groups, having no legal identity, lack incentives to repay the loans.

Also, there have been cases where individual farmers take control of wells in a command area and exploit others.

Public sector model

In another effort, the government, mainly through the Minor Irrigation Corporation, has sunk large numbers of shallow and deep tube wells and directly appointed operators to manage them. But because of inefficient management of the corporation and the lack of involvement by users, this scheme operated inefficiently in the majority of cases. In most instances, involvement in the scheme was uneconomical and maintenance was poor, and many farmers defaulted on their water payments.

Cooperative society

Yet another approach involves the construction of a battery of shallow tube wells by an irrigation cooperative society composed of small and marginal farmers. In some cases, the government subsidizes 50 percent of the capital costs. In the same way, deep tube wells may also be constructed by such a society. There are several advantages of cooperatives:

The level of water utilization is quite high.

The capital investment from the public sector is low because farmer cooperatives can obtain bank loans.

The cooperative society can charge beneficiaries economical water rates.

Water management is more efficient.

Case histories of two successful irrigation cooperative societies are given below. In the first case, a cooperative set up a river−lift irrigation scheme using three pumping stations, each with two 20 horsepower (hp) electrically operated pumpsets. This scheme has operated successfully for the past five years. In the second case, a cooperative drilled two deep tube wells.

It is the author's contention that irrigation cooperatives, such as those shown below, will ultimately lead to cooperative farming societies that can tackle most of the problems of small and marginal farmers and play a vital role in generating rural employment. Because individual marginal farmers cannot take effective steps to create irrigation sources, such cooperative irrigation societies offer them their only hope.

It is important to note that sinking tube wells is not possible in some parts of Eastern India. In such areas—almost half the land in the region—other measures, such as land shaping, drainage, tanks, and dug wells can be used to help the small and marginal farmers. Two case studies of youth club projects to excavate tanks and dig wells are reviewed later in the chapter to illustrate the effects of such activities.

Irrigation cooperatives: Two case studies

Case 1: Ghatal Vidyasagar Krishi Sech Unnayan Samabaya Smaity Limited, Shitalpur, Ghatal

Background. Shitalpur village is one of many farming villages situated along the Shilabati river. The entire rice land of Shitalpur and adjacent villages is flooded every year during monsoon, precluding the possibility of a wet season (kharif) crop in those villages. During the dry season (rabi), villagers construct temporary "boro bunds" so farmers with lands close to the river banks can get water to cultivate boro rice. However, because of the scant water supply in rabi, conflicts are common, the yield of boro rice falls short of expectations, and large areas remain fallow.

In the early 1980s a few progressive farmers of Shitalpur conceived of a scheme to construct a lift irrigation system. They approached the local branch of the United Bank of India, Ghatal, for financial assistance. The bank's agricultural field officer thought of several alternative schemes and met with the regional manager for Midnapore and the Farm Finance Division at the head office to discuss the availability of financing for the project.

Several other officials eventually participated in the project. They included the Additional District Magistrate, Midnapore; Assistant Registrar of Cooperative Societies, Midnapore; Subdivisional Officer (Executive), Ghatal; Subdivisional Officer, West Bengal State Electricity Board; Executive Engineer, Minor Irrigation Corporation;

Regional Manager, United Bank of India; and the Farm Finance Division of the United Bank of India.

In 1983 farmers and officials agreed on a scheme that would install three pumping stations with two 20 hp electrically operated pumpsets at each station on the bank of the Shilabati river. Water would be lifted and distributed in the command area through underground pipelines. The project was to be undertaken in two phases. The first phase, now completed, called for the construction of

pumpsets with water distribution only by aboveground, earthen channels. The second phase called for the construction of underground pipelines after farmers underwent training in improved rice cultivation practices. The project initially cost a little more than Rs254,000 and, at its completion, was expected to benefit 242.9 ha.

The entire process took less than two years from the time the scheme was conceived in December 1983. By mid−February 1984, the government and bank had approved the subsidy and loan. The pumpsets were commissioned on March 22, 1984.

The cooperative. Farmers registered as a cooperative society under the Cooperative Societies Act of 1973. In keeping with their agreement with the bank, villagers raised share capital of Rs 12,700, which was invested in fixed deposits under the cooperative's name, and agreed to abide by all the terms and conditions of the loan and the subsidy.

Currently, 196 members are enrolled in the cooperative. An additional 294 nonmembers, who receive irrigation facilities from the project, will be enrolled in due course. All members of the cooperative are small and marginal farmers within the command area.

The society is operated by a strong managing committee that is elected every year. The secretary, a key person, is changed by the committee every three years. The society has constructed an office using its own income. Additionally, the cooperative maintains a staff of one full−time manager and one seasonal pump operator. The manager earns Rs 550 a month, the pump operator about Rs 18 a day.

Cropping plan. Because the area is flooded every year during the monsoon, only one crop of boro rice is cultivated. The average yield is 5,436 kilograms per hectare (kg/ha), compared with a maximum of 6,425 kg/ha. The area actually irrigated has increased from a preproject level of 48.75 ha to 202 ha in 1989.

Financing and costs. Under the terms of the original agreement in 1984, the bank sanctioned a loan of Rs 127,000, which carried an interest rate of 10 percent a year. This was to be used for the construction of six electrically operated pumpsets in three pumping stations, power supply to the pumpsets, and construction of three mud houses with thatched roofs. The loan was to be repaid in fourteen equal, half−yearly installments beginning in June 1984.

For income, the cooperative charges fixed water rates of Rs 617.50/ha of boro rice for members and Rs 741.00/ha for nonmembers. Many of the nonmembers are medium−scale farmers.

According to the latest figures, between November 1988 and January 1989 the bank collected Rs 151,461, including a substantial amount of arrears. According to the society's regulation, Rs 100,000 should have been collected during the period.

The society resolved that all outstanding dues would be repaid by June 1989, at which time it would apply for a loan for completion of the second phase. Beginning in 1990, both income and surplus are likely to increase. However, the surplus will be kept for depreciation in a fixed deposit account in the bank.

Case 2: Lakhya Basantapur Boalia Balitaki Irrigation Cooperative Society Limited, Boalia−Balitaki, Sabang

Background. In this second case study, three villages—Lakhya, Basantapur Boalia, and Balitaki—did not have any irrigation source. The villagers, most of whom earned their income as mat makers, had formed a successful association of such laborers. Convinced of the advantages of an organized approach, the association approached the branch manager of the United Bank of India, Sabang, for advice about an irrigation source.

The manager explained the scheme of community irrigation and the provision of subsidies under a government plan. As it was known that shallow tube wells were not feasible in the villages, the group determined that deep tube wells would be the most appropriate source of irrigation. The difficulties in organizing farmers within the proposed irrigation command area were also explained to most of the promoters. The farmers agreed to organize a cooperative society composed of farmers from the three villages and to raise an equity share equivalent to 10 percent of the loan.

The executive engineer of the Minor Irrigation Corporation (MIC) was asked to prepare a plan and an estimate. The promoters and the Farm Finance Division of United Bank of India decided jointly that the MIC could construct the deep tube well and hand it over to the society on a turnkey basis. MIC agreed to act as a contractor.

The project envisaged construction of two electrically operated deep ube wells in two villages with an underground pipeline for water transmission. The irrigation command area under the first phase of the plan was expected to be 80.94 ha and the number of farmers affected was estimated at 224, all of them small or marginal. It was also estimated that, depending on the irrigation capacity, the command area could possibly be extended to 121 ha after three to four years.

The foundation was laid in June 1984. The government and the bank sanctioned a subsidy and a loan in August 1985. MIC began drilling the well in 1986. However, it took considerable time to receive government approval, start construction, and string the electrical lines to provide energy. The tube wells were powered up in the last week of January 1989. The underground pipeline was to be constructed immediately after the harvest of boro rice and in time for the next kharif crop.

To date, in the absence of a pipeline, the area actually irrigated amounts to 20 ha, using two deep tube wells with flood irrigation. The full potential should be realized upon construction of the underground pipeline. However, kharif rice was the only crop grown before the project. After the project, it is expected that cropping intensity might increase to as much as 225 percent.

Financing and costs. The cost of the project was estimated to run to Rs 1,037,402, split evenly between the loan and subsidy. The cooperative members agreed to generate a members' share of Rs 45,000. The loan of Rs 518,701 carried an interest rate of 10.5 percent a year and was to be repaid in nine years from the date of first disbursement.

The cooperative employs two operator−cum−supervisors at a cost of about Rs 800 a month each. One night guard was also appointed at Rs 500 a month. When complete, four operators and one manager will be appointed for the entire year. One of the promoters acts as a supervisor, at present on an honorary basis.

For income, the cooperative charges flat rates per hectare according to crop. Farmers who grow boro rice pay Rs 720, whereas farmers who grow wheat and other crops pay Rs 320.

To date, no repayment of the bank loan has been made as the deep tube wells are not complete in all respects. The first installment was due in December 1989. However, the society has realized that 76 percent of its income from water charges goes toward prepayment of the society's own water rates. To enable farmer−members to cultivate boro rice and also pay water rates, the bank provided the members with short−term crop loans. The irrigation component in this loan was deposited to the society's account for operating the tube wells and paying interest to the extent possible.

Salient features of the two case studies

Salient features common to both cooperative irrigation projects include:

A concerted effort was made by village agricultural leaders, government administrative and technical officers, and bank officials to coordinate all actions concerned with planning, scheme financing, and execution of the project.

All members are small and marginal farmers.

Government subsidies and bank loans cover 100 percent of the project cost; members raised share capital equal to 10 percent of the bank loan.

Water rates are set on the basis of fixed costs and variable costs.

Water rates are collected in advance. Beneficiaries were provided with short−term loans by the bank; the irrigation component in these loans was deposited to the cooperative as prepayment of irrigation charges.

One of the cooperatives was given a loan for opening an Agro−Service Center (ASC) for its members. The other cooperative will request a similar loan for an ASC in the third phase.

With a view to broadening the base of leadership, the managing committee was reelected every year. The secretary was also changed twice in the past six years.

The cooperative using deep tube wells set water rates for boro rice at Rs 1,778/ha compared with the Rs 593/ha charged by public tube wells.

Small farmers associations

Another approach tried in eastern India is the Association of Small Farmers. One notable example is the Vaishali Area Small Farmers Association (VASFA), which originated in 1970. The association is a registered society under the Societies Registration Act as laid out by the government of Bihar. All such associations that have come into existence in the area after VASFA are also registered under the same act. The central VASFA office is situated in Vaishali, about 60 kilometers (km) from Patna, the capital of Bihar, and is well−connected with different parts of the state.

The association began with 167 farmers drawn from five adjoining villages. Over time, it has extended its services to fourteen other villages, and

now has 769 members. The membership includes 52 percent of marginal farmers with holdings of less than 1 ha, 42 percent of small farmers holding 1 ha−2 ha, and 5 percent of medium and large farmers with more than 2 ha. The large farmers have been included in the association mainly because some water channels in the irrigation scheme pass through their lands.

Organizational structure

All members of the association constitute a general body that meets once a year to examine income and expenditure, to review the year's activities, and to plan the program for the next year. There is a thirteen−member Executive Committee headed by a General Secretary who is chosen from among them. Executive Committee members are elected by the general body for two−year terms. The committee is responsible for the management and development of the activities of the association and is assisted by group leaders and group organizers selected from the general membership.

The number of group leaders and group organizers depends on the number of tube wells installed by the association. Each tube well point has one group leader and one group organizer. While the group leaders look after the functioning of tube wells, the maintenance of channels, and the like, the group organizers are responsible for the association's accounts, the maintenance of public relations, and the settlement of disputes among water users. A functional team of paid operators, accountable to the association's group leaders, are responsible for the operation, care, and maintenance of the tube wells.

Aims and objectives

The association bases its philosophy on the principle of "joint means of production with individual farming activity." The objectives behind this founding philosophy are as follows:

To increase the knowledge, attitude, and practice level of the farmers in modern farming.

To ensure supply of irrigation and other inputs to poor and needy farmers and to support the cropping pattern and its diversification.

To increase productivity and production of the land.

To mitigate the impact of drought and its effect on farm practices in the area.

To change the "life and living" of the target group.

Activities

The association has implemented activities ranging from construction of tube wells to supply of farm inputs. Groundwater irrigation through deep tube wells has been carried out since the group's inception. To date, the association has constructed thirty−six deep tube wells with an approximate command area of 320 ha, for an average area of about 9 ha each.

The association also offers it members benefits and assistance in several other areas, including an agro−service center−cum−workshop, short−term bank loans for agricultural inputs to individual farmers, bio−gas plants for individual farm families, and skill training of farmers' sons in agro−based and other trades. The members of the association receive financial support from several sources, ranging from bank loans to government grants.

Expansion and development of small farmers associations

The expansion of the small farmers association concept began in 1977. Twenty associations are now functioning in Bihar and Uttar Pradesh. All of the associations have almost the same organizational structure as VAFSA and similar program activities. Over time, some development has taken place in three areas: organizational structure, membership, and the irrigation scheme.

There is a proposal to divide each association into zones. Each zone will have a Village Development Committee consisting of members elected from among the general membership of the zone. The committee will plan, execute, and monitor the zone's program activities. The Zonal Plan will be submitted to the association's Executive Committee and will be approved in the annual general meeting. Funds allotted to zone programs will be transferred to a separate account kept by each village committee in its local bank. The village committee will remain accountable to the zonal body, which in turn is accountable to the Executive Committee. The associations that have been formed after 1980 follow this pattern and practice.

All of the associations, except VASFA, have included a sizable number of landless wage laborers in their membership since 1980. With technical and financial support from a range of sources, the as−

sociations intend to facilitate skill−training and self−employment opportunities for the landless, resource−less people.

To implement the irrigation scheme, most of the associations have installed shallow tube wells, while three have launched lift irrigation schemes.

Financing

Sri J.C. Mathur, the guiding force behind the formation of farmer associations in the area, extended his full cooperation in arranging funds for the associations from internal and external sources. The main funding sources are foreign contributions and bank loans, and so on. During the formation of VASFA, Sri Mathur helped the association get funds from two foreign donor agencies through the Freedom from Hunger Campaign Society (India).

The donor agencies were the Norwegian Solidarity Fund (NSF) and the Danish International Development Agency (DANIDA). These agencies have also given financial support to sixteen other associations. Additionally, the German Agroaction Fund has contributed to one association and the People's Action for Development India (PADI) arranged for funds for two associations. These agencies have given funds for expenses not financed by the banks. The banks have given short−term and long−term loans for installation of deep or shallow tube wells and for lift irrigation equipment, farm inputs, and the like. Costs of staff and construction of warehouses, workshops, and office buildings have been met by the mentioned donor agencies. Each association has a received total grant of Rs 600,000.

The Central Bank of India provided loans to the members of eighteen associations and the State Bank of India to the other two. For the irrigation equipment, the members authorized the associations to draw the loan amount sanctioned to them. The repayment of loans is undertaken by the member borrowers (table 11.4). Associations collect service charges for the agro−service centers and water charges from users and each irrigation site, and use this income mainly for operation and maintenance.

Recovery of loans has been affected by several factors:

Loan recovery is satisfactory in places where the farmers belong to poor families. It is poor in places where the borrowers are from well−off families.

Lack of coordination among the banks, the

Table 11.4 Total loans provided by banks and recovery made from farmers, as of June 30, 1988
(in thousands of rupees)

Associations	*Total loan demand*	*Recovery*	
Bibipur	494	223	(45.1)
Kamtaulia	70	28	(40.0)
Gangoi	46	162	(35.1)
Muza	471	124	(26.3)
Govindpur	109	109	(100.0)
Bahddinpur	269	203	(75.5)
VASFA	477	262	(54.9)
TASFARCA	591	103	(17.4)
SASFARCA	640	88	(13.8)
Kamtarajpur	16	−	−

− Not available.

Note: Numbers in parentheses indicate percentage of recovery.

associations, and the borrowers affects loan recovery.

Although at the initial stages of association development the banks placed sufficient field staff in the project areas, gradually they have decreased the number of field personnel. This has weakened contact with borrowers.

Each association is spread over a number of villages, making it difficult to maintain contact with all members of the Executive Committee. The committee does not have a monitoring team to look after the progress of project activities, the repayment of loans, and the like. This has affected bank loan recovery. Recently, the Village Development Committees of some associations have begun to look after these activities.

During natural calamities such as earthquakes, drought, and flood, the government often forgives farm loans from banks and other government agencies, either in part or in full. Some people have given a political shape to this policy and have told the borrowers in the small farmers association scheme that they need not repay the bank loan because the government will forgive it.

Because of the poor recovery of loans, the banks are now reluctant to issue further advances to most of the associations or to their members.

Benefits to members

A total of 10,610 farmers and 4,380 landless wage laborers from 270 villages comprise the twenty associations modeled on the VASFA. As revealed by one study, 2,700 farmers—25.4 percent—receive irrigation water and other farm facilities; the remaining 74.6 percent receive the benefits of an agro−service center, farm inputs, bio−gas, and so on.

Individual farm plots covered by 305 deep and shallow tube wells total 1,183 ha, while land irrigated by lift irrigation totals 132 ha. Cropping intensity has increased after the introduction of irrigation, from 100 percent to 200 to 250 percent.

Another benefit is that the cropping pattern has diversified. Before irrigation, the major crops were barley and maize, with monsoon rice and wheat cultivated on a limited number of plots. With irrigation, crops now include summer and monsoon rice, summer and winter maize, wheat, pulses, and oilseeds. Finally, the yields of different crops have increased in the command areas (table 11.5).

Prior to introduction of multicropping practices in the area, an agricultural wage laborer received barely 120 man−days of work a year; this has now increased to 280 man−days on average. Before the introduction of multicropping practices, the wage rate for agricultural work varied between Rs 6 and Rs 8 a man−day; it is now between Rs 12 and Rs 15.

In non−institutional credit, village moneylenders once carried on their operations in full swing in the project area, charging very high rates of interest—72 to 120 percent—on loans to poor and needy farmers. But with the introduction of the project, the lending operations of traditional lenders have been checked. And the increased purchasing power made possible by association membership has improved the standard of "life and living" of beneficiary families.

Table 11.5 Crop yields before and after irrigation

Crops		*Previous average yield (kg/ha)*	*Present average yield (kg/ha)*
Rica	Summer	−	4,940
	Monsoon	1,320	2,964
Wheat		1,235	2,964
Maize	Winter	1,976	3,705
	Summer	−	2,470

− Not available.

Problems encountered by the associations

From the very beginning, the founders of the associations emphasized the development of the local agro−economy through agriculture and other rural economic pursuits. They did not pursue development of local leadership among farmers in a well thought out way. And the associations now suffer from lack of proper leadership.

Another difficulty is that an effective system of supervision and monitoring has not yet been developed in each project area. Additionally, the motivation of the average member is poor. For example, water channels are not cleaned regularly by participating farmers. Many think that "everybody's work is nobody's work." Hence, the group leaders and the group organizers have trouble maintaining the water channels properly.

The poor record for recovery of bank loans from many associations is another problem. The banks are reluctant to give further loans to the associations' members, even to those who have repaid their loans on time. And collection of irrigation water charges in some associations is not regular, creating financial difficulties that hinder maintenance of machinery and tube wells, payment of electricity bills, the purchase of diesel fuel, and so on.

Several requirements have been identified to expand the small farmers association approach:

Selection of a compact area.

A base line survey before planning irrigation and other farm activities.

Orientation of local people on the philosophical connotation of association, that is, joint means of production with individual farming capacity.

Development of local leadership and a group of efficient workers.

Planning at the grass−roots level for a restricted coverage of area.

Assured credit and financial support.

A system of supervision, monitoring, and evaluation.

A mechanism for the recovery of loans from funding agencies.

Coordination among agencies that are key players. These include agencies concerned with irrigation, agriculture, the banks, the management committees, project−level and field−level staff, and the like.

Youth club model

The Ramakrishna Mission Lokasiksha Parishad has been contributing to rural development for more than thirty years, particularly in West Bengal, by modeling village youth groups into youth clubs. Currently, this group is at work in 1,510 villages in twelve districts with 443 youth clubs. Two case studies of youth club projects are discussed in this section to illustrate the potential for implementating minor irrigation programs using dug wells and small tanks.

Although this chapter focuses on the working of shallow tube wells and deep tube wells and the problem of credit delivery to small and marginal farmers, other methods of irrigation are mentioned here to highlight the fact that sinking shallow tube wells and deep tube wells is not feasible in all parts of eastern India. Because of agroclimatic conditions in this part of the country, almost half the land is unsuitable for groundwater exploitation. In these areas, suitable irrigation measures include surface irrigation in the form of land shaping, drainage systems, and the excavation of tanks and dug wells. These types of irrigation are suitable for the small and marginal farmers who can contribute their labor in developing irrigation sources.

The two case studies described below involve the excavation of tanks in the alluvial, coastal−cum−saline area in the district of 24−Parganas South and the excavation of dug wells in the red laterite zone in the district of Purulia. The author is of the opinion that extensive utilization of such irrigation methods in these and similar areas could benefit a large number of small and marginal farmers.

Case 1: Excavation of tanks in the district of 24−Parganas South

In 1985 the Ramakrishna Mission Lokasiksha Parishad and its associated organization—the Baradrone Social Welfare Institution—initiated a tank irrigation scheme that excavated 130 tanks in a group of twenty villages in the 24−Parganas South district of West Bengal. The villages are 48 km southeast of metropolitan Calcutta. The main occupation of the people in this area is cultivation of their mostly rainfed land. The tank excavation work was completed during 198587.

To assess the impact of the scheme, a short−term investigation was conducted, covering a random sample of seventy−six small tanks in ten villages. The study revealed that, of 76 farmers in the sample, 66 are marginal farmers, 9 are small farmers, and 1 is a medium farmer. Half the farmers have brought up to 0.1 ha under irrigation, 26 between 0.1 and 0.2 ha, and the remaining 12 more than 0.2 ha.

Although the area brought under tank irrigation is small, the farmers have been able to raise more than one crop from their command plots. Increased production has raised their family income (table 11.6).

Thus, about 60.5 percent of the farmers have been able to increase their annual income by up to Rs 1,200, 25 percent by between Rs 1,200 and Rs 1,800, and the remaining 14.5 percent by between Rs 1,800 and Rs 2,400.

Table 11.6 Increase In annual Income from tank irrigation
(*number of famers)*

	Increase in income per family per year (Rs)			
Farming categories	*> 1,200*	*1,2011,800*	*1,8012,400*	*Total*
Marginal	39	17	10	66
Small	7	1	1	9
Medium	−	1	−	1
Total	46	19	11	76

− Not available.

For excavation and re−excavation of their individual tanks, the farmers received a loan for part of the total investment, arranged by the Parishad. Table 11.7 shows the credits and the individual contributions.

