LOCAL ORGANIZATIONS FOR SOCIAL DEVELOPMENT

CONCEPTS AND CASES OF IRRIGATION ORGANIZATION

DAVID M. FREEMAN

WITH VRINDA BHANDARKAR, EDWIN SHINN, JOHN WILKINS-WELLS, AND PATRICIA WILKINS-WELLS

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To the farmers and irrigation managers
who made this book possible

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PREFACE

Much of the work reported here was accomplished as part of the Water Management Synthesis II (WMS II) Project at Colorado State University by the United States Agency for International Development under contract DAN-4127-C-00-2086-00. All reported opinions and conclusions are those of the author and not those of the funding agency or the United States Government.

The Water Management Synthesis II (WMS II) Project included as part of its mandate the establishment of a program of special studies. The purpose of this program was to increase the capacity of participant universities to serve USAID irrigation program objectives in technical assistance, training, and technology transfer globally and in specific Asian countries. During the course of deliberations with representatives of Cornell University, Utah State University, USAID/Washington, and USAID missions, Colorado State University (CSU) developed a program of special studies focusing on the following theme: interfacing farm water management with main system management through development of local command area irrigator organizations. This book presents the information, data, and analysis that developed as that theme was pursued. The larger body of work, from which this book has been drawn, was reported in *Linking Main and Farm Irrigation Systems in Order to Control Water*, WMS Report 69, Water Management Synthesis Project, Colorado State University, Fort Collins. This report series includes:

Volume 1: Designing local organizations for reconciling water supply and demand (D.M. Freeman).

Volume 2: A case study of the Niazbeg distributary in Punjab, Pakistan (Edwin Shinn and David M. Freeman).

Volume 3: A tank system in Madhya Pradesh, India (Vrinda Bhandarkar and David M. Freeman).

Volume 4: The case of Lam Chamuak, Thailand (Kanda Paranakian, W. Robert Laitos, and David M. Freeman)

Volume 5: Two tank systems in Polonnaruwa District, Sri Lanka (John Wilkens-Wells, Pat Wilkens-Wells, David M. Freeman).

David M. Freeman

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D.M.F.

PART ONE

Concepts

I

INTRODUCTION

> "...It must be stressed that irrigation is as much an expression of human organization and its adaptation to the physical environment as it is a technical achievement."
>
> (Cantor 1967:62)

> "The best structure will not guarantee results and performance, but the wrong structure is a guarantee of non-performance. All it produces is friction and frustration."
>
> (Drucker 1974:519)

The idea of social development has been much confused, polemicized, and debated (Riggs 1984). Although the concept has not been defined to the satisfaction of even a substantial minority of scholars and practitioners, social development has generally been viewed as centering on the advancement and diffusion of new choice opportunities--permitting improved options regarding food, clothing, shelter, health care, transportation, educational and cultural experience, and social mobility. Furthermore, the idea of social development has also generally included some conception that people would meaningfully participate, individually and collectively, in making decisions about the patterns of choice available to them and affecting them.

It is the purpose of this book to examine one aspect of the larger development effort in some detail and in one particular domain--the development of irrigated agriculture. The specific aspect being examined here is the development of local organizations which can link individuals to state bureaucracies. The central thesis is that properties of local organization, mediating between the agendas and resources of state bureaucracies and those of the local community, have everything to do with the ultimate productivity of the state supplied, and locally managed resources.

In the world of large-scale gravity-flow irrigation, it is the state bureaucracy which captures the water supply in remote watersheds and constructs, at great cost, the impressive engineering works to store and deliver water, but all this investment is exploited only to the degree permitted by local organizations which, at some point in the delivery system, must assume responsibility for delivering water to individual irrigators. The organizational conditions under which that water is, or is not, delivered have everything to do with the productivity of irrigation water. Yet, local organizations, interfacing local people and state bureaucracy, are frequently overlooked in development project planning.

Some choice opportunities can be advanced and diffused by interaction in marketplaces where rational, self-seeking behavior is rewarded according to the extent to which people can produce goods and services which fulfill choice demands of exchange partners. Yet, other choice opportunities are not adequately supplied by the logic of individual self-interested behavior in marketplaces; these are choice opportunities which are produced by organized collective action in the realm of public goods. Examples abound--e.g., traffic control and street lighting, flood protection, police and fire protection, national defense, programs supplying public health and educational services. The particular example, central to this effort, is that of providing controlled supplies of irrigation water in large-scale gravity-flow systems.

An individual can go into the private marketplace and purchase seeds, fertilizer, herbicides, pesticides, and various agricultural implements with which to grow food and fiber. But, in no society or culture can an individual go into the private marketplace and purchase a unit of water control with which to irrigate the crop if local rainfall patterns are insufficient to sustain the plant population. Irrigation water, to be productive, must be controlled. Irrigation water control, in turn, is dependent upon the quality of collectively constructed human organizations. In large-scale gravity-flow systems, if irrigation water gets to the plant root zone at the proper time, and in the proper amounts, it is because people have organized collectively to perform tasks beyond the capacity of individuals.

Creating and operating organizations has always been a central concern of human beings who have recognized, for thousands of years, that they must make permanent arrangements to secure and collectively manage what they could not obtain individually. Irrigated agriculture, therefore, has always meant the organized collective attempt to control water to better fill crop consumptive needs. The progress of people in a diverse array of cultures has always depended on how they have organized their collective lives; the progress of irrigated agriculture depends upon the quality of irrigation organizations.

The analysis which follows is rooted in a fundamental proposition--social development requires effective local social organization productively linked to state bureaucracy such that people can collectively provide themselves essential choice opportunities not provided by markets. Effective local organizations, in turn, make possible both exploitation of private goods and services exchanged on marketplaces, state provided resources, and meaningful participation of citizens in social development. The objective is to carefully examine the manner in which individuals in several cultures organize, or fail to organize, to provide themselves with controllable irrigation water supplies. Lessons learned about effective irrigation organization may well instruct us not only about the nature of viable forms of water management, but also shed light on attributes of local organization effective in developing improved choice opportunities in other spheres of social life.

The objective of Part One is to present an analysis of organizational breakdown between main system bureaucracies and farmers, and to formulate strategic variables and relationships that contribute to improved design of local irrigation organizations. Part Two reports empirical case studies of middle-level irrigation organization in three nations--Pakistan, India, and Sri Lanka--and the impact of such organization on agricultural production. Part Three presents implications and conclusions.

The emergence of early civilization has been associated with the development of the more complex forms of human organizations necessary to settled irrigated agriculture (Fukuda 1976; Mann 1986; McNeill 1963). In river valleys such as the Tigris, Indus, Nile, Jordon, Ganges, and Yangtze, earliest forms of complex organization emerged as people organized to deal collectively with controlling irrigation water. Writing emerged to sustain joint agreements among people who required ways to record promises made regarding irrigation water, land, grain, and animals (Mann 1986). An article of irrigation practice traceable to the Code of Hammurabi read: "If anyone opens his irrigation canals to let in water, but is careless and the water floods the field of his neighbor, he shall measure out grain to the latter in proportion to the yield of the neighboring field" (Framji and Mahajan 1969:cxi). In India, by 300 B.C., the written record tells us that the state had established a standard practice of taking a 25 percent share of the produce of irrigated agriculture as a tax to support irrigation construction, operation, and maintenance beyond the capacity of local farmers to manage (Framji and Mahajan 1969).

Irrigation systems have been built for many reasons--to provide insurance against drought, to suppress rebellion (which tended to flare after bad harvests), to increase tax revenues, to fulfill ritual obligations of monarchs, to obtain goods for foreign exchange, to settle the landless, to secure loyalty of groups close at hand or on the frontier, and to enhance voter prosperity. Within the last 200 years, another motive has emerged--a vision of steering societies toward economic and social development by transforming low input/low output agriculture into high input/high output agriculture. This involves:

1. Producing agricultural surpluses so that farmers can sell, rather than consume, most of their output.
2. Increasing livestock numbers to provide increased draft power, hide, and meat protein.
3. Obtaining greater productivity per person per hour, liberating increasing numbers of people from the soil to move to industry and to provide services.
4. Making food and fibre a smaller part of household budgets, and thereby leave resources available for obtaining products and services of a technologically more advanced society.

This vision has everywhere rested on newer technologies and organizational arrangements to harness and manage technology in agriculture--especially irrigated agriculture.

The earliest recorded dams were constructed a little over 5,000 years ago, and it has been estimated that by 1800 A.D., worldwide irrigation was about 8 million hectares (19.8 million acres). Irrigated agriculture rapidly expanded during the nineteenth century, pushing global irrigated acreage to about 48 million hectares (118.6 million acres) by 1900. Expansion of irrigated land during the twentieth century proceeded at an even greater pace. By 1969, total global irrigated area was roughly 200 million hectares (494.21 million acres) (Framji and Mahajan 1969). From 1950 to 1970, the gross irrigated area of the world doubled. By the 1970s, the rate of increase had declined to about 5 million hectares per year, and due to constraints associated with cost, decline in suitable acreage, and adverse terms of trade for agriculture, the rate of growth in the mid-1980s fell off to approximately 4 million hectares per year (Rangeley 1987).

Irrigated agriculture has been disproportionately productive (Table 1). Only about 18 percent of the world's cultivated land is irrigated, but it produces roughly 33 percent of the planet's human food supply. However, the fact that many landscapes of the world are dominated by dams, reservoirs, and canals cannot hide a disquieting fact: many irrigation projects in many nations and cultures have not served the needs of farmers and agricultural production as planners have hoped.

Table 1. Contribution of irrigated acreage to food production.

Country	% Cultivated Area Irrigated	% Contribution to Total Food Production
India	30	55
Pakistan	65	80
China	50	70
Indonesia	40	50
Chile	35	55
Peru	35	55

Source: Rangeley 1987:30.

The story of the typical irrigation project is one of failure to fulfill projected economic returns to investment. It is also a story of farmers who fail to exploit their relatively expensive water supplies to the degree planned, and who frequently exhibit irrigation behavior viewed by main system managers as detrimental to the functioning of the systems. Montague Yudelman (1987), reflecting on World Bank experience, has suggested that Bank irrigation projects seldom have met expectations. Expressions of disappointment have been many (Bottrall 1978, 1981, 1981b; Chakravarty and Das 1982; Levine, Capener, and Gore 1972; Lowdermilk, Early, and Freeman 1978; Pant and Verna 1983; Posz, Raj, and Peterson 1981; Reidinger 1974; Sharma 1980; Steinberg 1984; White 1984). Everywhere, the picture of poor irrigation water management unfolds around low levels of water use efficiency marked by inequities in distribution, disappointing cropping intensities and yields, and irrigation bureaucracies which perform with insufficient regard to the needs of farmers to control water to produce food and fibre. The three case studies which constitute Part Two of this volume add to this literature by documenting specific problems on irrigation projects in Pakistan, India, and Sri Lanka.

Given a projected decline in rates of expansion in irrigated acreage and the widely observed disappointment with the performance of irrigation projects, attention has shifted to rehabilitating existing works. Only about 28 percent of the desired increase in agricultural output in the next few decades is expected to come from increasing the quantity of cropped area (FAO 1979). Qualitative irrigation improvement must play a significant part in increasing the capacity of poor nations to feed their growing populations. A dollar or rupee invested in rehabilitating existing systems promises to provide a better return than investing in a new system. However, whether constructing a new system or rehabilitating older works, irrigation development efforts will be doomed if proper attention is not given to the social organization(s) necessary to operate and maintain the works (Bromley 1987; Freeman and Lowdermilk 1985).

Some have envisaged a "water revolution" brought about by rehabilitated irrigation systems and reformed administrative structures that would be analogous to the "green revolution" (Bottrall 1981b; Chambers 1980a). A "water revolution" promises to increase productivity at favorable cost-benefit ratios. Many new crop varieties need controllable irrigation water and would benefit from a "water revolution." Furthermore, a "water revolution" promises increased social justice, since benefits could be delivered to least advantaged farmers. Water control is critical to farmers in determining what crops to grow and whether or not to adopt new technologies such as fertilizers, pesticides, and high-yielding varieties. Since least advantaged farmers must pay the highest prices for insecure water in high demand periods, and because the poor and powerless are least able to influence water distribution, an increase in irrigation water control is a potentially powerful tool in the policy maker's kit for promoting agricultural development with social justice.

2

ORGANIZING FOR WATER CONTROL

Reconciling Main System Supply with Farmer Demand

Water control by farmers, defined as the capacity to apply the proper quantity and quality of water at the optimum time to the crop root zone to meet crop consumptive needs and soil leaching requirements, is a fundamental yardstick used to measure the effectiveness of irrigation systems. Water control is a function of the manner in which people organize at several levels--the main system and one or more tiers of middle-level organization between main system management and individual water users (Figure 1).

Water control for main system management means something different than water control at the farm level. This shift in meaning necessitates the existence of effective middle-level irrigation organizations to provide an interface for the different, even incompatible, requirements of main and farm systems.

Water control is critical, not only to improving production in any given season, but also to sustaining the production environment across seasons. Greater water control permits less water to be used per unit of production, which translates into reduced energy consumption, soil erosion, waterlogging, and salinity (Mathur 1984; J. Mohan Reddy 1986). Because high-yielding plant varieties demand adequate, timely water applications, farmers with inadequate water control will refrain from investing in such varieties and associated costly inputs of fertilizers and pesticides. As control over water diminishes, it becomes necessary to apply increasing quantities of water whenever available to attempt to ensure the survival of at least a portion of the plant population. Over-irrigation, even in the context of general water scarcity, can lead to erosion, waterlogging, and salinity.

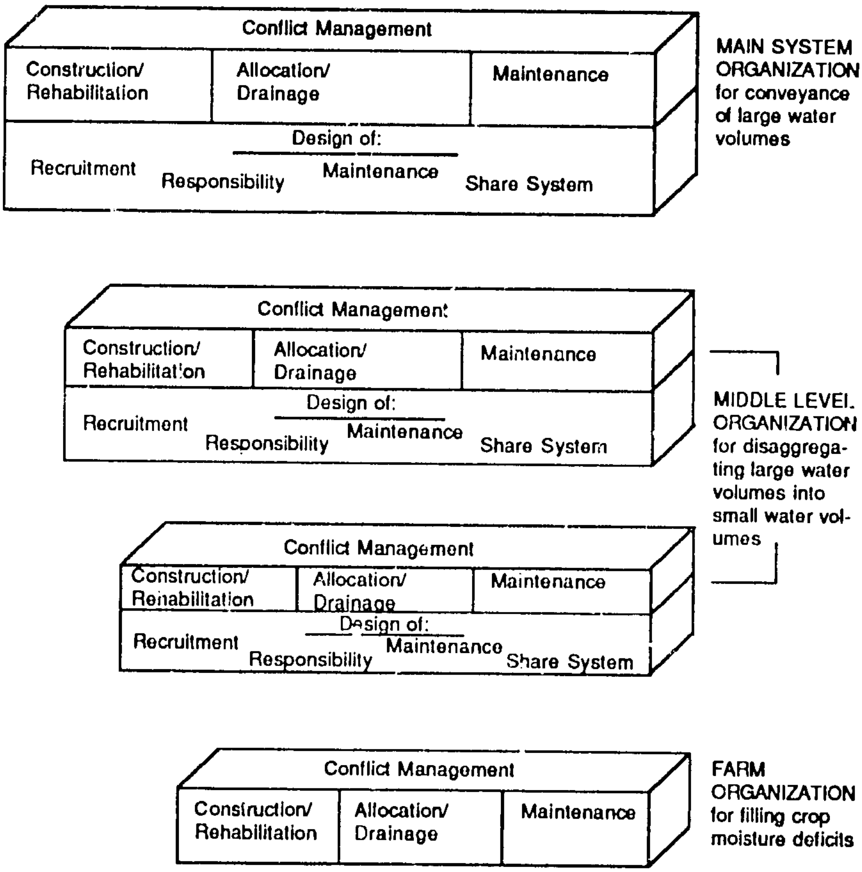


Figure 1. Organizational levels of irrigation systems.

Irrigation water management in large-scale gravity flow systems is the process by which bureaucracies capture and control water in central irrigation works and pass it on to local command areas, which divide and control it further. In turn, local organizations (Figure 1) pass the water on to farmers, who must place it in crop root zones at times and in amounts which make it most productive and least damaging to the production environment.

Years of careful experimentation have established that applying the right amount of water to crops at the right time, as defined by properties of the plant, soils, and climate, is critical to crop productivity. Doorenbos and Kassam (1979:2) have plainly stated the problem in its technical aspects:

> The upper limit of crop production is set by the climatic conditions and the genetic potential of the crop. The extent to which this limit can be reached will always depend on how finely the engineering aspects of water supply are in tune with the biological needs for water in crop production. Therefore, efficient use of water in crop production can only be attained when the planning, design and operation of the water supply and distribution system is geared toward meeting in quantity and time...the crop water needs required for optimum growth and high yields.

The extent to which the water supply can be tuned to crop biological requirements is a function of the organizational operations conducted at the several levels (Figure 1).

At the farm level, water control is fundamentally determined by the operation of organizational networks established to operate upstream physical structures. How effectively irrigation water reaches the root zone is a function of an organization's ability to rehabilitate, operate, and maintain works, and to manage conflict. Farmer control over water in the field is critical. Only the farmer combines the factors of production in a particular field to bring in a crop. If water comes too soon, too late, in amounts too much or too little, the productivity of that water is sharply reduced. Because different plants exert different consumptive demands in varying stages of growth and in varying soil and climatic conditions, irrigation water can fulfill consumptive demand only if it is subject to precise control that allows farmers to be rapidly adaptive in managing it.

A rice cultivator in Southeast Asia working in an irrigation system designed to deliver continuous simultaneous water supplies to hundreds of farmers in a given command faces different water control problems than does a farmer in northern India or in Pakistan who works within a rotational delivery system to serve the consumptive requirements of wheat or cotton. Even within a given irrigation system, the consumptive demand of crops can be expected to be highly varied. A farmer growing shallow-rooted vegetables on lighter soils faces different water application requirements than a neighbor who grows deeply rooted crops in heavier soils. Furthermore, a rain which delivers two inches of water to a particular site may deliver only a fraction of an inch to another farm site only a few miles away.

Farmers in irrigation systems around the world are faced with the common task of hitting a moving target--a varying moisture deficit in the crop root zone--within irrigation systems which typically have been designed by remote engineers, managers, and politicians whose professional responsibilities were to aim a quantity of water in the general direction of a command area. In most large-scale systems, especially in Asia, the upstream control systems have been designed without adequate regard to the problems faced by farmers in securing local control (Bottrall 1981b, 1985; Bromley 1982; Freeman and Lowdermilk 1985; Kathpalia 1981; Lowdermilk 1986; Wade 1979, 1980, 1982a, 1982b, 1987).

The fundamental problem is that main system managers cannot control the strategic variables that determine water demand and water productivity farm by farm and field by field: site specific variations in soil moisture holding capacity, soil moisture availability, planting times, crop variety, root zone depth, daily crop moisture depletion, specific evapotranspiration rates, and margins to the permanent wilting point. Such matters are known to main system managers as general tendencies, not as field-by-field particularities.

On the other hand, individual farm operators cannot adequately control variables that establish the pattern of main system water supply, such as watershed yield and distribution, storage and canal capacity, intra- and inter-state (provincial) allocation, river and canal hydraulics, regional or district strategies for conjunctive use of surface water and groundwater, and the management of large main system storage, canal, and drainage structures. Therefore, main system supply and farmer demands must be matched. In gravity-flow surface irrigation systems, the best way to make this match is to create an intermediate tier of organizations which accept main system water deliveries within the constraints which the main system must impose, control such water, and disaggregate water flows to fit the unique demands of individual farmers.

Reconciling the Knowledge Held by Main System Managers and Farmers

At least two general, but very different, formats exist for knowing about the world--a particularizing mode emphasizing the uniqueness of events, and a generalizing mode extracting larger similarities and arriving at abstracted patterns of relationships. One can distinguish between *idiographic*, or unique, knowledge of substantive content and *nomothetic*, or generalizing, kinds of knowledge (Nagel 1961). Distinguishing between nomothetic and idiographic knowledge is helpful in viewing differences between the central bureaucracy and farmers.

The knowledge of irrigation officials educated in the professions depends heavily upon generalized principles abstracted from the rich flow of natural and social processes (i.e., nomothetic knowledge). Highly-processed, abstract, organizing principles have pride of place in science and in the training of irrigation engineers and managers who possess formalized knowledge of other disciplines. This general, cross-culturally viable, scientific knowledge renders propositional knowledge out of particular facets of the whole system, but does not comprehend the richness of the whole. It is limited to shedding light on particular, abstracted slices of reality in the form of economic supply and demand curves, cost-benefit ratios, bars of tension, pounds of pressure per square inch, yield responses to fertilizer, thermodynamic behavior, channel hydraulics, sedimentation and scouring, capillary action, soil intake dynamics, evapotranspiration processes, and administrative notions of span and control. Sciences abstract general rules to construct logically connected sets of propositions about relationships among phenomena. These abstracted propositions are employed in central planning units to design and operate those parts of the irrigation system under the management of the central bureaucracy.

On the other hand, local people possess extensive idiographic knowledge, built through long experience and encoded in tradition and custom. Their knowledge is of unique, site-specific circumstances and their particular situation relative to those circumstances. Whereas the bureaucratic analyst must grasp general tendencies across broad systems, the individual farmer is intensely interested in the specific outcomes of his or her particular situation. Whereas the central manager obtains knowledge to make decisions by employing methodological devices to control extraneous variables that might confuse the analysis of central tendencies in the system, the individual farmer responds to factors excluded by central management because they are important in local contexts.

Irrigation is practiced in a great variety of conditions (e.g., social, economic, topographic, soils, climatic, and crop). These vary within a farm, and they vary widely among farms and among command areas within an irrigation system. Given that each setting represents a unique arrangement of the generalizable properties known by central management, a condition that seems to exist across the whole system does not necessarily exist in any specific subset of that system. Farmers, who are employers of rich idiographic knowledge, have much reason to distrust the nomothetic understandings of main system managers.

The problem is that the generalizations of irrigation managers in large, remote bureaucracies are not legitimate where farmers' individual and unique settings are concerned. The lack of mutual understanding is rooted in differences in types of knowledge and experience. There need be no hypothesis of irrationality or ill will on the part of any party to account for fundamental differences in orientation.

Reconciling the Logic of Public Goods with Individual Rationality

Main system managers control water by providing a transport system for water using rivers, canals, reservoirs, and diversion structures. They have assumed that if water is moved in the direction of targeted cultivable command areas, water control at the local level will automatically evolve because it is needed. In the light of history, this optimism is known to have been naive. In the light of pressing needs for increased production and social justice, this optimism has been badly misplaced.

Local organizations that provide an interface between main and farm systems do not evolve because they are needed. It is necessary to understand that individually rational people, who fully comprehend the need to organize collectively to provide themselves with a water supply and control over it, often will not do so. This is because individual rationality and collective rationality differ and are frequently mutually opposed.

There has been much discussion of the logic of collective action during the last two decades (Olson 1965; Frolick and Oppenheimer 1970; Mueller 1979; Blair and Pollack 1983; Frohock 1987). Some have applied this reasoning directly to the problem of irrigation organization (Freeman and Lowdermilk 1981; Lusk and Riley 1986). The argument is straightforward. One begins by distinguishing between private and public goods. If benefits can be captured by the investor-owner and denied to those members of the community who do not invest in it, a good is categorized as "private." Private goods are exemplified by possessions such as clothing, automobiles, home appliances, and personal work tools--an individual invests in them and enjoys the benefits of ownership.

A good is "public" or "collective" if its benefits cannot be denied to those who do not help to bear the costs ("free riders"). Many important goods are public. Flood control projects indiscriminately benefit all those subject to a rampaging river, whether or not they have paid their share of the cost. A pollution control program generating cleaner air and water cannot be denied to all those who breathe the air and use the water, but who do not pay for the program.

Herein lies the problem in regard to collective goods: the logic of the individually rational utility seeker may not coincide with the logic of the community. If, for example, farmers individually observe that their leaky and misaligned watercourse requires improvement, they will not invest in corrective action on individually rational grounds. Assuming a sizeable number of farmers, each will calculate as follows. If one farmer invests time, energy, and money required to improve the channel going through his or her own land and other farmers do not make comparable corrective investments in a coordinated fashion, then the payoff in improved water supply and control (the collective good) is negligible.