As far as the recovery of loans is concerned, about 40 percent of the borrowers did not respond to this query, while the remaining 60 percent had repaid part of their loan, with amounts paid ranging from Rs 1,000 to Rs 2,000.

Table 11.7 Credits and own contributions for tank excavation
(*number of farmers)*

	<Rs 1,000	*Rs 1,001 Rs 2,000*	*Rs 2,000 Rs 3,000*	*>3,000*	*Total*
Credit	29	21	18	8	76
	39	19	14	4	76

Own contribution

Case 2: Dug well irrigation in Purulia district

Purulia is a drought−prone district in West Bengal. Modern farming is not unknown to the farmers, but they depend mainly on the vagaries of the monsoon. Lack of irrigation is the main obstacle to making cultivation profitable and to sustaining and improving the livelihood of these people.

Since 1980, the Ramakrishna Mission Lokasiksha Parishad, Narendrapur, has carried out developmental activities in Purulia district. The main channel for program promotion and implementation in Purulia is KALYAN, a federation of rural youth organizations that is an associate organization of the Parishad. Based on the people's plans developed through their local youth organizations, the Parishad initiates developmental activities in its operational areas. In Purulia, the people's plans stressed the need for creation of low−cost irrigation infrastructure to reduce uncertainties resulting from total dependence on the monsoon.

After a baseline village survey conducted by the Parishad in 1983, it was decided to introduce well irrigation in small plots of land on an experimental basis. From 1984 to 1986, about 136 dug wells were excavated in twenty villages.

To ascertain the impact of the scheme, a short−term evaluation covering eighty beneficiary farmers was conducted. The sample included 29 marginal, 34 small, and 17 medium farmers. Fifteen farmers brought up to 0.1 ha under irrigation, 55 between 0.1 ha and 0.2 ha, and the remaining 10 more than 0.2 ha.

Although the area brought under well irrigation is very small, the farmers are now raising more than two crops annually, which has boosted their incomes. Income generated due to access to well irrigation is shown in table 11.8.

Thus, although 30 percent of the farmers succeeded in increasing annual income by up to Rs 1,800 and almost the same number experienced rises between Rs 1,800 and Rs 2,400, more than 40 percent had increases of more than Rs 2,400 because of access to irrigation.

As was true for the tank irrigation scheme discussed above, the costs of the well excavation was financed by the farmers partly through their own financial and labor contributions and partly by a loan arranged by the Parishad. The importance of credit and of individual contributions is shown in table 11.9.

Concerning loan repayment, twenty−two of the farmers did not reply to the relevant question and are presumed not to have made any repayments. Of the 72.5 percent that had made repayments, 30 had repaid up to Rs 1,000, 13 had repaid between Rs 1,000 and Rs 2,000, and the remaining 15 had paid more than Rs 2,000. However, the Parishad considers that, in general, loan recovery is satisfactory.

Table 11.8 Increase in annual income per family attributable to dug well irrigation, Purulia
(*number of farmers)*

Categories	*<Rs 1,800*	*Rs 1,800 2,400*	*>Rs 2,400*	*Total*

Marginal	11	10	8	29
Small	10	10	14	34
Medium farmers	3	3	11	17

Table 11.9 Credits and own contributions for dug well excavation
(*number of farmers)*

	<Rs 2,500	*Rs 2,501 Rs 5,000*	*>Rs 5,000*
Credit	5	62	13
Own contributions	47	26	7

Water management in West Bengal—the experience of a decade

The West Bengal Comprehensive Area Development Corporation (CADC) is a statutory autonomous body with its chief minister, other ministers, and secretaries serving as the members of the board. It is not formally part of the government. However, the act that brought the corporation into being makes it a powerful group. The corporation has the power, for example, to force farmers to adopt specific crops and cropping practices and to construct field channels. But in practice, such powers have not been exercised.

The CADC has sought to modernize agriculture and thereby eradicate poverty and backwardness in West Bengal without imposing a heavy burden on the state budget. The organizational approach was to:

Promote self−supporting and bankable activities by providing 20 percent margin money from the government.

Create irrigation facilities, mainly tube wells, in rural areas so that, in combination with appropriate inputs, technical advice on crop planning and agricultural practices, and credit from banks via farmers service cooperative societies, farmers can make a profit from at least two crops a year and pay the full cost of irrigation water, including depreciation and bank interest, and other inputs. Thus the multiplier effect of the tube wells or other types of irrigation installations would increase productivity and create employment opportunities. Complementary programs, such as small business assistance and adult education, were also planned.

Set up projects in some forty to fifty villages in different districts to implement these irrigation and related programs, so that gradually all or at least the rural parts of West Bengal would be covered by CAD Projects—popularly known as CADP in the 1970s.

The West Bengal CADC Act was passed in 1974 and the program began to be implemented during 197576. The period from 197576 to June 77 saw a high level of activity. Twenty projects in almost all the agroclimactic regions of West Bengal, except the Sundarbans Delta Zone, were established.

The CADC sank and supplied energy to over 1,000 tube wells during this period and supplied farmers with irrigation water and the necessary inputs and credits. It also arranged to provide ser−

vices and assistance, such as advice for crop planning, agricultural practices, storage, and marketing. However, between July 1977 and the end of 1978 the CADC stagnated for several reasons.

First, a cost−benefit analysis undertaken by the CADC did not conform to the socioeconomic reality in the countryside. Poor farmers within the irrigation command area were not able to pay the full cost of irrigation. Rich farmers intentionally did not repay the loan in full. And profit generated from agriculture was not as high as was expected. Second, irrigation tube wells were underutilized or not utilized at all, which made irrigation more costly. Farmers compared rates charged by the government for irrigation with CADC rates and were discouraged to find government rates almost one−fifth the CADC rates in some cases. Third, inputs and services were overemphasized, while the human element was neglected. Programs were imposed from above and were not based on need. Several other problems more political in nature were also suggested.

From 1979 on, the CADC experienced a change in its approach and role and an expansion of its activities. The corporation was deemed to have two strong points. First, its integrated approach made it the only organization capable of seeing the full potential in diversifying the rural economy by identifying the linkages between various activities. Second, the CADC was capable of ensuring coordination between rural people and the many different government, quasi−government, and nongovernment agencies engaged in rural development activities.

The decision was made to strengthen the organization and expand its activities. Local leaders were involved in decisionmaking to ensure popular participation. But water management remained the core central activity.

The water management issue gained increased importance in the CADC from then on. The idea of charging the full cost of water to farmers was discarded and a subsidized rate, almost on par with the government rate, was set. This encouraged farmers to use the installed capacity; however, the increase in utilization was remarkable only during rabi.

By 198081, only 38 percent of the anticipated command areas were irrigated. Of this, 65.4 percent occurred during rabi, 13.7 percent in pre−kharif, and 7.3 percent during kharif. This resulted in serious consequences: first, heavy withdrawals of water during the dry season caused a fall in groundwater levels; second, the cost of operation and maintenance skyrocketed; third, only a few farmers enjoyed the benefit of rabi rice (boro) irrigation while the vast majority were deprived of the water required, which is often twelve times higher than the water requirement of other crops—4872 acre inches for boro as against 6 acre inches for mustard. By converting about 50 percent of the command area from boro to winter vegetable pulses, wheat, and potato cultivation, the total production and total number of man−days could increase remarkably.

In view of this situation, the CADC engaged commission operators to run the tube wells. (Previously, CADC staff, known as Water Management Assistants, had operated the tube wells.) The operators collected water taxes from the farmers, keeping a substantial part as a commission and depositing the rest with the CADC, which used the funds to meet operation and maintenance costs. This system was introduced in 198182 and then withdrawn by 198384 because of operators' demands for higher wages and regular employment.

However, during this period the total area under irrigation increased. The number of deep tube wells rose to 175, of shallow tube wells to 1,300. Some 500 manually operated bamboo shallow tube wells were also constructed. Additionally, from 198485 on, it was realized that the farmers' sense of belonging was a key factor in the efficient use of irrigation installations, and irrigation sources were handed over to users wherever possible.

Today, the deep tube wells are operated by CADC staff, but whenever the command area is more than 12.1 ha, one casual operator is selected by the users from among their own ranks. Technical guidance is provided but construction or reconstruction of old or new pump houses is managed by the users.

Users themselves collect the water tax and pay the electricity charge. The annual rate for such charges is now Rs 1,104 for shallow tube wells and mini−deep tube wells (shallow tube wells with submersible pumps). The tax rate is determined by users in consultation with CADC officials. The repair and maintenance costs are also borne by the farmers in many projects.

Several lessons have emerged from the CADC experience with tube wells:

Farmers are not able to bear the capital cost for installation of deep tube wells or mini−deep tube wells or in some cases even shallow tube wells.

Farmers can, however, bear the cost of operation and maintenance and effectively manage the operation.

Users' sense of belonging is the key factor in the proper and most efficient use of irrigation sources.

Users should be involved from the earliest stage of planning.

Credit delivery to small and marginal farmers

This chapter's review of different approaches to the delivery of credit to small and marginal farmers for irrigation has revealed that no single approach is perfect. Moreover, the applicability of a particular approach in a given situation is conditioned by the availability of local leadership and organizational management.

One point, however, is clear. Improving organization of beneficiary groups improves delivery of credit to farmers and overall management of the irrigation system. There is a growing realization that along with making credit available, emphasis should also be placed on the methods of credit delivery and the organizational pattern that should be promoted in a particular area.

In fact, India today has several schemes sponsored by the government of India and various state governments to provide loans or credit to small and marginal farmers. But for many reasons, including political pressure, the repayment process has been badly abused, and financial institutions have become reluctant to extend further loans. Tables 11.10 and 11.11 show the extent of overdue loans.

Conclusion

User−oriented organizations

The case studies presented above have shown that wherever users are involved in the management of the irrigation system, the utilization of water and the use of credit improves considerably. To involve users, however, it is necessary that management units remain relatively small. Cooperative societies might be one promising approach.

It is heartening to note that during the Seventh Five−Year Plan period, the Indian government, realizing the importance of involving users, initiated an elaborate scheme to promote such organizations. The effort was sponsored by the Department of Rural Development. At present, many training

Table 11.10 Overdues of state cooperative banks, central cooperative banks, and primary agricultural credit societies, 198182

	Overdue loans (Rs lakhs a)	*Percentage of total due*
State cooperative banks		

West Bengal	3,398	51.7
Orissa	2	–
Bihar	3,286	51.4
Uttar Pradesh	1,413	6.6
All India	18,285	8.2
District central cooperative bank		
West Bengal	15,475	64.0
Orissa	4,181	30.6
Uttar Pradesh	19,389	49.7
Bihar	5,417	80.3
All India	123,232	38.5
Primary agricultural credit societies		
West Bengal	16,968	69.0
Orissa	4,613	41.3
Bihar	5,864	74.8
Uttar Pradesh	20,158	50.4
All India	131,823	40.9

a. A lakh is one hundred thousand.

Table 11.11 Recovery performances of scheduled commercial banks
(*percentage of total due)*

Year	*West Bengal*	*Orissa*	*Bihar*	*Uttar Pradesh*	*All India*
June 1977	40.1	41.2	40.6	56.4	50.0
June 1978	40.9	41.8	35.8	56.6	51.2
June 1979	39.8	45.5	31.7	57.1	53.1
June 1980	31.3	44.7	35.5	53.5	52.1
June 1981	30.3	34.9	37.8	54.9	52.9
June 1982	27.3	40.6	39.5	51.5	52.3

Source: Rural Planning and Credit Department, Reserve Bank of India.

programs are being organized around the country to promote such associations. Although the scheme has yet to take definite shape, this as a major breakthrough for rural development in general, and for agricultural development for small and marginal farmers in particular.

Need for composite planning

To make investments for irrigation cost−effective, it is necessary not only to arrange credit for small and marginal farmers, but also to make the most economical use of water through composite farm planning. As the investment cost for shallow and deep tube wells increases, this aspect of agricultural development should be given more emphasis. Effective planning will also include new technical inputs available for agricultural production.

In the case study of deep tube wells managed by a cooperative society, it was shown that farmers are willing to repay the loan, including the cost of investment for the wells, whereas in cases where the government is directly involved through its CADC, the investment cost of deep tube wells is not being recovered. Those connected with irrigation for small and marginal farmers should take into account this aspect of water management for the benefit of the target group.

Supervision

One of the major reasons for loan defaults is the lack of supervision by the funding agency. Where there is proper supervision, the repayment rate improves and, in another argument for supervision, we have seen in the above case studies that whenever organizations maintain contact with users, the implementation of the irrigation scheme is far more successful.

Subsidies for tube well investment

Subsidization as practiced in India should continue. At present, farmer groups in India receive the following subsidies for investments in shallow tube wells and deep tube wells:

Small farmers−25 percent.

Marginal farmers−33.33 percent.

Cooperative societies with a majority of resource−poor farmers−5 percent.

Farmers belonging to Scheduled Castes and Tribes−50 percent.

In summary, irrigation for small and marginal farmers is dependent, not merely on making water for irrigation available, but on multiple factors for which an integrated development approach is needed, including user participation and cooperation, effective (composite) farm planning, supervision, and subsidies. The case studies presented above highlight the integral character that is essential in development programs for the rural poor.

Reference

Reserve Bank of India. 1984. Report of the Committee on Agricultural Productivity in eastern India.

APPENDIX— LITERATURE REVIEW

G.Levine
S. Abeyratne
U. Pradhan

This review of the literature relevant to the question of groundwater utilization for poverty alleviation in South Asia was commissioned by the World Bank to serve as a basic reference for the 1214 April 1989 World Bank Colloquium on the subject. It is as comprehensive as time would allow, though the recent growth of research interest in the topic and the ephemeral nature of much of the literature means that some important materials may not be included. We would appreciate identification of any such references for inclusion in the final review.

Sources of reference material searched include computerized data bases, Cornell University Libraries, the World Bank Library, and ADB Reports. In addition, letters were sent to approximately twenty−five researchers and to organizations in South Asia requesting input for the review. Almost all responded and their assistance is gratefully acknowledged.

Importance of groundwater irrigation for poverty alleviation

Conceptualizing poverty alleviation

"Trickle−down"

"Growth with equity"

Poverty is fundamentally a relative, rather than an absolute condition, and is therefore conditional upon the existence of substantial degrees of inequality. The poor are not a separate society or culture, or even a subsocity or subculture. Their poverty is the result of societal processes rather than of their own making, and their situation can only be effectively viewed as part of a *total system,* and in terms of the relationships between rich and the poor. Indeed, the word "poor" would have no meaning without the opposite word "rich" (Bromley and Gerry 1979:1112).

There is no natural barrier to the satisfaction of the basic human needs of Bangladesh's people. But there is the manmade barrier of a social order—reinforced by aid from abroad—which benefits a few at the expense of the many. Until this social order is fundamentally transformed by and for the poor, needless hunger will persist in Bangladesh (Hartmann and Boyce 1981:210).

Social research to date gives us few clues for coping with this mass of humankind (the

poorest of the poor)liberal reforms have helped and probably can help only the upper poor. But to helpthe poorest of the poor—the critically poor—we do not know how in any practical, politically feasible sense (Thiesenhusen 1978).

Groundwater and poverty alleviation

Groundwater development offers a large underexploited resource and opportunity and has been acclaimed as the "last frontier" for countries such as India and Bangladesh (Chambers and Howes 1980). It has the potential in these countries to create additional livelihoods for at least 60 million people, if intensively used. As such, few if any areas of technology and investment can compete with groundwater in its potential to generate productive employment. However, an appropriate share of this last frontier will not go to those whose need is the greatest without positive policies to safeguard their interests (Chambers and Howes 1980).

While effective redistribution of land remains desired but unachieved, control over groundwater does provide an opportunity to shift the balance of benefits in the direction of the poor. On a macrolevel, this impliesa choice between whatmay be more rapid and laissez−faire development, which favors mostly those who are already less poor, and more controlled development, which may be slower but more equitable and less preemptive (Chambers and Howes 1980).

Groundwater programs targeted to benefit the poor can operate through several mechanisms:

Helping the poor to develop their own water supplies by credit programs that can be directed to individuals or groups and additional programs that provide training in the technical and financial requirements of managing the asset.

Providing publicly run deep tube wells (DTWs) that pump additional water into the canal system, providing water on the same terms as canal water, or selling water directly from the well, at a small profit, at cost, or on subsidized terms.

Government installation of deep tube wells or shallow tube wells (STWs) that are subsequently sold or rented to groups of farmers to manage themselves, at cost or on subsidized terms.

Influencing the conditions by which groundwater is sold from private wells, by encouraging as many farmers as possible to invest in wells (thus increasing competition) and by manipulating the tariff on electricity in the case of electric pumps, so that a flat rate makes it attractive to sell water at cheap prices (Toulmin and Tiffen 1987).

However, the question of how far equity should take precedence over productivity is still open to debate; although there is skepticism about the extent to which "poverty planning" can succeed, Chambers (1986) considers that increased production in itself should be given less weight than the provision of secure and viable incomes to vulnerable groups.

In India, rural equity and the improvement of the position of small and marginal farmers have been identified by policymakers and researchers as important goals. Irrigation development has been pursued as particularly relevant in promoting greater welfare among the poor, due to it being a "livelihood−intensive" sector, providing employment and income not only to farmers directly involved in irrigated agriculture, but also to those in a wide range of related activities (Chambers 1986).

In India, the unexploited potential is still large: estimates of the renewable recharge of groundwater roughly doubled between 1969 and 1983, and 1984 estimates were that 33 percent was still unexploited, which Chambers claims is a substantial underestimation.

Much of this unused potential is in the lower Gangetic Basin in both India and Bangladesh, which is also where there is the greatest concentration in the world in numbers, density, and desperation of poor people (Chambers 1986). The numbers of landless and asset−poor have in fact reached alarming proportions in India, Nepal, and Bangladesh. In Bangladesh, for example, nearly 50 percent of all rural households live below the poverty line, with 60 percent of them living in extreme poverty (that is, unable to buy 82 percent of a minimum necessary diet).

A survey conducted by ARTEP (1977) for Nepal shows that 10.3 percent of all households are landless and that 23 percent of households in the Terai possessed no land. Irrigation can affect these landpoor households in a number of direct and indirect ways. Undoubtedly the key indirect way in which land−poor men and women can gain from irrigation is through employment, including increases in the number of days employed in agriculture, increases in the wage rates for agricultural labor, and leveling off in the seasonality of agricultural employment.

Data for the Punjab, for example, show that tube wells can offset the labor−displacing effects of tractors and other forms of farm mechanization, on all farm size groups (Agarwal 1981). Poor people can also benefit through nonagricultural uses of irrigation water through secondary growth in nonfarm employment, lower food prices, and return migration (Silliman and Lenton 1985).

Social science research into the impact of groundwater development, however, has tended to point out the negative features of the new technology on the grounds that technology has been used inefficiently, that it is mainly only of benefit to larger landowners, and that it has been responsible for transforming the structure of rural society to the disadvantage of smaller landowners and tenants.

This category of literature can be classified into two kinds: the first has tended to emphasize the difficulties arising as a result of the social composition of groups themselves (for example, factionalism) and the existing socioeconomic structure, or factors relating to the physical location of the technology; the second tends to emphasize the "external" factors, particularly official inadequacies of various kinds. These include such factors as disincentive effects of state subsidies and the failure of state agencies to make available spare parts, diesel, and technical expertise.

Thus, while groundwater development offers a massively underexploited resource and an opportunity for redistributing rural incomes, there are mixed reviews on its actual impact. Some early studies (Wood 1980) suggested that assistance to impoverished groups to deploy irrigation water through STWs and low lift pumps (LLPs) can be successfully done and agricultural production and distribution of income can be achieved simultaneously.

Others claim that aid agencies, governments, and local manufacturers have tended to concentrate on larger rather than smaller lifting devices, and that in turn, large landowners have been the main beneficiaries as they have had better access to credit to buy the pumps and thereafter to appropriate communal groundwater with those pumps, through heavy state subsidies on electricity and diesel and through their ability to use the new seed, water, and fertilizer technologies.

Benefits to poorer people have, as a result, been more coincidental than a matter of deliberate policy, and much less than what they could have been (Chambers and Howes 1980). Carruthers and Stoner are equally pessimistic about the benefits of groundwater programs, which they declare are "likely to be a relatively unsuccessful area for income redistribution policies" (1981:33).

According to them, the "lumpy" capital investment leads to local monopolies in favor of richer farmers and is clearly illustrated by the experience from India, where the "water lord" phenomenon is alleged to be common. Their conclusion, supported by other studies, is that groundwater development is generally profitable, but monopoly control of the limited supplies can rapidly rise once this profitability is demonstrated.

Most researchers, however, are uniform in their views that the main opportunity for alleviating poverty in the rural areas of countries such as Bangladesh is to place in the hands of the poor the control of a productive asset. While the most familiar response to this problem in the subcontinent has been land reform, it is recognized that it remains an institutionalized and custom−bound institution where even modest redistribution runs into opposition.

Groundwater on the other hand is a relatively uninstitutionalized and undeveloped rural asset that can be more easily captured and controlled by the landless and near landless, especially through joint action. Thus, it is a resource that can allow previously neglected groups to participate in the rural economy as owners of commodities and services, rather than as supplicants whose labor value is undermined either through personal ties of dependency or availability in the market (Wood 1984).

While this may be brought about by policies that attempt to shift the benefits of groundwater development toward smaller farmers and landless laborers, it must also include supporting policies because groundwater development can contribute to poverty alleviation, but cannot be considered a panacea (Chambers and Howes 1980).

Organization for water sharing has also been promoted in the case of larger−scale lift technology, as a means of providing access for resource−poor farmers. In India, for example, success has been reported under the Pani Panchayat system involving small and weaker farmers. In Bangladesh, considerable experience has been gained with the organization of landless groups with pumps who sell water and sometimes their labor to farmers under the auspices of PROSHIKA. However, organizations for water sharing face problems of scale and although such arrangements can be very liveli−

hood−intensive, it is not clear how widely and rapidly they can be replicated (Chambers 1986).

Technical factors affecting access to groundwater

The technical factors affecting access of the poor to groundwater can be classified into a variety of categories associated with obtaining and distributing the water. Among the more important are: characteristics of the groundwater reservoir, wells, pumps, power, and the size and nature of the water distribution system. The literature has been reviewed from the perspective of these categories.

Groundwater characteristics, and other factors that affect access to groundwater by the poor, vary widely in the region. Since policy and program action are dependent upon a reasonable ability to generalize, and useful generalization is difficult in the context of variation, it is appropriate to attempt to characterize more homogeneous units.

For policy purposes, homogeneity is most logically based on those relevant and significant factors that are either of a permanent nature or are not considered amenable to change. These factors may be physical, economic, political, or social; in the context of groundwater development all are relevant. The appropriate "policy mapping unit," therefore, should reflect the various types of significant factors. Unfortunately, our present stage of knowledge precludes identification of a single, appropriate typology.

From a physical perspective, the characteristics that have relevance include depth to aquifer, dynamic and static pumping depths, water yield/drawdown characteristics, and water quality. All have clear implications for feasibility of access on the part of the poor and for the utility of that access. Unfortunately, the literature is rarely specific in defining these parameters and, therefore, it is not possible to draw definitive conclusions. To the extent possible, however, we have tried to review the literature with these parameters in mind.

At this stage it may be appropriate to consider five physical situations that have broad differentiating power. These can be defined as:

Shallow aquifer: low pumping lift, good water quality.

Deep aquifer: low pumping lift, good water quality.

Deep aquifer: high pumping lift, good water quality.

Areas with a subsurface drainage need.

Shallow aquifer: low pumping lift, poor water quality.

Each of these situations has different implications for the size of investment required for access, the type of appropriate technology and problems of operation and maintenance, and the utility of the pumping for agricultural purposes. Depth to the aquifer influences the type of well drilling equipment; shallow wells can be developed with a wide range of drilling technology, including simple, hand−powered equipment and relatively low cost well casings; deep wells (typically deeper than 3040 meters) are usually drilled with mechanized equipment, are larger in diameter, and require more expensive casing and screening materials.

Pumping lift is variable, depending upon the static lift (non−pumping condition), the rate of pumping, and the yield/drawdown relationships. It is not necessarily related to the depth at which the aquifer is found; artesian pressure can raise water in deep, confined aquifers substantially above the aquifer elevation, sometimes to the surface. The power required for lifting is directly proportional to the dynamic lift, thus determining required size of the power unit as well as power cost per unit of water delivered. Additionally, pumping lift dictates the feasible options for pumping technology. A very significant index related to pumping lift is the lift beyond which it is no longer feasible to use surfacemounted centrifugal pumps. This limit is 9 meters,1 and typically is considered the dividing point between shallow and deep pumping.

Yield/drawdown relationships are a function of the water transmission characteristics of the aquifer and the construction and development characteristics of the well. Situations of high yield per unit drawdown have relatively lower pumping costs and lower potential for inter−well interference. Conversely, wells with low yield/drawdown characteristics tend to have higher operating costs and potential for greater well interference.

The foregoing list describing the various physical situations of groundwater generally represents situations of increasing difficulty of access and utility. However, from the standpoint of development potential, fundamental to all of these situations is the magnitude of safe yield2 of the aquifer. Ongoing World Bank−supported studies are intended to

provide improved estimates of safe yield in the region, and this part of the general problem will not be considered further in this review. The identification of policy options is possible without these estimates, but the appropriateness of individual options is highly dependent on them.

The following discussion of findings based upon the available literature is organized by country, with a sequential discussion of aquifer characteristics, wells and pumps, power, and distribution system characteristics.

Bangladesh

Aquifer characteristics

The basic aquifer characteristics suggested as differentiating characteristics—depth, pumping lift, and yield/drawdown—all vary within Bangladesh. Water quality, in general, tends to be good, except in the lower delta zone, which is subject to salinization (Barber 1988).

Since poor quality water resulting from sea water intrusion is difficult to utilize for agricultural purposes, and since the most feasible remedy requires a reduction in extractions from the aquifer, the situation of a shallow aquifer with low pumping lift and poor water quality offers little opportunity for productive access by the poor and will not be considered further, here. A definition of areas with this characteristic, however, is important for the determination of appropriate development policies.

From a technical perspective, customary terminology used in Bangladesh makes it difficult to be definitive in relating published data to the suggested characteristics. STWs and DTWs are descriptive of the particular configuration of wells and pumps used in projects identified as STW and DTW projects, and do not relate specifically to aquifer depth.

Bhuiyan (1984) describes STWs as usually drilled less than 45 meters (m) deep (customarily less than 30 m) with 10.2 centimeter (cm) casings, and powered by 45 kilowatt (kw) diesel or electric motors. Discharge usually varies between 14 and 21 liters/second (l/s) (nominally considered onecusec pumps).

Similarly, DTWs are characterized by a depth of penetration of more than 46 m, but usually less than 91 m, with 4 cm casings and screens, with a turbine pump powered by a 15 kw diesel engine or electric motor. Nominal discharge capacity is 56 l/s.

Hand tube wells (HTWs) are approximately one−half as deep as an STW (612 m), constructed of 5.1 cm pipe with a hand−operated reciprocating pump. Average discharge is about .56 l/s.

These wells basically are the same as those used for domestic water supply; when used for irrigation, they often are called manually operated shallow tube wells for irrigation (MOSTI). In recent years, other forms of MOSTI pumps have been developed (for example, the treadle pump), with greater discharge, and their use is spreading gradually (Chawdhuri and Gisselquist 1984).

Depth to aquifer

Bangladesh has large areas of shallow, relatively thick sedimentary aquifers, with some areas in which the aquifers are accessible only at greater depths. Thus, there are areas accessible to shallow wells, others accessible to both shallow and deep wells, and others accessible only to deep wells.

In addition, there is a special situation with respect to "very deep" aquifers in the South Asia region. At a World Bank seminar in 1986 (IBRD 1986b) the presence of deep artesian aquifers was identified. In the case of Bangladesh, six hydraulically separate aquifers were identified at depths greater than 1,524 m.

Shallow aquifers and their associated low pumping lifts offer significant possibilities for access by small and marginal farmers. Howes finds access to DTWs highly skewed in favor of rich peasants (RP),3 who comprise only 6 percent of households but hold 37 percent of the irrigated land, and middle peasants safe (MPS), who also have a disproportionate share in terms of population share; and middle peasants danger (MPD), who have disproportionately low access.

The MOSTI wells have a more equitable distribution, though still not fully in proportion to their share of the population. Howes notes, however, that the pattern of inequality evident in the DTW access is "broadly repeated if one looks at the fig−

ures for land as a whole. The introduction of the technique may not necessarily have led to an increase in the overall degree of inequality in social relations."

Biggs and Griffith (1987) make a similar case for MOSTI wells, stressing the labor−intensive nature of the MOSTI technology, both in the construction of the wells and in the pumping, which biases it toward the resources of the poor. However, in the three major programs to foster adoption of this technology,4 most of the sales went to larger farmers. The explanation offered suggests that "it is quite probable that the larger farmers who have access and influence in the institutions are able to preempt the supply of subsidized goods, resell them to the poorer user, and appropriate the value of the subsidy to themselves.

Shallow aquifers of substantial thickness can be accessed at a range of depths, with resultant implications for appropriate technology, investment requirements, and operational needs. Deeper access permits greater rates of extraction and provides a larger effective reservoir (with possibilities for increasing recharge and for improved ability to deal with extended drought periods).

While deep wells in these aquifers in Bangladesh can be constructed by manual technologies, early projects of the World Bank emphasized the use of machine−power drilling, fiberglass screens, and other types of imported materials, although wells of this type (with their associated pumps) typically cost three times more than those constructed manually and utilizing local materials and pumps (Hanratty 1983; Thomas 1972). Table A.1 illustrates the cost differentials of the different types of wells and related equipment.

The greater costs associated with drilling to deeper depths has two related impacts on potential for access to groundwater by the poor. First, there is economic pressure to have a higher pump−

Table A.1 Cost of irrigation by different types of groundwater system, based on 197677 prices
(*taka)*

Item	*Deep tube wells*	*Shallow tube wells*	*Hand tube wells*
Capital cost	223,000	24,100	1,380
Capital cost/hectare meter of water	753	282	388
Operation and maintenance cost/hectare meter	659	648	471
Total cost/hectare meter	1,412	930	859

Note: US$1.00 = Tk 14.39 in 1977.

Source: Adapted from Table 6, Bhulyan (1984) referencing Government of Bangladesh and the World Bank (1982).

ing rate and a larger benefited area. The service area, therefore, usually would be greater than that of an individual farmer, suggesting the need for government ownership, group ownership, or water selling, all of which are directly related to possibilities for access by the poor. Second, the larger service area increases the need for a more elaborate distribution system with direct implications for expression of social factors influencing access.

The very deep aquifers present a special case. To access this resource would require relatively large capacity wells drilled by modern equipment. This clearly would be a public sector enterprise, and access to the water by the poor would be at the distribution, rather than the extraction part of the system. At the World Bank seminar, there was consensus that there were sufficient data in Bangladesh to justify an exploratory drilling program to determine specific characteristics of the aquifers.

Pumping lift (head)

Few reports explicitly indicate the pumping conditions that exist in the region. By implication, STWs with surface−mounted centrifugal pumps have pumping lifts of less than 7 or 8 m. DTWs may function with similar lifts, though turbine pumps or similar submerged equipment is required to take advantage of the potential in the extended depth.

Three characteristics associated with pumping lift are important: total pumping head, magnitude of "suction lift," and the variation of these over time. As suggested earlier, operating power cost is directly proportional to total pumping head, but the literature reveals little of these data. Since most wells discharge at or near the ground surface, there is a close correlation between depth to the water in the aquifer and the total head (though head "losses" in screen, piping, valves and the pump can add significantly to this figure). There are some data for DTWs but very little for STWs and HTWs (Murray−Rust 1983; Bhuiyan 1984).

Water table variation is normal in monsoon climates, as a function of precipitation variation. Water table change tends to increase as groundwater irrigation develops. Bhuiyan (1984) suggests that in Bangladesh, this variation generally is between 3 and 9 m, with an average of 3.6 m.

Murray−Rust (1983) indicates that under prevailing irrigation practices, seasonal water table fluctuations over much of the country would be on the order of 6.1 m. As the fluctuation reaches 6.1 m and beyond, a number of HTW and MOSTI wells

will become nonfunctional by the latter part of the dry season, and, depending upon the original static water level, may be sufficiently nonfunctional and noneconomic as to preclude their use or lead to their abandonment. This is particularly true in areas where DTWs are operating.

This is supported by the IBRD (1981), with the additional question, "can Bangladesh afford additional costs of full DTW developments, including the financial costs of compensation for dry shallow wells?" Bhuiyan (1984) suggests that "areas particularly suited for HTWs should be kept out of bounds for DTWs, so that the shallow waters remain accessible to small farmers willing to use HTWs.

As development proceeds, seasonal variations can be expected to increase with the greater extractions, resulting in expansion of the times in which the pumps will not operate effectively. Even while functional, centrifugal pumps subjected to this range of variation have highly variable operating efficiencies. Centrifugal pumps can be designed to operate very efficiently under constant lift conditions, but typically lose efficiency relatively rapidly when operated at other lift conditions.

Careful matching of pump to lift conditions and opportunities to vary the speed of operation can result in relatively high efficiencies, even in the context of lift variation, but this does not appear to have been done in Bangladesh (Murray−Rust 1983; Biswas and others 1978).

Variation in pumping lift generally has a smaller effect on turbine pumps, though the effect on efficiency still can be significant if pump design does not take into account the expected variation.

The emphasis in the preceding discussion is on the implications of increased depth to the water table, but the situation of very shallow depths is of major concern in many parts of the country. Typically, however, this situation is addressed in the context of drainage problems, rather than irrigation. If water is of good quality, as in most of Bangladesh, subsurface drainage through pumping can provide both irrigation and drainage benefits.

The foregoing and subsequent observations about well and pump technology, power, and systems are equally applicable to this situation, with the exception of the evaluation of the economics and of some of the socio−organizational implications. Since drainage benefits can be anticipated, this benefit should be a factor in policy analysis, especially since the benefit will be of the "externality" type, that is, not fully captured by the individual pumper. Thus, policies that share this externality benefit equitably should be explored. Similarly, situations with significant externalities have implications for requirements for group action as well as for opportunities for group benefit.

Yield/drawdown

Pumping of water table wells results in lower water levels in the wells than in the aquifer; the difference in levels increases with increases in the pumping rate. The water table in the aquifer surrounding the well takes the form of a "cone of depression." Interference, characterized by reduced discharge and lower efficiency, occurs when two cones intersect. The Bangladesh Agricultural Development Corporation attempts to avoid interference by maintaining 600 m between adjacent DTWs, 420 m between a DTW and adjacent STW, and 240 m between adjacent STWs (Bhuiyan 1984).

If well spacing limits can be enforced, a monopoly status is accorded to the prior well owner to the extent of approximately 7 hectares (ha) for the DTW and proportionately smaller areas for the other limits. HTWs/MOSTIs have such low pumping rates that there is essentially no cone of depression and no interference problem.

Wells in artesian aquifers exhibit cones of depression similar to those found in "phreatic" aquifers, though the depression is in the pressure surface rather than the water surface itself. The interference effect is less because the aquifer is not "dewatered" in the process of pumping. Thus, spacing of wells in artesian aquifers can be closer (without adverse effect) than in water table aquifers of similar transmission characteristics. In the case of the very deep aquifers, it has been stated that "they may supply water indefinitely often without use of pumps, once tapped by wells" (IBRD 1986b).

Power

Three power sources are customarily used in pumping in Bangladesh: manual, diesel, and electric. Since human beings have a maximum power of 0.1 hp, and less with sustained effort over extended periods, manual pumping can serve only limited areas. While manual pumping is arduous (Mandal 1978) it is the easiest route to groundwater accessibility by marginal farmers (Howes 1982).

In addition, human power available at low opportunity cost represents a significant resource, with more than 160,000 HTWs in operation in 1982 (Bhuiyan 1984). The fraction of the total irrigated area served by manual methods (all traditional types) was 42.6 percent. In Bangladesh, it is estimated that 80 man−days would be required to irrigate one hectare of rice, providing a significant labor opportunity, though at relatively low productivity. Johnson (1983) suggests the cost ratio of manual to electric energy to irrigate 2.024 ha (5 acres) of rice is approximately 18 to 1, implying either a very high labor cost5 or an extremely low wage rate.

Diesel power is the power source most widely used for pumping in Bangladesh. There are only scattered reports of nonavailability of fuel, though there are complaints of quality problems (Murray−Rust 1983). Five manufacturers are licensed to produce engines locally. However, only one has significant manufacturing capacity, with the others importing most of their units (Murray−Rust 1983).

Lightweight engines, characteristic of the imported engines, require relatively careful attention during operation and have special requirements for repair, including the importation of spare parts. Cast iron construction characteristic of locally made handpumps and low lift pumps is feasible for diesel engine construction, and results in engines that are sturdier (though heavier) and more able to be repaired by local workshops. Government tax, subsidy, and import policies, however, have favored imported technology (Hanratty 1983).

Electric motors have a number of theoretical advantages as a source of pumping energy, including relatively high efficiency, suitability for continuous operation, ease of operation, and potential for minimum maintenance. However, these potential advantages are realized only when electric power is available and stable. Fluctuating voltages, often a result of overloaded transmission and distribution systems, have damaging impacts on electric motors. Very little is revealed in the literature about the use of electric pumping in Bangladesh. Murray−Rust (1983) identifies pumps and motors as a deterrent to expansion of electric pumping because of their high cost. He also suggests that local manufacture of electric motors is entirely feasible.

Distribution systems

The distribution systems associated with wells typically are much smaller than those of surface water sources. The opportunities for greater control of supply, especially in timing, the relatively fixed rate of delivery, and the typically higher costs of pumping, suggest that irrigation distribution systems for pumps should have significant differences from surface systems. From a technical perspective, distribution systems consist of conveyance channels, measurement and control devices, and operating rules. Different combinations can be used to achieve similar objectives, but local conditions determine the most appropriate system.

For conveyance channels, the options include materials that differ according to water loss during delivery, though there are other implications relating to maintenance requirements. The degree of measurement and control that are desirable are dependent upon the operating rules. Operating rules of specific technical concern include those that affect hours of operation and type of irrigation service—individual or multiple.

Concern for the gap between anticipated and actual irrigated area is reflected in almost every reference to irrigation in Bangladesh. "Defective water conveyance and distribution systems" have been identified as contributing to the gap (Bhuiyan 1984), but there are relatively few studies that examine the problem comprehensively. Much of the available work was presented at a workshop held in Dhaka in 1984, and reported in the proceedings (BARC 1984).

Though five functions of the distribution system are identified—that is, convey water from pump to field; facilitate enforcement of scheduled access to the water; deliver specified amounts of water to separate irrigation points; permit flexibility in irrigation decisions across fields and time; facilitate efficient field application of irrigation water (Gisselquist 1984)—the major emphasis of the studies was on reducing water losses in conveyance.

Given the magnitudes of water losses that can occur, often as high as 50 percent (Biswas and others 1984), this emphasis is understandable. However, most of the reports dealt with the effect of channel lining materials on leakage (relating to the first function), with relatively little emphasis on the nonphysical factors that influence water losses and essentially no consideration of those factors that influence "transaction costs."

The improvement techniques—soil compaction, linings of various types, and buried pipelines of different materials—show significant physical and economic benefits as well as different implications for operation and maintenance and for relations among system farmers. The economic analysis did not include transaction costs that can be expected to increase because additional research relating to the organizational implications was stressed.

Nepal

Aquifer characteristics

The Terai of Nepal is characterized by variable subsurface materials, ranging from relatively coarse sediments in the northern area, to finer sediments of the Gangetic plain (Paudyal and Das Gupta 1987). There is significant recharge from rainfall and inflow from the rivers and streams of the region.

The data available for the Terai generally cover widely separated project areas but are adequate for reconnaissance and feasibility studies (Svendsen, Macura, and Rawlings 1984). More systematic evaluation of the groundwater aquifers is taking place by the Groundwater Resources Development Board of the DHIM (ADB 1988).

Depth to aquifer

The variability of the geologic material introduces major variability in depth to the aquifers, but the finer sediments usually are very thick, on the order of hundreds of meters. The coarser materials found in the more northerly parts of the Terai usually are thinner strata, frequently interspersed between layers of more impervious materials. STWs usually access sufficient water at depths that vary between 11 to 27 m (ADB 1988), although an economic depth is considered to be as great as 150 m (Svendsen, Macura, and Rawlings 1984).

Deep aquifers, definitely identified in Bangladesh and India, are also indicated for Nepal at depths of about 1,524 m. They are thought to be highly permeable, unconsolidated gravels and sand, with recharge at the foothills of the Himalayas (IBRD 1986b). Access, as in Bangladesh and India, would be a public enterprise. Most wells are drilled by local drillers, using low−cost indigenous technology, and there are few instances of failed wells (ADB 1988).

Pumping lift (head)

Some areas of the Terai have artesian conditions, including flowing wells, but artesian pressure reduces rapidly upon pumping (Svendsen, Macura, and Rawlings 1984). The literature does not detail static or dynamic lifts, but from the fact that the STWs use centrifugal suction lift pumps and that there have been few cases of failure, it can be inferred that pumping lifts are less than 7 or 8 m (ADB 1988). The combination of aquifer depth, thickness, and water table location makes for little risk in the siting of STWs.

Yield/drawdown

Well discharges, with customary STW pumps, are between 10 and 251/s. At these discharge rates, and given anticipated recharge rates, long−term depletion of the groundwater is unlikely. However, short−term depletion and well interference problems have been identified as a result of high−capacity DTWs installed under World Bank sponsorship in the Bhairawa and Lumbini areas. Farmers in nearby areas complain that their STWs produce very low outputs when the DTWs are in operation and that there are groundwater declines that make some STWs nonfunctional (ADB 1988).

Power

Diesel power is the most common power source used for pumping in the Terai. Five−horsepower units are most common, with some 7 hp or 8 hp pumps also used. The literature does not indicate significant problems due to lack of fuel or parts for the Indian−made pumps and engines. Svendsen, Macura, and Rawlings (1984) suggest that "with the development of water resources, electric power will be required for pump operation." They also identify wind power as a potential source for low−yield wells.

Distribution systems

The distribution systems in the Terai suffer the same problems as those identified in Bangladesh and India. The 2.5 ha actual command area for each tube well is approximately half of what was anticipated in the early project design. "Small holdings, fragmentation of land holdings which dominate the agriculture lands in the Terai, lack of cooperation among neighboring farmers in constructing distribution channels, and limited mobility of the pumpsets [because of] transportation difficulties are major factors that limited the area that can be effectively irrigated by STWs" (ADB 1988).

India

Aquifer characteristics

The Gangetic area of India is characterized by relatively fine, very deep sediments, with both water table aquifers and artesian aquifers. The water table aquifers in a number of areas are recharged significantly from surface irrigation systems, as well as from rainfall. It has been estimated that 40 percent of the water supply in canal systems infiltrates into the groundwater (Saxena and Singh 1988), representing, in some systems, greater recharge than direct rainfall.

Depth to aquifer

Much of eastern India has aquifers accessible at shallow depths. Many are relatively thick, though others are layered, with water−bearing strata interspersed with more impervious materials. The relatively thick water table aquifers are accessible by both DTWs and STWs; the artesian aquifers usually are accessible only with DTWs.

At least four regionally extensive aquifers exist at depths approximating 2,158 m (IBRD 1986b). These aquifers represent a potentially very large water resource to supplement dry season surface and shallow groundwater supplies. With well life estimated at fifty years, and with expected artesian pressures, water cost would be about one−fourth that from a standard DTW in eastern Uttar Pradesh (IBRD 1986b).

Pumping lift (head)

In much of eastern Uttar Pradesh, the water table is within the range of surface−mounted centrifugal pumps (Kolavalli and others 1988). Similar conditions can be expected in other parts of eastern India. In many areas where surface irrigation systems are functional, the water table is rising, resulting in drainage problems, including waterlogging, salinization, and alkalinization (Saxena and Singh 1988).

From the standpoint of physical accessibility, these shallow groundwaters are readily accessible with simple wells and pumps. However, within surface irrigation system commands there may be little inducement to utilize the groundwater (Shah 1988) given the availability of low−priced surface water, notwithstanding the potential drainage benefit from groundwater pumping. In addition, in the low−lying areas susceptible to waterlogging, there frequently is susceptibility to flooding.

The presence of relatively easily accessible groundwater aquifers, and the drainage problems that frequently develop in conjunction with surface water irrigation systems, suggests the need for more effective planning of conjunctive use (Shah 1988; O'Meara 1984).

The literature does not identify significant problems with pumps, and the preference for Indian pumps on the part of Nepalese farmers suggests that the Indian pumps are reasonably appropriate for the conditions of the region. This does not mean that improvements are not possible or that matching of aquifer and pump is carefully done.

By contrast to Bangladesh, there is very little in the literature relative to HTWs, or even dug wells. This suggests that the opportunity cost for labor must be significantly higher than in Bangladesh.

Yield/drawdown

The basic considerations of yield/drawdown relationships identified earlier function in the east India context. Interference between wells is not identified as a significant problem, nor is the long−term decline of the water table. There is some evidence that seasonal declines may be affecting the utility of dug wells, with a shift to mechanized STWs.

There also are no studies identifying the impact of seasonal declines on traditional methods of water extraction, both from wells and from the base flows of streams. Yet, that there are impacts is obvious from the problems of access to drinking water supplies during the drought of 1985, access which was made more difficult by the irrigation pumping.