However, if many farmers undertake the improvement effort on each of their sections, and one individually rational decision-maker does not do so, she or he will still enjoy a substantial share of the benefit provided by the work of others, at no personal cost. Therefore, the rational, calculating individual will choose to do nothing either way. The collective good will not automatically evolve, even though the individuals in question may possess full and accurate information about the potential benefits of improving the channel and may have the required know-how and resources to do so.

This situation can only be changed by establishing an effective organization that can ensure that the contributions for providing a given public good are predictably obtained from all beneficiaries through the use of enforceable joint agreements that define a "fair share" of contribution. This obligation to bear costs must be tightly interconnected with delivery of benefit. If individuals believe that the organization will deliver its benefits without regard to member investment, then incentive to bear obligation is diminished. It becomes rational to be a "free rider," and the organization's ability to provide the collective good is compromised. Or, if the collective good is provided by an outside altruist--i.e., a unit of government or a charitable organization--the collective good will be allowed to deteriorate as everyone individually chooses to take a "free ride" to their short-run advantage, but at the expense of allowing the public good to deteriorate in the longer term. Organizations scaled to manage the required collective good, and designed to control "free riders" by carefully connecting delivery of the good with fulfillment of membership obligation, can defeat individually rational logic and can make local irrigation development possible.

Social Organization and the Changing Meaning of Water Control

The problem, then, can be summarized as follows. Local irrigation organizations functioning between main and farm systems are of strategic importance because: (1) the interests of farmers (on the demand side) must be reconciled with the interests of main system management (on the supply side); (2) the general understandings of main system managers must be reconciled with the site-specific knowledge of farmers; and (3) local collective goods in the form of water delivery structures and water control must be protected from the depredations of "free riders." By attending to these needs, appropriately designed local irrigation organizations make irrigation water much more productive. They can disaggregate large main system water volumes, control smaller streams, and deliver irrigation water to specific farms and fields when it is most needed to fulfill crop consumptive demand. Water at the right time in the right place in the right amount is simply much more productive than water poorly controlled.

It is now possible to synthesize the irrigation problem by employing concepts of water control, the distinction between nomothetic and idiographic knowledge, and an appreciation of water supply and control as a public good. In large, gravity-flow irrigation systems, public bureaucracies build and manage main system works (Figure 1). Large public goods, such as high dams, large reservoirs, and major canals, cannot be provided by small local organizations.

At the main system level, good water management means controlling the flow of large volumes of water in large-scale capital works so that water moves predictably toward aggregated demands of many farmers. The emphasis is on dealing with farmers in categories by focusing upon average needs and conditions. Main system managers are not rewarded or punished according to the farm productivity of the water they manage. Main system operators, while adapting their system to general features of local topography and to local histories of demand, depend heavily upon their processed, disciplinary, nomothetic knowledge of engineering, public administration, economics, and the like without having the time or the particular need to know specific local details of individual farms. Water control at the main system level means managing water flows so as not to exceed the physical limits of the system.

As water flows from rivers and reservoirs through primary, secondary, tertiary, and quaternary canals, it maintains its nature as a collective good. When it reaches the farm gate, it is transformed into a private good, which can easily be denied to "free riders." Prior to its arrival at that point, however, it requires collective management.

Appropriately scaled, middle-level organizations (Figure 1) that are fitted with tools permitting the measurement, division, and control of water in reaches below those effectively administered by the main system, that combine nomothetic principles with increasing amounts of idiographic knowledge, and that are capable of effectively controlling "free riders" and delivering water to the farmer in a predictable and controllable manner, have not typically been made a priority by main system management in most third world countries (Jain, Krishnurmathy, and Tripathi 1985; Owens and Shaw 1972; Coward 1986a, 1986b, 1987; Esman and Uphoff 1984; Whyte and Boynton 1983). Such organization is found in traditional systems, especially communal systems, where traditional irrigation behavior has not been seriously disrupted (Hunt and Hunt 1976; De Los Reyes 1980; Korten 1982; Martin and Yoder 1983; Bray 1986; Coward 1980, 1986b). Also, such organization is found in the rich nations of North America, Europe, and Northeast Asia (Rangeley 1987; Bray 1986; Maass and Anderson 1986). The successful functioning in Japan of local farmer irrigation organizations and their transfer to Taiwan and Korea under the auspices of Japanese colonialism has been well documented (Kelly, 1982a, 1982b; Bray 1986). Furthermore, devolution of water management using local organizations has been demonstrated to be a key to efficiency and equity in the Meiquan system in the People's Republic of China (Nickum 1974, 1980) and the Dhabi Kalan in Haryana, India (Vander Velde 1980).

Stargardt (1983) has shown that the large-scale, ancient irrigation systems of south and southeast Asian arid zones in upper Burma, South India, Sri Lanka, and Cambodia all gradually developed from pre-existing, small, local irrigation systems. These small systems relied heavily on local, quasi-autonomous organization, management, and investment. Local control over resources was a central necessity, and responsibility for operation, maintenance, and conflict resolution was devolved to local units. When central authority systems disintegrated, locally organized components of the systems survived independently.

Many centrally managed systems of the third world, constructed in the rush of the nineteenth and twentieth century expansion and administered by nomothetically trained elites who largely stood outside the traditional local organization of their own societies, have not sufficiently preserved or promoted middle-level irrigation organizations (Coward 1980; Keller 1987). Lack of decentralized, local organizations has been acknowledged to adversely affect the effectiveness of irrigation projects in South Asia generally (Vaidyanathan 1983; Chambers 1980b). Given the lack of effective autonomous or quasi-autonomous middle-level, local organization, main system managers have been forced to administer water flows further and further downstream, where their concern with keeping water flows smooth to accommodate main system agendas are inappropriate in the face of local farmer desires for rapid adaptation to fulfill varying crop consumptive requirements.

Good water management at the farm level (Figure 1) must focus on controlling water such that relatively small volumes are productively placed in particular crop root zones in specific and unique individual settings. Water must be moved at the proper time in the required amount so that the micro-environment of the plant is conducive to maximum production. Controlling water to provide proper micro-environments for crops requires a great deal of skilled labor. Above all, farmers must rapidly adapt to field-specific changes in demand. They confront various crops planted in different soils at different stages of growth under variable weather conditions, all the while bonded to expectations of dynamic kinship and other social networks.

At the farm level, delay of a water issue for three or four days (under typical conditions of crop, soil, and climate) at a critical period in plant growth can cause severe decrements in plant yields (e.g., thirty percent or more). As farmers witness their plants moving toward the permanent wilting point, they actively seek ways to obtain water, authorized or not, from the main system. The quality of their farm life is at stake. Farmers are not persuaded to act on central tendencies in the irrigation system, but are attentive to the unique conditions of particular fields and crops. Farmers cannot depend heavily upon processed disciplinary knowledge, except as it is adjusted to their particular situations. Unlike main system managers, farmers are directly rewarded and punished according to the productivity of water.

In the absence of effective intermediary organizations that can reconcile main system management of water supply with farmer demands for water, lower-level main system managers are generally faced with an impossible dilemma; either to maintain as much distance as possible from local patterns of privilege and "free riding," or to become entangled in countless energy-absorbing, local conflicts, complaints, and demands in relation to which their training, knowledge, and organizational resources are grossly inadequate.

If main system managers are in an area long enough to become deeply knowledgeable of local circumstances, they tend to become attached to local power alliances that defend existing distributions of advantage. In the absence of effective local organization, even if local power alliances could be altered by the intervention of main system managers, a somewhat different pattern would arise to the advantage of others, who would just as quickly undercut the benefits to the whole group of the collectively provided water supply and control. The distribution of misery would simply shift from group to group, but the total quantity of misery would probably be little changed.

If main system personnel are transferred regularly to prevent the emergence of local attachments, adequate local knowledge and linkage must be sacrificed. Small groups of local irrigators will be no less free to arrange whatever pattern of local advantage is available to them, possibly at considerable cost to overall functioning of the system.

At some point, the level of water disaggregation becomes too remote from main system nomothetic knowledge of central tendencies, and too close to local crop consumptive demands, to be effectively managed by the main system. At this point, farmers and their site-specific knowledge must come into play in an organized way. Fundamentally, two options exist: (1) design an organization which guides farmer participation so as to protect main system supply agendas and farmer requirements, or (2) allow farmers to opportunistically form whatever alliances emerge with lower echelons of the main system bureaucracy. Irrigation bureaucracies vary widely in their approaches to managing the transition from state bureaucracy to farm, but in every instance, some form of routine, organized interaction emerges to manage water, however well or poorly. Farmers will participate, for better or for worse. The question is: Will the form of farmer participation be organized to enhance water control and agricultural productivity across the system?

Effective organization at the middle level is essential to providing a link between farm water demands and main system supply. Effective organization requires jointly negotiated agreements with main system operators and among irrigators. These negotiated agreements, written or unwritten, formal or informal, for the use of physical water delivery and control structures are the stuff of organization. The question is not whether such negotiated joint agreements appear at the middle level, but is whether a given set of joint agreements serve a defensible conception of irrigated agricultural development with social equity. Conscious organizational effort must be undertaken with both farmer and main system support, or else emerging opportunistic organizational agreements will reflect individual "free riding" rationalities, not arrangements which best serve the community of irrigators as a whole. Cases presented in Part Two amply document this point.

The Issue of Cultural Sensitivity

Is it overly presumptuous to suggest that a central problem in the complex world of irrigation can be usefully and meaningfully stated without placing it in specific local cultural contexts? A problem stated in the manner presented in the foregoing section does require connection to specific times, places, and cultures. For this reason, the field research was conducted in three nations: a site in the large, gravity-flow system of the Pakistan Punjab, a small tank system in the central Indian state of Madhya Pradesh, and two relatively large adjacent tank systems in the Dry Zone of Sri Lanka. Cultural differences are pronounced among these three irrigation sites and systems, and substantially different irrigation problems are posed by their differences in scale, climate, crops, and social structures. Yet, the research was shaped by a view that beyond cultural diversity, topographical uniqueness, climatic differences, and scale of water control efforts there is, at bottom, a common problem in effectively linking farmers to state bureaucracies. Structural solutions exist that have the potential to be adapted to distinctively different cultural contexts because there is a fundamental distinction between culture and social structure.

Herein, culture refers to the content of social meaning which people create with their languages around their technologies and problem solving activities. Nothing in this study denies the uniqueness of culturally diverse systems. Cultural content does not travel well; it is inherently unique and site-specific. Sinhalese Buddhist culture in Sri Lanka is different from Islamic Punjabi culture in Pakistan, or Hindu culture in central India. One must recognize, appreciate, and work appropriately within these respective systems of cultural meaning. However, analysis of social life is informed not only by careful investigation of cultures, but also by patterned or structured forms of interaction that are not culture-specific. Such "forms" can be identified, each of which possesses consequences for human life and organization independent of the specific cultural content which flows through them.

A practical example illustrates the point. Restaurants in Madhya Pradesh, the Pakistan Punjab, and the Sri Lankan Dry Zone can clearly be viewed as culturally distinct. Many aspects of local life associated with preparing and serving food and the definitions of expected eating behavior are culture-specific. Yet, the structural form, or framework, of typical restaurants bear great similarity in all cultures. The organized structure of restaurants provides for control over customer seating, a menu is available from which customer demand can be integrated with kitchen supplies, and menu choices are connected to specified customer payment, which is made before departure. Structurally, all restaurants in all cultures keep delivery of the meal closely tied to payment of obligation. Any restaurant that did not do so would be quickly out of business. Within this general structural form of restaurant organization, many unique cultural contents can be accommodated.

To offer a more abstract example: in relations between the very powerful and the weak (an asymmetrical "form" of power distribution), weaker parties can be expected to prefer withdrawal from the relationship to active, close cooperation with the powerful. That is, the "lambs" tend to not prefer close cooperation with "lions" in any culture because the agendas of cooperation tend to reflect the interests of the powerful to the disadvantage of the weak. Weaker parties find defense in keeping distance between themselves and the powerful, in outward passivity, and in measures to reduce dependence on the stronger. Therefore, nomothetic statements may be made about power asymmetry and propensity for cooperation across cultures. The following analysis of irrigation organization that follows advances statements of social structural form which are viewed as not being limited to any specific cultural site. However, this analysis is not intended to imply a lack of respect for particular cultural systems.

3

COMPONENTS OF ORGANIZATIONAL DESIGN FOR WATER CONTROL IN THE INTERFACE BETWEEN MAIN AND FARM SYSTEMS

If one accepts that main and farm systems have different requirements for water control and knowledge, and that effective middle-level organizations can link and reconcile otherwise incompatible irrigation agendas to provide water supply and control to farmers, then it becomes necessary to design organizations to harness farmer participation and make it productive in the operation of middle-level organizations functioning between main and farm systems. Local irrigation organizations are assemblies of joint agreements between farmers and main system managers which make it possible to produce, through provision and use of physical structures, a collective good (water control) not available through individual effort. If an intermediary irrigation organization can provide sufficient water supply and control to its members while denying it to "free riders," then members will pay the organizational costs of supplying and controlling water (i.e., the costs of allocation, maintenance, and conflict management).

The following joint agreements compose a middle-level organization: (1) joint agreements about the direction of staff authority, (2) joint agreements about patterns of staff recruitment, and (3) joint agreements about mobilizing resources, distributing water by way of distributional share systems, and connecting maintenance to water allocation. The essential choices defining the nature of optional organizational joint agreements are outlined in Figure 1. Figure 1 also states the essential working hypotheses regarding which agreement options, when combined, are thought more likely to earn farmer endorsement of a local, middle-level organization.

Source of Recruitment
- 0 Local
- ● Cosmopolitan

Staff Responsible
- 0 to local authority
- ● to central main system authority

Distributional Share System

- 0 water delivery dependent on fulfillment of organizational obligation
- ● water delivery not dependent on fulfullment of organizational obligation
- 0 removes head/tail distinction
- ● accentuates head/tail distinction

Maintenance Structure

- 0 specialist staff paid in cash/kind
- ● general periodic labor mobilization

Farmer Water Control

- 0 high
- ● low

- 0 favored option
- ● less favored option

Farmer Propensity to Support Middle Level Organizations

- 0 high
- ● low

Figure 1. Strategic variables in analysis of middle-level organizations.

Staff Authority Relationships

A critical variable in middle-level organizations is that of establishing authority relationships (Hunt n.d.). Shall the staff of the local organization be fundamentally responsible to main system authorities or to farmers? Responsibility to main system authority is indicated by dependence of organizational staff upon the main system for renumeration, and affiliation with managers. Responsibility to farmers is typically indicated when farmers hire and dismiss organizational staff without regard to civil service regulations, and when rewards for services are established by farmers.

It is hypothesized that as staff of a middle-level organization look to farmers for direction and definition of success, they become tuned to local idiographic requirements and acquire incentive to creatively seek methods to fulfill local farmer water demand within main system constraints. As staff look to main system authority for definition of adequate job performance, they become local agents of the main system. They do not have substantial incentive to seek the most workable fusions of nomothetic and idiographic understandings to bring water control to local reaches of a system. Therefore, an organizational design which ensures that middle-level managers derive their authority from the community of irrigators, whose representatives can hire and fire these managers, is thought to be superior to a design that places authority for the organization in the hands of the main system management.

Staff Recruitment

A middle-level irrigation organization may be staffed by "cosmopolitans" or "locals." "Cosmopolitans" are defined as professionals who are recruited from outside the local command area, who are typically selected based on educational qualifications which emphasize comprehension of nomothetic knowledge in a given discipline, who usually exhibit considerable social distance from local farmers, and whose career aspirations are for upward mobility and departure from the local irrigation command.

On the other hand, "locals" can be recruited on the local labor market and hired based on their local experience and local social connections. They exhibit little or no social distance from the farmers served and have aspirations to spend a lifetime of work in the local command area. The greater the proportion of "local" staff, the greater is the propensity for staff to integrate idiographic understanding into main system operational requirements for serving local water control needs.

Distributional Share Systems for Water

Distributional share systems greatly influence the appropriate design of joint agreements for establishing membership, capturing water from the main system, allocating water to farmer demand, and mobilizing resources to pay the organizational costs of water management. Effective joint agreements regarding water allocation and system maintenance center on the concept of "water share."

A water share is a two-sided concept: (1) it confers legitimate access to the water resource within certain pre-arranged rules, and (2) it imposes on the user a specified obligation to share in paying the water management costs. Therefore, the concept of share unites two essential aspects of organizational operations --resource allocation and resource acquisition.

Productive and equitable water distribution is not a matter of good intentions; it is primarily a function of the way organizational rules and tools resolve the problem of defining and allocating water shares. Even though models are now becoming available to probe aspects of the problem (Molden 1987), the subject is complex, and no comprehensive analysis of the problem has been performed. For now, it is only possible to briefly mention strategic considerations and issue a call for sustained, cross-cultural investigation of the problem. This discussion of water distribution systems has been heavily influenced by, but is not identical to, that proposed by Anderson and Maass (1987). Essentially, middle-level organizations can specify water shares according to some combination of the following distributional principles.

1. Distributional shares may be organized by fixed percentage allotments:
    a. by volume (e.g., a percentage of the total acre-feet or cubic meters estimated to be available).

   b. by time period rotation (e.g., a percentage of a day or week).
2. Distributional shares may be organized by a priority system:
   a. priority by location (e.g., head to tail of a channel).
   b. priority by farm characteristic (e.g., time of settlement).
   c. priority by crop (e.g., market or subsistence value).
3. Distributional shares may be organized by user demand:
   a. demand placed upon storage in a surface reservoir.
   b. demand placed upon storage of groundwater.

Many combinations of distributional principles are possible depending on local circumstance. Share systems may be combined by constraining one type of share with another. For example, shares by volume may be subjected to crop priorities. Distributional systems may employ two share types simultaneously, as when shares by time rotation are supplemented by higher priced demand water. Share systems may shift within seasons in response to change in the environment, as in cases where shares by volume are shifted to shares by time of settlement or crop priority during severe drought. The diversity of irrigation allocation arrangements observed around the world represents various combinations of these basic distributional principles.

As one example, the *warabandi* systems of the Pakistan and Indian Punjab (Reidinger 1974; Kathpalia 1981) are combinations of distribution by percentage of weekly time period combined with priority by location. Water is run from the channel head to tail and allocated to farmers for a time period calculated to be proportionate to area as follows:

$$\frac{\text{hours per farm}}{\text{168 hours/week}} = \frac{\text{area per farm}}{\text{total area in watercourse command}}$$

Whatever water runs in the channel during that time period goes through the channel outlet to the farm.

Given the lack of an appropriately designed middle-level organization to administer the system at the Niazbeg site in

Pakistan (Chapter 5), water control is low and crop potentials are far from fulfilled. Chapter 6, the case study of a small tank system in Madhya Pradesh, India, reports that the *de jure* design calls for a demand contract system on reservoir water. However, with the lack of physical means to control water delivery and the lack of effective organization to connect water delivery with local water assessments, farmers and main system management have experienced much loss of water control and consequent loss of crop production.

In two tank systems located in the Sri Lankan Dry Zone (Chapter 7), the case study reported that no effective share system has been devised for managing distributaries controlled by the main system in the lower reaches of the commands. However, a traditional authority (no longer having clear official status within the main system) administers a rotational share system (a combination of time period and proportion of channel flow) with varying success on channels ostensibly controlled by the main system, but which in fact are controlled by farmers. Variation in the effective administration of the distributional share system was found to substantially affect water control, yields, and farmer willingness to support the local organizational arrangements.

Martin and Yoder (1983) have presented a case study of two Nepali systems (Chherlung and Argali), which makes clear how farmers have successfully created distinctly different organizations around water share arrangements--each of which closely tie water delivery to farmer payment of assessments. In Argali, farmers allocate channel flow in proportion to the area irrigated. At Chherlung, water is shared by fixed proportions of flow volumes which could be detached from any given piece of land. The latter was observed to provide an incentive to increase water use efficiency since water saved could be transferred to irrigators with deficient supplies who were willing to pay for it.

Water Distribution Systems and Water Control

Water control problems assume different forms depending on which combination of water share distributional principles are employed to manage the resource from the main system to the middle-level organization and from the middle-level organization to the farm gate. Different kinds of organizational problems emerge in the middle level to confront farmers and managers, depending on choices made in establishing water shares. Three facets of the problem can be abstracted: (1) defining membership in the irrigation organization, (2) connecting water supply and control with member fulfillment of obligation to the organization, and (3) addressing the effects of head and tail location in the system.

To be a member of an irrigation community, one must be defined as a member by some legitimate organizational principle associated with a definition of water shares. One does not become a member of an irrigation community simply by living in an area proximate to canal flows. Each water distribution system specifies criteria for membership. For example, in a typical Indian or Pakistani *warabandi* system, one becomes a member of the irrigation community by virtue of owning or operating cultivable land within the approved command area. However, if a local irrigation organization operates on the principle that proportions of investment (purchase of shares) in the organization can be made without regard to acreage, then ownership of organizational shares define the organizational membership--e.g., Chherlung in Nepal (Martin and Yoder 1983), the Philippines (Coward 1985), and some systems in Spain and Colorado (Maass and Anderson 1986). Therefore, joint agreements about distributional shares become agreements about who is or is not a member of the irrigation organization.

Creators of water distribution systems must confront another strategic choice: how closely will water service be connected to fulfillment of organizational obligations. Farmers cannot pay to "own" water; virtually everywhere water ownership is retained by the state for public purpose. Yet, everywhere water supply and control exacts costs lower in a system, just as it does in the upstream reaches under the jurisdiction of main system management.

Controlling water on tertiary or quaternary channels, closer to specific farmer demand schedules, may present problems substantially different from managing water in a set of primary and secondary canals. Even so, the costs of water control (for personnel, measurement and division devices, channel maintenance, conflict management) must still be paid. If a design calls for recruiting local people to be responsible to the farmer irrigation community, then the local organization must pay at least a significant fraction of their wages and salaries. If the organization does not pay, its members will lose control over the ability to hire and dismiss such personnel and to define the nature of their job priorities. Therefore, middle-level organizations do not raise resources in order to "own" water, but resources must be mobilized to pay operation and maintenance costs for managing water under the organization's jurisdiction.

Two strategic questions arise:

1. Are organizational joint agreements about water share distributional systems established such that water service directly depends on a member paying his or her share of the cost? Or, is water delivery divorced from fulfillment of member's cost obligations?
2. Are farmer shares of management costs at least roughly proportionate to water service received?

Patterns of water management observed at the three case study sites (Part Two) established that there was no close connection between water delivery and farmer payment. In Pakistan (Chapter 5), the Niazbeg farmers paid an assessment based on crop type and estimated yield. They made such payments regardless of the water supply or control received at the farm gate. That is, a farmer receiving relatively good canal water service paid according to the same assessment schedule as one who received relatively poor service. This system, which largely divorces charges from water service. does not earn the enthusiasm of irrigators who are more disadvantaged.

In the Indian (Chapter 6), and Sri Lankan (Chapter 7) cases, water service and fee collection were divorced. In each of these cases, those who failed to pay their assessments were not meaningfully penalized. "Free riding" on each other and on the main system was the norm. In the Indian system, uncollected revenues have mounted to considerable sums. Farmers are quick to see that it is rather foolish to pay assessments, especially when water supply and control is decidedly inferior. To disconnect farmer payment of assessments from water delivery is to invite "free ridership" and organizational decay.

Farmers are intensely interested in having their water assessments reflect the amount or proportion of water obtained. A share system which connects variation in assessment to variation in supply and control is likely to earn greater enthusiasm from farmers than one which does not do so.

Does a share system reinforce or resolve the problem of "head" and "tail" location? Water must flow in channels from point A to point B. By definition, farmers toward point B (nearer to the tail), all else being equal, will be disadvantaged in the matter of receiving water allocations relative to those increasingly near point A (the head). The more one proceeds toward the tail of an irrigation channel, the more one is vulnerable to losses due to leaks, seepage, and evaporation; the self-interested manipulations of irrigators intervening between farmer "X" and the head; and non-routine breakdowns in the system. More can go wrong when one depends on longer channels. Engineers must construct canals with head and tail positions, but it is up to designers of social organizations to determine by their specification of social rules for the use of physical structures whether or not head-tail distinctions are realized by organizational share systems.