Power

Problems with the electric power supply are considered to be the most critical factor responsible for the poor growth of water development in eastern Uttar Pradesh (Pant 1988; Saxena and Singh 1988; Sharma 1988). Limited extension of rural electrification and erratic supplies and voltages hamper groundwater utilization. Electric−powered pumps are less expensive than diesel, more easily operated, and more easily maintained (when served by reasonably stable power).

The lack of electricity development and problems with service are causing greater utilization of diesel. In eastern Uttar Pradesh in 1980, for example, 66.4 percent of private tube wells used diesel, an increase that reflects both the increase in wells and the utilization of diesel as backups for wells with electric pumpsets. This, combined with the purchase of larger pumps to pump more water during the times electricity is available, reduces both technical and economic efficiency (Sharma 1988).

Publicly operated DTWs, even with electricity, encountered power problems sufficiently difficult to result in poor utilization. Power outages and mechanical failures combined with managerial problems to reduce utility (Singh and Satish 1988). The World Bank−supported tube wells, designed to overcome these problems with dedicated electric lines and modern control equipment, are not immune to the major difficulties. "What can be said with relative certainty is that the wells are operating far below their potential and the needs of farmers in the command are not being met. Private wells are flourishing: in fact, new wells are being constructed in the vicnity of old wells and outlets" (Kolavalli 1989).

Distribution systems

Distribution systems associated with wells suffer many of the same problems as those with surface systems—poor maintenance, inequitable distribution of water, and a lack of cooperation among users. To avoid these problems, the World Bank financed a number of systems with automatic modern pumps supplied by an uninterrupted supply for 1618 hours per day. These tube wells, discharging 0.042 m3 /sec (1.5 cusecs) with command areas of 11 ha, cost approximately US$65,275 (Rs 500,000).

The distribution systems consist of two underground pipeloops with six to ten outlets each. Water is supplied on demand except during periods of peak demand when a 21−day rotation is used. The rotation is among the outlets, each of which serves several farmers. Individual farmer schedules are determined by a local, Day Area Committee (Kolavalli and others 1988). Even in these systems there are serious problems. In a study of two well clusters, maintenance was found to be minimal, most outlets were not in working condition, and some could not be closed at all (Kolavalli 1989). Problems of distribution, physical and managerial, reduce the utilization of both public and private wells.

Improving Access of the Poor to Groundwater— Sociopolitical and Managerical Issues: Bangladesh

New groundwater exploitation presents unusual room for maneuver in choosing social and economic policies (Chambers 1980). In this section we review the available literature for Bangladesh and look at the sociopolitical and management issues that surround the development of groundwater resources.

The issues that are highlighted are those that have invited research by Bangladesh scholars and others. Although there are several studies on irrigation in Bangladesh, as noted by Biggs and others (1978), "there is a lack of publicly available papers which attempt to pull together these individual studies and discuss the broad range of closely interrelated topics" that surround irrigation.

The discussion has been divided into three sections which look at:

The differential impact of the diverse groundwater technologies.

The rural social structure as it affects the distribution of irrigation benefits and is affected, in turn, by the introduction of irrigation.

Linkages with the state in terms of an evaluation of the different types of management for groundwater development.

Groundwater technologies and their differential impact on the poor

The four types of groundwater irrigation systems in use—DTWs, STWs, HTWs, and dug wells—appeared on the irrigation development scene in an order inverse to their scale (Bhuiyan 1984). The literature about the differential impacts of ground−water technologies on the rural social structure focuses, however, mostly on DTWs, which have also been the most capital−intensive and heavily subsidized by the government.

Hamid (1978), in a study in northwest Bangladesh, drew comparisons between DTW group members and nonmembers. Their major finding was that large, medium, and small landowners with access to DTWs all experience considerable gains in net income, with the income−per−hectare (or acre) gap between rich and poor becoming smaller, but with the gap in total income becoming larger.

Haque (1975) on the other hand suggests that "the process of increasing farm size in irrigated areas is continuing with the concomitant problem of increasing landlessness among dispossessed small scale farmers." He relates this to the use of LLPs whose users display larger average farm sizes than nonusers in the same area than DTW group members elsewhere. A significant drawback, however, is that it is not clear whether disproportionate numbers of

LLP users were initially recruited from the larger landholding stratum (Howes 1985).

In addition there is little mention of the implication of the different types of technology for landless laborers, other than the suggestion that employment opportunities increase relatively little because of the surplus labor already available within landed households.

Information on STW performance is heavily dependent on a single evaluation conducted in northwest Bangladesh by Hamid and others (1982). According to them, the sharing of benefits from STWs often has been assumed to be more inequitable than from any other groundwater technology because most of them are, in effect, privately owned and because, having a relatively small coverage, they offer richer farmers greater opportunities to capture the benefits.

However, though there is some evidence to support this assumption, it is not conclusive. According to Shawkat Ali (1983), STWs are in great demand and clearly represent a preferable technology to DTWs wherever aquifer conditions permit, because of lower capital and foreign exchange costs, greater ease of installation and management, and so on. He does add the cautionary note that while STWs are frequently commended on the grounds that they are virtually unsubsidized, they may be widely provided with hidden subsidies, so that their assumed advantage over other technologies would greatly diminish (1983:5).

Bhuiyan (1984) poses the basic question of "what type of tube well technology is relevant and appropriate for Bangladesh today?" From an economic standpoint he concludes that STWs are the most suitable for "the needs of individual large farmers or groups of small farmers tapping shallow groundwater." According to him, "the appropriateness of the STW technology is proven by its great popularity" (1984:199). He backs this up by claiming that STWs are about 50 percent cheaper than DTWs in making a unit volume of groundwater available for irrigation, are operated by motivated farmers (in the absence of government subsidies), and require relatively less farmer cooperation for successful operation, given that command areas are smaller. Bhuiyan corroborates the evidence that has labeled handpump irrigation as "arduous labor," but cites its relevance as an "option to the small farmer who may not have access to other means of irrigating the land" (1984:199).

A 1982 study by Howes points out that the DTW, as a relatively capital intensive technique, tends to favor the already wealthy; while the highly labor intensive handpump bears more directly upon the needs of the poor and goes at least some way toward arresting their decline. A later study by Howes (1985), which is also concerned with the role of DTWs as opposed to handpump irrigation for the distribution of income between social classes, concludes that:

Access to DTWs is clearly inequitable, but the introduction of this technology may not necessarily have led to an increase in the overall degree of social inequality.

With handpump technology, access is also unequal, but poorer households do relatively better than with DTWs. Not only is more additional income generated but indirectly the technology contributes to making more land available for sharecropping. As such it provides a "safety net" for the marginally landed, counteracting the tendency for landlessness to grow at an increasing rate (1984:114).

Mandal claims that despite higher operation and maintenance costs, yields and returns from STWs are generally higher than under DTWs. Moreover, he states that since STWs are small and easily movable, they tend to be owned and operated by the medium farmers, who are not necessarily "landlords−cum−waterlords" (1988:3). An interesting fact that surfaces from his research (in the Tangail dis−

trict) is that the proportion of tube well owners who owned land under their own tube well was as low as 17 percent for DTWs and 29 percent for STWs. While this does not mean that these same people do not have land under other tube wells, it does call into question the contention that tube well owners have the most land to irrigate, to the detriment of other cultivators.

Several studies have highlighted the merits of handpump irrigation, especially for poor groups, as handpumps are small, locally produced, and use local labor and skills for installation, operation, and maintenance (Hannah 1976; and Howes 1985). Their arguments in favor of the promotion of handpumps as against STWs and DTWs are:

Handpump technology employs unskilled laborers who would otherwise be out of employment in the dry months.

Handpumps save foreign exchange instead of using it on imported tube wells and pumps.

Handpumps are small and thus suitable for fragmented landholdings, which characterize much of rural Bangladesh.

Handpumps are not dependent on the availability of fuel, lubricants, and expensive spare parts, which are needed for mechanized pumps.

Handpumps are movable and can be liquidated as and when required (Biggs 1987).

An early study by Jansen (1979) emphasized the positive income distribution effects of handpumps for poor farmers and sharecroppers. He further suggested that handpumps generate enough additional income for the poor so as to weaken relationships of dependency, and thereby lead to structural changes in the rural areas. Howes (1984) is equally positive about handpumps and cites the benefits that accrue to poor farmers as a result of their use.

A recent report by Mandal, however, refutes these findings on the grounds that they have little to no empirical basis (1988:39). According to Mandal, yields under handpumps can be considered to be higher than under DTWs and STWs, a finding also supported by Howes (1985) who attributes this to more timely and adequate application of water under handpumps.

It is also possible that handpumps are installed and operated on good quality land and on sites where the water table is very high, so that seepage and percolation losses are minimal. For example, Biggs (1987) mentions that the average depth of MOSTIs is 12 m.

The question about the opportunity cost to labor for operating handpumps remains, however. According to Mandal, labor for pumping has to be valued at more than 55 percent scarcity prices in many areas of the country (1988:41). Hussain (1982) made a detailed computation of pumping labor by weeks and months and by age and sex. His data showed that 33 of 54 handpumps used only family labor, and only a small percentage accounted for hired labor, contrary to the argument preferred by Howes, who stated that hired labor was used for extra pumping, especially in drought years.

Instead, it appears that family labor was exploited to the extreme, often causing sickness and cardiac illnesses (Mandal 1988:42). The drudgery cost is thus higher to family labor, including women and children, who were found to constitute 17 percent of total pumping labor. Mandal also points out the level of exploitation evident with handpump irrigation, which according to him is "not necessarily low if one accepts the evidence that 50 percent of handpump users either cultivated sharecropped land or sharecropped and owned land in combination." Moreover, he cites certain data (unfortunately, from a single village example) that show that 66 percent of gross output produced by a handpump went to land and capital owners, so the sharecroppers were left with very little to pay for family labor (1988:43).

Perhaps the most vexing question is why handpump irrigation has not spread more rapidly in the face of the withdrawal of STW and DTW subsidies. The explanations can be many. The first, according to Mandal and corroborated by Palmer−Jones (1988), is the declining profitability of high yielding variety boro rice production itself (which is investigated in more detail elsewhere in this literature review).

Other reasons can be stated in terms of certain prerequisites for the expansion of handpumps:

Good aquifer with a very high water table.

Good quality soils.

Nonavailability of wage employment so that the opportunity cost of labor is very low.

High foodgrain prices so that people must produce rice for survival.

Nonexistence of mechanized irrigation facilities (Mandal 1988:45).

However, the specific advantages of handpumps are that they are suitable for small and inconvenient patches of land between mechanized

tube wells, that they can be used for certain crops that require plant−to−plant irrigation or irrigation through furrow/strips, and that they are effective for the cultivation of vegetables that need greater reliability and independence of water supply. How crops other than high yielding variety boro rice under handpump irrigation can be utilized to the advantage of poor groups still needs to be explored.

Groundwater development and structural change

There has been some exploration of the processes by which social structural conditions determine access to groundwater and how access then leads to changes in social structure. However, the findings have been conflicting in terms of exactly how irrigation development has impacted on patterns of land distribution, terms of tenancy and sharecropping, and income levels and distribution. Part of the confusion is because the findings are generalizations of location−specific conclusions to other areas (Turnquist 1983:4).

Howes' study (1984) falls into this category as it is based on an investigation of a single village in which DTW pumping technology has an effect on the distribution of benefits from irrigation. This he qualifies with two further points: first, the actual value appropriated is marginally greater than one would expect on the basis of access to land alone; and second, the rate at which surplus is appropriated is likely to be far greater than in the case of traditional agriculture.

However, with this in mind, according to Howes, "it is almost certainly the case that the absolute increase in the wealth of the rich peasants class has been accompanied by an increase in the relative share of the total wealth which it enjoys. On the other hand, absolute income levels of those either laboring for others or taking land in sharecrop will also have risen, although not by so much" (1984:111).

What this signifies for poorer groups is that the tendency toward increasing landlessness is somewhat stymied, while for the pure tenants and the landless laborers, there would be the benefit of less competition for work opportunities and for land to rent, than would otherwise have been the case.

"Whose Rural Development?: Socio−Economic Change in DTW Pumpgroups in Bogra District, northwest Bangladesh," by Chisholm (1984), is a comprehensive report that evaluates the socioeconomic effects of a World

Bank− and Canadian−sponsored irrigation project (197480) designed to triple foodgrain production through the cultivation of high yielding variety rice under DTWs. The study selected four pump groups to reflect domination of large landowners and small farmers (two of each) and collected continuous data for five years. Four sets of effects were closely monitored:

Output and efficiency

Employment

Income and wealth distribution

Power relations.

Yields under the project were found to almost double. However, there was no improvement in real wages (and they probably fell), income inequalities increased with no change in the social status of landless or women, and the impact on hired labor was not substantial.

The study is able to conclude that large landowners may block the use of technology or, alternatively, may control it but allow broad access, and that cooperation between farmers is not guaranteed even if all are smallholders. It recommends that irrigation policies be viewed within a broader antipoverty rural development strategy if they are to have a more positive impact.

Research by Mandal (1985) to investigate the economics of minor irrigation under different institutions in two areas of Bangladesh also dealt with changes in land ownership, tenancy, and credit relations. He found that the distribution of benefits is skewed strongly in favor of those with control over water sources and land, and that the process is accelerated by the contractual terms for water, including sharecropping practices, usufructuary land mortgaging, and usury money lending, all of which were found ultimately to affect the performance of irrigation.

Recent research by Glaser (1988) explores the patterns of change in connection with the introduction of mechanized irrigation, in the form of the STW, in an area of the Rajshahi district (in northwest Bangladesh). Her conclusions were:

Cultivation/irrigation costs are biased against "poor" and "coping" households.

Returns to labor and levels of employment rise with irrigated cultivation.

STW irrigation is associated with absolute improvement; relative polarization of household positions with the introduction of irrigation

depends on the structural features of society in general and on the use of irrigation technology in particular.

In the case of the latter, group irrigation was found to provide higher returns to a wider range of poorer households than individually owned STWs. This of course has important implications for policy.

The "landless irrigation" experiment under way in Bangladesh uses as its point of departure the fact that irrigation water constitutes an important rural asset that can be readily (in contrast to land) captured and controlled by the landless and near landless, especially through joint action. In this way, it is believed that the more impoverished groups can participate in the rural economy as owners of commodities and services, rather than as supplicants whose labor value is undermined either through personal ties of dependency or because of its surplus character in the market (Wood 1984).

PROSHIKA's experience with mobilization of landless groups to do just this has been evaluated by Wood (1984). The institutional aspects of the program are discussed in the next section. Here we will summarize the social implications of the program.

Wood sets out to answer the following important questions:

Are profits from irrigation activity being used merely to honor past unproductive debt obligations or are such debt relationships completely severed?

Is the dividend used collectively for further productive investment or dispersed to individuals for immediate consumption?

His data do not allow conclusive answers to these questions, but they do show some attempts by groups to disengage from bondage, as well as group savings being utilized to assist individuals in emergencies so that no group member was obliged to borrow from moneylenders.

Wood poses several other important questions, such as whether the enhanced value of land as a result of irrigation serves to displace sharecroppers. His data unfortunately are too limited in time and location to adequately answer these questions. Longer time−series data are required, as is more detailed information on input costs, yields, and the like.

The issue of longer time−series data becomes pertinent especially in terms of trying to answer questions in relation to longer−term, structural implications of landless control over irrigation technology. For example, what would be the opportunities and constraints for reproducing and expanding landless control over other rural property rights, and is control over irrigation technology leading to long−term disengagement from bondage? Research of this nature is important and desirable now that sufficient time has elapsed since the commencement of these programs aimed at the landless groups.

Management institutions and their implications for poverty alleviation

Groundwater development in Bangladesh has come under the umbrella of different institutions, with different management styles, and has sometimes targeted special groups. For DTWs these institutions include the BADC rental programs for DTWs and sales programs of DTWs (and STWs), the BRDB−KSS program for the development of DTWs, along with the BIADP, which has responsibility for installing 3,000 DTWs in the Barind tract, and the Irrigation Management Program (IMP), which integrates the services of a number of agencies related to the agricultural development programs.

There are also special programs such as the DTW Irrigation and Credit Program (DTICP) of CARE−BADC−BKB, Landless−Owned Tube Well Users Support (LOTUS), a program of CARE−PROSHIKA, the landless irrigation programs of PROSHIKA, Grameen Bank, BRAC, and BRDB−KSS.

The different forms of irrigation organization and management have been substantially influenced by the nature of the technologies involved and like the technologies, they were introduced at different points in time and coexist and compete with each other for financial and political support. The conventional approach has been based on the assumption that, after pump allocation has been approved and installed, most management functions should be delegated to irrigators' groups (most DTWs) or individuals (most STWs); and that the role of the government agencies should be limited to advice and support (Shawkat Ali 1983).

Choice of technology can also have far−reaching implications for the type of management system that is most appropriate. For example, DTWs irri−

gating at full potential require close cooperation among many farmers—perhaps 100—with major differences in socioeconomic background, a situation calling for, according to Shawkat Ali (1983) "very substantial skills in man management."

This is reflected in the fact that most DTWs have management committees with employees for specialized functions. Shawkat Ali goes on to state that experience in Bangladesh has shown that effective management systems for DTWs cannot usually be expected to develop without substantial administrative support, especially in the initial stages. According to him, STWs on the other hand do not require group leadership and "can perform well, in productivity terms at least, without a backup" (1983:7).

One of the most definitive pieces of research to emerge comparing the different groundwater technologies and the different management institutions is by Mandal (1987). The survey, which was conducted in 1985, covered DTWs, STWs, and low−lift pumps and compared their performance on criteria of productivity and equity, under different management institutions. The latter included: a) the rental and sales program of BADC; b) Farmer's Cooperative Society (KSS) and Irrigation Management Program (IMP) of BRDB; c) privately owned STWs sold under the irrigation program of the Bangladesh Krishi Bank (BKB); d) Grameen Bank−sponsored tube wells; and e) the DTIC Program of CARE−BKB−BADC.

Little difference in the nature and extent of functions was found between these institutions, except that BADC's role in providing after−sale care has been somewhat curtailed by the growth of private dealers. According to Mandal's analysis, there were no significant differences in yield or gross output between DTWs under different management institutions,except that the BRDB−KSS−managed DTWs in both areas performed less well than others (1987:24648).

While the DTWs under IMP and DTICP had larger command areas and higher yields, which could be explained by strong institutional support for credit, repair, and maintenance and extension advice, whatever initial success these institutions achieved was seriously affected by the high dropout of schemes from these programs (Biswas 1985).

In terms of STWs, those under the Grameen Bank landless groups and those purchased for BADC or BKB had larger command areas and gross output than the KSS−managed STWs. Mandal (1988) attributes the poor performance of KSS−managed rented, as well as private, tube wells to several problems of which the most acute is the failure to deal with problems of cooperation among nominal KSS members, and between KSS and non−KSS members. In particular, he found that a few dominant members control the tube wells and utilize them far below their nominal potential. BRDB has no means at its disposal to control this and to prevent the larger landowners from enjoying the major share of KSS credit and revenues from water selling through their exercise of control and "free riding" (Mandal 1988:11).

A study by Palmer−Jones and Mandal (1988) in the upland areas of Shokhipur also supports evidence that there was no difference in command area or yield performance between BRDB−KSS and non−KSS DTWs, or more simply, the BRDB−KSS−managed DTWs did not appear to have any better performance in terms of productivity or equity criteria.

The conclusions emanating from Mandal's 1985 study and later writings (1987 and 1988) are that:

The major institutional innovations, in terms of groundwater irrigation management, have "failed to recognize the real world situation," which includes highly unequal access to land, power, and other resources (which makes cooperation unlikely), monopolies, and externalities.

As a consequence, "the performance of irrigation did not improve appreciably, nor could they address the poverty alleviation goal" of government policy (1987:365).

As for the special programs of CARE and IMP, even though they showed some initial successes in terms of productivity, both approaches were found to be too heavily dependent on the active coordination among a large number of agencies to make their long−term viability feasible.

They also demand a high level of cooperation among command area farmers, despite high degrees of differentiation among them. Mandal concludes that "the high dropout rates of these programs demonstrate that these mainstream irrigation innovations are inappropriate to the physical and socioeconomic settings of rural Bangladesh" (1987:365).

The policy implications emerging from his earlier study (1985) evaluating the economics of minor irrigation under different institutions in two areas of the country are worth reiterating: "In spite of variations in performance of irrigation schemes between institutions, management approaches or

contractual terms, it is indicated that there are overall inefficiencies in irrigation schemes caused by a number of economic as well as technical factors, and the irrigation management institutions per se have little to do with it" (1985:76).

His point, and one worth considering, is that measures for improving irrigation performance have to be sought not only in terms of restructuring management institutions and approaches, but also by addressing the broader issues of interlocking factor markets, contractual arrangements for water, land, and other inputs, and credit policies.

The landless pump group activities of PROSHIKA have been the object of substantial review (for example, Wood 1982). The program aims to facilitate the acquisition and use by the landless of LLPs and STWs to enable them to sell water to owners and cultivators of land. This would allow them to develop a source of income, share in the benefits of the enhanced productivity of the land, and achieve a more efficient use of water by challenging existing landlord−dominated monopolies of water resources.

Early results of the program contributed to enthusiasm. According to Wood (1982), the action research program conducted shortly after the commencement of the program (mid−1970s) showed that landless groups, with support, can establish command areas and gain access to the technology; they can use unsubsidized equipment to full capacity and derive an income; they are creditworthy even without land as collateral; they can maintain agreements with farmers and secure their fees; they can fend off rich landowners and moneylenders and they can deploy their income to disengage themselves from dependence relationships.

Quite apart from the claims made by Wood, it appears that there are at least three main benefits deriving from this particular approach that have relevance to water management enterprises in the country. First, it does provide an alternative to the conventional approach of trickle−down by bringing into play a new resource and directing the stream of its benefits into the hands of the poor. Second, it shows evidence of appeal to rural landowners by spreading some of the risks associated with agriculture, such as lack of diesel or spare parts. Third, there is some evidence that farmers are eager to have someone else shoulder the tasks of organizing them, arbitrating conflicts, and so on (Blair 1983:26).

These "transactional costs" are relatively high for minor irrigation, however, and it is not clear whether in the long run landless groups can take on these costs and still make a profit. This remains an issue to be researched.

The Grameen Bank program, aimed primarily at providing credit to the rural poor, has according to Blair (1983) shown considerable promise. He attributes the success of the project to two factors: first, the groups receiving loans are homogeneous in that all are landless or near−landless, thus precluding an elitist takeover; second, almost all the management effort is devoted to maintaining credit discipline. This experience refutes two widely held beliefs—that loans cannot be made to the poor as they will not repay them and that loans cannot be issued without collateral to pledge.