The Pakistan, Indian, and Sri Lankan rotational water delivery systems accept, reinforce, and solidify the head-tail distinction. When water allocations by time and location are combined in a rotational scheme that is insensitive to water supply delivered and timing of deliveries, one reinforces what engineers and geography have already done--creating a fundamental difference in interest between irrigators at the head and tail positions that will threaten the solidarity of any local farmer organization.

Irrigators toward the head of such a distributional system do not experience the same water supply and control problems faced by their neighbors located toward the tail. Farmers toward the head typically find their relatively advantageous situations to be threatened by the desires for reform on the part of tail farmers. Tail farmer demands for more water and more timely water appear to come at the expense of farmers at the head, who quite rationally tend to show less interest in solving problems for tail farmers.

Water supplies at tail positions are a problem only to the extent that organizational design of the share system fails to overcome them. If the middle-level organization employs a combination of distributional principles which impose the costs of "water loss" on all members without respect to location, then all members have equal incentive to pay costs of maintenance and operation of the system as a whole. If channel losses anywhere are distributed by the distributional share system to all, irrigators at all locations have equal concern to reduce losses at any point.

For example, if an organization distributes water by volume, or by volume combined with some form of demand, and if volumes are measured so that losses anywhere on the common channel reduce volumes to all irrigators, and if assessments against shares are proportionate to volume received, then all farmers absorb the water loss and all have incentive to reduce losses. Views of "head" and "tail" conditions as an inevitable natural phenomenon must be set aside. Uncritical willingness to accept "heads" and "tails" in irrigation commands, in respect to social rules and physical structures, is a function of poor organizational analysis of distributional share types, and is not a reflection of universal physical necessity.

Maintenance

There are at least two strategic options for organizing routine maintenance. The first option is to perform routine maintenance by staff hired full- or part-time and paid in cash or kind with resources mobilized by member water share obligations. This arrangement develops specialized competence in irrigation maintenance. Or, tasks can be performed periodically by mobilizing farmers or their surrogates, who may be required to perform maintenance within a specified time or be subject to penalty.

It is hypothesized that if routine maintenance is performed by specialized and paid staff who are employees of the local organization, water control within the organizational domain will be enhanced for the following reasons:

1. These individuals acquire specialized skills, job-related contacts in the irrigation community and market places, and knowledge not developed through annual or semi-annual general labor mobilizations.
2. Full-time paid staff can promptly respond to problems in the command area, whereas periodic labor mobilization tends to defer routine maintenance to slack seasons. Farmers will quickly set aside their personal farming agendas to

mobilize when their system is seriously threatened by emergencies, but the general pattern of intermittent labor mobilization does not place a priority on constant, careful, detailed attention to common maintenance problems emerging incrementally.

3. General labor mobilization provides much opportunity, even incentive, for organizational "free riding." Farmers who are "free riders" may find it in their interest to schedule other activities during the time that labor is to be mobilized for maintenance. In that way, they secure the benefits of maintenance without contributing a "fair" share of work, however "fair" is defined. The organization is then on the defensive. It must proceed against "free riders" in ways which threaten to erode support for the organization or at least impose substantial costs on the organization. Costs will be high because those with sufficient influence and power to attempt "free riding" are those who are most difficult to keep harnessed to organizational norms.

It is thought that collecting operational and maintenance revenue according to some legitimate conception of water shares, and using the payments in cash or kind to support a continuously employed full- or part-time maintenance staff, is much less disruptive to an organization and provides higher quality and more timely maintenance.

Farmer Propensity to Support Local Organizations

The final variable on Figure 1 is that of farmer propensity to support local, middle-level organizational arrangements between farm and main systems. Support is taken to mean (1) a willingness to invest personal resources to sustain the distributional arrangements for controlling water, and (2) abiding by organizational rules.

It is posited that farmers are willing to make such investments and to accept organizationally imposed regulations as long as their water control requirements are at least minimally fulfilled. For this to occur, the middle-level organization must provide an arena of security and predictability within which farmers can count on: (1) organizational joint agreements about allocation, maintenance, and conflict resolution being enforced; (2) assessment revenues being spent locally on water supply and control problems which they experience; and (3) water being delivered to fulfill their crop consumptive demands. Evidence was collected on farmer propensity to support local organizations in Pakistan, and Sri Lanka (Chapters 5 and 7). Farmers in each case evidenced desire for improved organizational arrangements and a willingness to give their support by way of payment and loyalty--if organizations providing effective water supply and control could be developed.

In summary, the more the middle-level organization is staffed by "locals" who look to the authority of farmers, the more the organization provides continuous maintenance performed by employees, and the more the system of water shares denies water to "free riders" and distributes the water loss to all members without regard to location, the greater will be the water supply and control afforded across the system, and the better will be the opportunity for farmer involvement and investment. Farmers will display a higher propensity to support such an organization.

4

ASSEMBLING THE COMPONENTS OF MIDDLE-LEVEL ORGANIZATIONS

The components of an effective middle-level organization have been specified. However, the properties of an effective, functioning organization are considerably more than a list of the parts. Furthermore, no universal blueprint exists for assembling the components into a local organization. Despite the lack of a blueprint, however, farmers are capable of building new or improved organizations that are adapted to site-specific circumstances if they are given support to do so. The problem is less one of farmer capability and more one of recognizing need and providing the required balance of constraint and autonomy, incentive and direction.

Researchers on each of the case studies shared one common experience. Key informants and sample farmers at the studied sites were not awed by the thought of building new or improved farmer-managed organizations to locally supply and control irrigation water. At each of the case study sites, at least some farmers had been discussing this option for years.

In general, farmers do not have to be convinced of the wisdom of getting organized to improve their water supplies and control. Nor do they generally resist the idea of hiring local people with their own resources, who would be subject to farmer water management priorities. Nor do they resist the idea of having organizational leverage over violators of rules by making water delivery conditional on fulfilling organizational obligations. Farmers generally indicated an understanding that water service must somehow be connected to gathering resources required for running water.

Farmers seek predictability and control over a vital resource, and they are, given what they believe to be a credible arrangement, willing to organize to get water control and keep it. Yet, farmers are skeptical. They expressed concern that locally influential people may subvert local organizations to their private purposes and that authorities may not give sustained support to organizations if such support conflicted with the desires of well-connected individuals. They tend to be concerned that local elites may be allowed latitude by main system management to control local organizational personnel and other resources, and that non-elite farmers might not be allowed the latitude necessary to organize themselves in ways seen practical for themselves. Generally, irrigators see problems with investing their resources in a system where they possess no officially sanctioned roles or responsibilities. Why tax oneself for a collective effort on a system where one has no officially recognized and legitimate function and where one can easily fall prey to the interests of local elites and the whims of remote main system managers?

Therefore, it is necessary to briefly examine the conditions under which chances improve for assembling the necessary components of local farmer organization in a manner acceptable to farmers and main system managers. The discussion revolves around three topics: (1) basic design premises, (2) fundamental conditions which must be fulfilled prior to any farmer-organizing effort, and (3) general organizational structure and processes.

Fundamental Design Premises

Thoughts advanced here about the assembly of local organizations are rooted in three fundamental premises which must be brought forward for acknowledgment and inspection regarding the importance of farmer participation, the legal context at the site, and devolvement of responsibility to the local organizational unit.

The Importance of Farmer Participation

In implementing any organization-building process, experience gained through the successes and failures of farmer participatory approaches tested in several nations must be employed and integrated with the sense of organizational design advanced in this research. Much has been learned about promoting farmer participation in development projects in general and in irrigation systems in particular (Bagadion and Korten 1985; Cernea 1983, 1985; de Silva 1981; FAO 1985; Illo and Chiorg-Javier 1983; Korten 1982; Lowdermilk 1986; Lynch 1985; Montgomery 1983; Moris 1981; Siy 1982; Uphoff 1986).

This rich literature is not reviewed here, but it suffices to note that a sense of organizational design remains inert unless farmers are activated to give shape and life to the design components. It is equally the case that attempts to promote farmer participation without a clear sense of organizational design unproductively pushes unorganized farmer demands up to main system management, which cannot cope with poorly designed organization of farmer demands given its different supply agenda.

Meaningful farmer participation requires that an organizational vehicle be designed to focus participation on performing specified responsibilities in particular reaches of the system. Design without participation is a dead exercise. Participation without careful organizational design is futile for farmers and threatening to main system managers.

The Legal Context at the Site

The issue of designing organizations must be viewed in the legal context appropriate to the specific site. Much can be said about the manner in which different legal traditions cast the problem of water rights and responsibilities (Radosevich, 1986, 1987). Given the complexities of legal reasoning about water, one must advance generalizations with caution. One generalization can be advanced, however, which enjoys broad validity: nation-states generally reserve ownership of water for the public domain.

Such public legal ownership of the water does not, however, pose an obstacle to farmer organization because ownership of water is not a requirement for effective local organization. The issue centers on defining responsibilities for managing publicly owned water and organizing the means to pay the costs of management. Farmers may not be able to own, buy, or sell water, but they can organize to manage water which the public domain has placed in their trust and pay the local costs of management. When farmers organize, they purchase water control rendered out of good management; they do not purchase water *per se*. It is possible for farmers to "own" a segment of the facilities for water control and to collectively "buy" water control without "owning" water.

Devolving Responsibility to the Local Organizational Unit

The issue of linking a local water users' organization to main system management is less an issue of centralization versus de-centralization and more an issue regarding how to "devolve" responsibilities to the local organizational unit within parameters acceptable to higher authority and subject to specified oversight by main system management (Esman and Uphoff 1984; Montgomery 1974).

There is little promise in organizational visions that assume the local farmers' organization is simply an extension of main system bureaucratic management. Nor does promise lie in a vision of de-centralized farmers' organizations working to obtain water from the main system in whatever opportunistic ways are made available by local circumstance. Devolution of water management responsibility means that the local organization is empowered to act as an autonomous or quasi-autonomous unit, with its own authority to operate with its personnel, budget, and management procedures (within standards and criteria established by the main system).

If the local unit should significantly violate its mandate by allowing physical structures and tools to deteriorate or by being taken over by local forces unsupportive of its mission to equitably serve all the farmers in the command area as stipulated by the charter, then the main system management must exercise its one meaningful sanction. Main system management can withdraw water supply in proportions appropriate to the nature of the problem.

Conditions Precedent

Prior to initiating organizational design with authentic farmer involvement, political authorities and administrative managers of the main irrigation system must arrange to recognize and support farmer water user organizations. Bagadion and Korten (1985) summarize the need for main system administrative support in the context of promoting farmer involvement. At the very least, the following conditions must be fulfilled before proceeding with organizational design and development.

Political and administrative authorities responsible for main system irrigation must legally recognize local farmer irrigation organizations. There must be clear agreement that, at a given point in the system, specified farmer organizations will accept responsibility for managing and controlling water (allocation, maintenance, and specified conflict management). Without such administratively recognized and legally enforceable recognition of the local organization, "free riders" will be able to exploit unresolved definitions of responsibility and make it difficult for local organizations or main system management to exert control over farmers whose behavior threatens others who do meet their organizational obligations. If "free riding" becomes a successful strategy, incentive is quickly lost for all farmers to contribute to providing the collective good (i.e., the rules and tools necessary to provide water control). This leads to the following condition.

Main system authorities must be prepared to support local irrigation organizations as they exert control upon "free riders." Main system authorities, after having endorsed a charter and by-laws specifying operational procedures for local water users associations, must be willing to uphold judgments made in accordance with those procedures. If "free riders" learn that main system management is less than firm in its support of local organizational procedures, local organizational leaders will be much less able to control "free riders", who will find support and shelter in any lack of resolve by main system management.

In addition to paying property, income, or other taxes imposed by the state, farmers must be permitted to raise and retain their own revenue through their organization's distributional share system. This revenue must be locally managed and invested to address local water supply and control problems as defined by the local organization. Annual or seasonal costs of running the local reach of the system must be totaled and assessed to water user members in a manner somehow proportionate to the water service received as defined by the organization's share system. Revenues must be raised in cash or kind to cover costs of hiring local staff, purchasing local materials, and possibly hiring local contractors and temporary labor. It is essential that water delivery to each farmer water user directly depend on paying organizational assessments.

Organizational Structure and Process

The Form of Local Irrigation Organization

The essential structural form of a local water users' association is diagrammed in Figure 1. It is adaptable to a rich variety of diverse cultural systems.

Member shareholders elect representatives to a governing board or council. This body is empowered by joint agreements with the main system and local irrigation community to direct the affairs of the local organization in accordance with the established charter and by-laws, to which the shareholders have publicly and legally pledged themselves.

The board or council representatives (chosen to represent different categories of water users (e.g., head, middle, tail reaches; caste or sub-caste groups) would meet periodically to establish policy and hire the daily operating staff to implement policy. Generally, the board or council members would be elected for two- or three-year (or seasonal) terms in a staggered manner. That is, some fraction of the members would be elected each year or season so that no complete turnover in board or governing council membership could occur at any one time. Overlapping terms preserves continuity, while also allowing for change.

Members of the board oversee local conduct of water allocation, maintenance, and conflict management by a local manager and staff. Farmers can generally be expected to prefer locally hired staff who are fully responsible to the local organization, especially if farmers are paying all or a considerable fraction of the costs of staff employees. In any case, farmers serving on the board must have discretion in hiring and firing the local manager and staff without having to take their personnel cases to the main system for review and final decision.

The local manager and staff work either full- or part-time to do the following:

1. Allocate water according to the organized share distribution system.

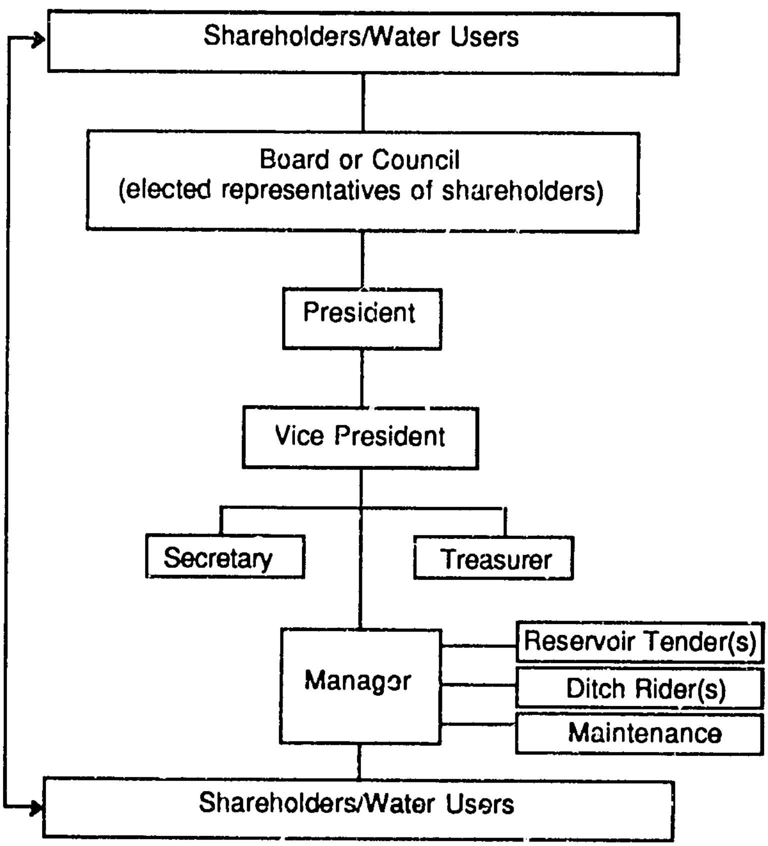


Figure 1. General structure of local water organizations.

2. Maintain the local irrigation facilities for which the organization is responsible using resources collected from the shareholding membership according to the rules specified by the share system (volume of water received, proportion ditch flow received, acreage or crops irrigated).
3. Manage conflicts among irrigators by administering policies of the board. Appeals would be addressed by the board. If conflict cannot be satisfactorily resolved at that level, the case would have to go to the legal system provided by the state.

Daily needs of the local water users, as defined by the particular water share distributional system, are thereby served. Water users elect representatives to the board and complete the organizational cycle of authority.

Local organizations, composed as they are of negotiated agreements with which to conduct collective action, are the outcome of continuous bargaining and maneuvering for advantage. Furthermore, compliance with organizational expectations must always be secured within a nested set of other relationships rooted in family and kinship organizations, credit and other supply organizations, marketing organization, and religious and political networks. Therefore, organizational structures must possess some attributes which will permit them to adapt to shifting situations. The structure of the organizational rules, and the joint agreements for guiding the use of physical tools and structures, must possess specific attributes if the rules are to provide an effective framework for organizational behavior (Figure 2).

Note that nowhere in the cases reported in Part Two are the conditions specified in Figure 2 fulfilled. However, where management capacity was higher in certain Sri Lankan distributaries, there was evidence of greater approximation to the criteria presented in Figure 2. Failure to define organizational rules so that they possess in full measure the properties given in Figure 2 will undercut the viability of an organizational structure without respect to the local cultural content which fleshes out this form.

Analysts, farmers, and main system managers must continuously evaluate the following questions and design specific joint agreements in response to each question: Is "free riding" behavior

Premise: The organization delivers a service--water control at the farm gate--which pays off for the farmer-member. Water service is tightly connected to fulfillment of member obligation.

Rules must:

1. Be known by all
2. Be clear, consistent
3. Be perceived as unbiased toward their subgroup
4. Be a source of reward for adherence in experience of members
5. Be supported by norms of local groups

Violators of rules must quickly be identified.

Procedures of investigation must:

1. Be known by all
2. Be clear, consistent
3. Be perceived as unbiased toward their subgroup
4. Be a source of reward for adherence in experience of members
5. Be supported by norms of local non-irrigation groups
6. Be conducted by authorities independent of executive management

Organizational participants will support local organization and employ it for allocation, maintenance, and conflict management.

Figure 2. Principles for analysis of organizational behavior.

emerging? What kind of behavior is it? What local organizational responses to "free riding" are possible? What local organizational responses to the "free riding" are most efficacious given local resources and water control agendas? What main system responses are possible to "free riding"? What main system responses will be most efficacious given main system water control resources and agendas? What threats to water supply and control (and therefore water productivity) are being encountered in the main system and in the local organizational system? What adjustments are required in main system operation to respond? What adjustments are required in the command area internal to the local water users' organization (share types, authority and staffing patterns, and maintenance policies)? Continuous attention to questions such as these, combined with rapidly adaptive organizational responses and support from main system management, is the essence of successful local management.

Linking Local Irrigation Organizations: An Analysis

Now that the essential features of the form of a local irrigation organization have been addressed, two interrelated issues arise. How many such organizations are required; and if more than one is to be developed, how are multiple organizations to be linked with each other and with main system management? Just as there can be no universal road map for all locales, there can be no recipe which adequately addresses the richness and complexity of conditions found in diverse irrigation projects. It must be acknowledged that designing optional linkage arrangements among local organizations was not a focus of the research reported in the following case studies. Yet, years of discussion with thoughtful informants representing a diverse array of socio-cultural and technical irrigation backgrounds make it possible to tentatively advance some general thoughts to prompt discussion, reflection, and future research. There are at least three general options for establishing linkage.

The first option is to design and employ one local irrigation organization to accept water management responsibility for the entire project area. The main system would deliver water to one or more transfer points, and one organizational staff would disaggregate the flow(s) along one or more distributaries according to one distributional share system under the guidance of one board or council. One set of rules for operating and maintaining one set of tools would serve all users on all canals within the jurisdiction of this organization. If there is sufficient social and cultural homogeneity among the farmers, and if cropping systems, agro-climatic circumstances, and market conditions are sufficiently similar such that one distributional share system can be expected to adequately satisfy consumptive demands, one organization for managing multiple distributaries across considerable area may be a highly desirable option. It has the advantage of being able to aggregate water demands and local resources from a larger set of farmers. This makes it possible to mobilize more personnel, specialized talent, and capital, which makes it possible for the main system to turn over a greater proportion of the system to such an organization, thereby conserving its own state-provided resources from the general treasury. In effect, the middle-level organizational interface between farmers and main system management potentially can be moved further up the irrigation system.

If other factors are equal (e.g., income, educational levels, soil and water quality, and availability of inputs) smaller middle-level irrigator organizations cannot be expected to mobilize the resources necessary to sustain the specialized skills and more expensive physical structures available to larger organizations. A design for small organizations (for example, deciding to organize relatively small numbers of farmers below each quaternary turnout) brings the middle-level organizational interface lower in the system. This implies greater investment and water management responsibility by central management, and greater commitment of main system resources as central treasury monies substitute for local revenue raised through farmer water assessments. Nevertheless, if one wishes to push the interface further upstream to conserve limited main system resources and to reduce central management's responsibility for local water allocation, maintenance, and conflict management, it is possible to link smaller organizational units together to assume increased water management responsibilities farther upstream. There are two major options for stitching together smaller farmer organizational units and linking them to main system organization: unitary and federal.

In the unitary model, lower organizations are vertically integrated by at least three devices: budget flows, leadership recruitment from lower units, and review of lower unit decision-making by each higher unit. Lower-level organizations gather fees from farmers within their jurisdiction, retain a specified proportion, and send the remainder to one or more higher levels. Each higher-level organization functions with at least some resources raised by units at the lower level, plus whatever subsidies are granted by main system management.

Linkages are established by overlapping leadership; i.e., leaders at each higher unit are recruited from leadership boards or councils at the next lower level. To be a member of the board or council at the primary level one must have simultaneously held membership at the secondary and tertiary levels.

Policy at each lower unit is subject to review and potential veto by each higher organizational unit. This model reflects a traditional, pyramidal organizational structure. Policy decisions are supposed to flow down; money and information is to flow up. A general working hypothesis is that main system management on the whole will tend to prefer unitary linkage arrangements more than will farmers.

Money and information, at least officially, is to flow toward main system managers, who make supply decisions based on whatever farmer demand considerations filter up through the multiple organizational levels. Several concerns arise regarding design of unitary organizational linkages.

First, resources and decision-making tend to be divorced from need. Problems of water allocation, maintenance, and conflict occur at specific points at specific times in the canal network, not at remote upper levels where organizational meetings must, by necessity, be scheduled periodically (monthly, quarterly, seasonally, or biannually). If a section of a tertiary canal should wash out on a particular day at a particular site, the affected farmers will need to address the problem immediately. They will tend to be less than supportive of organizational designs that draw a large portion of their resources high in the network, necessitating that they petition for resources though a time-consuming hierarchy until a level is reached where adequate resources are to be found, and where they have sufficient political alliance so that resources will be directed toward them rather than toward problems faced by other farmers at other points in the system.

Second, the center tends to become overloaded, and decisions are slowed. The range and variety of allocation, maintenance, and conflict problems crowd agendas at the upper layers because that is where the network is designed to place them. Leaders serving on the boards or councils of the higher units must act as lobbyists for the interests of their sub-unit(s). Because meetings must be intermittent, because each representative must attempt to advance the interests of his or her particular constituencies, because leaders simultaneously serve on multiple governing bodies, and because leaders must consume time to consult with their leaders and followers across levels, decision-making delays typically occur which further crowd upper-level agendas.

Third, power and formal authority tend to be concentrated with a relatively few leaders and brokers. Because membership of governing boards and councils at each higher level is drawn from the membership at each lower level, power and influence rapidly concentrates among a few. By the time someone maneuvers to the top, he or she has made many political promises to narrower subgroups, possibly without adequate consideration for the needs of the whole irrigation system. This person must seek to fulfill such promises to sustain sufficient political support. Power games supplant responsiveness to specific irrigation problems.

Fourth, as one proceeds up the hierarchy, demands of various sub-units will typically exceed the supply of resources. To respond to the petition of sub-unit "X" will necessarily mean allocating fewer resources to the demands of sub-unit "Y." Generally, either one of two things can happen:

1. Power alliances may be balanced and check each other into gridlock. Therefore, the system becomes unresponsive to demands from below.
2. Power forces are not in balance. One set of sub-units wins disproportionately, and losers seek ways of withdrawing their resources of money and information from the organizational network as they attempt to circumvent agendas of higher authority.

Either way, the system becomes unresponsive to local farmer requirements for good water management. It is hypothesized that farmers will tend to show less support for, and will tend to withdraw from, systems designed and articulated on the unitary model.

There is, however, a third organizational option--the federal model--which represents a promising alternative to the unitary model. Federally organized organizational units possess independent control over their respective revenue-raising activities, expend their own budgets in service of their own priorities, and memberships of governing bodies are kept distinct (i.e., a council or board member at a lower level is not simultaneously a member of the higher unit's governing body, and clear boundaries are drawn between jurisdictional areas). Each lower unit contracts with the higher unit for picking up water at a specified transfer point and then allocating it to lower organizational units in accordance with a distributional share system uniquely designed for the management problems faced at that level. Each share system raises revenue by charging an assessment to lower units. Payment of the assessment is contingent upon delivery of the specified shares of water, and the water shares are delivered contingent on payment of the assessment. Each unit is controlled by its own governing body, which is responsible for administering water allocation, maintenance, and conflict resolution within its jurisdiction. Should anything go wrong, farmers know: (1) who is responsible for taking action within each jurisdictional domain (a specific board and staff); (2) exactly how much revenue was paid to that level for operations and maintenance in a given season or year; and (3) that future payments of assessment to that level are contingent upon corrective action being taken within constraints imposed by available resources.

There are some clear advantages of such articulation of organizational linkages. Resources and decision-making are kept closely married to site specific allocation, maintenance, and conflict management needs. Each organizational level is clearly responsible for a specific segment of the river, canal, or reservoir network. A problem arising at a given point must be addressed by the particular organization having jurisdiction for that segment with the resources raised by that particular organization's water share system without the necessity of inter-level negotiations and approvals from higher authorities. At each level, anticipated costs of water management in the particular segment of the system are projected, the costs are then allocated to shares of water delivered to member units below, and revenues thereby raised are spent within that unit and network segment. Insofar as the distributional share system has successfully removed the head-tail distinction by sharing the water losses among all unit members, there will be an incentive to spend the available resources to solve problems which will have the maximum effect of reducing water loss and increasing water measurement and control. A loss to one member will be a loss to all, without respect to location in the system.

Second, each organizational leadership and staff establishes its own agenda to respond to its own problems with its own resources. The agenda is not crowded by problems arising in other units above, below, or lateral to a given organizational unit. Failure to respond to problems of members will threaten a reduction of assessment revenue to that level, which creates incentive for rapid response.

Third, power and influence will tend to be distributed among several units at each of the several levels. Concentration of power in the hands of a few leaders and brokers who obtain position at the upper levels is much mitigated. Upper-level leaderships are constrained to operate only within their specified jurisdictions and cannot interfere in daily operations of higher or lower organizational units.

Fourth, politics will not be eliminated, but the politics of irrigation organization will be re-shaped in a federal linkage system. There will of necessity be struggle among members of a given organizational unit over expenditure priorities and operational plans. However, the federal linkage arrangements are thought to offer a distinct advantage. Insofar as the distributional share system of each organizational level forces a sharing of water loss upon all members, organizational politics will be primarily focused within each organizational level on which set of priority expenditures and uses of staff time will most reduce problems of water loss and control at that particular level. Political life will necessarily continue, but without an emphasis on mobilizing lower-level constituencies to extract revenues from higher levels at the expense of neighboring organizations, who would oppose expenditure of such funds on their neighbors rather than upon themselves. A nasty edge to political life is thereby organizationally removed because factions representing different segments of the system are not pitted against each other in a struggle for resources from the higher central unit.

In addition to the above considerations, note that water control problems vary significantly from level to level and unit to unit within levels. Each organizational unit must have specific social rules and physical tools designed for its particular problems of water supply and control. As one moves up, down, and across irrigation systems, different configurations of staff recruitment and authority patterns may be appropriate, different configurations of water distributional rules and tools are likely to be required, and different approaches to maintenance may be most effective. The federal model is thought to offer a greater degree of latitude for such site-specific adaptations.

When designing linkages among irrigation organizations, it is recommended that option one (one organization) or three (federal) be employed in preference to option two (unitary model). Again, the case studies presented in Part Two do not marshall data in support of this hypothesis. Rather it has emerged out of the years of work, field observation, and discussion occasioned by working with many thoughtful individuals farmers, managers, and scholars in the course of doing research on irrigation organization. It represents a hypothesis in need of inspection and empirical testing.

Linking Local Irrigation Organizations: An Example

Since the discussion of organizational linkage has been abstract, an example may be helpful. Figure 3 represents a two-tier, set of middle-level organizations functioning between main system management and individual farmers.

The Upper Tier. It is taken as given that main system management operates and maintains a sizable reservoir requiring specialized skills and capital beyond the capacity of local farmers to manage. Furthermore, it is taken as given that the system will be organized on federal principles. Main system management turns water over to two autonomous organizations. Functioning as the upper tier of the interface, each is designed to deliver water along one of two main canals (left and right bank) to the several secondary distributaries.

Each canal organization has drawn a charter specifying its purposes and a set of by-laws containing essential operating procedures, within which the governing board, staff, and membership must conduct organizational affairs. A written memorandum of agreement, written as a legally enforceable contract, has been constructed and accepted by both the main system authorities and the governing bodies of each of the main canal organizations. The memorandum of agreement specifies the terms under which each canal organization legitimately can call for water from the reservoir and specifies terms of water assessment to be exacted by the main system from canal organizations.

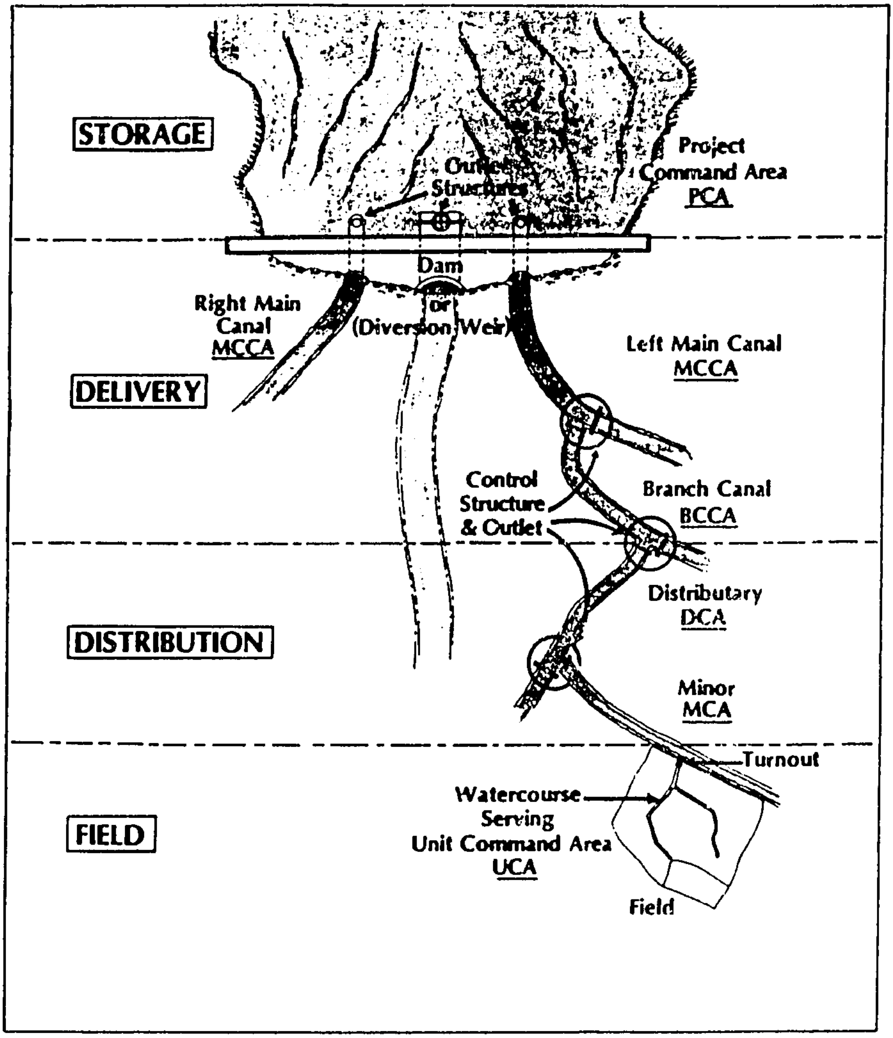


Figure 3. Example of a tank system
(Source: Keller et al. 1988).

Because reservoir levels are expected to vary from season to season, main system officials have chosen not to guarantee a specific volume of water during any given season, but they have agreed to portion out fractions of the water available in the reservoir at a given time prior to the beginning of the irrigation season. Therefore, the reservoir is divided into a given number of water shares (1,000, 10,000, or some other convenient and workable number). The more water available in the reservoir, the more volume appropriated to each share by the canal board before the beginning of the irrigation season.

If, after adjusting for expected inflows, evaporation, seepage, and other losses, there is 200,000 acre-feet of deliverable water in the reservoir and it has been divided into 10,000 shares, then each share will deliver 20 acre-feet at the reservoir outlet during the season. Each of the two canal organizations is allocated its fraction of water shares according to the stipulations of its agreement with the main system. Such a contract might allocate shares by irrigable acreage, by crop priorities, or purchase on an open market by the lower organizational units which run water to farmers on the secondary and tertiary distributaries.

Each canal organization has its governing board or council elected directly by farmers, with each irrigator having one vote. Therefore, it is conceivable that competent, interested, and trusted smaller farmers can be elected to the main canal board. The governing body probably could be expected to divide its membership by locational or other socially relevant criteria; e.g., so many representatives from specific locations, ethnic communities, or social factions. There may or may not be at-large representatives, but council members could serve staggered, three-year terms so that no single election results in a wholesale turnover of experience or breaks continuity.

Prior to each irrigation season, each main canal council estimates the costs of water management in the particular segment of the system for which it has responsibility. First, the canal organization will determine the cost of the reservoir water assessment to be paid to the main system. This is the cost of constructing, operating, and maintaining the reservoir, less whatever subsidy the state wishes to provide. Then, costs of managing water in the main canal will be projected for the season (employing a manager, any staff assistants, equipment, and materials). When all projected costs of water management have been identified and summed, they are distributed to the shares of water owned by organizational members; i.e., the lower distributary organizations in the second tier of the interface. Thereby, the water share unites the cost of water management with water delivery. If a given lower-level distributary organization does not pay its share of main canal cost, it will be denied water by the canal organization. The principle is simple and effective: no payment, no water. Prior to each irrigation season, the governing board or council calls a meeting of all members to inspect and approve its proposed budget and plan of expenditures.

If left bank canal organization "X" possesses 7,200 of the 10,000 reservoir shares due to greater water demand in its command as compared to right bank canal organization "Y," it would pay 7,200/10,000 of the costs of water management of the reservoir minus any state subsidy, and it would have a right to 7,200/10,000 of whatever deliverable water is available. Canal organization "X" would then add the costs of its water management in its main canal segment and apportion the sum of these costs to its own water shares, which are owned by the several distributary organizations. These distributary organizations are designed to pick up water at main canal turnouts and to manage water in the distributaries through watercourses to farm gates.

Canal organizations "X" and "Y" may have varying water share distribution systems and operating procedures appropriate to their site-specific circumstances. For example, left bank canal organization "X" might serve 15 distributary organizations and divide its water into 1,000 units, whereas right bank canal organization "Y" might serve 9 distributary organizations and find it most useful to divide its water into 300 shares. "X" may devise a rotational system of service for delivering its volumes to its member distributaries, whereas "Y" might deliver volumes on demand constrained by minimum volumetric orders so as to minimize ditch losses.

If problems are found in water delivery and control, there is a clear line of responsibility easily followed by farmers and main system officials. The canal organization board and staff are responsible for addressing water supply and control problems in their segment of the network with the resources made available to them by the water share assessment system. If too many resources were mobilized, the next season's assessments to members can be reduced. If too few resources were made available, the board must make a case to its members for greater assessments to cover the costs of water management.

Farmers, who contribute resources to the canal organization through their respective distributary organizations, know exactly how many resources have been contributed in cash or kind and what can be reasonably expected to be accomplished in the local environment by competent organizational management. Incompetent management will result in dismissal of local management staff, who are responsible, through the board, to the community of farmers. Replacements will be locals who can be found on the local labor market.

The agendas of left and right bank canal organizations do not come into conflict in any higher order organizations. Each addresses its problems independently with whatever assistance it may secure from the main system and other state agencies. Farmers can, at each seasonal organizational meeting, evaluate the trade-offs between increased expenditures to resolve specific problems in particular segments of the system as proposed by their representatives on the governing board, or accepting losses of water supply and control occasioned by choosing not to invest in remedies.

The Lower Tier. Proceeding to the lower tier of the interface, autonomous organizations are created for each distributary and associated network of watercourses which deliver water to farm gates. Each distributary organization possesses a charter, a set of by-laws, a governing body, and a locally hired manager and staff responsible to the farmer board or council for administering the particular water share distributional and assessment system. Furthermore, an agreement has been made with the canal organization under which water is delivered by the main canal organization. Each distributary organization pays its assessment to the canal organization in proportion to the number of main canal shares owned.

Board members at the distributary level are not board members at the canal level. They are elected for multiple seasonal terms on a staggered basis by farmers on the distributary who vote their water shares at each seasonal organizational meeting. Farmers vote on distributary and watercourse organizational issues according to their ownership of water shares: one who owns more shares obtains proportionately more of the available water, possesses more votes, but also pays proportionately more of the organizational management costs. There is no incentive to capture ownership of shares in excess of those needed for one's farm because each share must pay its fraction of the total organizational water management cost. If a particular distributary, given its number of farmer members, its main canal supply, and its crop water demand, chooses to divide its water into 200 shares and distribute those shares among 80 farmers, each share will deliver 1/200 of the water and bear 1/200 of the total cost of running water in that particular network of canals to the 80 farms. If shares can be transferred from those who find they have an excess of supply to those with an insufficient supply, and if each share delivers a roughly equal volume of water anywhere in the system, then incentive is created to efficiently apply water, reduce share ownership to a minimum, and transfer unused shares to users with greater need, thereby reducing farm production costs.

The distributary organization measures its water at the distributary headgate, at the head of each watercourse, and at the last farm gate of each watercourse. Water losses are calculated between distributary and watercourse head and tail points. The time of water rotation to each watercourse and within each watercourse is then adjusted as a linear function of distance from the respective headgate and water measurement point. That is, in the absence of capacity to measure water to each individual watercourse field outlet, watercourse headgates toward the tail are apportioned greater time for their turns as a linear function of their distance from the head.

Within each watercourse the procedure is repeated. The greater the losses over the run of the distributaries and watercourses, the greater the time required to deliver approximated volumes as one moves farther from the head to tail positions. Water lost in servicing a tail-end farmer is lost to head-end farmers; the loss has been shared, with the result that all have an equal interest in improving the performance of the delivery system. Heads and tails have been effectively organized out of the system. As investment is made in delivery channels to reduce water losses, head-tail measurements will reveal the reduction in losses and the length of turns can be appropriately reduced. When tail farmers can be served their shares in less time, the value of everybody's water shares will be greater as each share delivers more supply. With increased productivity of water, resources may well become available to measure water volumetrically at many more points in the system, eventually making possible volumetric water supply on demand, given the necessary alterations in main canal operation.

Prior to each irrigation season, the distributary board prepares a budget and an operational plan for expenditures reflecting the costs of that organization's water management for its segment of the system, including the cost of obtaining water from the main canal organization. The board, after learning what the main canal system is expected to deliver during the coming season, appropriates a given water volume per distributary share, making certain that sufficient water is left to pay distributary delivery losses. Let us say the distributary is located on the left bank canal, which divides its water supply into 1,000 shares, and the distributary organization has collectively purchased 80 main canal shares. It then owes the main canal organization 80/1,000 of the main canal's seasonal water management costs, minus any main system subsidy. Thereby, this distributary organization obtains 80/1,000 of the seasonal water volume delivered to its distributary share system after main canal delivery losses have been subtracted.

To the costs of water obtained from the main canal, the distributary board adds the costs of its water management within the distributary and watercourse network. It then parcels these costs out according to its own share system, and it also parcels its projected water volume out to its 200 shares. If the distributary organization divides its water into 200 shares, it will total the costs of owning 80 main canal shares, employing its staff, and purchasing its materials and will allocate the total of these costs (and its water, less estimated delivery loss) equally to each of its 200 shares. A farmer owning 12 of those shares will then pay 12/200 of the distributary organization's water management costs and obtain 12/200 of the water supply after water loss has been absorbed by the organization. A farmer possessing 3 such shares will pay 3/200 of those same costs and obtain 3/200 of the water.

If the main canal performs poorly, all distributary organizations at all locations will be penalized. The greater the water volume required to deliver water past a particularly problematic point in the main canal to fulfill the share of a distributary organization near the tail, the less water available to head distributaries. The loss is thereby shared among all irrigators and incentive is created among all irrigators to improve the performance of the canal. Improved performance will mean more water volume per share for all. Likewise, if distributary canals and watercourses perform poorly, all farmers in that organization will be negatively affected and will have a similar incentive to make improvements so as to make their shares deliver more water.

The canal organization delivers water on a rotational and volumetric basis measured at the distributary headgate. As each unit volume of water passes through the headgate, the water account of the distributary organization on file with the main canal organization is reduced accordingly. When all of the water has been delivered that has been appropriated to main canal shares owned by the distributary organization, the water supply to that distributary is ended.

Each main canal water management problem is addressed by the main canal organization with its own staff and financial resources. A distributary canal problem is likewise addressed by the distributary organization. There is no confusion or haggling among organizations over distribution of costs and benefits. If farmers on one distributary are willing to assess themselves more than their neighbors on another distributary, there need be no discussion of such matters between the respective organizations. Those who pay more reap whatever benefits are obtained by their investment on their canal. Each organization accepts responsibility for its segment of the system.

Although this discussion has assumed a reservoir system, the essential principles of organizational design can be applied to a run-of-the-river system, in which the river assumes the position of the main canal in the example above. Furthermore, the principles can easily be adapted to a combination of river and reservoir systems.

Summary

Chapters of Part One have made the case that effective development of irrigated agriculture centers on the quality of social organization constructed for controlling irrigation water. If incomes and social well being are to be enhanced, irrigation water must be productive. Water, however, to be productive must be controlled, but control over water is a function of social organizational effectiveness. The argument has taken as a premise that these are, typically, deficiencies in organizational linkages between main system state bureaucracies and individual farmer irrigation water users. Chapter 1 introduced the problem and placed it in historical and global perspective; Chapter 2 explained strategic dimensions of the problem--i.e., the need to reconcile main system supply with farmer demand, the need to reconcile main system processed nomothetic knowledge with local idiographic knowledge, and the need to reconcile individual rationality with the logic of public goods--all of this while respecting the value and diversity of cultural meaning systems. Chapter 3 presented essential design choices to be made in organizing at the middle-level and Chapter 4 has presented strategic conditions requisite to organizing farmers and major options for assembling smaller farmer sub-organizations into larger organizational units. Now the discussion, in Part Two, turns to an exploration of specific cases.

PART TWO

Cases

5

IRRIGATION ORGANIZATION ON THE NIAZBEG DISTRIBUTARY IN PUNJAB, PAKISTAN

David Freeman and Edwin Shinn

Introduction

The research objective was to investigate water control, water distribution, and water productivity on six sample watercourses on the Niazbeg Distributary. It was posited that the social organization that links main system management of water supply to farmer demand for water centrally affects water control and, in turn, agricultural water productivity.

The irrigation system of Pakistan was designed to serve an agriculture which typically had an annual cropping intensity of 75 percent and emphasized the cultivation of drought-resistant crops (Michel 1967). With the advent of the Green Revolution and the promotion of moisture-sensitive, high-yielding varieties, farmers required increasing control over irrigation water. To increase their water control, farmers have often circumvented central bureaucratic rules and have invested in private tubewells.

The cumulative effect of both strategies is a continuing erosion of organizational agreements at the main system and the farm levels. Organizational deficiencies at the intermediate level between main system managers and farmers leads to an inefficient use of canal water, inequitable water distribution, and reduced productivity. M. Jameel Khan, Director of the Punjab Economic Research Institute in Lahore, has estimated that Pakistan's production of major crops was half that of other developing nations, particularly Mexico and Egypt (Table 1). Khan (1985) concluded that a four-fold increase in production

Table 1. Yield per hectare of major crops in Pakistan and selected countries.

Country	Wheat	Rice (paddy)	Maize	Cotton	Sugarcane
	kg/ha				
Pakistan	1567	2604	1258	338	38,639
India	1602	2050	1207	170	56,844
Bangladesh	-	1950	-	-	-
USA	2394	5462	6898	542	88,802
Turkey	1908	-	1897	634	-
Canada	2123	-	5874	-	-
Egypt	-	5411	-	923	83,575
Mexico	3717	-	1812	892	-
France	5177	-	-	-	-

Source: Khan 1985:7.

is possible if strategic improvements were to be made in the agricultural sector; among these, improvements in the organization of water management are central. Recognizing constraints built into the irrigation system, Pakistan's leaders have launched an ambitious Command Water Management program, (CWM), incorporating seven subprojects, with at least one subproject in each of Pakistan's four provinces (Figure 1). It was within this program that this case study was conducted.

Background and Setting

Geography

The Niazbeg subproject area is located in the Punjab region of the Indus Basin. The Himalayan mountains tower over the relatively flat basin, where the slope averages about one foot per mile in its descent to the Arabian Sea. The basin has been constructed of silt and sand deposition by the Sutlej, Beas, Ravi, Chenab, Jhelum, Kabul, and Indus Rivers (Table 2).

The Indus River, the largest and longest, winds over 400 miles until it descends to the plains where it is at an elevation of about 1300 ft above sea level and is 1100 miles from its mouth. Five of the rivers--the Indus, Jhelum, Chenab, Ravi, and Sutlej--converge approximately 450 miles from their emergence from the Himalayas. This area has historically been called the Punjab, or "land of five rivers." Lands lying between

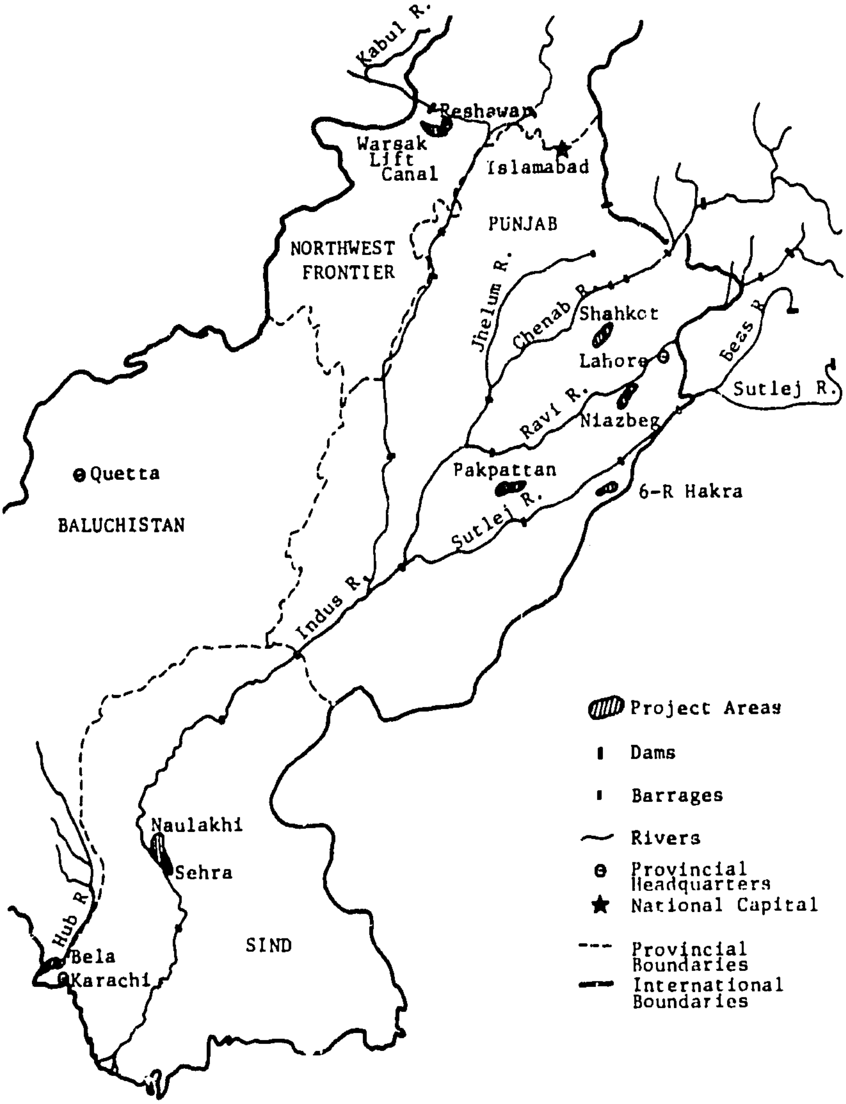


Figure 1. Pakistan Command Water Management Project areas.