While the initial evaluations of these programs were encouraging in their assessment, later reviews were not as complimentary. Problems such as the extent to which PROSHIKA staff have had to act as brokers between the landless groups and the water users, technical deficiencies in pump operation and maintenance, and difficulties in obtaining satisfactory contracts between the landless pump groups and water users have all been cited as plaguing the program (Shawkat Ali 1983).

Above all, the extent to which the equity−based approaches have actually brought additional benefits to the landless and smaller farmers has not been documented adequately. It is also apparent that these projects—especially those of the NGOs—are inherently pilot projects and cannot meet the needs of the whole country. The criticisms in this regard are worth mentioning: these programs are management−intensive and may well flourish under "hothouse" conditions that include inspired leadership, a heavy infusion of funds, an enthusiastic cadre of field managers, direct communication between headquarters and field units, a genuinely participatory management approach, and rigorous monitoring of all project activities (Blair 1983:24). However, it is not clear how a similar "momentum" can be maintained and expanded to have national coverage.

One of the interesting facts to emerge from Mandal and Palmer−Jones' research (1987) is that in many cases the groups managing and selling the water have shrunk to one or two or three relatives. This did not mean that the command area has also diminished. Rather, what it seems to point out is that the costs to farmers of belonging to a cooperative or of group ownership of a well could be too high if they have to take an active part in management decisions, resolving conflicts, and the like. In some cases farmers were found to prefer to concentrate on farming and to buy water. The difficulties farmers sometimes have in forming and sustaining a cooperative led to various special programs, such as the Irrigation Management Training Program, to give farmers management training and to organize them into more cohesive subunits by dividing the command area into blocks.

There are claims that these programs have succeeded in doubling the command area of assisted DTWs, but some have doubted the durability of the effects and have questioned whether intensive training can be replicable on a large scale (Toulmin and Tiffen 1987:13).

A recent paper by Mandal (1989) sums up the available evidence to date on some of the programs targeted to the landless. According to him, the PROSHIKA Landless Irrigation Experiment has shown mixed results. On the positive side, the program has shown a 75 percent loan repayment rate, which compares favorably with the low recovery rates typical of agricultural loans. On the negative side, the profitability of PROSHIKA irrigation schemes has been declining. This has also been the case with other irrigation schemes, but the declining return from irrigation has affected the landless irrigation managers more seriously as they depend on borrowed capital for the bulk of their capital and operating expenses.

In terms of employment, the evidence is more complicated. Estimates from available samples (from two districts) show that there were no significant differences in per−harvest labor use between landless and private schemes for shallow tube wells. As a matter of fact, increased command area, rather than increased labor intensity per unit of land, appeared to be a more important source of increased employment in landless irrigation schemes. According to Mandal, the implication is that the major advantages of landless irrigation have to be sought not in productivity and employment terms, but on broader equity grounds encompassing greater access of the poor to irrigation and incomes (1989:6).

Nonetheless, a significant factor reported by Palmer−Jones (1986) is that nearly 50 percent of the 309 PROSHIKA groups that started at one time or another have since dropped out. The main reasons for this are related to financial losses caused by poor yields and small command areas, which in turn are the fault of topography, mechanical troubles, and social and political factors associated with command area farmers.

The Grameen Bank program has shown remarkable loan repayment rates (Hossain 1988). However, their focus on this aspect "paved the way for a few to take advantage of the joint liability loan and gradually divert the productive resources from collective benefits to serve private interests" (Mandal 1989:8).

Furthermore, the collective enterprises sponsored through the joint liability loans did not expand as fast as individual enterprises and about one−fifth of the collective enterprises undertaken in the initial years failed (Hossain 1988). Consequently, the bank took up direct management of the collective enterprises from 1986. This seems to have been a positive step, although high operation and maintenance costs were reported for the first season.

However, Mandal anticipates that command area and yields will improve as farmers gain confidence in Grameen Bank management of DTWs. He cautions, however, that bank management means that instead of obtaining one−fourth or one−third share of the crop, landless farmers will benefit only indirectly through wage employment and dividends on their share of capital (1989:12).

Mandal's overall evaluation of the landless programs bears mention. Landless irrigation constitutes an insignificant proportion of total mechanized irrigation; hence, its contribution to overall agricultural production is negligible. In the context of inequality in the access of the poor to rural resources, landless pump groups owning subsidized equipment performed as well as private water sellers and better than cooperative groups.

Since accumulation from irrigation under these programs accrue by and large to the rural poor in terms of profits and increased production and employment, landless groups can benefit, but landless groups need appropriate policies and continued institutional support to build their management capabilities to withstand adverse social, technical, and natural conditions (1989:14).

Nepal

Unlike India and Bangladesh, Nepal has had little experience with the exploitation of groundwater resources. It is only in recent years that the government has initiated some tube well projects that include Narayani (2,700 ha), Bhairawa/Lumbini (7,500 ha), Janakpur (8,400 ha), and Kailali/Kanchanpur (8,000 ha); and Farm Irrigation Water Utilization Division−Western Lumbini (900 ha) and other FIWUD projects.

At the institutional level, the ADB/HMG report (1982) identified the need for a qualified, experienced technical cadre and for the creation of an adequate institutional framework for investigation, implementation, monitoring, and control of groundwater irrigation. Improvement of the technical data base, as well as the improvement of construction industry, is also recommended.

The study showed that several issues warranted careful thought and implementation, including: problems that result from overexploitation of groundwater and that create undesirable hydrogeological consequences for continued use of tube wells; the need of updating data bases for future planning; and proper processes for site selections and monitoring.

Under the Sixth Five−Year Plan, several groundwater projects were implemented, either through the Ministry of Water Resources or through integrated rural development projects. Investigations and feasibility studies were to be carried out in several places in the Terai for potential groundwater development.

During the Seventh Five−Year Plan (1985), the short−term irrigation policy laid down was to dig wells and ponds in the hills and in the Terai with government financial aid and with local skills and technologies where irrigation is feasible, and to initiate extensive small tube well irrigation projects operated by electric, diesel, or physical power.

In regions where power is readily available, emphasis was to be on electric−powered tube wells in conjunction with rural electrification. However, the long−term irrigation program's emphasis would be on developing and preserving the large and medium−size surface and groundwater irrigation projects and on undertaking feasibility studies of prospective new projects to be implemented. As much as possible, these new projects will be multipurpose in nature.

The Water and Energy Commission Secretariat's report on the analytical survey of the laws on water resources in Nepal states that the Canal, Electricity, and Related Water Resources Act of 1967 (CERWR) is applicable to groundwater resource. There are no specific provisions for the exploitation or development of the resource as separate from other surface water resource (WECS 1987).

This act honors the doctrine of prior appropriation as long as it does not hinder or have any adverse impact on any of the government's (existing or future) projects. The ultimate ownership rights of all water within Nepal are considered by the Water and Energy Commission (WECS 1987) to be the state's.

Groundwater irrigation institutions

Before the merger of FIWUD and the Department of Irrigation of Hydrology and Meteorology, FIWUD had pump irrigation and tube well projects. At its establishment as part of the Department of Agriculture in 1985, FIWUD had installed forty−six tube wells, providing irrigation to 7,000 ha.

Under the Development Board Act of 1956, special projects involving considerable foreign capital were to be implemented under a certain board. These boards come under the Department of Irrigation. Projects could be solely for surface water or groundwater or for both. The Narayani Zone Irrigation Development Project is conjunctive, whereas the Bhairawa Lumbini Groundwater Project is exclusively for groundwater.

Most of the groundwater projects come under the Groundwater Development Board. These boards would have representations from the agriculture, irrigation, and finance ministries. These boards are empowered to fix their own water tax and prescribe their own collection methods.

A recent comparison between BLGWP, an agency−managed system, and Chattis Mauja, a farmer−managed system where the command area coincided and the farmers were taking advantages of either or both options, reveal insights relating to group formations and proper functioning of conjunctive systems. Shrestha and Sharma (1987) point out that participation declined because the farmers were not involved in the design of the channel system of BLGWP.

They cite the following reasons for the farmers' aversion to paying the water charges at the rate fixed by the BLGWP even when they consider the rate reasonable:

Water from the tube well is less preferred by the farmers because it does not contain any of the fertilizing elements that are found in the Chattis Mauja surface water.

The tube well is considered by most as a secondary source of irrigation water.

Farmers prefer contributing labor to having to make cash contributions. It is not the rate that is unacceptable to them, but the nature of the contribution.

Smallholdings, the fragmented landholdings that dominate the agriculture lands in the Terai, a lack of cooperation among neighboring farmers in constructing distribution channels, and limited mobility of the pumpsets because of transportation difficulties are major factors that limited the area that could be effectively irrigated by a STW, the study notes.

Although the introduction of irrigation has led to adoption of improved agricultural practices, the difficulties of obtaining all the necessary ingredients of the technological package, as well as the lack of farm−to−market roads, have constrained the marketing of farm inputs and outputs.

India

Differential access to groundwater irrigation

The proposition that the benefits of tube well irrigation tend to favor the more prosperous regions and the more wealthy farmers has been addressed by a number of studies. Most studies tend to be confined to particular states and within them to a few selected villages; nonetheless, they appear to confirm the supposition that groundwater development in India could lead to greater absolute income disparities in the countryside unless there are clear and sensitive policies that would focus on enhancing benefits to the rural poor.

At a micro level, this has spawned many innovative efforts by NGOs and voluntary organizations to achieve an equitable distribution of the groundwater irrigation surplus. Others (for example, Shah 1987a) proffer the argument that although private exploitation of ground water is by definition inequitable, it does leave the poor better off in an absolute sense. Benefits for the poor, according to this school of thought, are derived when those owning groundwater technologies experience a greater need to sell water to others in order to spread their fixed costs over a larger command area (Shah 1987a). In other words, efficient water makers can maximize the benefits of private exploitation of groundwater for poorer sections of the community.

The reason larger farmers have greater access to groundwater irrigation is that digging a well and installing some form of water lifting device requires capital investment and wealthier farmers are most likely to be able to mobilize their own resources or obtain credit for this investment (Meinzen−Dick 1989).

Available data show that the costs of investment and the barriers to small farmers are even higher for wells with pumpsets to lift the water. Copestake (1986) reports that electric pumpsets cost US$375US$520 (Rs 4,8756,750) and diesel engines cost up to US$620 (Rs 8,050), as opposed to bullock−powered lifts that cost only US$154 (Rs 2,000) to install. However, pumpsets—especially electric sets—give higher water discharges and are cheaper to operate because of reduced labor requirements. This technology thus provides greater benefits than manual lifts to farmers who are able to make the investment and make use of the water (Meinzen−Dick 1989).

A recent analysis of research data from North Arcot by Meinzen−Dick (1989) demonstrates conclusively that larger landowners are more likely than small farmers to have access to groundwater through wells. The data further show that the relationship between land and pumpset ownership is even stronger than the relationship between land and well ownership and is in keeping with the greater level of resources required to purchase such machinery.

Harriss (1988) collected data on the history of land sales and economic mobility from a separate sample of households from the same villages and his analysis shows the dynamic relationship between land and wells, especially the instances of downward mobility that could be attributed to failure of a well. Meinzen−Dick (1989) also investigates the employment generated by groundwater irrigation development. Her data show that the employment of long−term hired labor shows a distinct relationship to groundwater irrigation. This relates to the contradictory nature of pumpsets as both labor−displacing and land−augmenting mechanization, where pumpsets reduce the demand for labor to lift water, but increase the demand for labor in other agricultural operations. With the intensification of production and the likelihood that crops can be grown throughout much of the year, cultivators wish to enter into long−term arrangements for labor.

Prahladachar (1989) investigates the factors that inhabit or promote the access of small farmers to well irrigation in Karnataka state. His sample villages were in areas where the water table had been depleted over the years because of climatic factors and overexploitation. As a result, the drying up of open wells had become a common phenomenon and existing wells had to be revitalized by boring, and in the case of new wells, by going for greater depths. This resulted in prohibitive costs for owning and maintaining a well. The factors found to particular inhibit the access of small farmers to tube well irrigation were:

The water table depth, where farmers operating traditional water lifting devices have found them to be of little use and have been forced to liquidate assets such as land, livestock, and jewelry to finance the purchase of mechanized lifts.

Problems in obtaining institutional credit, mainly because of collateral restrictions and a rigid repayment schedule.

Problems with power use and supply.

Legal problems to do with classification of the land under groundwater irrigation as dry or rainfed land, so that land ceilings do not apply to curb groundwater exploitation by large farmers.

Factors found to be promoting the access of small and marginal farmers were:

The subsidy offered under government programs to small farmers for wells and pumpsets.

Assistance provided under the "100 wells scheme" launched by the government in 198384 where a subsidy was paid to individual farmers, at the rate of 25 percent, 33 and one−third percent, and 50 percent for small, marginal, and tribal farmers respectively, on the unit cost of the equipment.

Farm diversification and proximity of markets for intensive high−value crops like vegetables and flowers.

Exemption of stamp duty for dug wells, bore wells, and community wells.

Creation of "a single window" agency for credit disbursement at the *taluk* (block) level to expedite loan applications by small farmers (1989:11).

A study in three different areas of western Uttar Pradesh compared different modes of lift technologies according to holding size to ascertain the level of access of small and marginal farmers to groundwater resources (Chawla and others 1989). Marginal farmers were found to constitute 72 percent of the sample, but to own only 22 percent of the 107 private tube wells installed in the three study areas. The rest of the tube wells are with the medium and large farmers who account for only 28 percent of the sample.

The reasons for small and marginal farmers not owning private tube wells were found to be:

The fact that owning a tube well was a nonviable economic proposition.

The unreliability of electrical supply.

The difficulties in obtaining loans and subsidies.

The availability of sufficient surface irrigation water for their smallholdings (specific to some locations).

The availability of purchased water from neighboring farmers.

Private versus public tube wells

While canal irrigation in India is dominated by state initiatives, in the case of groundwater private farmers have played the dominant role. The direct participation of government in groundwater development has been limited to 40,000 state tube wells, concentrated mostly in the Gangetic plains, while there are more than 8 million private water−lifting devices, which together irrigate more than 30 million ha of land (Shah 1987a).

Private ownership of groundwater technologies has tended to be highly skewed and this tends to increase across regions as differences in aquifer characteristics increase the initial capital costs involved in establishing these technologies (Shah and Raju 1986). Thus, in the Gangetic plains, where the water table is close to the ground surface and hydraulic conductivity is high, the cost of STWs is not as prohibitive. Hence the skewness in ownership of water−lifting devices is far less than in hardrock areas of the southern peninsula or in areas of Gujarat where much higher initial investment is required (Shah and Raju 1988).

Another reason for these skewed numbers is the distribution of landholdings; to earn an adequate return on investment, a farmer must have a captive, irrigable command area of a certain size. Although there are possibilities of selling water, farmers with large landholdings have a natural advantage over small and marginal farmers.

Public tube well irrigation has been compared to private tube wells in a number of studies and unfortunately the verdict has not been too favorable (for example, Moorty and Mellor 1973). However, given the indivisible nature of investment in a tube well, public tube wells have been found to have a definite role to play in regions where landholdings are small and fragmented, as in the Indo−Gangetic plains (Satyasai and Dhawan 1989:2). Clearly, most parcels are below the minimum size for a tube well and therefore economic success depends on cooperation among farmers (Dhawan 1977).

The experience of Andhra Pradesh in terms of public tube wells is the subject of research undertaken by Satyasai and Dhawan (1989). They studied a sample of eighty farmers benefiting from public tube wells. The analysis found that each tube well, on average, irrigates about a 14 crop/ha area, barely one−fifth of the potential irrigable area.

Each irrigated hectare augments the agricultural output by about US$426 (Rs 5,500). This is about four times the unirrigated output obtained in the area and is attributed to improvements in yields and cropping intensity. In terms of national income, each irrigated crop hectare under public tube well irrigation generates an additional income of US$286 (Rs 3,700), which is more than three times an unirrigated hectare.

It also generates additional on−farm employment of 134 man−days, a level which is about 236 percent higher than labor employment on a rainfed hectare. With an internal rate of return of 18 percent and a benefits−cost ratio of 1.06, the incremental benefits accruing from each public tube well are found to be just sufficient to cover the costs (1989:25).

Sharma (1989), in his study of groundwater management in Bihar, investigates what he designates as "a peculiar type of underdevelopment" where underutilization is taking place, despite growing investment and over−capitalization in groundwater and where marginal farmers who account for more than 75 percent of the population are lagging behind other categories of farmers.

His data show that the extent and rate of adoption of groundwater technology has been higher in areas and among farmers endowed with privately operated tube wells and open wells. The programs of credit and rural electrification have been contributory factors, along with the expansion and technical progress of the domestic pump industry, which brought cheaper and lower−capacity pumps into the market, allowing more and more smaller farmers to capture the benefits of private irrigation.

According to Sharma, the state tube wells, whose commands are geared to be at least 100 ha, are inefficient and not geared to poor farmers whose holdings are small and fragmented. In addition, in the case of state tube wells, there are often inordinate delays in repairs and maintenance and a lack of discipline on the part of tube well operators, with serious repercussions for periods of high demand.

Apparently in the 1985 period, more than 66 percent of state tube wells were inoperative for want of maintenance. A further problem is that the construction of channels through the lands of different owners often leads to conflicts. Sharma concludes that above all, state tube wells are not catering to the needs of the poorer farmers. In fact, during times of scarcity, it is the relatively better off and strong farmers who corner the major portion of the limited, but highly subsidized irrigation provided by the public tube wells.

He is emphatic in concluding that "the World Bank loan which the government of Bihar has recently taken for the installation of 500 new state tube wells appears to be a case of misperceived priority, at least on economic grounds. The same end could be achieved more cheaply and in a better way by supporting the development of private tube wells by providing adequate and cheap electric power and subsidies on tube wells and pumpsets" (1989:19).

Chawla and others, in their study of the performance of tube wells in west Uttar Pradesh, are equally denigratory of state public tube wells and according to them, "the maintenance of state tube

wells and their water courses has been awfully hopeless and poor" (1989:22). Some wells have remained closed and out of use for months together, due to a paucity of funds available for maintenance.

Some of the water courses have been damaged by farmers themselves in the attempt to obtain more water for their fields, but nothing has been done to repair them. Despite these shortcomings, farmers in the survey, whether large or small, stated a preference for state tube wells because water is cheaper as compared to water from private tube wells. They also cited the advantages of paying for the cost of state tube well water over a period of six to eight months, whereas most private tube well owners desired immediate cash payments.

Another study of public tube wells in Uttar Pradesh—in this case World Bank−assisted—was undertaken by Satish (1989) to investigate the returns to investment on four tube wells in the districts of Lucknow, Gorkhopur, Varanasi, and Aligarh. According to the author, the World Bankassisted "public" tube wells were designed originally to circumvent the deficiencies encountered with the state tube wells.

In contrast, these new wells have decidedly superior technology and field distribution systems. Electricity is also assured for 1618 hours a day from dedicated feeders. Farmers' participation is a significant component of the program and farmers are held responsible for maintaining channels beyond outlets (1989:1).

Returns on investment were found to vary considerably from one tube well to another and to depend on technical and institutional factors of water accessibility, resulting in returns not being commensurate with investment in two of the four sites. The factors cited were: inadequate power, improper location of *kundis* (outlets), larger command, and lower discharge in the case of the technical factors; and level and type of interaction between farmers and other external (government) agencies in the case of institutional factors. Unfortunately, the study makes no assessment of the impact of these tube wells on poor groups even though the public tube wells in question were introduced "to benefit the economically poorer sections of the farm community" (1989:3).

According to Shah, "the World Bank tube wells in eastern Uttar Pradesh offer perhaps the only example of a situation in which private water markets have shrunk on account of stiff competition from state tube wells" (1989:28). However, Shah goes on to state that a field visit undertaken by him, Pant, and Chambers in the Deoria district left (them) "wondering whether these STWs with advantages of much superior technology, dedicated power supplies and highly subsidized water rates were really leaving their patrons better off" (1989:28). To quote Singh, "in villages saturated with private tube wells or pumpsets, such as Pichari, Mundera, Buzurg, or Bishunpur and experiencing difficulty of farm labor, marginal and small farmers having command over the labor pool have a decisive role in influencing water allocation.

"In the villages served primarily by state or World Bank tube wells, the big or high caste farmers comprising the water allocation committees or working as *Thok* leaders hold sway" (1989:29).

The only significant mass of evidence that works against the thesis of the extreme vulnerability of poor groups to competition from water markets comes from Gujarat, where groups of users, organized as water companies have not only withstood competition from individual sellers, but have actually grown stronger and in areas like north Gujarat, have become the backbone of water markets (Patel 1988:4877).

A survey of the users of two public tube wells by Singh and Satish (1988) indicates that more than 94 percent of the users were small or marginal farmers. The incremental net income from irrigation was US$24.54 (Rs 188) per acre for users of one well and US$84.71 (Rs 649) per acre for the other.

As these wells were in different areas, cropping patterns were different. The users whose incremental income was less than US$26.1 (Rs 200) cultivated cereals while the other group cultivated sugarcane and potato. The cost benefit ratio was less than 1 for the well with cereals and 1.2 for the other well. The technical performance of the wells was not encouraging for reasons of poor maintenance and leaking underground pipes.

Private or individual ownership is the most common type of ownership of groundwater technology and will continue to be so "especially because the experience with state tube wells, the only distant alternative to private domination, is uniformly disappointing on grounds of both equity as well as efficiency" (Shah 1987).

Surveys have found that ownership of private wells is not restricted to large farmers. In a study conducted in Uttar Pradesh, farmers owning less than 4 ha accounted for ownership of 64 percent of the wells (Shankar 1989). The typical pattern, however, was for small and marginal farmers to own a tube well jointly with one or two others, generally relatives. It has also been reported that some well owners provide water free to marginal farmers to encourage them to work in their fields (Singh 1988b).

Community tube wells

One institutional alternative pursued to provide access to groundwater to more impoverished groups is the development of cooperative tube wells. The reasoning behind this approach is that pooling of resources to establish a tube well with joint ownership would overcome some of the problems of disproportionate access by large farmers. A few studies have been undertaken that attempt to test the validity of this approach.

Research by Ballabh (1989) in the Deoria district of Uttar Pradesh is one such study. It attempts to draw lessons from a project established under the Indo−Norwegian Agricultural Development Project (INADP), which incidentally was also studied by Pant and Rai (1985) sometime earlier. Under the project, the tube wells are owned jointly by the group members and water is sold to members as well as to nonmembers. The members of the group should have contiguous land to be served by a joint tube well and landholdings should not exceed 2.02 ha. Water distribution is in the form of a rotation (*para lagna)* and this and other tasks are overseen by the group leader.