Table 2. Catchment areas and runoff of the rivers in the Indus Basin.

River	Catchment Area ($miles^2$)	Average Annual Runoff, 1922-1961 (million acre-feet)
Sutlej	18,550	14
Beas	6,500	13
Ravi	3,100	7
Chenab	11,400	26
Jhelum	12,900	23
Kabul	26,000	17.4
Indus	102,000	93

Source: Michel 1967:33.

the rivers, called *doabs*, were largely uninhabited prior to the 1850s.

The Niazbeg subproject area lies between the Ravi and Sutlej rivers, approximately 150 miles from where the five rivers of the Punjab meet. The area is less than 50 miles from the India-Pakistan border and is about 30 miles long (Figure 2). It is narrow and flat, with the width of the command area ranging from 1 to 8 miles and elevations ranging from 635 feet to 670 feet above mean sea level (WAPDA, 1983, pp. 1-17). The marketing center, Bhai Pheru, is located about 40 miles southwest of Lahore, and a national highway passes through the center of the subproject area. Eighty-three percent of the Niazbeg acreage is well-drained and suitable for good irrigated agricultural production.

History

Beginning in the 1840s, the British undertook a massive irrigation construction program. By the end of the colonial era, (1948), British engineers had built the most extensive irrigation system in the world and contributed many of the engineering formulas now used for canal construction and operation. Today, the Indus river network is the largest contiguous irrigation system in the world. Each year, this system irrigates approximately 34.5 million acres. More than 100 million acre-feet of water are annually distributed through three major storage reservoirs, 19 barrages, 12 link canals, and 43 canal commands to deliver water to about 90,000

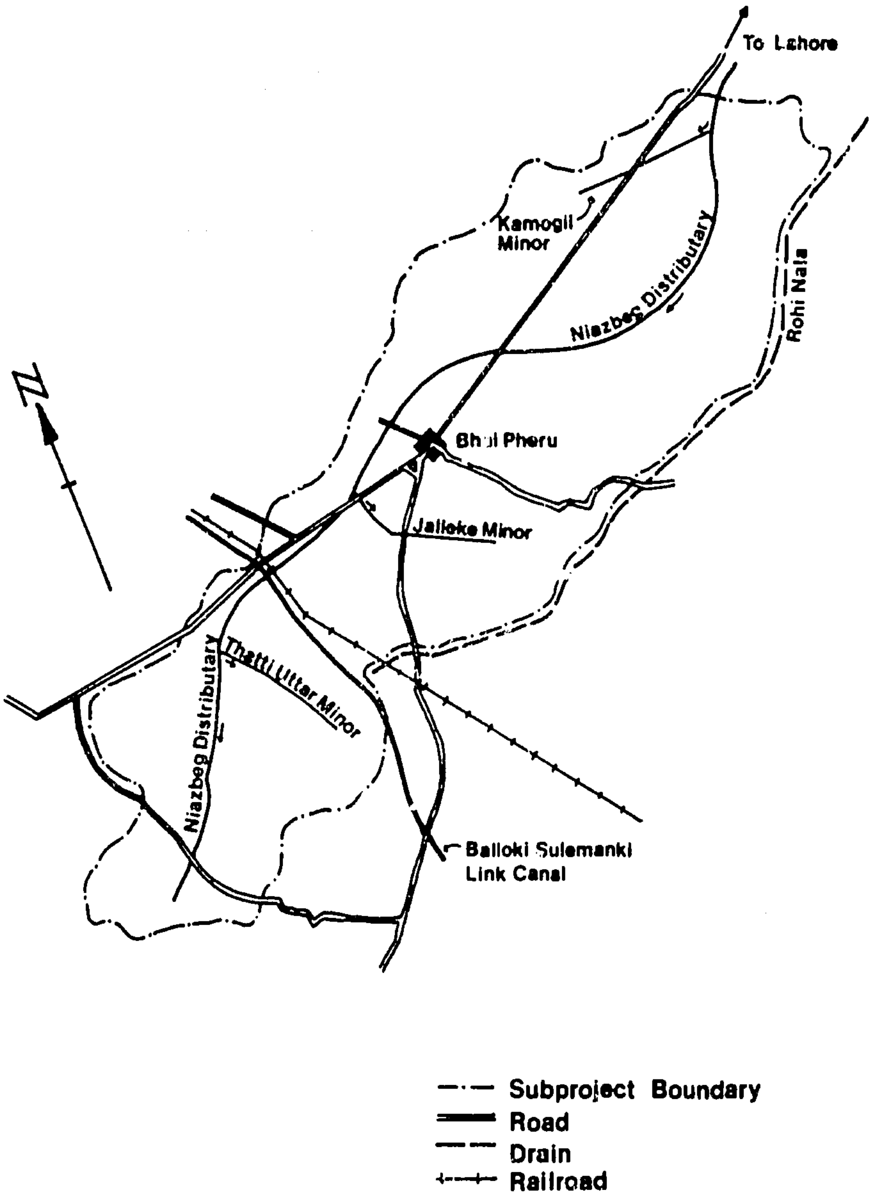


Figure 2. The Niazbeg subproject.

watercourses, each of which commands 400 acres on average (Michel 1967).

The British developed the system of barrages and canals which provided the basis for new flexibility in the distribution of water in the Punjab. Barrages, a series of concrete bases and steel gates, could raise the water level for diversion to canals crossing *doabs*. By controling the height of water, they determine the quantity, and velocity of the river flow. Canals could transfer water from rivers having excess supplies to rivers and canals where inadequate supplies restricted further development of agricultural lands.

This leap forward in irrigation technology was designed to serve an agriculture which depended on drought-resistant crops. The goal was to spread water thinly over as large a portion of land as possible. The precise timing and measured quantities of water now required to cultivate high yielding varieties was not of concern. Cropping intensities ranged from 70 percent to 80 percent, and land productivity was sustained by allowing it to periodically lie fallow (Michel 1967).

Niazbeg canal water passes over a drop structure and travels the upper Niazbeg Canal at a volume of approximately 180 cubic feet per second (cusecs). The canal continues for approximately 20 miles before its water enters the project site.

The officially sanctioned supply of the Niazbeg distributary at the beginning of the subproject site is 123.5 cusecs. Of the 44,721 acres included in the Niazbeg area, 41,068 acres are considered commandable. The designed water duty of each watercourse head has been set at 330 acres/cusec, or roughly 3 cusecs/1000 acres.

The Niazbeg subproject area is served by three minors: the Kamogil Minor near the head of the subproject area, the Jalleke Minor near the middle; and the Thatti Uttar Minor at the far end of the system (Figure 2). The Niazbeg Canal delivers to 98 watercourses, three-fourths of which are directly on the main canal, while the other one-fourth draw water from one of the three minors.

Approximately 63,000 people live in the 34 villages of the Niazbeg communal area. Farming is the primary occupation of 98 percent of the 240 sample farmers in the Niazbeg study. Of these, 71 percent reported that they depend exclusively on agriculture. The majority of sample farmers are small operators (Table 3). Eighty-one percent owned less than 12 acres, and more than 50 percent owned less than 6 acres. The

Table 3. Land and property owned and operated by sample farmers.

Acres	Acres Owned: No. of Culti-vators	% of Culti-vators	Cum. %	Acres Operated: No. of Culti-vators	% of Culti-vators	Cum. %
0	65*	25.1	25.1	2	0.9	0.9
0- 5.99	65	28.1	53.2	69	30.4	31.3
6-11.99	63	27.7	80.9	97	42.7	74.0
12-24.99	33	14.0	94.9	42	18.5	92.5
25-49.99	6	2.6	97.4	9	4.0	96.5
50-98.00	6	2.6	100.0	8	3.5	100.0

*Includes 40 farmers from watercourse 3 who have no title to their land; it is owned by the Government of Pakistan.

sample included 40 landless farmers on watercourse 3 who lease their land from the Pakistan government.

Design of the Research

Variables and Hypothesis

Four variables and their interrelationships at the three levels of analysis were explored (Figure 3). The dependent, independent, and intervening variables and their measures are listed in Table 4.

The variables listed in Table 4 were combined into the research hypotheses diagrammed in Figure 3. The essential logic is straightforward: the effectiveness of collective organizational relationships determine the extent to which water can be controlled in quantity and timing. Water control, in turn, was hypothesized to importantly affect crop production (cropping intensities, yields, and patterns) and farmer propensity to support local organizational arrangements, which, in turn, are viewed as affecting organizational effectiveness.

Table 4. Variables examined in the Niazbeg study and their measures.

Variable	Measure
Dependent	
Organizational support (local level)	1. Farmer reports of willingness to pay assessments for existing and potential water control. 2. Farmer compliance with canal or tubewell organization rules. 3. Farmer willingness and ability to control "free riders."
Crop production	1. Cropping intensity, or percent of land cultivated. 2. Crop yield. 3. Cropping pattern, or degree to which moisture sensitive crops are grown as distinguished from lower yielding drought tolerant crops.
Intervening	
Water control	1. Capacity to measure and regulate water flowing to the minors, and farmer water control on watercourses. 2. Capacity to maintain canals to design specifications (main system). 3. Correspondence between water delivery and water assessments (main system). 4. Ability of an irrigator to respond to crop water requirements at various stages of plant growth in terms of quantity and timing of water delivery (farm level). 5. Capacity to overcome locational bias in distributing water among and within watercourses (intermediate level).
Independent	
Organizational effectiveness (main system) Local watercourse system	1. Correspondence between <u>de jure</u> water water allocations and <u>de facto</u> water water deliveries. 2. Ability of main system management to control or sanction "free riders" who gain benefits without meeting obligations.

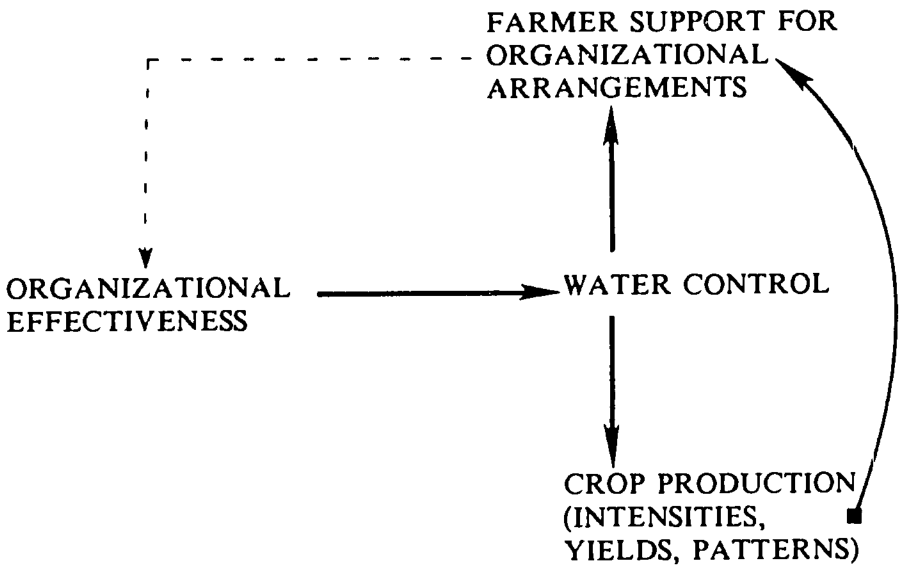


Figure 3. Logic of research.

Sampling Design

The Niazbeg subproject area is one of seven project sites in Pakistan chosen to be part of the Command Water Management Project. Because more than half the agricultural activity in Pakistan takes place in the Punjab Province, the Command Water Management Project selected four of the seven sites from Punjab (Figure 1).

The need to maximize variance in location guided the selection of the sample watercourses. Head and tail watercourses from the Kamogil minor (head), from the Jalleke minor (middle), and from the Thatti Uttar minor (tail) of the Niazbeg distributary were chosen. To maximize variance within each watercourse, a purposive sample of 40 farmers was drawn from the head and tail of each of the six sample watercourses. A list of all farm units was constructed for each watercourse from head to tail; the headmost 20 farmers and the tail-most 20 farmers were selected. The total sample of farmers from all six watercourses was, therefore, 240. In the few instances where a selected farmer was unavailable to participate in the research, a replacement sample farmer was selected by incorporating the next farmer on the census list.

Water Control, Location, and Individual Attributes

Introduction

Before proceeding to investigate the main research hypotheses, a preliminary question can be asked: Is canal water control on the six sample watercourses a function of individual farmer attributes, (i.e., caste, formal education, acreage owned, and acreaged cultivated) or is control over canal water a function of farmer location in the command? Significantly different policy implications are generated depending on the answer. If location in the system, given the structure of the canal rotation system (*warabandi*), is a major contributor to inadequate water control and lower agricultural productivity, then an organizational solution, such as development of effective water users associations, is needed. On the other hand, if the problem lies in the individual attributes of the farmers themselves, programs must be constructed to alter such attributes for the better (e.g., land ownership).

This section examines the explanatory power of the locational and individual farmer attribute arguments. The central research hypothesis is that location drives the distribution of water in the system. Canal *warabandi*, water share arrangements, which allocate water by time and location, favor farmers nearest the source of supply, while farmers farther from the source suffer a loss of control over water quantity and timing without respect to individual attributes of farmers.

Water Control

There are two types of canal water rotation systems (*warabandi*) for distribution in the Niazbeg system (Table 5). The *pukka warabandi* of watercourses 1 and 2 is a formal, written set of agreements for water distribution adjudicated by the Irrigation Department. *Kutcha warabandi* of watercourses 3-6 represent informal system by which farmers make water rotational arrangements among themselves. Engineering and sociological measures were used to assess farmer water control.

Table 5. Sanctioned and actual water supply at sample watercourse moghas.

Minor and Watercourse	Sanctioned Supply (cusecs)	Percent Received	Size of CCA* (acres)	Type of Warabandi
Kamogil minor				
Watercourse 1	1.37	156	457	pukka**
Watercourse 2	1.95	171	650	pukka**
Jalleke minor				
Watercourse 3	2.07	66	413	kutcha***
Watercourse 4	4.00	21	799	kutcha***
Thatti Uttar minor				
Watercourse 5	2.47	73	824	kutcha
Watercourse 6	2.50	54	832	kutcha

*Cultural command area.
**Pukka warabandi: water distribution has been formally adjudicated by the Irrigation Department and water share arrangements are written agreements.
***Kutcha warabandi: water share arrangements are worked out informally by the watercourse farmers.

Engineering Measures

Sixteen measurements were taken of canal water flows entering the inlets (*moghas*) of the six sample watercourses. Measurements were also taken at various outlet (*nukka*) points along each watercourse. These measurements were used to:

1. Compare the sanctioned water supply with the actual quantities of water delivered to the watercourse *moghas*.
2. Determine the range of water deliveries to the individual watercourses.
3. Determine the amount of water loss as the water moved from the watercourse inlet (*moghas*) to the tail.

Two factors condition the interpretation of water measurements. First, the research was conducted as part of a larger national project, funded and monitored by international agencies. The staff of the Command Water Management Project insisted that the Irrigation Department push additional water to the tail of the system before assuming responsibility for the site.

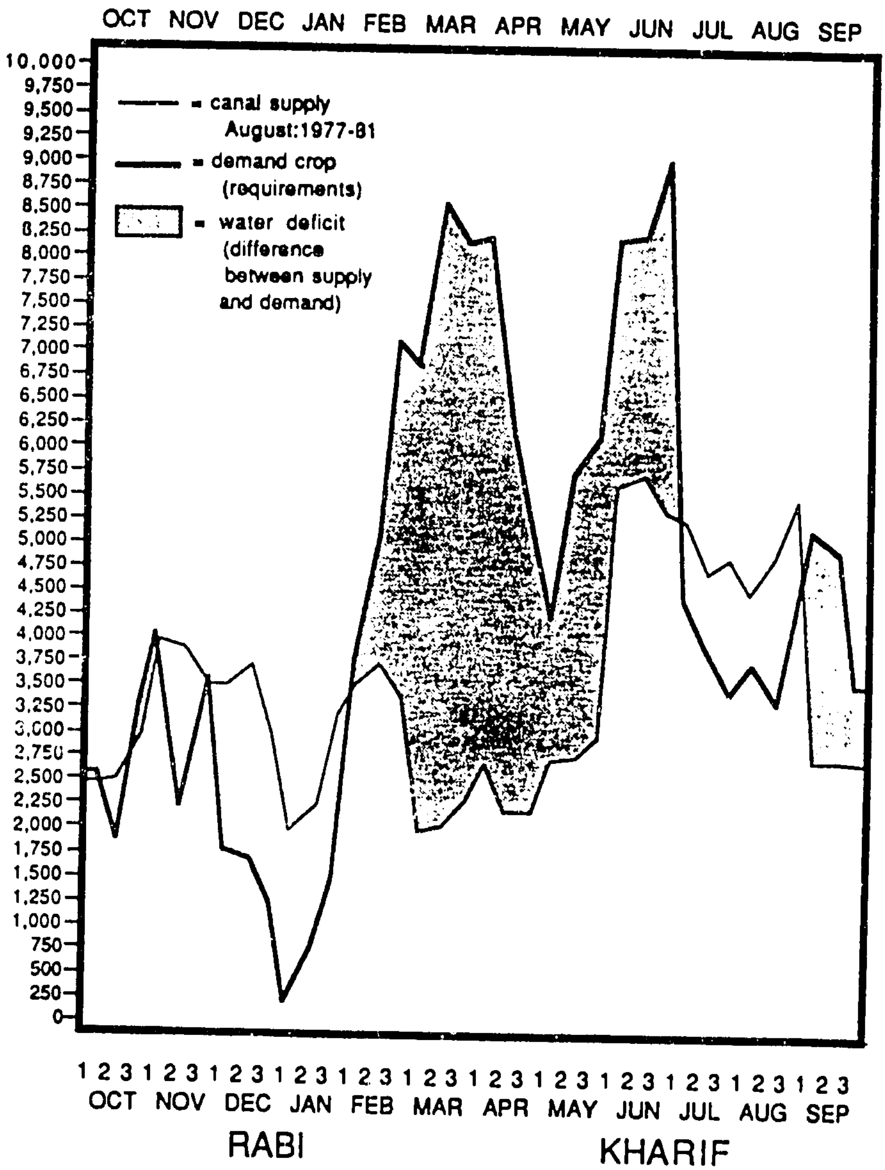


Figure 4. Water supply and demand for the Command Water Management Project: Niazbeg subproject area.

Some farmers at the tail of the system stated they had not seen so much water in the system for 20 years. Second, the current sanctioned water supplies were inadequate to serve demand. The last adjudication for the Niazbeg subproject was in 1931 when the water supply was established at 3 cusecs/1,000 acres. This calculation assumed a cropping intensity of 50 percent during summer (*kharif*, June-Sept.) and 25 percent during winter (*rabi*).

The inadequacy of the current water adjudication is indicated by the extent of water deficits revealed in Figure 4. Measurements taken between 1977 and 1981 indicate that the amount of water delivered to the Niazbeg system was inadequate to meet the crop demand for at least six months out of the year for most years. Furthermore, Table 5 indicates that the watercourses at the middle and tail of the system suffer greater water shortages compared to those at the head. The two sample watercourses along the Kamogil minor, at the head of the distributary, receive an average of 163 percent of their sanctioned supply, while all of the middle and tail watercourses received substantially less than their sanctioned amount. These discrepancies were measured during a time when a relative abundance of water flowed through the system.

Sociological Measures

Sociological data were obtained through interviews with sample farmers, designed to ascertain the degree of farmer water control. Questions were asked regarding percentage of canal water used for irrigating crops, whether or not serious water shortages occurred during various crop phases, and how water exchange was used to gain more water control. The sociological results produce a pattern parrelling those generated by the engineering analysis. The impact of location was evident in regard to both the amount and timing of water. Farmers at the head consistently reported that they obtained more water than those at the tail. Furthermore, the data indicate that farmers strive for better water control by circumventing canal *warabandi* rules by engaging in exchange.

Farmer reports of percent of canal water used for irrigation indicate that the canal *warabandi* system is not meeting farmer crop water demands (Table 6). Furthermore, the majority of sample farmers stated that less than 25 percent of their irrigation water was obtained from the canal *warabandi* system.

Table 6. Number of farmers in categories representing percent of canal water used (n=227).*

Watercourse	Percent of Water Used from Canal**														
	None			5-25			26-50			51-75			65-100		
	H	T	Total	H	T	Total	H	T	Total	H	T	Total	H	T	Total
	number of farmers														
1	1	4	5	0	11	11	11	1	12	3	1	4	5	3	8
2	0	0	0	6	13	19	6	6	12	6	1	7	2	0	2
3	0	0	0	16	14	30	0	0	0	0	0	0	0	0	0
4	1	7	8	18	12	30	0	0	0	0	0	0	0	0	0
5	0	4	4	11	16	27	2	0	2	0	0	0	7	0	7
6	12	14	26	6	6	12	1	0	1	0	0	0	0	0	0
Total	14	29	43	57	72	129	20	7	27	9	2	11	14	3	17

*There were 40 sample farmers on each sample watercourse.
**H = Head; T = Tail.

When analysis focuses on the differences among watercourses, the overall availability of water degrades as one moves toward the tail of the system. The majority of farmers who receive no water from the canal are from watercourse 6 at the end of the system (Table 6).

The data also indicate that the locational bias operates within, as well as among, the watercourses (Table 6). Watercourse 1 and 2 are water-rich relative to the others. Farmers at the head of these channels receive a greater percentage of their irrigation water from the canal than do those at the tail of these channels.

The seven farmers from watercourse 5 who rely exclusively on canal water are too poor to buy private tubewell water. All reported that their water supply is never adequate to meet their irrigation needs. Farmer reports for percentage of canal water used were virtually identical for summer (*kharif*) and winter (*rabi*) seasons.

Table 6 also indicates that the locational bias evident from head to tail along the main Niazbeg distributary is reproduced from head to tail along each sample watercourse as water losses increase. Farmers at points most distant from the *mogha* receive diminished supplies relative to their counterparts located closer to the *mogha*. The exceptions are watercourses 4 and 6, where losses are consistently high throughout the watercourse. This departure from the overall pattern is explained by low flows at the *mogha*. All farmers on watercourses 4 and 6 are without adequate water. The relative equality is the result of absolute deprivation.

Timing and reliability of water deliveries is perhaps even more critical than absolute quantity. However, in the canal *warabandi* system,a farmer receives a share of water as a function of a unit of time, regardless of whether or not water is available during that allocated time. Figures 5 through 10 indicate that reliability of canal water is low for most of the sample watercourses. During a six-week period, only watercourse 2 had its supply fall within 10 percent of the mean of total water delivered. Therefore, in addition to problems in the aggregate quantity delivered to watercourses, water deliveries fluctuated widely.

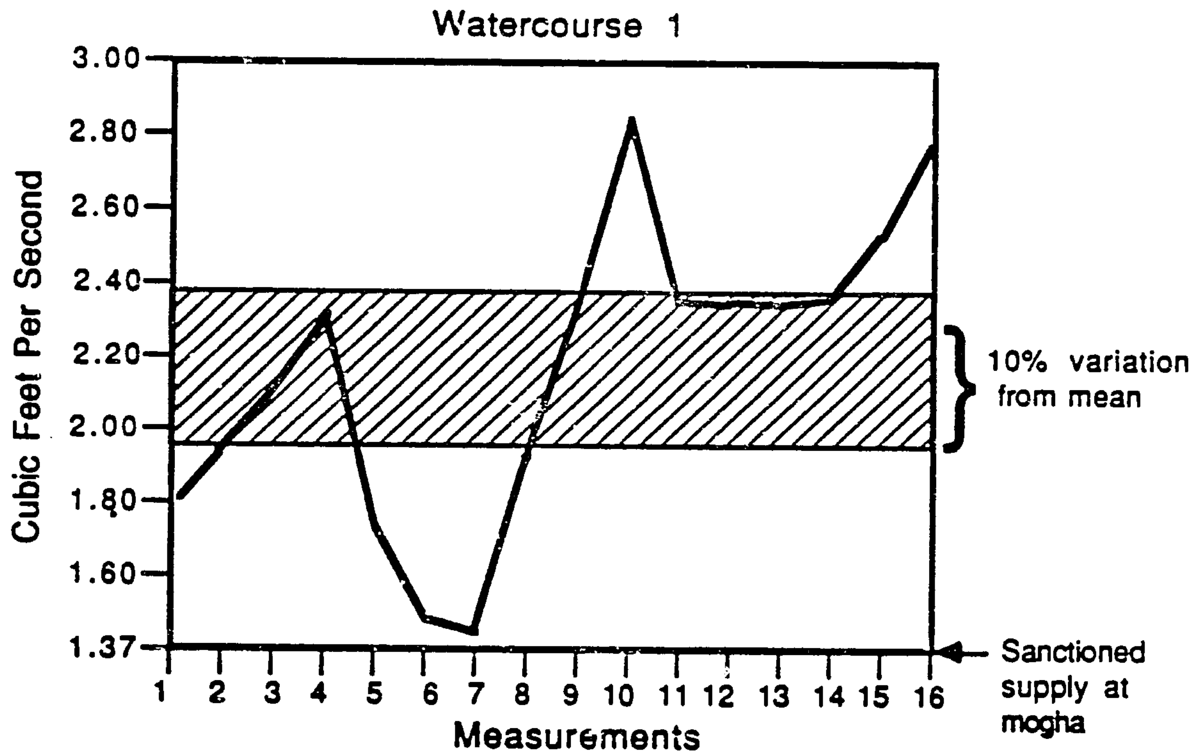


Figure 5. Variation in supply for sample watercourse 1 outlet over a six-week period.

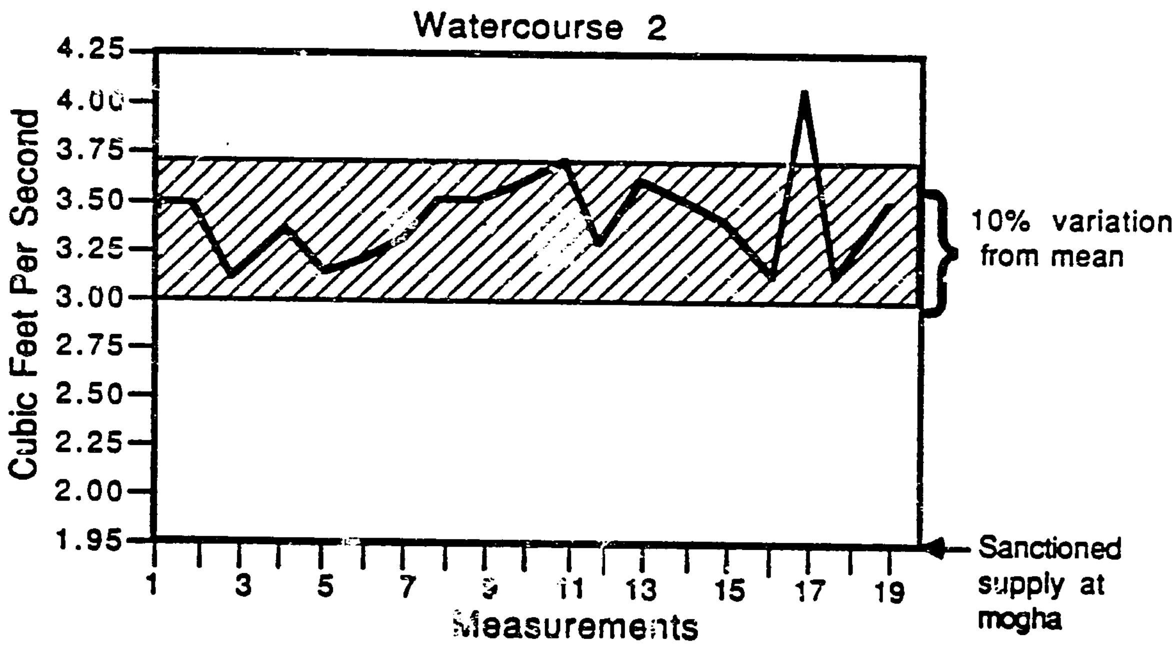


Figure 6. Variation in supply for sample watercourse 2 outlet over a six-week period.

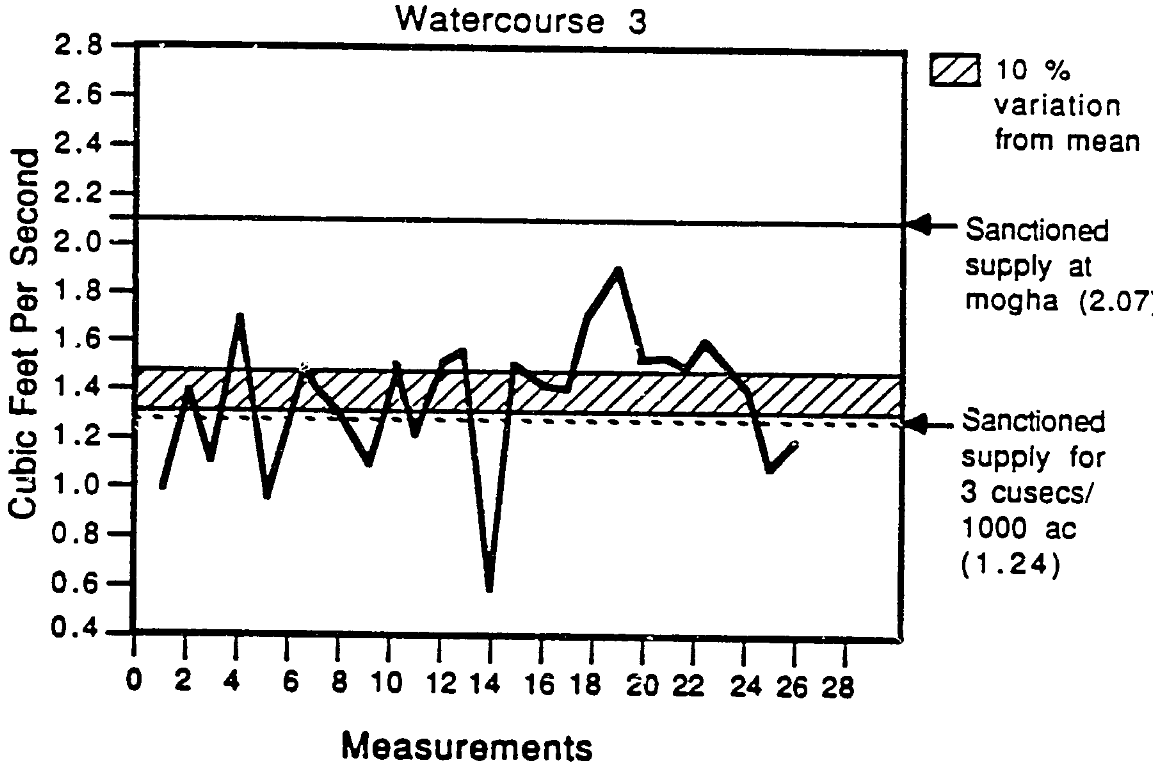


Figure 7. Variation in supply for sample watercourse 3 outlet over a six-week period.

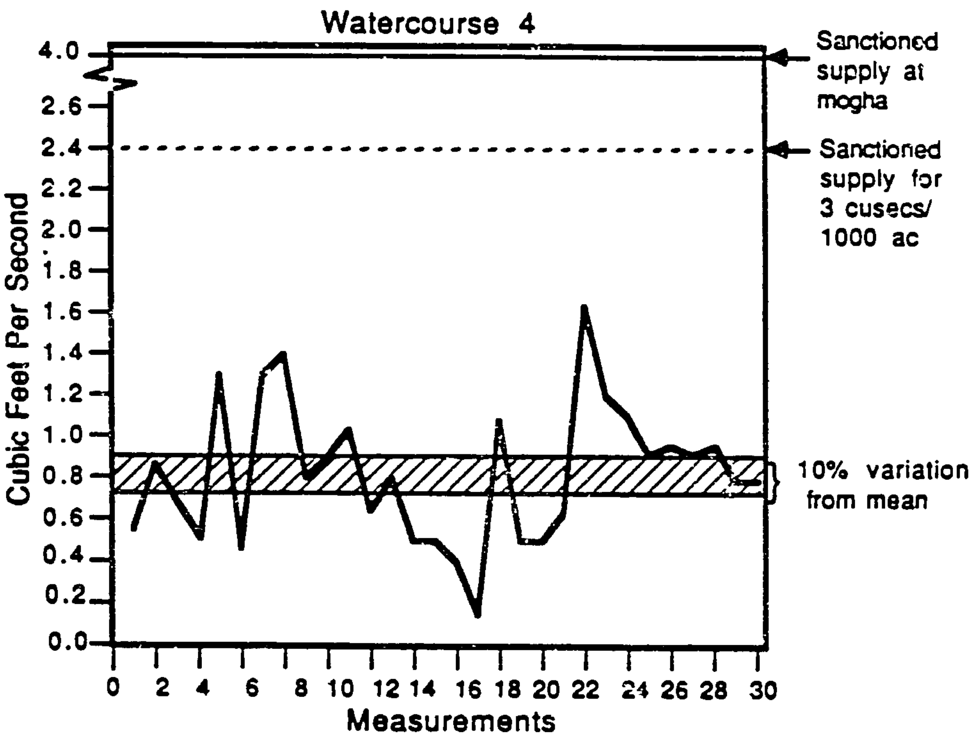


Figure 8. Variation in supply for sample watercourse 4 outlet over a six-week period.

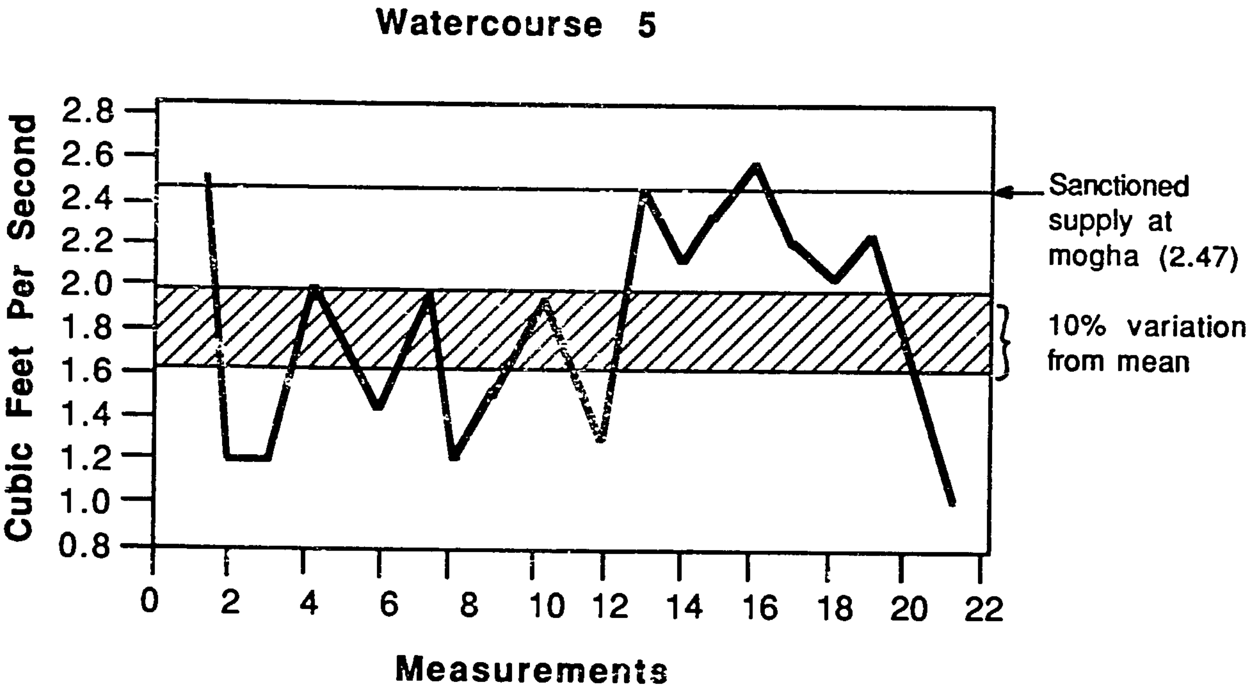


Figure 9. Variation in supply for sample watercourse 5 outlet over a six-week period.

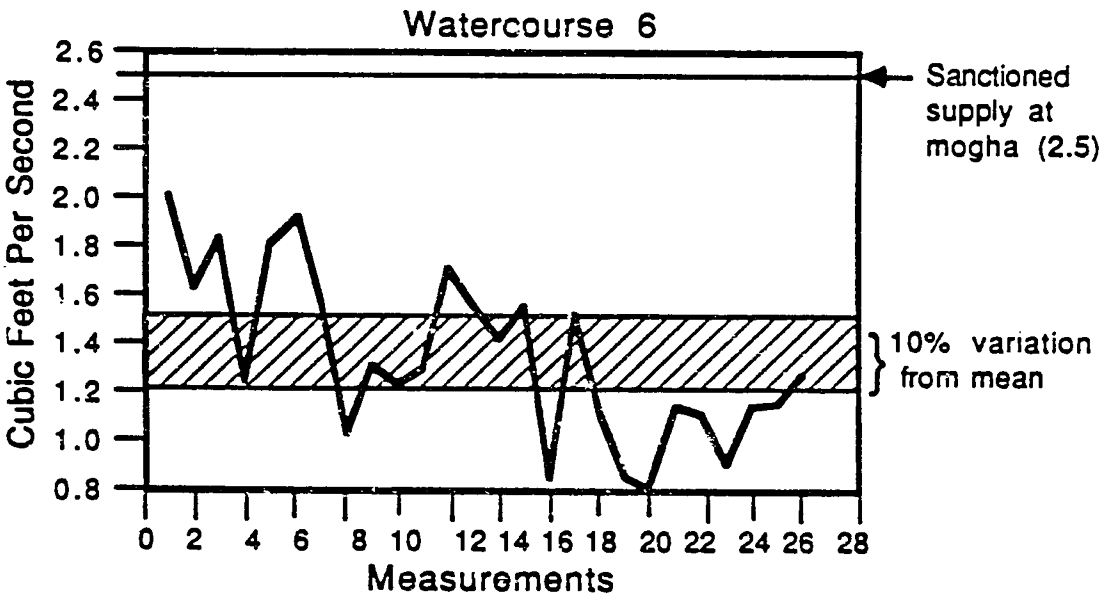


Figure 10. Variation in supply for sample watercourse 6 outlet over a six-week period.

Table 7. Number of farmers reporting serious shortages of canal water, by watercourse (n=220).*

Water-course	Rauni Kharif	Rauni Rabi	Seeding Kharif	Seeding Rabi	Growth Kharif	Growth Rabi	Flowering Kharif	Flowering Rabi	Maturity Kharif	Maturity Rabi
1	21	24	13	7	10	6	21	31	1	5
2	24	27	12	2	11	3	22	30	1	3
3	3	2	4	17	26	12	17	9	11	9
4	2	8	6	35	24	9	22	0	5	18
5	18	23	6	6	14	1	5	15	1	2
6	11	8	3	0	8	1	5	10	0	22
Total	79	84	44	67	94	32	92	95	19	59

*There were 40 sample farmers on each sample watercourse, but the "n" is less than 240 because some farmers did not respond to this question.

Table 7 suggests that shortages of irrigation water are widespread among sample farmers on all sample watercourses. Data indicate that sample farmers suffer shortages during different crop phases and reports of shortages occurred for both head and tail farmers within the respective watercourses. Interestingly, farmer reports of serious shortages are much higher for the relatively water-rich watercourses than for those watercourses which have absolutely inadequate supplies. This seeming contradiction may reflect a sense of relative deprivation as distinguished from absolute deprivation. In any case, the system is failing to deliver adequate supplies to many farmers on all watercourses.

Legally, exchange of canal *warabandi* water turns is strictly prohibited in the *pukka warabandi* of watercourses 1 and 2. More flexibility among farmers is permitted in the *kutcha warabandi* of the remaining four watercourses, but exchange is still considered by many as water theft. Table 8 indicates that many farmers, particularly those on the *pukka* watercourses ignore these prohibitions in order to gain more water control. Because exchange is illegal, farmers were often reluctant to candidly discuss it; therefore, these data probably underestimate the extent of water exchange among farmers.

Table 8 indicates that sample farmers at the head of the system practiced exchange more than their counterparts on tail watercourses, and farmers on the head reaches of the individual sample watercourses were more likely to practice exchange than those toward the tail. Only farmers with relative abundance of water have the flexibility necessary for water

Table 8. Sample farmer reports of water exchange on most important field (n=211).

Water-course	(n=)	No Exchange H	No Exchange T	No Exchange Total	Some Exchange H	Some Exchange T	Some Exchange Total	Often Exchange H	Often Exchange T	Often Exchange Total
1	(38)	6	13	19	7	5	12	5	2	7
2	(40)	5	14	19	15	6	21	0	0	0
3	(27)	13	9	22	1	4	5	0	0	0
4	(29)	11	12	23	3	2	5	1	0	1
5	(40)	12	11	23	6	7	13	2	2	4
6	(37)	13	18	31	2	0	2	3	1	4
Total		60	77	137	34	24	58	11	5	16

Average Frequency of Exchange*

*H = Head; T = Tail.

Table 9. Degree of water control on sample farmers' most important field (water quantity and timing) (n=206).

Water-course	(n=)	Poor Head	Poor Tail	Poor Total	Moderate Head	Moderate Tail	Moderate Total	Good Head	Good Tail	Good Total
1	(39)	2	10	12	12	9	21	4	2	6
2	(40)	3	12	15	12	8	20	5	0	5
3	(27)	9	7	16	5	6	11	0	0	0
4	(30)	8	8	16	8	6	14	0	0	0
5	(36)	10	10	20	8	8	16	0	0	0
6	(35)	14	16	30	2	3	5	0	0	0
TOTAL		46	63	109	47	40	87	9	2	11

Degree of Reported Water Control

exchange. The flows at the tail reaches of the watercourses tend to be too small and unreliable to allow water exchange. Exchange partners require water predictability in both timing and quantity. There is no greater disincentive to water exchange between partners than uncertainty about quantity and timing of water flows. Farmer "X" is unlikely to exchange water with farmer "Y" if farmer "Y's" supply is uncertain.

By combining sample farmer responses to questions measuring both quantity and timing, an overall measure of water control was constructed. Table 9 indicates that a majority of farmers reported poor canal water control. Consistent with the locational bias hypotheses, the number of farmers with poor water control increases as one moves from watercourse 1 to watercourse 6. Within the two head watercourses, greater numbers of farmers have moderate to good water control than have poor water control, while the reverse is true for farmers located on watercourses 3 through 6. While water control is relatively better at the head of the system, the data in Table 9 suggest that farmers throughout the system have substantial problems with water quantity and timing. the number of farmers on the head watercourses with poor water control indicates that the organization of the canal *warabandi* is inadequate for a substantial minority of those located in even relatively favorable positions.

Location, Individual Attributes, and Water Control

The analysis of water control among and within watercourses suggests that location is a dominant factor in determining which farmers have the greatest water control. The analysis also suggests that the entire canal *warabandi* organization in Niazbeg is problematic. While this analysis provides strong evidence supporting the relationship between location and water control, a statistical analysis which permits controlling the effect of other variables lends further support to the argument.

Table 10 summarizes the relationships among individual farmer attributes, location, and water control. Table 10 indicates that distance of the field outlets from the *mogha* is generally the dominant factor in determining farmer water control. In the cases of watercourses 1, 2, 4 and 5, the analysis indicates that location has a strong influence over water control when controlling for the effect of land owned, land cultivated, and years in school. On the other hand, the explanatory power of location is not strong for watercourses 3 and 6.

In watercourses 1 and 2, the strength of the locational variable is reduced by the relatively favorable positions of these watercourses. Thus, aggregate quantity of water is not as much a problem as timing. Furthermore, the extensive use of exchange by farmers at the head of the watercourses (Table 11) reduces the effect of location on water supply.

Table 10 indicates that the relationship between location and water control is strongest on watercourse 5. Several factors have combined to produce this situation. Watercourse 5 is populated by the poorest farmers of the six watercourses, and the channel is badly in need of repair. It receives only 73 percent of its sanctioned supply of 2.47 cusecs, an amount of water that is insufficient to meet the needs of the more

Table 10. Water control, location, and personal attributes.

Water-course	Correlations	Variables: Land Owned	Area Cultivated	Years in School	Distance from Mogha
1		(40)[3]	(40)	(40)	(39)
	Zero-order[1]	-.03	.01	-.12	-.38
	Partial[2]	-.02	.02	.00	-.36
2		(39)	(40)	(40)	(38)
	Zero-order	-.05	-.14	-.10	-.48
	Partial	-.04	-.10	-.10	-.48
3		(0)	(28)	(31)	(39)
	Zero-order	*	-.25	-.36	.16
	Partial	*	.16	-.32	.12
4		(39)	(39)	(40)	(33)
	Zero-order	.05	-.45	.15	-.42
	Partial	.11	-.47	.02	-.41
5		(40)	(40)	(40)	(37)
	Zero-order	-.31	-.19	.02	-.68
	Partial	-.29	-.16	-.16	-.77
6		(40)	(40)	(40)	(38)
	Zero-order	-.24	-.17	-.09	-.10
	Partial	-.17	-.08	-.05	-.13

*The land on watercourse 3 is owned by the Government of Pakistan and leased to the farmers.

[1]Zero-order correlation: The correlation between water control and the indicated variable without removing the effects of the other variables in the table.

[2]Partial correlation: The correlation between water control and the indicated variable with the effect of all other variables in the table removed.

[3]()indicate the number of farmers.

Table 11. Distribution of caste across watercourses (n=233).

Water-course	(n=)	Caste*: Rajput H	Rajput T	Rajput TL	Jat H	Jat T	Jat TL	Doga H	Doga T	Doga TL	Arain H	Arain T	Arain TL	Kamboh H	Kamboh T	Kamboh TL	Other H	Other T	Other TL
1	(40)	18	16	34	0	2	2	1	0	1	0	0	0	0	0	0	1	2	3
2	(40)	12	3	15	0	2	2	3	8	11	4	1	5	0	2	2	1	4	5
3	(33)	6	5	11	0	4	4	0	0	0	1	1	2	3	6	9	6	1	7
4	(40)	10	6	16	4	6	10	0	0	0	3	4	7	1	2	3	2	2	4
5	(40)	18	11	29	1	0	1	0	5	5	0	2	2	0	0	0	2	1	3
6	(40)	2	3	5	14	16	30	0	0	0	0	0	0	2	0	2	2	1	3
Total		66	44	110	19	30	49	4	13	17	8	8	16	6	10	16	14	11	25

*H = Head, T = Tail, TL = Total.

than 800 acres in the command area (Table 8). Table 10 indicates there is no strong relationship between water control and location within watercourse 3. Unique circumstances are found on watercourse 3; farmers have installed jointly owned, privately managed, cooperative tubewells. These farmers have created local organizations to distribute water and to control "free riders" within the tubewell organizations. Through conjunctive use of canal and tubewell water, the farmers on watercourse 3 have managed to overcome the generally poor water control provided by the canal system (Table 9). In organizing to circumvent the canal *warabandi*, they have substantially overcome locational bias.

The conditions on watercourse 6 are similar to those of watercourse 5, but are more severe. Of 39 farmers asked about use of canal water, 26 reported they had dropped out of the canal rotation (*warabandi*) altogether. Furthermore, 12 of these 26 farmers are located at the head of the watercourse. In short, the canal water deliveries in watercourse 6 are so inadequate that the importance of location within the watercourse is diminished.

Because farmer caste membership is a nominal categorical variable, it was not included in the statistical analysis. However, caste was considered one to be of the potentially important variables which might influence water control. Table 11 reports the distribution of caste among and within watercourses. The Rajput caste numerically dominates within the system as a whole, except on watercourse 6, which is dominated by Jats.

An examination of watercourse caste distribution (Table 11) reveals that Rajputs are numerically dominant on watercourses 1 and 5. However, given the contrasts between watercourses 1 and 5, the observed dominance of Rajputs does not appear to be associated with improved water control. Watercourse 1 is water-rich and 27 farmers reported having moderate to good water control. Watercourse 5 is water-poor; none of the farmers reported having good water control and only 16 reported having moderate control. Caste cannot meaningfully be advanced as a rival hypothesis to location in explaining water control differences among watercourses.