The total cost of the project is distributed among the group members in proportion to the area of their land under the tube well command. The members enter into a direct agreement with the bank, in which the amount borrowed is treated as a term loan borrowed by the individual from the bank. Each farmer is required to pay installments, with interest every six months for five years.

Pant, in 1985, came up with more positive results than Ballabh studying the same project four years later. Pant's data show that 97 percent of the marginal and poor farmers were beneficiaries. However, nonmembers were found to benefit more, with 59 percent of the total beneficiaries being nonmembers who were irrigating 63 percent of the land area.

The fact that these nonmembers preferred to pay higher prices for the water than become members is significant—the "transaction costs" of joint ownership far outweigh the benefits of joint ownership. That joint ownership is a preferred mode was apparent mostly in cases where relatives constituted the group (Singh 1988b). This was evident in yet another study conducted in Allahabad district where joint ownership was found to be prevalent among only those with kinship links (Shankar 1989).

Ballabh, in his survey in 1987, found that there were two kinds of deterioration in community tube wells since their establishment in 1974: first, not all community tube wells were working in terms of the group concept. Two groups disintegrated at the inception and three of them have been privatized. In seven other community tube wells, electricity was disconnected either permanently or temporarily. Second, the new public tube wells financed by the World Bank have affected at least two of the community tube wells (and more are anticipated) by giving access to cheaper water; this has led to the closure of many of the cooperative wells.

The thirty−one remaining community tube wells that are still operating were found to be besieged by intragroup conflicts. These conflicts were not about the distribution of water, but rather over the collection of electricity dues, water charges, and maintenance of pumps and motors. A major problem was that members rarely paid the water charges and no mechanism was in place to penalize defaulters. Hence, nonpayment of water charges was the norm, rather than the exception.

Ballabh cites an interesting "evolution" in the case of community tube wells, through three different stages, which perhaps explains the different picture portrayed by Pant in his earlier survey. The first stage is when the community tube well introduces irrigation into an area hitherto unirrigated. The groups tend to command respect and sell enough water to nonmembers to meet their operating costs.

In the second stage, a market in water develops due to new private and community tube wells. The command area decreases. In the third stage, which is roughly a decade from the inception, community tube wells go out of business as it becomes cheaper to buy water from the market than to become a member of a community tube well. According to Ballabh, groups might have been able to counter this entropy if their organization had not been so weak and if policy decisions in terms of electricity supply and the siting of World Bank−assisted tube wells did not go against them.

A study by Nagabrahmam (1989) of more than 150 small groups of farmers and their management of groundwater resources is one of the more comprehensive studies, covering different agro−ecological areas and a number of groups formed spontaneously or through external intervention. Though much variability can be explained by ecological differences, some interesting factors contributing to the "success" of groups were identified.

These included homogeneity of the group members and sufficient water and catalyst agency support. Factors going against group formation were failure or wrong location of wells, lack of proper organization, and an erratic electrical supply. Nagabrahmam also makes a preliminary attempt at a typology of the appropriate conditions for group formation according to the ecological nature of the region (1989:14).

The concept of the Pani Panchayat, an experiment organized by the Gram Gaurav Pratishthan (a voluntary organization working in the drought−prone areas of Maharashtra), is an interesting program targeted to provide the rural poor with irrigation water. Sathe (1989) has made a detailed study of the workings of ten different schemes under the program.

The factors unique to each scheme will not be elaborated upon here, though it does bear mention that the more successful schemes displayed strong local leadership; this was a factor that also led to additional community−based initiatives being taken, for example, development of a secure and dependable drinking water facility (1989:9).

The overall conclusions from the survey are:

The need to determine a lower size limit to a scheme for cost effectiveness.

The need to determine the extent of the government subsidy to small farmers, which has ranged at different times from 50 percent to 80 percent with no apparent logic behind the change.

The concept of the Pani Panchyat has been further extended by the Aga Khan Rural Support Program in Gujarat where water shares of members are fixed at 1.01 ha (2.5 acres) per member of the cooperative lift irrigation program, irrespective of the member's total land falling in the command area. But in loan repayment, a member's share is in proportion to his total land falling in the command.

In the Gonda district of eastern Uttar Pradesh, where water tables are high and aquifer recharge abundant, the Deen Dayal Research Institute, a local nongovernmental organization, has promoted a policy of saturation whereby it has enabled about 10,000 small farmers to own low−cost STWs, so that everyone has access to this common property resource (Chambers and Joshi 1983). Unfortunately, there seems to be no evaluation of either project to assess their impact on the poor or their potential for replication in other areas.

Mechanisms for the management of groundwater resources

Excessive groundwater exploitation has become a concern among hydrogeologists and financial institutions that support groundwater development in India (Dhawan 1987). Concern rests on two counts:

Groundwater resources may be rendered unfit for irrigation use if saline waters from adjacent areas intrude into the voids created by the receding water table (a danger more in coastal plains and in border regions of Gujarat, Uttar Pradesh, Haryana, and Punjab than in the Gangetic area);

The lowering of the water table and interference between wells (as described previously).

Direct regulatory measures were outlined in the model bill called "The Groundwater (Control and Regulation) Bill" of 1974, but this has not been enacted by state legislatures. According to Dhawan (1989) legislative enactments are of little practical value in the particular environment of small and fragmented landholdings as found in India. In particular, these conditions cannot ensure proper spacing without denying latecomers permission to install their wells in the radii of influence of existing wells. And often latecomers to an aquifer are farmers with comparatively small landholdings.

Thus, the task for groundwater legislation is twofold:

Controlling the location of the wells.

Controlling the wells for a year to ensure the long−run stability of the groundwater table.

According to Dhawan (1987), the problem of overexploitation of groundwater resources is a far more serious problem than mutual interference. Carruthers and Stoner likewise state that for India, "no major interference between wells has been noticed" (1981:35).

Overexploitation, however, is a particularly serious threat in shallow aquifer regions where the intrusion of brackish water can damage the aquifer. Rural electrification may have compounded the

problem because it is suited for continuous pumping of water from any depth. In addition, electric power for agricultural pumpsets is heavily underpriced, in comparison both to its resource cost and to alternative sources of energy for lifting water.

Despite the recognition of these problems, indirect institutional measures, such as restricting electricity connections or finance in endangered areas, have proved less than satisfactory. Farmers are able to bribe officials and procure the needed certification for electricity.

Similarly, the stoppage of institutional finance when a tract has witnessed overdevelopment of well irrigation may have slowed down further overexploitation of groundwater water resources, but only where benefit−cost ratios based on funds drawn from noninstitutional sources are not found to be favorable by farmers in that tract.

There are, moreover, two problems associated with this:

Coping with strong political pressures that prevent declaring a tract ineligible for fresh financing for well irrigation.

Ineligibility declared rather late in the day, after overexploitation has become a reality.

However, according to Dhawan, groundwater exploitation in the east Gangetic plains through public tube wells, instead of individually owned wells, is suitable, given the preponderance of small farms and the small danger of intrusion of saline waters.

In principle it appears that controls on withdrawals, including the setting, monitoring, and reinforcement of abstraction quotas for each private well, would be a fair method of allocating scarce supplies. However, the detailed mechanisms for enforcing quotas are, as yet, undefined and the practicability of operating them, extremely vague (Carruthers and Stoner 1981).

Improving Access of the Poor to Groundwater— Economic and Financial Issues: Bangladesh

Underlying the efforts to promote expansion of the minor irrigation sector in Bangladesh is concern about increasing food production and the belief that a strategy focused on small−scale irrigation investments would provide a quick payoff in terms of food production. From this concern emerges the issue of identifying polices and strategies that most effectively utilize groundwater resources, which have been identified as an excellent source of water for the dry season.

Economic and policy background

DTW irrigation was the first mechanized technique to be developed, and installation of DTWs has grown by 500 to 1,000 a year since the mid−1970s. The numbers of STWs sold per year increased steadily in the 1970s and rose dramatically between 1980 and 1983. Since then, however, the absolute levels of STWs have declined sharply.

A policy of privatization was introduced in 1979 and involved the selling of existing DTWs and an acceleration in the sales of STWs, both from BADC with credit from the BRDB and through private dealers with credit provided from commercial banks. Payment on commercial terms was supposed to lead to improved capacity utilization. Almost all LLPs and a number of DTWs have been sold, normally to either KSS or other informal groups, although recently the policy has reverted to selling to KSS groups only (Palmer−Jones and Mandal 1987).

The prices of STWs have risen rapidly. The real cost to buyers depends on the level of credit repayment, which, as with agricultural loans, has been very low. The downturn in demand for tube wells has been ascribed to privatization policies and the removal of subsidies since 1980 and the failure of rice prices to offset these cost increases. Others argue that, following a period of rapid growth of sales in the early 1980s, the decline is due to the technical and institutional factors causing poor capacity utilization of the irrigation equipment.

Palmer−Jones and Mandal (1987) and Hossain (1982) also suggest that a large part of the trend can be explained in terms of unsatisfied potential demand in the early 1980s. According to them, this period was followed by a process of rationalization from 1983 to 1984 because the most favorable sites had been used up, the unfavorable trends in price

incentives that had followed privatization were not reserved, and credit became less freely available.

It is also possible that agronomic problems arising from increases in cropping intensity were limiting responses to fertilizer and high yielding varieties. Thus, there may have been a reassessment of the profitability of boro rice cultivation. Mandal expands on this in a recent document, stating that the major variables explaining the decline in profitability of boro rice production are the decline in yields of rice, increase in production costs because of increases in nominal wage rates and input prices, and at the same time very low harvest prices for boro rice (1988:5).

However, other sources suggest that there is still considerable unexploited potential for further expansion of tube well irrigation and attribute the downward trend in achieving the potential private benefits from irrigation to failures of group irrigation management, which have inhabited full capacity realization (for example, Gill 1983).

Costs and returns to groundwater irrigation

Starting with the premise that groundwater irrigation is socially desirable, previous evaluations have concluded that groundwater should be developed wherever it is considered technically feasible. And feasibility assessments have been based on the availability of groundwater resources and simple crop budgets, using suggested average conditions of soil, water supply, and input and output prices.

A recent survey by Palmer−Jones (1988), which aimed at assessing the costs and returns to groundwater irrigation, attempts to go beyond these early evaluations and develop a model that will throw some light on the differences among survey results. The model developed suggests that groundwater availability and water−demand conditions make it possible for groundwater irrigation to be profitable over a wide area of Bangladesh.

However, the margins have not been overwhelmingly attractive in recent years, and any inferiority in the quality of soil, evaporation, or aquifer conditions is likely to make groundwater irrigation unprofitable (at recent prices). Thus, Palmer−Jones concludes that there will be many places where groundwater is technically feasible but economically unattractive under present conditions (1988:5).

It can be anticipated that in the future, irrigation costs will increase as irrigation development moves to less favorable areas. Thus, much of the area projected for future growth of groundwater irrigation may be in relatively unfavorable ecological conditions. Unless economically higher−value, low−water−demand crops that can justify high infield losses and improved conveyance systems can be found, the rate of development is likely to be inhibited. Wheat appeared initially to be suitable, but its slow growth rate since 198081 has precluded this possibility (Palmer−Jones 1988:12).

In the realm of pricing policy, the declining, but still very large, subsidies on the capital costs of DTWs enabled, indeed encouraged, DTW managers and owners to operate them well below capacity. Subsequent reductions in the subsidy should have helped to improve DTW performance, though clear data are not available to determine whether this did take place.

In light of the movement toward privatization, a caveat in the literature is that formal cooperatives seem to work either more efficiently or more equitably than the more informal management systems found in the private sphere. Initial results from a research project conducted by the Bangladesh Agricultural University (BAU) indicate that there are no significant differences in levels of productivity and efficiency between wells operated under different systems of management (Palmer−Jones and Mandal 1987). Comparative research in other areas would be useful.

Small (1983) draws attention to the high "transaction costs" associated with an expanded command area; given the small average size of farms, expanding the command area requires dealing with a large number of people. Not only is this time−consuming, but the larger the number of people to be included, the greater the likelihood that there will be serious conflicts among them.

Negotiations on the location of the increased number and length of channels and on factors related to landholding boundaries will all contribute to making it difficult to lay out channels. Associated with all this is the management effort. As Small points out, these transaction costs are in a sense "hidden," but nonetheless significant in calculating the costs of expanding command areas.

Though based on a slim data base, Small's observation that there may be very little cost advantage to increasing the utilization of STWs and DTWs is an important one. For STWs the calculated cost per .4 ha served (in 1983 costs) was virtually identical for command areas of 4.1 and 8.1 ha (10 and 20 acres). The same was found to be true for the DTW at full cost. In the case of a DTW with 57 percent of the equipment cost subsidized, the calculated cost per acre for a command area of 32.4 ha (80 acres) is about 15 percent greater than for a command area of 16.2 ha (40 acres).

The reason for this, according to Small, is that the subsidy, by reducing the financing cost, reduces the benefit of spreading the cost of financing over a larger number of hectares. As a result, the benefits of spreading the financial cost are no longer great enough to outweigh the increase in the per hectare operating cost. Thus, what he concludes is that neither from the perspective of the individual farmer, nor from the national perspective, is there a substantial cost savings associated with the utilization of irrigation equipment at a level approaching its technical capacity.

In other words, if there are no substantial cost savings to be realized from efforts to expand command areas from their current typical levels, then the substantial expenditures being made in this direction are ill advised (1983:18). Small makes a recommendation that additional information permitting better quantification of the factors involved be obtained, but these data do not seem to be available even now.

Another consideration in understanding the economics of low rates of equipment utilization is the risk of yield loss or crop failure due to mechanical breakdowns. Predictably, the more hours a pump is run the greater will be the expected rate of mechanical failure per season. If repairs are frequent and there are delays in making them (as apparently is the case of BADC−owned DTWs), it may be more economical to keep the area served lower than would otherwise be optimal, with the relevant consideration being to maximize the expected returns after deducting the expected losses due to mechanical failure (Small 1983:19).

From the perspective of the individual, the economics of equipment utilization will be influenced in large part by the institutional arrangement associated with the ownership of the tube well and, by implication, by the ownership of water rights. If the tube well is owned communally by members of a cooperative, the members will be influenced in their decisions about expanding the command area by the impact of such expansion on their costs of water. If, as suggested previously, there is little or no cost reduction on a per hectare basis, then members have little economic incentive to expand the command area as they are the ones most likely to shoulder the transactions costs of organization for the expanded command area.

On the other hand, if the well is private, then the relevant economic consideration is not simply the impact of the expansion on the cost of water, but the differential between the cost of water and what it could be sold for. In this situation, an individual tube well owner might find it attractive to sell water to neighboring farmers at a price far enough above his costs to make it worth his while.

Income distribution effects

The first point to mention here is the dearth of material relating to income distribution effects of groundwater development, including its impact on employment. The little that exists draws heavily on a single season's data in one particular area or studies the impact of groundwater technology too soon after its introduction to adequately assess the resultant processes of social and economic transformation.

One of the earliest papers reviewing the impact of the development of groundwater irrigation on agricultural output and employment was by Biggs and others (1978). The authors contend that, given the conditions in Bangladesh, MOSTI (standard manual handpumps) are beneficial to poorer farmers and should be supported. However, they caution that despite this technique being an "appropriate," divisible technology and one that is labor intensive and highly productive, many of the benefits are accruing to the larger landowners because of their preferential access to financial capital, land, and agricultural inputs. As such, they advocate changes in government policies that would try to resolve the contradiction between:

The divisibility of the fragmented landholdings and the indivisibility of "lumpy" groundwater technology.

Private production and collectively owned irrigation equipment.

A study by Howes (1982), compared the handpump and the DTW introduced into one rural area of Bangladesh during the boro season of 1989. He found that in terms of the DTW, the results are mixed: access to DTWs was heavily skewed in favor of the rich peasants and, to some extent, the middle−income peasants. This reflected the generally unequal nature of land distribution and did not suggest a growing inequality, although he qualified his findings by saying: first, the actual value appropriated is marginally greater than one

would expect on the basis of access to land alone; second, the rate at which the surplus is appropriated is likely to be far greater than in the case of traditional agriculture.

What this signifies is that it is almost certainly the case that the absolute increase in the wealth of the rich peasant class has been accompanied by an increase in the relative share of the total social wealth that it enjoys. On the other hand, absolute income levels of those either laboring for others, or taking land in sharecrop, will also have risen, although not by much (1982:20).

In terms of the near−landless group, the significance of Howes' findings is that the tendency to increasing landlessness has been somewhat stymied, as this in turn would benefit the landless hired workers, who would now be subject to less competition for work opportunities or land to rent than otherwise would have been the case.

But are rich peasants beginning to acquire more land because of the greater profitability of DTW irrigation? Howes' data show early signs of this, but are not sufficient for proof. Unfortunately, longer time series data would be needed to ascertain if indeed this has occurred or whether the general unreliability of the water supply has worked against the large−scale acquisition of land. If this were happening, it would follow that a policy of increasing the capacity of the DTW would almost certainly squeeze out members of the middle−peasants−in−danger class, to a mixture of benefits and liabilities for the already landless. Present data, however, can only confirm that DTW irrigation brings some benefits to members of most classes, while overall tending to benefit the richest.

With the handpump, the results are clear. Handpump irrigation is a major benefit to the middle−peasants−in−danger class—the most vulnerable landed class—in terms of generating additional income and making more land available for sharecropping. As such it provides a "safety net" to this class, while it has simultaneously prevented additional pressure being put on the landless class at the rate it would otherwise have occurred. Handpump irrigation has also directly increased employment opportunities for the landless. Howes finishes by advocating that handpump irrigation be an integral part of a broader development strategy focused on the poor (1982:22).

Mandal (1988) also addresses the question of the choice of technology and states that the important questions to be asked in relation to handpump irrigation in Bangladesh are:

Is handpump irrigation for high yielding variety boro rice profitable?

If profitable, is it more profitable than other technologies such as DTWs and STWs?

If more profitable than other technologies, at what scarcity price is the pumping labor valued?

Given the extreme drudgery involved for male, female, and child labor, is the employment created really desirable and productive?

Is handpump irrigation free from exploitation of poor farmers' labor by the rich?

Unfortunately, as Mandal points out, there has been no study of handpumps that has countrywide coverage or relevance. Hence, the answers to his questions have to come from the fragmentary evidence derived from different case studies. Mandal, citing these, states that "there are reasons to believe that yields under handpumps are higher than under DTWs and STWs" (1988:40). However, there is evidence that high yielding variety boro rice production with HTWs can be more profitable only when opportunity costs of labor were considered zero (Jaim and Rahman 1978).

In terms of opportunity costs of boro for operating handpumps, Howes and Biggs, according to Mandal, imply that because of underemployment in the rural areas, especially in the dry season, the gross returns from manual pumping still exceed the available wage earnings. However, this fails to appreciate the opportunities for off−season employment in activities such as road construction and the Food−for−Work Programs.

Hence, Mandal concludes that there is a need for further investigation of this aspect. The question of the desirability of creating employment by promoting handpump irrigation is in part answered by Hussain's study (1982), which shows that hired labor accounts for only a small percentage of the extra labor needed. The drudgery cost remains very high for family labor, including children and women. And last, the level of exploitation with HTW irrigation was not found to be low, based on the evidence that 50 percent of handpump users sharecropped most of their land. According to Mandal's calculations from a case study in Sharishabari, those who sharecropped land and hired HTWs from the landowners, ended up with negative returns, since as much as 66 percent of gross output produced by a handpump went to land and capital owners.

A study on DTW pump groups conducted in the Bogra district (Chisholm 1984) provides some comprehensive data on employment and income effects, including the status of women. In general the effects on employment have not been large—employment increased by up to 40 percent with at least half the increase absorbed by family workers and permanent labor.

The study further records a slight decline in real wage rates, no organized wage bargaining, and few signs of change in the status of women. Mechanization was found to be limited, but some rice hulling and threshing machines were being introduced and it could be anticipated that this would reduce work available to poor women.

In terms of land tenancy and transfers, a new situation was emerging. Land was being given to tenants solely for irrigated production and was being taken back for self−cultivation of *aman*. The effects on tenants were found to depend on the previous system: they benefit if the land was fallow before, but tend to be worse off if they held rented land all year before the tube wells were introduced. In addition, in several pump groups it was evident that land transfers in the direction of medium to large landowners were substantial and possibly associated with a lack of access to informal credit by poor farmers. Household incomes rose compared with levels before irrigation, but the largest increases went to the largest landowners. Income inequalities increased. In terms of consumption patterns, there were no significant changes and, as before, most additional income went for consumption. There were no clear improvements in access to education, health care, or family planning (Chisholm 1984:vi).

A recent paper by Ahmed and Sampath (1988) investigates and estimates the welfare implications of tube well irrigation, in the context of the existence of monopoly power in the irrigation water market. Their data on water prices showed that the landless irrigation groups, on average, charged 39 percent less than the estimated monopoly price for water. At this price, the demand was for 1,176 pumping hours per STW, 55 percent more than the output (hours) under a monopoly situation.

Thus, irrigation by the landless groups was found to generate a substantially higher output of water compared to the monopoly situation. These findings prompted the author to suggest that:

The irrigation water in market be made more competitive.

Efforts be made to give control of irrigation assets to the landless and poor farmers, thereby enabling them to sell water to landowners, which will lead to a more competitive water market.

The authors conclude that the competitive pricing of water will increase the technical efficiency of groundwater irrigation by expanding the command area.

The market for irrigation water

Owners of tube wells have the ability not only to capture the economic surplus from irrigation by using the water on their own farm, but also to sell water and capture at least a part of the surplus that this water generates on the land of the purchaser of the water. The extent to which the surplus is shared between the seller and the purchaser of the water will depend on the relative bargaining positions of the two parties, and will be reflected in the price of water.

While selling water may, by definition, make the owner of a tube well a "waterlord," any prohibitions on the sale of water can only worsen the position of the potential buyers of water, since it removes an option that they might find attractive, in preference to being totally unable to obtain water.

The inequities associated with the "waterlord" thesis arise not because the individual is selling water, but because the individual has been given, through the sale of the tube well, the right to pump water (Small 1983:37).

As Small (1983) points out, there is a potential conflict in this context between production objectives and equity objectives. To the extent that rapid increases in production are desired, individual ownership of tube wells and a private market for water is likely to be a more successful approach than the cooperative ownership approach. On the other hand, the cooperative approach implies a more widespread distribution of effective water rights, so that more farmers are able to earn more of the economic surplus generated by water.

According to Mandal and others, a market for irrigation water from groundwater technologies has emerged in recent years, especially in areas where the water table is high and all types of technologies can be used. (In the upland areas, competition is less likely because only DTWs can be installed.) The main features of this incipient market have been identified as the competition between installations for favorable sites, command area plots, electricity connections, and water selling by the equipment owners/managers against water charges collected under different payment systems (Mandal 1988).