Watercourse 2 is the one watercourse where a caste group clearly clusters in one location: Rajputs dominate the head of this watercourse, which has relatively good water control. However, this tendency to cluster at the head position does not occur on other watercourses. Thus, there is nothing in the caste distribution within watercourses to suggest that caste membership might explain access to, and control over, water.

Any posited relationship between caste and water control is further weakened by the example of watercourse 3. On this watercourse, a relatively wide range of castes are represented. Yet, farmers on this watercourse have been able to organize around conjunctive use of tubewell and canal water to much reduce locational bias and achieve greater water control. Furthermore, this watercourse appears to have maintained a great deal of social cohesion. Caste differences do not appear to have been a significant barrier to collective efforts to improved water control.

The analysis of water control among and within the six sample watercourses suggests that farmer location is the most important influence on the degree to which water control is available to farmers within the Niazbeg system. Other variables advanced as rival hypotheses to location do not emerge as alternative explanations for variation in sample farmer water control. Furthermore, the locational effect maintains explanatory power in the analysis of water control throughout the system. The watercourses in which the statistical analysis failed to reveal the locational effect in sharp relief were those in which the canal *warabandi* system had broken down to such an extent that farmers at the head had lost their relatively favorable position or farmers had informally organized to allocate water to overcome the effects of distance.

The analysis points to the need for organizational policy that will reduce or eliminate the influence of location. Development of water users associations within watercourses capable of overcoming the effects of distance from the *mogha* is the most plausible remedial action. The farmers along watercourse 3 have already demonstrated how successful such an organization can be.

Individual farmers on watercourse 3 have been willing to invest in the relatively expensive development of groundwater. Furthermore, because the tubewell organizations safeguard their collective interests against individuals who threaten the organizational agenda, farmers on watercourse 3 have been willing to subordinate themselves to the rules and guidelines of such organizations. In short, the individual and collective interests were made to coincide to provide better water control to the farmers.

Organizational Effectiveness and Water Control

Now that it has been established that water control available to a farmer is heavily influenced by that farmer's location in the irrigation system, and that water control is not a function of education, land owned, land cultivated, or caste membership, the analysis proceeds to examine the capacity of the main system to deliver water to watercourse inlets (*moghas*). The main system bueaucracy delivers large volumes of water to the distributaries and manages water allocation along the distributaries to watercourses. Public management of the main system has a major influence on the degree of water control achieved at the watercourse and farm levels.

The first indicator of organizational effectiveness is the capacity of the main system to deliver officially sanctioned shares of water to watercourse outlets. In Pakistan, this share is based on several factors, including the size of the command area. One measure of organizational effectiveness is the degree of correspondence between the *de jure* (officially prescribed) allocations and *de facto* (observed) water deliveries. High correspondence indicates strong organizational effectiveness, while low correspondence indicates low organizational effectiveness.

A second indicator of organizational effectiveness is the capacity of the main system to control "free riders." If the main system monitors water distribution so that it can sanction water users who attempt to take advantage of other water users and violate prescribed rules for irrigation, then organizational effectiveness is high.

The preceeding section demonstrated that canal location dominated water distribution in the Niazbeg system. In the absence of a network of effective local water management organizations to correct locational bias on the distributary and watercourses, it is hypothesized that an organizational void will be filled by social forces that lead to problematic water allocation and maintenance. A hidden, unofficial organization can be expected to develop as water control is gained by those who can make unofficial arrangements with main system managers, arrangements which might serve specific interests at the expense of the larger irrigation system. This unofficial, hidden organization would undermine canal allocation rules and undercut legally sanctioned allocations.

Information about main system operations was gathered from 10 key informants in the Irrigation Department and additional farmer informants living on sample watercourses.

Main System Managers and Roles

Canal water control refers to the capacity of main system management to measure and regulate water flows throughout the distributary command area and to maintain the canals in such a way that water can be delivered according to plan.

Engineers, employed as civil service managers, are responsible for managing main system canals so that they deliver sanctioned supplies throughout the command areas under their jurisdiction. The staff employed under their supervision are commissioned to fulfill this mandate. The organizational role-set of the Irrigation Department on the Niazbeg Canal includes the chief operations officer or subdivisional officer (SDO) and one sub-engineer or overseer who is responsible for administering the canal from the 45,000' mark (about 8.5 miles from the beginning of Niazbeg Canal) to the end of the Niazbeg Canal. The sub-engineer supervises three to four canal overseers.

Canal overseers are responsible for canal maintenance, and they regulate canal water flows. They are also responsible for checking watercourse outlets for signs of illegal tampering. Several *belldars* (laborers) are assigned throughout the system to do the required maintenance work at the direction of the sub-engineer and overseers. There is also one gauge reader positioned near the end of the Niazbeg Canal whose responsibility is to daily check the height of the canal flow and communicate these readings to the signaler, who telegraphs them to the sub-engineer in charge and to the SDO's office in Lahore. Changes in the canal water level are made by increasing or decreasing water flows at the distributary outlet. Typically it takes three days for the results of any corrective action to reach the tail of the system.

While the Niazbeg system is staffed to manage water flows, adequate physical structures do not exist with which to control, measure, or monitor water. Although the sanctioned supplies for minors and watercourse command areas are specified, neither main system managers nor farmers have a way to check the actual supply. Field personnel cannot measure the water flow without installing a measuring device, and they rarely do so.

Few engineers or farmers are aware of the exact sanctioned supply. At one point during the research, records dating back to 1931 had to be opened to resolve differences of opinion among engineers about prescribed flows. Farmer informants generally did not know how much water they were supposed to receive, much less how much they were receiving.

Allocation and Distribution Rules

Three rules apply to water allocation at the main system level: (1) a rule for determining the sanctioned supply; (2) a rule for delivering the sanctioned supply; and (3) procedural rules for resolving conflicts due to violations of allocation rules. This section explores the correspondence between *de jure* rules and *de facto* behavior at the main system level.

Table 1.2. Sanctioned and actual water discharges on the Niazbeg Canal.

	Location (miles)	Sanctioned Supply (cusecs)	Actual Supply* (cusecs)	Percent of Sanctioned Supply Received
Niazbeg head	00.00	213.00	256.90	121
Project head	14.55	123.50	159.00	129
Kamogil minor	18.93	15.97	23.00	145
Watercourse 1	19.40	1.37	2.14	156
Watercourse 2	22.10	1.95	3.33	171
Jalleke minor	29.56	15.62	5.40	35
Watercourse 3	30.23	2.07	1.37	66
Watercourse 4	31.59	4.00	0.82	21
Thatti Uttar minor	33.25	12.99	4.90	38
Watercourse 5	33.80	2.47	1.80	73**
Watercourse 6	35.08	2.50	1.34	54**

*"Actual Supply" is an average of 5-29 measures taken over six weeks at each of the designated locations.

**Three public tubewells pump water into the tail minor.

Determining the Sanctioned Supply. Table 12 reports the sanctioned and actual supplies at various points in the Niazbeg subproject. Several criteria determine the officially sanctioned supply for the Niazbeg system. First, the Indus rivers system must be able to supply water to the Niazbeg command area without interfering with or reducing water delivery to other command areas. Once this condition is met, then the total cultivable area is established and the amount of irrigation water needed to supply the command area is calculated. A distributary is then designed to command this area; the design typically places maximum delivery capacity at or near the originally calculated *de jure* requirement.

Allocations for the Niazbeg system were last adjudicated in 1931, when a flow of 3.0 cusecs per 1,000 acres was deemed adequate for the Niazbeg Canal command. The allocation was based on an assumed annual cropping intensity of 75 percent (25 percent of the land was to be irrigated in summer (*kharif*) and 50 percent was to be irrigated in winter (*rabi*). The city of Lahore was allocated 195 cusecs of the total distributary flow for municipal consumption. Thus, the canal was designed to carry a total allocation of 402.5 cusecs, to be discharged at the Lahore-Niazbeg distributary outlet. According to engineers managing the system, the canal structure could accommodate no more than a 10 percent increase in water level.

Delivering the Sanctioned Supply. The primary responsibility of the main system is the delivery of the sanctioned supply to the watercourse outlets. Table 12 indicates that the main system has not been able to fulfill its obligation to supply the sanctioned water supply to any measured point in the system. The low correspondence between sanctioned and actual deliveries, with oversupply at the head and serious undersupply at the tail, suggests the system is less than organizationally effective.

Controlling "Free Riders." Conflict occurs within large-scale irrigation systems when farmers do not obtain their share of sanctioned water or when some farmers obtain more than their share by water theft or by installing unauthorized outlets. In the Niazbeg system, main system managers only become involved in these conflicts if they occur on a watercourse with an official (*pukka*) rotational (*warabandi*) schedule or if the issues of conflict concern the sanctioned supply at the watercourse outlet. On unofficial *(kutcha) warabandi* watercourses, all conflicts must be settled internally without the assistance of the Irrigation Department.

The procedure for gaining main system intervention in conflict resolution can be costly. The aggrieved party must travel to the office of the subdivisional officer in Lahore to make a formal application. If the application is accepted after review by the SDO, it is sent to the Office of the Assessor (*zilladar*). This office, through the local canal supervisors (*patwaris*), investigates the claim and makes recommendations. These recommendations are sent to the SDO office in Lahore for final judgment, which is communicated back to the *zilladar*. The *zilladar* informs the complainant of the decision. If the latter is not satisfied, an appeal can be made to the executive engineer, and then to the superintending engineer. If the decision is still disputed, the case may be sent to the civil courts.

Use of the formal grievance procedure, as reported by key informants, indicates that organizational effectiveness for conflict resolution at the main system is low. During 1985 *kharif*, 35 complaints were filed. However, none were filed by farmers; rather, they were filed by laborers who were reporting illegal activities of farmers. None had been followed through to completion, although some cases were in various stages of consideration.

Key informants on the watercourse reported that the biggest problem encountered in water distribution is controlling behavior of influential landlords, who are rarely prosecuted for their breaches of conduct. Some informants noted that the fine is not large enough to deter wealthy farmers from water theft and that influential farmers can pursue appeals for years. Furthermore, small farmers are reluctant to file complaints against larger and more influential operators. Small farmers are not the only ones who are intimidated. One official who had apprehended an influential landlord in the act of a major violation reported that the violator had warned him that he would lose his position if he pursued the case. According to informants, influential water users are often successful in obtaining extra-legal supplies of water simply by requesting it from the Irrigation Department.

Influential "free riders" have more immunity from main system sanctions than do less powerful farmers. Thus, power and wealth appear to undermine organizational effectiveness at the main system level. In short, the main system can neither fulfill its professional mandate to deliver sanctioned water supplies nor can it systematically control "free riders" who pursue their private benefits by violating prescribed allocation rules.

All of this is to make the point that, at the main system level, water control is problematic because no organizational means are available to deliver sanctioned supplies and control "free riders." No appropriately designed local organization exists with which to provide an interface between main system management and farmers.

Tubewell Water

In the face of the locational bias operating within the canal delivery system, Niazbeg farmers have attempted to improve water control by gaining greater access to groundwater through the development of tubewells. Furthermore, farmers have organized around these tubewells, established working agreements for cooperatively maintaining tubewell technology and distributing tubewell water. Not only have such farmers improved their individual water control, but they also have created an organizational mechanism for water allocation, channel maintenance, and control of "free riders."

In the Niazbeg system, tubewells are a significant source of irrigation water. Therefore, it is important to examine the impact of tubewell water organization before examining the impacts of water control on agricultural production.

Because untimely and inadequate water supplies adversely affect agricultural production, farmers can be expected to initiate and support measures that increase water control. One of the primary ways is to increase access to groundwater through tubewell development. Moreover, individual farmers organize collectively to purchase and maintain tubewells. They create roles and rules to manage tubewell technology and to allocate and distribute tubewell water. Tubewells are especially essential to farmers located at the tail of the system where the canal water supply is particularly inadequate and unreliable.

Public Tubewell Operation

In the Niazbeg system, both public and private tubewells are employed. Public tubewells are operated under control of the Water and Power Development Authority, whereas private tubewells are owned and operated by local farmers individually and jointly. Public tubewells were initially installed in the late 1960s to lower water tables and to supplement *warabandi* canal supplies. Water from these tubewells is pumped directly into original watercourses or minor canals.

Officially, public tubewells are supposed to operate 20 hours/day. A publically paid tubewell operator is assigned to each government tubewell. His responsibility is to operate according to the established schedule or as the tubewell subdivisional officer otherwise dictates. The tubewell operator keeps a daily log of the tubewell operations and records when the tubewell is inoperative because of mechanical or electrical problems, watercourse repairs, or lack of water demand. Public tubewell operations are not adjusted to make up for times when the tubewell is not operating as scheduled. Operation of the government tubewells is relatively inflexible, and the operators do not typically adjust pumpage to compensate for variation in canal flows.

De facto public tubewell operations are considerably different from the *de jure* rules. A review of the 1984 government logs for the 39 active public tubewells in the Niazbeg command disclosed that the tubewells operated on average of 12 hours-/day, well below the required 20 hours. On average, public tubewells were inoperative nearly 40 percent of the time; only 17 percent of down time was for the officially scheduled, 4-hour/day shut down time.

Because public tubewells are part of the water distribution system controlled at the main system level, water which they supply is viewed in this analysis as being part of the regular watercourse rotational supply (*warabandi*).

Private Tubewell Operation

Private tubewells are operated by farmers with a great deal more flexibility than public tubewells. If electrical power or diesel fuel is available, water can be applied at any time to meet farmers' demand. Furthermore, because most farmers are within 2,000 ft of their tubewell source, they have considerably less problem with channel water loss. Private tubewells are major water suppliers, each providing irrigation for 2 to 20 farm units. As would be expected, the number of private tubewells is greater at the tails than at the heads of the system. Within the sample watercourses, 16 tubewells are located at the heads of the six watercourses, while 37 are located at the tails. Thus, as access to canal water has diminished, the reliance on tubewells has increased.

Three measures were used to compare the contributions of tubewell and canal water to irrigation supplies. First, farmers were asked to estimate the percentages of tubewell and canal water applied to their crops. Second, engineering measurements were made: tubewell discharge, yearly electrical consumption, and acre-feet of water pumped during 1985. Third, farmers were asked to identify acreage irrigated by canal and that irrigated by tubewell.

Taken alone, each of the measures is problematic. Farmer estimates are subject to inaccuracies and engineering measures are unable to reveal the dependency of farmers on tubewell water versus canal water. Together, however, they provide a compelling pattern of evidence.

Farmer estimates (Table 13) reveal a heavy reliance on tubewell water. On the average, sample farmers reported that 73 percent of the irrigation water used by sample farmers comes from tubewells. Furthermore, the locational factor is extremely important in determining reliance on tubewell water compared to canal water. Farmers at the tails of all six watercourses depend more on tubewells than their counterparts at the watercourse heads; the average tubewell water supply for all six watercourse head sections was 66 percent, while the tail sections average 81 percent (Table 13).

Table 13. Sample farmer estimates of percent of tubewell and canal water applied to *kharif* and *rabi* crops (n=227).

	% of Tubewell Water			% of Canal Water		
Watercourse	Head	Tail	Watercourse	Head	Tail	Watercourse
1	42	66	54	58	34	46
2	49	67	58	51	33	42
3	78	77	78	22	23	22
4	83	93	88	17	07	12
5	52	87	69	48	13	12
6	91	95	93	09	05	07

Table 14. Distribution of surface and groundwater supply (1985).

Watercourse	CCA* (acres)	Avg. Mogha Discharge (cusecs)	Tubewell** Pumpage (cusecs)	Total Supply (cusecs)	Percent Tubewell	Percent Canal
1	457	2.13	1.33	3.46	38.4	61.6
2	650	3.55	4.41	7.76	56.5	44.C
3	413	1.37	1.27	2.64	48.1	51.7
4	799	0.82	5.51	6.33	87.5	13.5
5	824	1.80	2.85	4.65	61.4	38.6
6	832	1.34	2.30	3.64	63.2	36.8
Weighted Average	663	1.84	2.95	4.75	62.1	37.9

*Cultural commanded area.
**Tubewell pumpage expressed as continuous rate of discharge.
Source: Wattenburger et al. 1987:128.

Table 15. Summary of private tubewell pumpage.

Water-course	Number of Private Tubewells	Average Pumping Capacity (cusecs)	Average Yearly Operation (hrs)	Average Daily Usage (hrs)	Total Yearly Pumped (ac-ft)	Equivalent Continuous Discharge (cusecs)
1	3*	0.88	4,584	12.8	961	1.33
2	16**	1.06	2,283	7.1	3,192	4.41
3	2	1.29	4,303	13.5	920	1.27
4	11	1.43	3,389	11.8	3,992	5.51
5	9***	1.30	2,280	7.1	2,061	2.85
6	8****	1.38	1,999	6.3	1,664	2.30
Average		1.22	3,141	9.8	2,132	2.95

*Three tubewells that deliver water to owners only and provide tubewell water to brick factories were not measured and were not included in the calculations.
**Eight tubewells at the tail of watercourse 2 are not included in the <u>warabandi</u> schedule and serve areas not receiving canal water.
***Seven of the nine tubewells which deliver water to watercourse 5 are located outside the command area of watercourse 5. These tubewells primarily provide water to other watercourses. Appropriate adjustments have been made.
****Two tubewells that serve watercourse 6 were not measured; therefore, the contribution of tubewells to irrigation water is underestimated in this table.
Source: Wattenburger et al. 1978:127.

The average amount of tubewell water supplied to the head sections of the first three watercourses was 56 percent, while tubewell water supplied to the tail sections of the last three water-courses was almost 92 percent. Only on the heads of watercourses 1 and 2 do surface canal water supplies exceed tubewell water supplies.

Engineering measures support farmer estimates. During a one-year period (1985), the water pumped from private tubewells (Table 14) was much higher than generally assumed by key informants in the Irrigation Department. The equivalent continuous discharge from tubewells was found to equal an average of 2.95 cusecs in each watercourse, compared to the average *mogha* discharge of 1.84 (Table 14).

Table 15 summarizes private tubewell pumpage across the six sample watercourses, while disaggregating the data by number of tubewells on each watercourse. The relatively greater reliance of farmers at tail locations stands out. Farmers on the three head watercourses pumped an average of 1,691 acre feet of tubewell water, while those on the three tail watercourses delivered an average of 2,572 acre-feet to each watercourse.

Acres irrigated by tubewell and canal water were identified only in watercourses 1, 2, 5 and 6 the extreme head and tail watercourse commands. Significant seasonal differences existed in the use of tubewell water as compared to canal water (Table 16). While the ratio of tubewell water to canal water used was about 2:1 in *kharif*, it was 3:1 in *rabi*. Furthermore, the data in Table 16 again consistently indicate that farmer reliance on tubewell water is greater at the tail locations than at the head in both seasons.

Table 16. Percent of acreage served by tubewell and canal water supplies (n-126).

Watercourse and Distributary Position	Percent of Acreage Served					
	Head		Tail		Combined	
	Canal	Tubewell	Canal	Tubewell	Canal	Tubewell
Kharif						
Head (1,2)	64	36	43	57	51	49
Tail (5,6)	14	86	13	87	14	86
Total (1,2,5,6)	32	68	32	68	31	69
Rabi						
Head (1,2)	55	45	35	65	44	56
Tail (5,6)	13	87	09	91	11	89
Total (1,2,5,6)	25	75	24	76	25	75

There is no escaping the conclusion that private tubewell water is a primary source of irrigation water for Niazbeg farmers. The canal system supplied only 9 percent to 64 percent of irrigation water, depending on the season and location in the system; conversely, tubewell water supplied 36 percent to 91 percent of irrigation water.

Policy makers need to seriously consider the organizational implications of the development of private tubewells. Through their cooperative construction, maintenance, and operation of these expensive technologies, Niazbeg farmers have demonstrated that they are willing to invest in improved water control and to informally organize to sustain it. They have demonstrated a capacity for entering into long-term mutual agreements through which they allocate and monitor water distribution and control "free riders." Farmers will create, maintain, and support viable organizations if these organizations can deliver something otherwise unavailable--in this case, water control. The challenge to policy makers is to recognize farmer capacity for organizational effort in order to improve farmer water control in the canal system.

A most significant factor limiting farmer control of canal water is lack of appropriately designed organizations for the task. Local farmer organizations could provide a mechanism to remove the locational bias in canal distribution and generate support for canal operations and maintenance from farmers on all locations. *Warabandi* water is cheaper and generally of better quality than groundwater. If farmers can gain main system support for building the organizational "security zones" that local organizations can provide, they will be able to improve control over canal water, and improve their capacity for agricultural production.

Water Control and Agricultural Production

Given the analysis of the effects of location *vis-a-vis* individual farmer characteristics, examination of main system organizational capacities and understanding of the importance of private tubewells as supplies of irrigation water, it is now possible to focus on the central research hypotheses--i.e., that farmer water control primary influences agricultural production. Three measures of agricultural productivity were employed:

Cropping Intensity. Cropping intensity is defined as the percent of cultivatable land under cultivation during a particular cropping season or year. If a farmer plants crops on all possible cultivable acreage, the cropping intensity of the farm is 100 percent for the specific season and 200 percent for the year because Pakistani conditions in the research area sustain two crops per year (*kharif* and *rabi*).

Crop Yield. Yields were measured in maunds per acre. A maund equals 37.32 kg, or approximately 82 pounds. The two crops measured for yield were rice (*kharif*) and wheat (*rabi*); these measures relied on farmer estimates of yield. Although 97 (42%) of the sample farmers planted rice in *kharif*, only 79 of these reported yield estimates. Of the 240 sample farmers, 227 (97%) planted wheat in *rabi*. Information on yields was available for 191 of the sample farms.

Cropping Pattern. It was hypothesized that the greater the water control, the more a farmer would be likely to invest in high-yielding, more moisture-sensitive crop varieties. Two measures were devised to test this hypothesis. The first is a measure of drought resistance, and the second is a measure of the average seasonal evapotranspiration (ETA) of a particular crop. Drought resistance was based on crop yield reduction in response to a missed irrigation at four cropping phases: growth, flowering, grain formation, and maturity. The average daily evapotranspiration rate differs from the drought resistance measure in that it does not consider plant stress at various growth stages. These two measures were employed in both *kharif* (rice) and *rabi* (wheat).

Water Control Measures

For both canal and tubewell water, water control was defined as the capacity of the individual farmer to apply sufficient quantities of water to crops before crops reached the permanent wilting point.

Measuring Canal Water Control. A canal water control scale was designed to measure the quantity, timing, reliability, and adequacy of the water supply. The reliability of the water delivery system indicates the extent to which a farmer can depend on it. While some might contend that reliability as a measure is included in the measures of quantity and timing, note that reliability of supply can be very high when quantity is very low. That is, the farmer can rely on the water never arriving, which is the case for more than 10 percent of the Niazbeg sample farmers. Adequacy of water was measured by obtaining sample farmer estimates of how often they received water sufficient to fill their particular crop's consumptive demand.

Data were obtained by asking farmers questions regarding adequacy of the canal supply. The selection for farmer responses were as follows: "do not receive canal water" (0), "not at all" at a particular stage (1), "little" (2), "moderate" (3), "good" (4), "excellent" (5).

The scale was constructed by summing reported values (0-5) for the quantity, timing, and reliability indicators. The value for canal water sufficiency was squared. It was judged that sufficiency should be given additional weight. The scale was transformed into a "percent of potential," with the resulting coefficients reflecting the percent of total points actually assigned relative to the greatest number possible--ranging from zero to a maximum score of 100 percent.

Table 17 reports that the four variables composing the canal water control scale correlate highly with one another. The component variables are also highly associated with the composite measure, ranging from .69 (reliability) to .88 (sufficiency).

Table 17. Correlation matrix: scale components for canal water control.

	Sufficiency of Supply (n=230)	Satisfaction: Quantity (n=229)	Satisfaction: Timing (n=227)	Satisfaction: Reliability (n=229)	Raw Scale (n=225)	Percent Potential Scale (n=225)
Sufficiency of supply	-	.50	.35	.33	.88	.88
Quantity satisfaction	.50	-	.78	.73	.80	.80
Timing satisfaction	.35	.78	-	.80	.72	.72
Reliability satisfaction	.33	.73	.80	-	.69	.69
Raw scale	.88	.80	.71	.69	-	1.00
Percent potential scale	.88	.80	.71	.69	1.00	-

Finally, the raw scale composite measure and its transformation into a percent of potential measure show the same high association.