Installation has been affected by the policy of privatization of minor irrigation equipment, beginning in the late 1970s. The policy resulted in the selling of LLPs and DTWs, both new and existing, beginning in 1980 and an acceleration in the sales of STWs. The sales of tube wells were promoted through liberalized credit, advanced from commercial banks, and as a result, cash sales of tube wells were very low, even for small−scale HTWs. Concomitantly, the potential for loan default was increased (Gill 1983).

According to Mandal, the dual structure for the distribution of DTWs and STWs since privatization of irrigation equipment began has some inherent weaknesses, resulting in the slowing down of sales. However, a secondhand market for STWs has emerged which, according to him, could be assisted in terms of credit and technical know−how (Mandal 1988:8).

Also there is room for improvements in how electrical connections are made to irrigation units. Currently, there is little enforcement of regulations in terms of electricity charges, and hence there is room for transgressions. As a result, even though an electrified tube well charges lower water fees than a diesel−operated one, the actual cost to the former tube well owner can be so high that water charges might not be significantly different from diesel−run tube wells (Mandal 1988).

In regard to this issue, it is pertinent to note that the Groundwater Management Workshop held in India in January 1989 highlighted the management of rural electricity supply as one of the priority issues for research.

Research by Palmer−Jones and Mandal (1987) has shown that in high water table areas, the exercise of choices by water users among water suppliers in different locations is shaping the emerging water market. As a result, inefficient tube well command areas are being squeezed by the relatively more efficient ones, and in some areas, DTWs are losing land to newly installed STWs.

This trend has meant that prices for water have been pushed down from one−third crop share charged a few years ago to one−fourth crop share or even one−fifth in some areas (BAU 1985). While such competition might be desirable in some respects, the market has failed to address the important equity considerations (Mandal 1988:11). This of course is related to the imperfect product market and unequal access to government institutions for irrigation equipment, credit, input supplies, electricity connections, and repair and maintenance services (Mandal 1988:15).

Palmer−Jones (1988) has explored the market for STWs. He explicitly deals with the equity implications of the different modes of STW development and the allegation that private sector distribution and ownership of STWs is characterized by monopoly "waterlords" and the evasion of spacing regulations, resulting in drawdown externalities. He argues that the current widespread distribution of STWs and associated commercialization of agriculture have given rise to a market for water that is relatively competitive and delivers market equity, which can be considered an improvement on the monopolistic circumstances that perhaps characterized the early stages of adoption.

According to Palmer−Jones, the arguments against STWs have turned out to be largely false because the quantity of groundwater available within the zone that can be exploited by a STW, in the areas for which they are suitable, is sufficient to irrigate almost all the irrigable land. Hence, competition between STWs (and between STWs and other modes of irrigation) prevents a monopoly. There is seasonal drawdown, but there has been no interyear drawdown, except in limited areas and then only in an exceptional year when drought affected recharge—and even then, the drawdown was recovered in the following year.

Payment systems for water

There are four major types of payment for irrigation water and systems vary between regions and within regions with respect to mode and amount of payment. The determinants of payment have been found to be a mix of soil type and topography, risk of cultivation given natural forces, area covered by irrigation units, availability of operating capital, and prevailing contractual arrangements for land and labor.

The system of payment for water has a strong impact on the performance of irrigation, and it is found that sharecropping is clearly an inefficient form of production in that it provides a less than adequate incentive to both water suppliers and users because they each receive only a part of the marginal product of water.

The DTWs that were operated under the fixed, cash payment system, had significantly larger com−

mand areas and higher yields than those operated under one−fourth sharecropping system. Similarly the DTWs operated with the managers supplying the fuel had larger command areas and higher yields than those operated under systems where farmers supplied the fuel (Mandal 1988:5). However, crop sharing seems to be the preferred mode in areas where risks of crop failure are high. The only effective means to reduce or compensate for these risks are policies that can ensure access to institutional credit.

In terms of rural equity considerations, Palmer−Jones is explicit in claiming that the spread of sharecropping "is likely to be adding considerably to rural inequality" (1987:34). However, there is little comparative material on sharecropping where water is the only input shared. Questions to be answered in this respect include:

What is the incidence of sharecropping with water and what are the particular features associated with it?

Are there not significant benefits to be derived by the water buyer from sharecropping with water by, for example, creating an incentive for the well owner to maintain reliable supplies of water as the assurance of his getting paid depends on continued irrigation of the share plots?

Is the high implicit charge per unit under sharecropping a function of the well owner's monopoly power or a function of bearing the risk of failure of essential supplies, such as fuel or spare parts? (Toulmin and Tiffen 1987:17).

Well siting controls and equity

Finally, there is the question of the pace of irrigation development. In Bangladesh there are many important reasons for expanding irrigation at a rapid pace. However, it is equally evident that the rapid expansion of irrigation facilities is itself a problem for good system performance and management (Shawkat Ali 1983).

The adverse effects of rapid expansion were evident in the major period of DTW expansion from the mid−1970s and during the STW boom, where haste in installation led to failure to observe group formation and siting requirements. Currently there is a slowing down of the sales and expansion of DTWs and STWs, which may present a good opportunity to reallocate resources to restructuring the irrigation planning and management processes.

The question of controls to development is an important one to address. A variety of controls are available to ensure levels of groundwater use according to groundwater conditions and administrative capacity, especially in the context of publicly owned wells.

With the policy of privatization, a different set of factors are operating that can be characterized as both "private and public anarchy" (Small 1983:33). Although there are rules supposedly prohibiting the siting of a new tube well within a certain distance of an existing well, there is no effective mechanism in place for the enforcement of such rules. Several reports and studies have indicated a need for government concern over the rapid groundwater development that has lacked direction from planning and management (Hanratty 1983; Radosevich 1983).

A special study was prepared for the Ministry of Agriculture to examine the available data and make a preliminary response to the seriousness of the problem (Harma 1983). The study concluded that in certain areas, limits of available groundwater may have been exceeded by "overprogramming" and oversaturation, endangering the use of HTWs, open wells, and STWs.

Harma also examined in detail the data generated by the Second Tube well Project (1982), which concluded that:

Limited water resources will place constraints on some proposed irrigation development.

Surface and groundwater will face competing demands.

There are areas where underutilized development potential exists.

The report also addressed the problem of conjunctive use of surface and groundwater.

The real concerns voiced are technical ones:

As a result of the effect on the water table, DTWs can render STWs useless if placed too close to them, as influence of the cone of depression will draw the water below 67 m.

STWs placed too close to one another may lower the water table to the limits of pumping capability and, particularly during the critical dry months, provide insufficient water for the farmers, or the well owners may eliminate distribution to some farmers in order to have enough water to mature their crop.

DTWs in particular, may deplete domestic

water supplies from tanks and HTWs as well as interfere with other surface water uses where the surface and groundwater supplies are hydrologically connected (Radosevich 1983:9).

The need for legal intervention and coordinated guidance in groundwater development has been highlighted by several documents (Shawkat Ali 1983; Harma 1983; Radosevich 1983). The report by Shawkat Ali is a detailed account of the legal and organizational problems that could be encountered by the government in attempting to manage and control groundwater. On the technical side, the report proposed that there be legal intervention to set standards for pump engines and equipment.

Radosevich analyzes the need for a groundwater law in Bangladesh and proposes the introduction of a "trip/lock system to groundwater management and control" (1983:18). Through this mechanism, he affirms that the law will be applicable nationwide and will "trip" the mechanism for implementing a more stringent or different set of operating criteria according to the needs of a particular area. The groundwater law he proposes is based on four components: monitoring of groundwater resources of the country, allocation and zoning to enable planned development, management, and enforcement.

The third component—management—has several important aspects. First is the question of well spacing to avoid the detrimental effects of drawdown from wells in close proximity to one another. Second is the setting of "pumping limitation" in certain areas based on the availability of groundwater and its transmissivity. And third is the establishment of "designated water management areas" where there are present or projected problems for control over the use of water. Here the idea is that the boundaries of the designated areas can be expanded or contracted over time as conditions dictate. Unfortunately no documentation is available to ascertain the direction this has taken.

Nepal

The Agricultural Development Bank/Nepal (ADB/N) grants loans for pump irrigation systems as part of an intensive pump irrigation program started in 1981. Under this loan program, over 11,000 STWs covering nearly 45,000 ha have been installed. These loans are given primarily to individuals to purchase materials and pumpsets. A labor subsidy up to US$166.60 (Rs 3000) is provided by the bank during the installation, and a seven−year repayment plan is set up. Maintenance and operation costs are to be borne by the pump owner (Pradhan 1985).

After the government's programmatic effort to introduce tube wells on a large scale, nearly 2,000 small tube wells have been installed by farmers on their own initiative and with their own investment.

In a 1984 study of operation and maintenance problems in Nepalese Irrigation projects undertaken by Shrestha, Shakya, and Shrestha (1984), the problems of recurrent costs are outlined. Along with the surface irrigation systems, three tube well irrigation projects were selected for the study.

The study notes that the current level of water charges collected from the individual projects is far below the annual requirement of funds for operation and maintenance. The systems have been heavily subsidized by the agencies. For projects under the Groundwater Board and DIHM, the rate is based on the discharge (in pump and artesianbased irrigation).

The authors note that reluctance of farmers to accept new rates has a negative impact on fee collection. The water charges in tube well projects are 4.1 and 3.1 percent of the incremental income of rice and wheat crops respectively. The administrativemanagement intensity is higher for FIWUD systems, where project staff/1,000 ha is 44 (for BLGWP it is 15). The expenditure for operation and maintence/ha was US$17.61 (Rs 317) for FIWUD, US$23.94 (Rs 431) for BLGWP, and US$39.67 (Rs 714) for Narayani tube wells. The difference between the expenditure for operation and maintenance against the money actually needed is 33 percent in Kankai (surface irrigation), 53 percent for Mansumara (surface), 76 percent for Narayani, and 5 percent for FIWUD.

These cost differences have brought about proportionate differences in the respective command areas. Per hectare yields and incomes of both rice and wheat are observed to be the highest in FIWUD and lowest in Mansumara (surface). In tube well irrigation, water is released strictly on a demand

basis and there is a relatively better cost recovery. Cropping intensity ranged from 186 to 202 percent. The subsidy on diesel has added a burden on the government treasury, the authors note.

APROSC's *Perspective Plan for Agriculture* indicates that although its introduction of STWs that cover morethan 30,000 ha with 10,000 STWs and that were undertaken with credit from individuals has been impressive, the DTWs have not been. It notes that "at present the greatest handicap in groundwater development has been the lack of energy for pumping."

Diesel fuel may not be readily available at all places and diesel imports are very erratic. The study advocates that priority be given to groundwater development in areas where electric power is available or will be available in the near future. A suggestion is made to the effect that transmission lines from the two major power sources in the eastern and western sectors across the Terai have to be extended to nearby potential groundwater areas so that diesel−driven wells can be converted to electric ones (APROSC 1987).

Past microlevel economic studies overwhelmingly indicate the superiority of groundwater development over surface diversion schemes. In the eastern Terai it was found that pump irrigation had strong impact on both yield and cropping intensity, with more than 79 percent and 34 percent increases in yield and cropping intensity respectively, attributable to irrigation alone (Khoju 1982).

Thapa and Roumasset (1980) contend that the mode of irrigation had an important effect on input use. They showed that while pump irrigation increased both labor and fertilizer use, canal irrigation increased labor use alone and the latter had a minimal impact on yield and cropping intensity.

The impact evaluation study of the Asian Development Bank's operation in the agricultural credit subsector in Nepal reports that the effect of bank−assisted projects would seem to have contributed to the expanded use of STWs among farmers (ADB 1988). The Janakpur Agriculture Development Project funded by the Japanese government has installed 2,300 STWs in the central Terai.

Nearly 2,000 STWs have been installed by farmers on their own. Roughly 21,270 pumpsets have been imported into Nepal from 1970 to 1988, of which 78 percent, or 16,570 units, were imported after 1980. Credit at low interest rates, made available by ADB/N, has helped farmers adopt STW technology. Shallow aquifers in the Terai have encouraged farmers to install STWs.

The widespread adoption of STWs is due to relatively low investment costs, quick−yielding results and simple technology. It is the individual, medium, and large farmers that have installed the STWs. They are privately owned, operated, and maintained. Community−based or group−owned STWs are limited. STWs have generated employment opportunities through well installation, operation and maintenance of pumpsets, construction of distribution channels, and the like. The operation and maintenance of a STW would require about 60 man−days a year. STW technology has contributed to the development of the local well−drilling industry and to the manufacture of STW parts and the expansion of spare parts supply agencies and repair shops. India has found in Nepal a substantially growing market for its pumpsets and accessories.

Bank−financed agricultural projects have only made a modest contribution toward achieving the desired impact in terms of equity and poverty alleviation. Equipment that generally required high levels of investment could be afforded by large farmers only. Due to their capacity to absorb financial losses, large farmers tended to adopt new technology more readily than small farmers.

The number of STWs and pumpsets distributed to small farmers, who would be organized into small farmer groups, was substantially less than envisioned (ADB 1987). Organizing farmer groups turned out to be much more difficult than expected, especially when no assistance was afforded under the bank−assisted project. Meanwhile, pumpsets procured under bank loans needed to be distributed speedily in accordance with the targeted implementation schedule. Therefore it was easier for ADB/N to distribute STWs and pumpsets to larger farmers who were in a better position than smaller farmers to obtain loans from ADB/N. Similarly, because the subsidies were given for each well installed, they naturally benefited large farmers who could afford to install STWs.

In BLHWP, where high−capacity DTWs were installed under two World Bank−assisted projects, farmers in the nearby areas complain that their STWs produce very low yields when the highcapacity DTWs are in operation. The substantially increased groundwater withdrawals resulted in a substantial decline in groundwater levels over broad areas, making suction lifting in STWs unfeasible. Measures have been introduced by ADB/N and BLGWP to prevent the well interference problem.

India

Boyce (1988) points out that the recent spread of capital−intensive "modern" irrigation technologies, such as STWs and DTWs and LLPs has led in several cases to the reversal of the inverse relations between farm size on the one hand and land and irrigation productivity on the other. Boyce further notes that the larger cultivators frequently obtain greater access to these new technologies for three reasons:

If allocation is left to the market, the larger cultivators are better able to afford the substantial outlays required.

If irrigation equipment or credit to buy it is rationed or subsidized by the government, the larger cultivators often receive preferential treatment owing to their political leverage.

Larger cultivators are better able to utilize such irrigation techniques to capacity on their own holdings only insofar as institutional mechanisms for joint water−use are imperfect, resulting in greater costs or risks than individual use.

The adoption or spread of private irrigation techniques may be affected by the degree of subdivision (the splitting of an agricultural holding into a number of smaller holdings) and fragmentation (the existence of a number of noncontiguous plots within a single holding).

Dhawan (1977, 1982) has calculated that the minimum farm size at which an STW becomes profitable on an individual holding in northern India increases towards the eastern Gangetic plains primarily due to differences in fragmentation and interest rates. The average holding size, at the same time, declines from the west to east. Dhawan points out that this combined effect calls for a greater need for institutional mechanisms for cooperative tube well use in the east than in the west. This helps to explain, he points out, why tube well irrigation in West Bengal and Bihar is lagging behind that in Punjab and Haryana.

Jairath (1985) reports a case of adverse impact when tube well irrigation was introduced as an alternative water source where the maintenance of a water course was the joint responsibility of all cultivators who shared a given outlet. Those farmers who had been able to install tube wells subsequently neglected watercourse maintenance, "thereby depriving even the others of water since it was not practical for them to clear the entire length" (Jairath 1985). It was the poorer cultivators who lost access to irrigation since they could not afford tube wells.

Boyce (1987) notes that an inegalitarian agrarian structure poses a serious impediment to water control development. His inferences are from Bangladesh, but we feel that the inference could be applicable elsewhere in India and Nepal as well. It is usually deduced that irrigation development would employ surplus labor by generating employment. Boyce (1988) points out that the mobilization of seasonally underemployed labor for water control projects in the slack winter season is impeded by the fact that those who have surplus labor (the landless or near landless) do not own the land that would be improved. Thus, they would need to be paid and supervised.

Boyce goes on to point out that in theory, the landowners could pool their financial and managerial resources for this purpose, but in practice they seldom do so because of:

Problems of cooperation among themselves.

The availability of capital−intensive irrigation alternatives that are often subsidized.

The presence of more profitable avenues of investment, often outside the agricultural sector.

The government rural works projects that agricultural laborers might organize if brough together to work in one place for an extended period of time, with potentially explosive consequences.

Little has been researched regarding the impact of the reliance upon external and foreign assistance and resources. There have been cases where such reliance has also entailed reliance on foreign technology and foreign institutional models.

Boyce (1988) notes that one frequent result is an increase in the capital intensity of irrigation development. This is partly because of the export−promotion in foreign assistance and the fact that the technologies being transferred were generally developed under conditions of relatively greater labor scarcity; and partly because of a preference among foreign and foreign−trained engineers and planners for "modern" techniques.

This bias is illustrated by the World Bank's Northwest Tube Wells Project in Bangladesh. From

a technical standpoint, the pumps were ill−suited to the less than ideal operating conditions of rural Bangladesh and, hence, vulnerable to breakdowns, which were often prolonged by the absence of trained mechanics and imported spare parts. From an economic standpoint, the high capital intensity of the project was inconsistent with the country's labor abundance and capital scarcity.

Dhawan (1985), in his interstate study of sourcewise productivity of irrigated agriculture, states that the interstate variations in productivity of irrigated agriculture do not reveal any marked positive relationship with the relative share of groundwater in total irrigation of a state.

He points out that in a linear correlation analysis based on cross−sectional data for states, the relationship between any two variables can be masked by other factors. Groundwater, as well as surface water irrigation, comprises a variety of irrigation works. There are differences in the technology as well as ownership status in the different groundwater systems.

Dhawan states that given such heterogeneity within each of the two principal categories of irrigation, a straightforward relation between proportional share of groundwater in total irrigation and productivity of irrigated agriculture may or may not prevail across states.

Dhawan's methodology (1985) is that of statistical decomposition of aggregate crop output of a state through the technique of multiple regression whereby district−wise crop output is regressed on source−wise irrigated areas and unirrigated area. He found out that for the two southern states of Tamil Nadu and Andhra Pradesh, where principal means of irrigation are dug wells, canals, and tanks, groundwater does score over canal irrigation, which in turn scores over tank irrigation. Productivity of groundwater irrigated lands has risen much faster than that of surface−irrigated lands. High yielding variety production has been biased in favor of farmers with access to private means of irrigation. The type of groundwater systems have changed for the better in relation to the public surface systems.

In the alluvial tracts, tube wells displaced dug wells and in hardrock areas dug wells have been deepened and equipped more and more with power pumpsets. In the first phase, diesel pumpsets displaced traditional water lifts and in a later phase, these are being substituted by electric pumpsets.

If output impact were the sole criterion for policy conclusions regarding the choice of irrigation, one might justify the concerted efforts of Indian planners to promote groundwater irrigation during the past two decades, though not uniformly throughout India (tables A.2 and A.3).

Dhawan warns us, however, with two observations. The dangers of overexploitation of groundwater in many parts of India are real, with deleterious consequences in the long run. He notes "development of surface irrigation has very beneficial impacts on the development of groundwater irrigation and vice versa. These externalities of irrigation are very powerful and can best be utilized to man's advantage by an integrated, or system's approach to the question of water development" (Dhawan 1985).

In a similar vein, Pant (1988) points out that the greatest sufferers of the tube well revolution in the Indo−Gangetic plains have been the small and marginal farmers. Such farmers, operating traditional water lifts in an area with tube wells, encounter serious problems when tube wells deplete their water level in the very short run.

Such reductions in the water table, which are likely to occur during peak times of crops when tube wells operate simultaneously, affect crops under traditional water lifts in an adverse way. The situation is further accentuated when there is a drought. The results of a number of ex ante and ex post analyses of returns on investment in groundwater, both to the economy as a whole and to the

Table A.2 Foodgrain production in Punjab and Haryana, India
(*tons)*

	Private tube wells	*Public canals*
Per net irrigated hectare		
Punjab	4.4	2.1
Haryana	5.3	2.0
Per gross irrigated hectare		
Punjab	2.2	1.0
Haryana	2.8	1.4

Table A.3 Foodgrain production in Andhra Pradesh and Tamil Nadu, India
(*tons per net irrigated hectare)*

	Groundwater	*Canals*	*Tanks*
Andhra Pradesh			
195759	2.6	1.8	0.8
197779	5.2	2.9	1.5
Tamil Nadu			
195658	3.3	1.2	1.4
196466	3.5	1.6	1.6
197779	6.0	2.1	1.8

individual farmer making the investment, are summarized in the table below. Abbie, Harrison, and Hall (1982) notes that the conditions and methodologies of these studies vary as they were carried out at different times and are thus not strictly comparable. They do give a broad indication of the level of returns on private groundwater investment. The returns are particularly high for STWs (table A.4).

Among the physical factors that limit returns to groundwater investment, Abbie, Harrison, and Hall (1982) point out that access to land and water limits the returns on investment in groundwater development. The size of the farms seem to be a critical factor in the adoption of tube well technology. The benefits of high yielding variety technology, together with reductions in the size and cost of pumpsets over the past thirty years, have reduced the minimum size of farms that can profitably use private irrigation equipment. Farmers who have small and fragmented holdings are unable to personally bear the capital costs of irrigation equipment even if their farms are located in areas with plentiful groundwater.

On the other hand those who do purchase the equipment, finding it profitable, still underutilize it because their holding size is simply too small or fragmented to use the pump capacity fully. The authors hypothesize that the rates of return will be higher in areas with larger fields. In India, they note, groundwater availability and its extraction costs are closely related to two broad categories of groundwater occurrence: areas of thick alluvial deposits in the major sedimentary basins (for example, the Gangetic plain) and on the coastal deltas; and areas of crystalline "hardrock" in the Deccan plateau.

Table A.4 Anticipated and actual rates of return to private groundwater investment

	Anticipated returns		*Actual returns*	
	Economy	*Farmer*	*Economy*	*Farmer*
Shallow tube well with pumpset				
Bihar	50+	48	..	43
Gujarat	23	30	20	30
Haryana	2227	3966	50+	1629
Uttar Pradesh	1641	1744	50+	2223
Dug well with pumpset				
Andhra Pradesh	2730	1826	3750+	1650+
Gujarat	23	26	15	12
Karnataka	12	19	26	21
Madhya Pradesh	17	35	41	37
Maharashtra	2350	2340	1850+	1150
Tamil Nadu	1920	2829	26	16

.. Not available.

Source: World Bank.

In the alluvial tracts, where groundwater is relatively abundant and easier to extract, the concentration has been in the investment of shallow tube wells. However, this has not led to an equal distribution of groundwater extraction. In the near east, the development has been slow because of small farm size and the generally better, natural soil moisture due to higher rainfall in those areas. In the near west, tube well adoption has been rapid and in places like Punjab, Haryana, and in western Uttar Pradesh it has been approaching saturation.

In such places, the rates of return might decrease due to excessive extraction and aquifer level decline. Rates of return in "hardrock" areas are inherently lower because of less favorable aquifer characteristics and higher extraction costs (Abbie, Harrison, and Hall 1982). In the northeast as compared to the northwest, rates of return have been low due to power shortages and low availability of electricity in the rural areas. Table A.5 shows the impact of village electrification and pumpset connections on tube well development.

However, estimates of rates of return for a particular site differ from one study to another. Satyasai and Dhawan's study of tube wells in the Khammam district of Andhra Pradesh shows that "the incremental benefits thus accruing from each public tube well are found just sufficient to cover the cost of public tube well irrigation. The public tube well investment gives a BC ratio of 1.06 and an internal rate of return of 18 percent. Thus the investment in public tube wells just breaks even. This finding is quite at variance with NABARD result that social returns to investment in public tube wells in Khammam district are impressive" (1989:38).

Within the growth of groundwater irrigation, a critical feature has been the major shift away from traditional, that is, human or animal−powered, energy toward electric power and fuel oil. As of

Table A.5 Groundwater development and rural electrification

States	*Groundwater development (% of potential)*	*Villages electrified (%)*	*Pumpset connections (thousands)*
Northwest			
Punjab	82	100	262
Haryana	80	100	203
Northeast			
Bihar	35	31	152
Orissa	19	38	13
West Bengal	19	36	24

Source: Abble, Harrison, and Hall 1982.

1982, electricity provided for 60 percent of the pumpsets.

Where institutional credit for groundwater was available through government and commercial banks, the high level of past due loans threatens the viability of participating banks as the main institutional lenders for such irrigation schemes and undermines resource availability for future lending. This weakened circulation of credit has had adverse equity consequences by excluding many farmers.

Where electricity is metered or where diesel is used, incentives for the efficient use of water under private irrigation are generally provided by the payment of pumpset operating costs for each unit of water. Abbie, Harrison, and Hall (1982) note that in some states, such as Uttar Pradesh, electricity is a fixed cost as it is charged on the basis of engine horsepower and that this provides no incentive for efficient use of energy, and hence water.

Toulmin and Tiffen (1987) warn us that we need to distinguish between economic efficiency (maximizing returns to the scarce resource) and other types such as water efficiency (preventing waste, maximizing returns to water) and energy efficiency (maximizing returns per unit of power). These three may very well coincide but do not always do so.

In the case of groundwater, case studies show that water may be paid for on the basis of quantity supplied, by an hourly pumping charge (with the farmer providing or not providing the diesel fuel required for pumping), or by metered supply. Sometimes it is paid for by an area charge or the crop planted.

Several research studies have been undertaken to test efficiency of water use under different charging systems. The use of electricity prices for promoting rural equity has consequences for levels of economic activity and welfare within both the irrigation and other sectors (Toulmin and Tiffen 1987; Shah 1989). Shah notes that groundwater markets are very responsive to interventions and therefore policies ought to be formulated to work through these markets (1986). He argues that in places where groundwater is relatively abundant, a flat−rate power charge lowers prices and expands groundwater sales. He feels that this should benefit poorer sections of the community since these people can afford to use more water for their own lands and there will be increased labor demand due to the adoption of more intensive crops by all farmers.

In areas where groundwater is in short supply in relation to demand, the main disadvantage to using a flat−rate power tariff is that it will encourage inefficient use of power and water supplies, with adverse distributional consequences for other actual and potential users of electricity and water. Copestake (1986) estimates from his work in Tamil Nadu that a farmer pays only one−fourth of what someone else with the same pump would pay if used outside the agriculture sector.

This heavy subsidy on electricity charges has resulted in demand for power far exceeding supply, therefore leading to the rationing of power by, for example, limiting the number of new connections available. Likewise there may be frequent power cuts and load shedding, resulting in uncertainty and loss of output (Chawla and others 1989, Shankar 1989). Shah and Raju (1986) deduce from their study in Anklav, a water−scarce village in Gujarat with a very deep water table, that charging for power on a high pro rata basis can generate high levels of water use efficiency. Here, many pump owners have invested in canal linings and the installation of pipelines to conserve water.

The pro rata power tariffs, however, do not always result in efficient use of power. Copestake shows that diesel pumps had been operated at efficiency levels equal to or less than those for electric pumps. Sharma (1989) points out that the process of growing dieselization and duplication (having an electric as well as a diesel pump for the same structure), along with keeping oversized electric pumps, constitute an element of growing overcapitalization of these structures in a capital−scarce region like Bihar. He notes that dieselization is a more costly alternative. The cost of a diesel pumpset is 50 percent higher than that of an electric one and operating charges are still higher. The subsidy on electricity supplied to agriculture would reduce the operating cost of the electric pumpset to 45 percent of that of the diesel pumpset.

One great advantage with electric pumps from the farmer's point of view is that since payment of the electricity bill is not daily or weekly, he can postpone payment for months. In the case of a diesel pumpset, he has to have cash if he wants to operate it. This hurts those who have cash flow problems, especially the marginal farmer.

Sharma notes that in areas in Bihar, where there is high groundwater development, even the marginal landholders have some access, unlike in areas where there is little groundwater development and where even large landholders do not have access. Where there is greater groundwater development, the sale price of irrigation water is moderate because of competition among tube well owners, thereby inducing more farmers to reap the benefits of irrigation.

Because of the low capital costs and low maintenance and operating charges of electric pumpsets, the sale price of water is lower than for water from diesel pumpsets. And in areas where both types of pumpsets are in operation and there is competition for the water market, even the water from diesel pumpsets sells at lower prices.

Sharma (1989) concludes that greater groundwater development through electric tube wells can be an important means of providing access to the benefits of groundwater irrigation for small and marginal farmers in the state. Shah's study of groundwater markets in Anklav describes a contractual form where water rather than land is being sharecropped (1986). The water buyer provides labor, land, and half of the fertilizer and the final crop is shared on terms varying from 33 percent to 60 percent.

Shah (1989) notes that spacing regulations create and strengthen the monopoly power of existing owners of the tube wells, protecting them from competition from other suppliers and keeping water prices higher than would otherwise be the case. If such spacing controls are only enforceable through institutional credit channels, they will mainly affect resource−poor farmers (Toulmin and Tiffen 1987).

Table A.6 shows the determinants of monopoly power enjoyed by water sellers as charted by Shah (1989).

Table A.6 Determinants of water sellers' monopoly power

Factor	*Low monopoly power*	*High monopoly power*
Physical and climatic factors	High and stable rainfall Abundant aquifer close to the surface Cropping patterns dominated by crops using small quantities of water Flat topography	Low and erratic rainfall High depth to water table Cropping patterns dominated by crops using large quantities of water Undulating topography
Institutional economic factors	Low cost of lift irrigation system installation No spacing or licensing norms High lift irrigation system density (installed hp/100 ha of cultivated land) High degree of rural electrification	High cost of lift irrigation system installation Stringent spacing and/or licensing norms Low lift irrigation system density Poor progress in rural electrification
Factors enhancing competition	Use of lined conveyance to supply water Operation of efficient state tube wells charging low water prices Access to canal or other irrigation sources	Use of unlined field channels by water sellers Inefficient state tube wells charging high water prices No canal or other irrigation sources

Source: Shah 1989.

Current research

It has been difficult to obtain information on current research on groundwater in the three countries under review. The available literature primarily reports completed studies and these have been included in the preceding discussions. One ongoing project of special significance being undertaken by CIRDAP in association with the Wageningen Agricultural University is entitled, "The Impact of Small−Scale Irrigation on the Rural Poor and Its Prospects for South Asia." This study promises to contribute important comparative data on small−scale irrigation and its poverty impact in India, Bangladesh, Sri Lanka, Nepal, and Pakistan. In each of the countries, local researchers are comparing small−scale, government−constructed systems with farmer−constructed irrigation systems. In India and Bangladesh the water source selected for study is groundwater. As the only study that takes a comparative perspective, this study should yield some interesting insights.

The role of the Ford Foundation in financing research with a poverty focus (that is, access of the poor to groundwater) has contributed to a significant knowledge base for Bangladesh and eastern

India. Additionally, continued work by Tushaar Shah, M.A.S. Mandal, Shashi Kolavalli, and Richard Palmer−Jones is providing important findings about water markets, contributing particularly to establishing degrees of competition and the conditions under which water markets can be promoted.

Some of the papers that were presented at the January 1989 IRMA Workshop on *Efficiency and Equity in Groundwater Use and Management* and that have been cited in the previous sections report preliminary findings of ongoing projects in India. The number and quality of the studies are testimony to the strength of the local research network in India.

Although much of the focus is on issues relating to the development of water markets (for example, work by Shankar, Phalsalkar, and Shah), there seems to be a concerted effort to assess the efficiency and equity implications of public tube wells versus community tube wells versus private ownership. In particular, research by Satish (in Uttar Pradesh), Satyasai and Dhawan (in Andhra Pradesh), Nagabrahamam (covering eight different agroclimatic areas), and Sathe (in Maharashtra) and Pant (east Gangetic plains) should be mentioned.

There appears to be less research in the northwest region of India and in Pakistan on issues related to access and management, especially from a poverty perspective. This could be a reflection of funding sources (or the lack thereof) for this type of research in these areas, combined with an acknowledgment that the primary poverty focus should be in the eastern and hardrock areas. However, it does present problems for a national groundwater management network and for developing useful cross−border linkages.

In Nepal, although monitoring and evaluation studies are sometimes conducted by the government and feasibility studies are occasionally done by the ADB/N, their scope remains limited. From information available to us there seems to be no independent research institutes/researchers conducting research on groundwater development, especially in terms of its socioeconomic impact.

Conclusion

We have attempted a review of the existing literature and grouped the issues under several headings. The issues presented were largely determined by the availability of materials on the subject. It is apparent from the above review that there is an array of literature on minor irrigation in general and groundwater irrigation in particular.

Unfortunately, much of the literature is either single−discipline microstudies or, in response to short−term interests of donor agencies and government, evaluations of single projects. This makes it difficult to synthesize the conclusions emanating from the literature into a more widely encompassing framework of analysis and even more difficult to attempt to derive policy recommendations from them. In the next section, we will attempt only to identify the main caveats for further research.

In comparison with Bangladesh, studies of the sociopolitical implications (including questions of access) derived from the introduction of groundwater technologies in India are few. There appears to be room for more longitudinal studies aimed at assessing the impact of groundwater development for resource poor groups. In particular, the longterm distributional outcome of groundwater development, including consequences for the process of capital accumulation and growth, needs investigation. A related area of research would be to determine whether groundwater development has brought about land concentration or the displacement of the landless, sharecroppers, or small−holders.

While there is some evidence that groundwater irrigation has generated increases in employment, the nature of this employment and the effect on real wages is not clear. Also, the impact on previously unremunerated groups, such as female labor, needs to be assessed.

Evaluations of particular approaches (for example, the Pani Panchayat approach) provide little information on their potential for replication in other areas or on a larger scale. Research results in terms of community tube wells have been mixed; early studies commend them while later studies have come up with negative results. What are the factors that impact negatively in the long term? Can anything be done to improve their long−term chances of success? Are transaction costs of joint ownership outweighing benefits?

Most studies indicate that the performance and

management of public tube wells in eastern India have been less than satisfactory when compared to private wells; and though they are justified on equity grounds, small and marginal farmers rarely seem to have been the primary beneficiaries.

Can it be conclusively stated that the only case for public tube well management lies in areas where heavy pumping is required for drainage purposes? What alternative form of organization should be advocated in areas with good quality aquifers but deeper water tables where larger−capacity wells are indicated? Should and could landless groups be organized to provide irrigation services as in Bangladesh? In particular, will privatization overcome the problems cited and under what conditions?

Some preliminary work has been done to construct a typology in terms of aquifer characteristics and access to groundwater technologies (for example, Shah and Raju 1988), with the underlying objective being to maximize equity in access in areas where the resource is plentiful and to minimize adverse ecological effects in areas under stress, with minimum damage to the interests of the resource poor. This may provide some important policy guidelines if tested and refined further.

While there has been some research pointing to the merits of competitive water markets in the eastern region, there is room for further research to determine under what circumstances they are likely to be most effective in promoting greater productivity and improving poor people's access, as well as where they may be less beneficial or have a negative impact on equity and sustainability.

A review of the experience with public regulations for managing groundwater access and use is necessary, especially to determine feasible alternatives to public tube well ownership. Can, for example, public regulations and technology interventions substitute for public ownership?

There appear to be various local adaptations that provide resource−poor farmers with access to groundwater. For example, well owners may provide water free to marginal farmers to encourage them to work in their fields. Are other arrangements prevalent and how do they include or exclude marginal farmers from access to groundwater? Can these be incorporated into viable institutional alternatives aimed at benefiting small and marginal farmers? The question of credit and subsidies and their role in promoting investments in groundwater by the poor remains unclear.

Electricity, especially the management of the rural electrical supply, appears to be an area of growing concern. The trade−off between diesel use and electricity, tariffs on these different sources of energy, and subsidies on them that have implications for resource−poor farmers warrant−further investigation.

In comparison to India and Bangladesh, there has been little research on groundwater development and its impacts in Nepal. One reason is that the government has only recently become involved in groundwater; moreover, there is a lack of a strong social science focus in Nepal and a lack of a tradition of research by academic institutions. The research that is done is primarily in the form of feasibility studies or project evaluations under terms of reference that do not adequately unearth social relations.

The research conducted has focused on the physical, technical, and operational factors of the project, rather than on a combination that includes the social and political issues. There is a clear need for additional research on the socio−political, management/institutional, and economic issues.

The studies from the three countries identify the importance of the pre−existing social structures' contribution to the differential impact on the various classes of these social structures. Those with greater access to productive assets and power benefited more. In Nepal, the emphasis on completion of specified targets has been a contributing factor to the bias toward the larger farmers. The landless have not been a distinct direct target group for providing access to groundwater technology, by contrast to Bangladesh. There has been no experimentation with community tube wells in Nepal.

The dearth of groundwater−focused research in Nepal means that almost all issues identified in this review have yet to be explored in Nepal. There are major needs relating to physical factors, but perhaps the most critical needs are in the realm of social impact and institutional requirements.

Notes

1. The actual limit is influenced by the internal characteristics of the pump and associated suction piping, as well as atmospheric vapor pressure. Each pump is characterized by a positive suction head that establishes the pumping lift limit.

2. Safe yield is usually defined as the amount of water that can be extracted from an aquifer without long−time lowering of the water table. In the context of a specific geographic region, this would be the amount that would not result in lowering of the water table by the end of a normal rainy season.

3. The definitions of rich peasant (RP), middle peasant safe (MPS), and middle peasant danger (MPD) are presented in full in the Howes article. They are based on the degree of surplus production, with the RP having disposable surplus, the MPS having reasonable security of production without significant surplus, and the MPD having insufficient production for basic needs.

4. Integrated Rural Development Program (IRDP), supported by UNICEF, the USAID−supported program with the Planning Commission, and the World Bank/ IDA−supported program.

5. With a cost for labor based on 400 kg of coarse rice at US$0.23 (Tk 6.4/kg), the total cost would be US$94.87 (Tk 2,572) versus US$5.31 (Tk 144) for electricity.

6. We sent out a suggested format for research reporting to several institutions in the three countries and

elsewhere requesting information about ongoing research projects, but obtained very little information.

7. The final report is expected in December 1989. The research leader is Mr. Salehudin Ahmed, 17 Topkhana Rd., GPO Box 2883, Dhaka 1000, Bangladesh.

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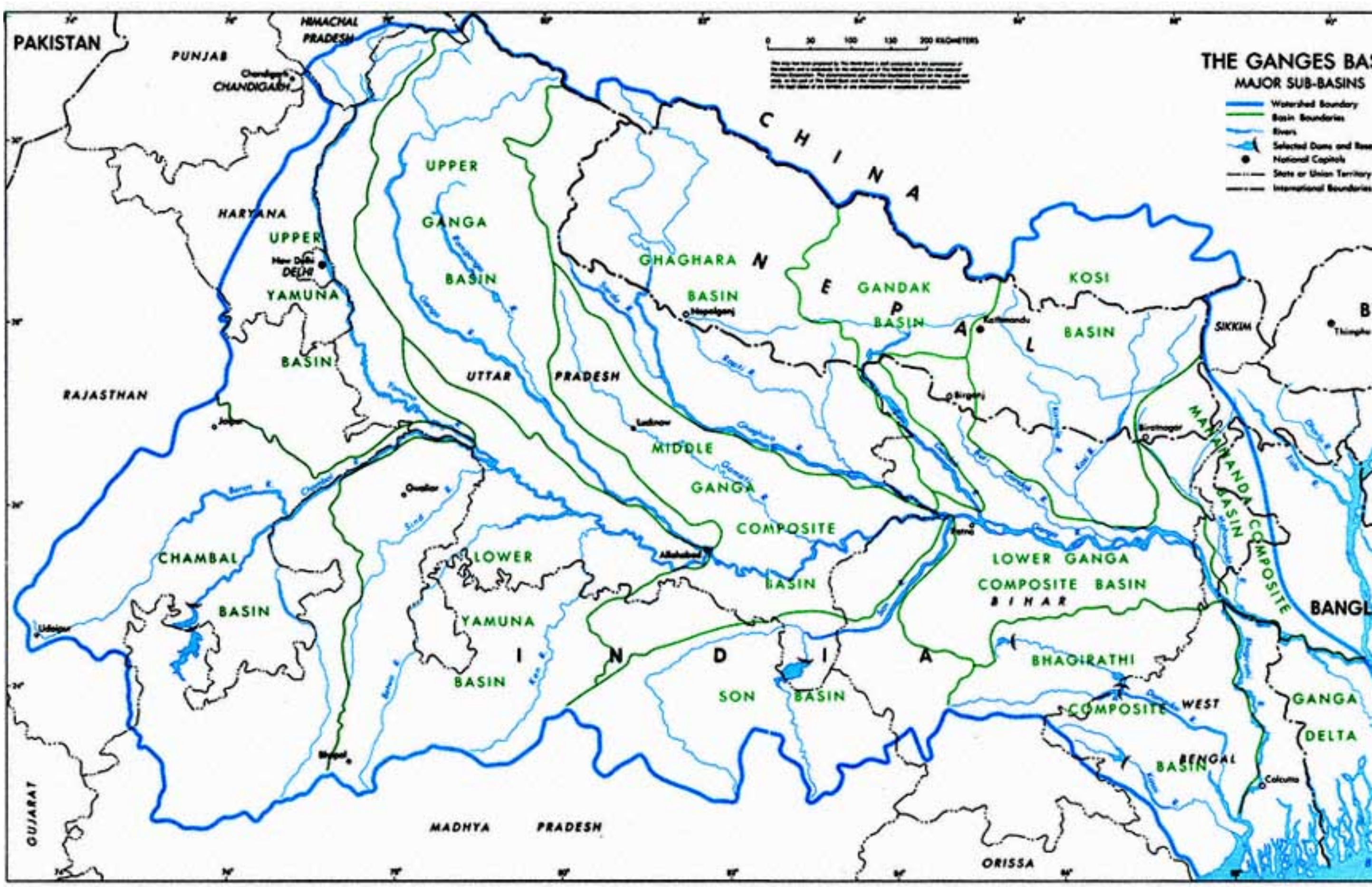
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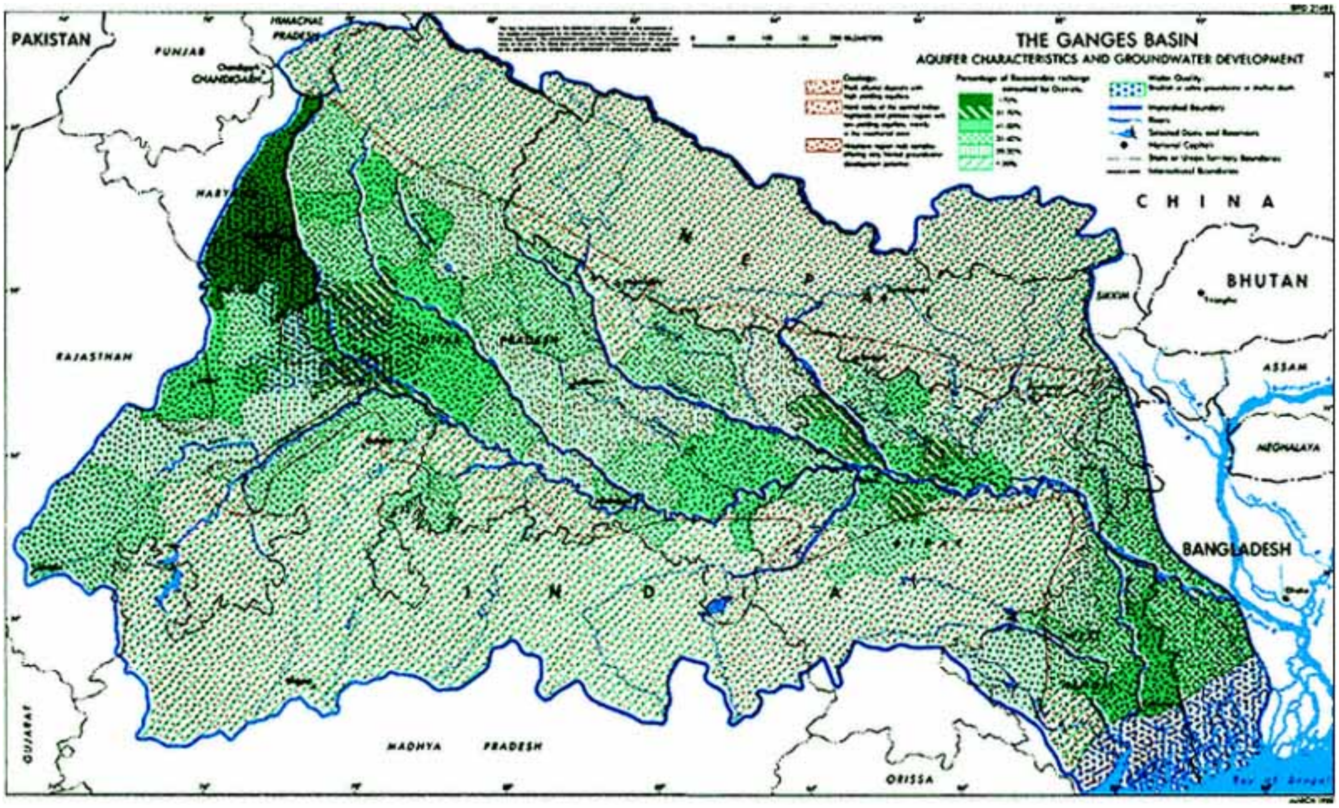
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