Measuring Tubewell Water Control. In constructing a scale for tubewell water control, somewhat different measures were employed. Two timing measures were used. The first was the time required for water to be delivered after being requested. the second measure used was the sample farmer estimate of number of times water was not available when requested. The values for this measure ranged from 0 to 10. If a farmer requested water five times and received it five times, the score was 10; if water was requested five times and was not available on one occasion, the score was 8; and so on. Farmers were also asked to estimate the sufficiency of their tubewell water supplies. Sufficiency values ranged from zero to five (0 = no sufficiency and 5 = totally sufficient). Like the canal water control scale, the sufficiency values were squared, providing a maximum of 25 points.

Finally, the indicator of reliability was employed on a straight 0-5 scale, ranging from "no tubewell water received" to "always received." Reliability is a genuine issue for tubewell water control since problems do occur with power, mechanical break-down, and tenuous agreements with suppliers. A maximum of 55 points was possible on the tubewell water control measure, and raw scores were transformed into a percent of potential scale ranging from zero to a maximum of 100 percent of potential tubewell water control.

Table 18 reports intercorrelations among the four tubewell water control measures. All four measures were highly correlated with the composite tubewell water scale, ranging from .66 (reliability) to .90 (sufficiency).

There is almost no correlation between components of the two sets of measures for canal water control and tubewell water control (Table 19). The two types of water control are largely independent of each other among sample farmers.

Analysis

Tables 20 and 21 report results of the analysis of water control and agricultural production for *kharif* and *rabi*. The six sample watercourses are ranked according to the degree of water control achieved. Rankings disclose the significant

Table 18. Correlation matrix: scale components for tubewell water control.

	Sufficiency of Supply (n=219)	Timing: Measure 1 (n=219)	Timing: Measure 2 (n=218)	Reliability of Supply (n=220)	Percent of Potential Scale (n=213)
Sufficiency of supply	-	.54	.46	.75	.90
Timing: Measure 1	.54	-	.38	.51	.80
Timing: Measure 2	.46	.38	-	.51	.66
Reliability of supply	.75	.51	.51	-	.79
Percent of potential scale	.90	.80	.66	.79	-

Table 19. Correlation matrix: canal and tubewell water control components.

	Tubewell Sufficiency of Supply (n=219)	Tubewell Timing: Measure 1 (n=219)	Tubewell Timing: Measure 2 (n=218)	Tubewell Reliability of Supply (n=220)	Tubewell Percentage Scale (n=213)
Canal sufficiency of supply	-.06	.02	-.19	-.18	-.08
Canal quantity satisfaction	-.22	-.04	-.05	-.21	-.16
Canal timing satisfaction	-.01	.16	.00	-.11	.05
Canal reliability satisfaction	-.01	.14	-.08	.00	.03
Canal percentage scale	-.08	.07	-.15	-.18	-.06

difference in water control achieved by farmers on watercourse 3, the highest ranked watercourse, and watercourse 5, the lowest ranked.

Tables 20 and 21 also reveal the important contribution of tubewell water to farmer water control. While the three head watercourses continue to have superior water control compared to the tail watercourses, the locational bias of the canal *warabandi* is somewhat alleviated by the access to tubewell

Table 20. Water control and agricultural production: watercourse rankings in *kharif*.

	Water Control Scores			Agricultural Production Scores			
	Combined Water Control (n-207)	Tubewell Water Control (n-213)	Canal Water Control (n-225)	Cropping Intensity Scale (n-234)	Drought Resistance Scale (n-234)	ETA* (n-234)	Rice Yield Maunds/ Acre) (n-89)
Watercourse Rank Order							
3	98.6	74.0	24.6	82.3	288	378	21.4
2	88.5	55.0	33.5	76.2	168**	330	20.4
1	75.6	48.0	27.6	73.9	182**	319	19.5
4	74.8	57.0	17.8	61.8	218	299	16.4**
6	71.3	65.5	5.8	62.6**	153	277	19.4
5	52.1	33.7	18.4	59.5	125	237	19.3
Average	(76.8)	54.5	21.2	69.4	187	306	19.0

*Average evapotranspiration per day.
**Out of expected descending order.

Table 21. Water control and agricultural production: watercourse rankings in *rabi*.

	Water Control Scores			Agricultural Production Scores			
	Combined Water Control (n-204)	Tubewell Water Control (n-210)	Canal Water Control (n-225)	Cropping Intensity Scale (n-234)	Drought Resistance Scale (n-234)	ETA* (n-234)	Wheat Yield Maunds/ Acre) (n-222)
Watercourse rank order							
3	98.7	74.1	24.6	94.5**	206	304	27.5
2	92.2	58.7	33.5	95.5	158	293	27.3
1	80.8	53.2	27.6	91.5	142**	265	25.0
4	75.6	57.8	17.8	81.4**	149	239**	24.2
6	74.2	68.4	5.8	87.5**	146**	262	24.9**
5	54.9	36.5	18.4	87.6	147	257	20.6
Average	(77.3)	57.1	21.2	89.7	158	270	24.9

*Average evapotranspiration.
**Out of expected descending order.

water within the head and tail sections. Hence, watercourse 3 enjoys the number one rank for combined water control, even though it is ranked third in canal water control. Also, watercourse 6, with an abysmally low degree of canal water control, owes its fifth place ranking almost totally to tubewell water. Without tubewell water, watercourse 6 farmers would be out of irrigated agriculture.

While there are exceptions to the expected descending order, substantial differences stand out in the agricultural productivity of watercourse 3 and watercourse 5. In both *kharif* and *rabi*, the differences in cropping patterns is marked. In *kharif*, the difference in cropping intensity is substantial, and in *rabi*, the relationship between water control and yield is even more dramatic than in *kharif*.

Table 21 reveals some other important seasonal differences. For instance, cropping intensity in *rabi* increased by more than 20 percent. This increase was most marked in the tail watercourses. The drop in values in *rabi* is explained by the relative dominance of wheat, a more drought-resistant crop. Because wheat requires less water, the average evapotranspiration is also lower.

Table 22 aggregates the values for the six watercourses to reveal the overall pattern between water control and agricultural production. Water control drops an average of 22.5 points from head to tail for both seasons.

Table 22. Water control and agricultural production by system head and tail, _kharif_ and _rabi_.

System Scores by Season	Water Control Scores			Agricultural Production Scores			
	Combined Water Control	Tubewell Water Control	Canal Water Control	Cropping Intensity	Drought Resistance	ETA*	Rice/ Wheat Yield** (Maunds/ Acre)
Kharif (n=207)							
Head (1-3)	88	59	29	78	210	342	20.6
Tail (4-6)	66	52	14	62	165	271	17.6
Rabi (n=204)							
Head (1-3)	91	62	29	94	169	287	26.6
Tail (4-6)	68	54	14	86	147	253	23.2

*Average evapotranspiration.
**Rice yield (n=84); wheat yield (n=202).

The effect on agricultural production is definitive in both seasons: cropping intensities drop, cropping patterns shift from more to less moisture sensitivity, average evapotranspiration drops 12 to 21 percent, and yields are noticeably reduced.

While these results strongly support the argument that water control is the critical factor determining the limits and potential of agricultural productivity on the Niazbeg distributary, the explanatory potential of other variables needs to be examined. The following analysis examines the impact of water control when controlling for the influences of location and size of landholding.

Partialing Out Effects of Rival Hypotheses

Tables 23 and 24 report results of a partial correlation analysis of four explanatory variables (canal water control, tubewell water control, location, and size of landholding) on the dependent variables (cropping intensity, yield, and cropping patterns as measured by crop ETA and crop drought resistance).

The partial analysis was performed on the aggregate of all sample farmers representing all positions on all six sample watercourses. Eta and the zero-order Pearson's "r" value express the strength of bivariate relationships between each independent and dependent variable. The partial correlation coefficient expresses the relationship between each independent variable and each dependent variable when effects of all other variables in the tables have been statistically removed.

A review of Tables 23 and 24 indicates that when the effects of location, landholding size, and tubewell water control are removed (Table 23), canal water control in *kharif* maintains its positive relationship with cropping intensity, loses any relationship with rice yield, and is only slightly related to the two measures of cropping patterns. When the effects of location, landholding size, and canal water control are statistically controlled, tubewell water control is related only weakly to cropping intensity, but is related to an increased degree with rice yield in *kharif* and farmer cropping choices (i.e., propensity to shift to more water-demanding varieties). This indicates the importance of tubewell organization to the functioning of the irrigation system.

Table 23. System-level, partial correlation analysis of competing explanations for agricultural productivity (kharif).

Independent Variables	Cropping Intensity (n=234)	Rice Yield (n=89)	Cropping Pattern: Drought Resistance (n=234)	Cropping Pattern: ETA/ day (n=234)
Canal Water Control				
Eta*	.38	.28	.20	.36
Zero r**	.35	.10	.15	.31
Partial***	.27	.00	.12	.26
Location	.00	.00	.00	.00
Landholding size	.00	.00	.11	.12
Tubewell water control				
Eta*	.23	.39	.36	.30
Zero r**	.13	.25	.29	.21
Partial***	.16	.24	.27	.23
Location	.00	.00	.00	.00
Landholding size	.00	.00	.11	.12

*Eta - the eta statistic (see Appendix D)
**Zero r - zero-order correlation.
***Partial - partial correlation with above four independent variables of canal water control, tubewell water control, location, and size.

Table 24. Partial correlation analysis of competing explanations for agricultural productivity (rabi).

Independent Variables	Cropping Intensity (n=234)	Wheat Yield (n=222)	Cropping Pattern: Drought Resistance (n=234)	Cropping Pattern: ETA/ day (n=234)
Canal Water Control				
Eta*	.28	.32	.24	.26
Zero r**	.24	.16	.18	.24
Partial***	.18	.10	.20	.22
Location	.00	.00	.00	.00
Landholding size	.12	.18	-.11	-.19
Tubewell Water Control				
Eta*	.20	.30	.26	.22
Zero r**	.13	.27	.20	.18
Partial***	.17	.27	.24	.24
Location	.00	.00	.00	.00
Landholding size	-.12	.18	-.11	-.19

*Eta - the eta statistic (see Appendix D)
**Zero r - zero-order correlation.
***Partial - partial correlation with above four independent variables of canal water control, tubewell water control, location, and size.

When effects of the same rival hypotheses are statistically controlled in *rabi* (Table 23), canal water control maintains a lower relationship with the three agricultural production variables than was observed during *kharif*. However, canal water control maintained a slightly stronger relationship with cropping intensity than did tubewell water control. However, tubewell water control maintained a stronger relationship with wheat yield and the two measures of cropping pattern than did canal water control.

Landholding size sustains no relationship with *kharif* cropping intensity or yields, and virtually no relationship with the two measures of drought resistance in the cropping pattern. In *rabi*, a low, but positive, relationship is found between landholding size and wheat yield; whereas larger operators tend to have slightly lower cropping intensities. However, this negative relationship is small and should not be considered substantively significant.

The partial correlation analysis suggests that the original relationships found between water control and agricultural productivity are not significantly altered when controlling for location and size of landholding. Tubewell water continues to be possitively associated with the shift to highter yielding but less drought resistant cropping patterns and crop greater yields, while canal water control is more likely to be associated with greater cropping intensities. The influence of both canal water control and tubewell water control on evapotranspiration rates remain roughly equal, although canal water control has more effect in *kharif;* tubewell water control has more impact in *rabi* season.

Analysis of cropping patterns provides insight into the relationship between water supply and agricultural production. Cropping choices are especially significant to small farmers who need to maximize production on limited acreage. Water-sensitive, higher-yielding varieties promise greater productivity per acre. The capacity to grow more water-sensitive, high-yielding varieties can dramatically improve the wellbeing of all farm families. However, such crop varieties require good water control, which is denied to many Niazbeg farmers by lack of effective local organizations between main and farm systems.

Water Control and *Kharif* Cropping Patterns

Kharif is a time of high water stress. The Niazbeg subproject area is located on the edge of the desert, where precipitation is low and the monsoon unreliable. Average maximum temperatures range between 90°F and 105°F. These factors make water control in *kharif* especially critical.

In Table 25, *kharif* crops characterized by higher moisture sensitivity are ranked from left to right in descending order of water demand. Table 26 likewise ranks less moisture sensitive crops. The further one proceeds to the right on Tables 25 and 26, the greater is the drought resistance.

The six sample watercourses (Tables 25 & 26) were ranked by degree of water control from highest (watercourse 3) to lowest (watercourse 5), and cropping patterns are reported in percentages of the irrigated area planted in each crop by head and tail sample farmers on each watercourse.

Results reported in Tables 25 and 26 support the hypothesis that the greater the water control, the greater is the propensity of sample farmers to select higher-yielding crops. The relationship is most apparent when one compares the pattern of watercourse 3 with watercourse 5. Overall, 40 percent of the land in watercourse 3 at the head and 43 percent at the tail was planted in highly water-sensitive crops, while only 10 percent of the land in watercourse 5 at the head and 5 percent at the tail was planted in such crops (Table 25).

When one compares cultivable land left fallow in watercourses 3 and 5, one observes (Table 26) that watercourse 3 sample farmers left less than one-fifth of their land fallow (head = 18%, tail = 18%), whereas watercourse 5 sample farmers left 53 percent of their land fallow at the head and 34 percent fallow at the tail reaches.

The distributions horizontally across Tables 25 and 26 show that acreages planted in the more and less moisture sensitive crops do not vary greatly between head and tail reaches of the watercourses. Farmers, with tubewell technology, have reduced the impact of head and tail location on cropping pattern. However, the proportions of cropped acreages (reading down the columns in Tables 25 and 26) reveal that watercourse location on the Niazbeg distributary produces pronounced effects on sample farmer shift to less moisture-sensitive crops (cotton, sorghum, fodder) and to leaving cultivable land fallow.

Table 25. Water control (tubewell and canal) and percent of sample farmer watercourse command area in more moisture-sensitive crops (*kharif*) (n=234).

Watercourse	Crop and Moisture Sensitivity Score* Rice (7.79) H	T	Maize (6.55) H	T	Veg. (5.03) H	T	S/Cane (2.70) H	T	Total % of Crop Acreage** H	T
3	12	10	3	13	19	18	6	2	40	41
2	12	8	4	4	0	2	3	7	19	21
1	11	13	10	7	6	4	0	1	27	25
4	13	20	2	3	4	8	3	5	22	36
6	13	4	7	2	1	21***	14	5	35	32
5	1	1	5	8	0	0	4	6	10	15
Averages										
1-3	12	10	6	8	8	8	3	3	29	29
Head & Tail	11		7		8		3		29	
4-6	9	8	5	4	2	10	7	5	22	28
Head & Tail	8.5		4.5		6		6		25	
1-6	11	9	6	6	5	9	5	4	25.5	28.5

*() indicate moisture sensitivity score for crop; H = Head, T = Tail; veg. = vegetables, s/cane = sugarcane.
**Values do not sum to 100% because some land was in crops reported on Table 26.
***Includes orchard.

Table 26. Water control (tubewell and canal) and percent of sample farmer watercourse command area in less moisture-sensitive crops (*kharif*) (n=234).

Watercourse	Crop and Moisture Sensitivity Score* Cotton (1.91) H	T	Sorghum (1.10) H	T	Fodder (1.09) H	T	Fallow (0.00) H	T	Total % of Crop Acreage** H	T
3	5	1	10	9	27	29	18	18	60	57
2	7	6	6	5	44	44	24	24	81	79
1	11	5	16	14	34	27	12	30	73	76
4	6	4	6	4	29	15	37	42	78	64
6	1	7	2	6	23	21	39	34	65	68
5	8	11	5	7	23	33	53	34	90	85
Averages										
1-3	8	4	11	9	35	33	18	24	71	71
Head & tail	6		10		34		21		71	
4-6	5	7	5	5	25	23	43	37	78	72
Head & tail	6		5		24		40		75	
1-6	7	6	8	7	30	28	31	31	75	72

*() indicate moisture sensitivity score for crop; H = Head; T = Tail.
**Values do not sum to 100% because some land was in crops reported on Table 25.

Table 27. Water control and percent of watercourse command area in *rabi* crops, and head-tail moisture sensitivity scores (n=234).

Water-course	Crop and Moisture Sensitivity Score*															
	Veg. (6.55)		S/Cane (2.70)		Oilseed (2.27)		Berseem (1.98)		Wheat (1.42)		Oats (1.00)		Fallow (0.00)		Total Score	
	H	T	H	T	H	T	H	T	H	T	H	T	H	T	H	T
									%							
1-3	6	7	1	1	1	1	20	19	60	57	6	8	6	9	176	178
4-6	1	2	1	1	14	12	10	12	57	50	3	1	14	23	146	139
1-6	4	4	1	1	7.5	6.5	15	15	59	54	5	5	10	16	161	159
Averages																
1-3 (head & tail)	6.5		1		1		19.5		58.5		7		7.5		177	
4-6 (head & tail)	1.5		1		13		11		53.5		2		18.5		143	
Total	4		1		7		15		56		5		13		160	

*() indicate moisture sensitivity score for crop; H = Head, T = Tail, veg. = vegetables, s/cane = sugarcane.

Water Control and *Rabi* Cropping Patterns

A time of cool weather and low evapotranspiration, *rabi* is the main crop producing season in the Niazbeg subproject area. During *rabi*, wheat is grown on 57 percent of all the cultivated land. However, more moisture-sensitive crops are also grown, and it is predicted that in *rabi*, as in *kharif*, the greater the water control, the greater is the likelihood of increased planting of more moisture demanding crops.

Table 27 supports the anticipated relationship. However, the relationship between water control and the cultivation of moisture-sensitive crops is not as strong in *rabi* as it is in *kharif*.

Water Control and Projected Cropping Patterns for *Kharif* and *Rabi* Seasons

The following analysis, reported in Tables 28 and 29, is based on farmer estimates of cropping changes they would make if they had "adequate" water during *kharif* season.

Table 28. Water availability and potential cropping patterns for kharif (n=233).

Position	Rice (7.19)	Maize (6.55)	Veg (5.03)	S/cane (2.70)	Cotton (1.91)	Sorghum (1.10)	Fodder (1.09)	Fallow (0.00)	CMS Avg.**	% of Change
	Crop Water Sensitivity/Demand*									
	% of cultivable area									
Head										
Existing	11	7	8	3	6	10	33	22	2.31	
With "adequate" supply	29	12	10	10	6	8	17	8	4.04	
% change	264	171	125	333	0	-20	-54	-64	175	57
Tail										
Existing	9	5	4	6	6	5	24	41	1.77	
With "adequate" supply	30	10	8	14	4	5	15	14	3.78	
% change	333	200	200	233	-33	0	-37	-65	214	47
Total										
Existing	20	12	12	9	12	15	57	63		
With "adequate" supply	59	22	18	24	10	13	32	22		
% change	295	183	150	266	-17	-13	-44	-65		

*() indicate moisture sensitivity score for crop. High moisture sensitivity scores indicate crops that are high in response to a missed irrigation and are, therefore, more sensitive to water stress. Low values indicate crops that are more drought resistant.

**CMS = Crop moisture sensitivity score. High values indicate crops that are high in their response to a missed irrigation and are, therefore, very sensitive to water stress. Low values indicate crops that are more drought-resistant.

Table 29. Water control and cropping patterns (kharif) on watercourses 3 and 5 (n=233).

	Crop and Moisture Sensitivity*									
	Rice (7.19)	Maize (6.55)	Veg (5.03)	S/cane (2.70)	Cotton (1.91)	Sorghum (1.10)	Fodder (1.09)	Fallow (0.00)	CMS Avg.**	% of Change
	---% of cultivable area---									
Watercourse 3										
Existing	12	9	16	4	3	9	28	18	3.01	
With "adequate" supply	18	12	21	12	3	8	17	9	3.90	
% change	150	133	117	300	0	-10	-54	-50	130	77
Existing		43				58				
With "adequate" supply		63				37				
% change		147				-36				
Watercourse 5										
Existing	1	6	0	4	9	7	27	46	1.12	
With "adequate" supply	42	13	4	18	3	5	13	2	5.03	
% change	4200	216	400	450	-67	-29	-52	-96	449	22
Existing		11				89				
With "adequate" supply		77				25				
% change		700				-72				

*() indicate moisture sensity score for crop.
**CMS = Crop moisture sensitivity score. High values indicate crops that are high in their response to a missed irrigation and are, therefore, very sensitive to water stress. Low values indicate cropping patterns that are more drought resistant.

Table 28 depicts the potential changes in cropping patterns in *kharif* if sample farmers were to obtain "adequate" water. Data were collapsed for head watercourses 1-3 and tail watercourses 4-6. Crops are listed horizontally by degree of drought-resistance, from more to less moisture demanding. The cropping pattern moisture scores for each watercourse were aggregated to system head (watercourses 1-3) and system tail (watercourses 4-6). Table 28 also indicates the percent of change between the existing cropping patterns and the potential cropping pattern that would result from a hypothetical increase in water availability to a farmer-defined level of "adequacy."

Table 28 indicates that a dramatic shift toward cultivation of more moisture-sensitive crops would occur in *kharif* if sample farmers had "adequate" water. At the time of data gathering, Niazbeg farmers planted approximately 27 percent of their land in higher yielding more moisture sensitive crops. Table 28 reveals that with improved water control, sample farmers would plant approximately 62 percent of their land in these crops. The largest projected increase would be in production of rice, while the largest decrease would be in production of fodder. Furthermore, cropping intensities would increase; the percentage of fallow land drops from 63 to 22 percent.

According to sample farmer reports summarized in Table 28, if Niazbeg farmers were to have "adequate" water supply, the greatest change in cropping patterns and cropping intensity would occur on tail watercourses. The farmers in tail positions would increase their cultivation of water sensitive crops by 258 percent compared to the 210 percent increase among farmers on head watercourses. However, it should be noted that farmers on head watercourses indicate nearly as great as willingness as farmers on tail watercourses to shift from drought resistant to water sensitive crops and to increase cropping intensity. This willingness suggests that all farmers are producing below their desired capacity and would welcome the opportunity to increase cultivation of water sensitive crops and to increase cropping intensity. The lack of effective local organization to supply a public good (i.e. water control) is clearly constraining use of private goods (i.e. improved seeds, land, labor).

Table 29 compares cropping patterns and cropping intensities of watercourse 3 (where farmer water supplies and control is greatest) to watercourse 5 (where farmer water supplies are least favorable). The differences between the two watercourses underscore the significance of the relationship between water control and agricultural production.

Table 29 indicates that improved water control would have the most dramatic positive effect on the least advantaged groups of farmers in the Niazbeg area. Given the scenario of "adequate" water, farmers on watercourse 5 projected a 700 percent increase in cultivation of water sensitive crops and a 96 percent reduction in fallow land. In short, with improved water control, the greatest degree of change in cropping patterns and cropping intensity could take place where it is most needed--among the most disadvantaged at the tail of the system. That watercourse 5 farmers now leave about half of their land fallow during *kharif* testifies to the desperate need for improved irrigation organization to enhance water supply and control at the tail of the system. Improving water control could create the security necessary for farmers to take innovative steps on their own behalf.

Table 30 compares cropping patterns and intensities under existing and "adequate" water conditions during *rabi* season. The values in Table 30 indicate that the water control situation for Niazbeg farmers is much better in *rabi* than *kharif*. The degree of correspondence between *rabi* cropping patterns associated with existing water and those associated with "adequate" water is much higher than *kharif* for both head and tail watercourse farmers. In addition to more favorable climatic conditions, the improved agricultural situation can partially be explained by strong market demand for wheat. Farmers reported that they would increase their cultivation of wheat if water control situation improved.

With the exception of the increase in wheat cultivation, Table 30 supports the hypothesis that more adequate farm water supplies will lead to increased cultivation of more water-sensitive crops. Overall, there would be a 22 percent increase in cultivation of vegetables and a 250 percent increase in sugarcane cultivation.

The most dramatic change is among farmers on tail watercourses, who projected a 600 percent increase for area in vegetables. Farmers on head watercourses projected a 400 percent increase in sugarcane production, while farmers on tail watercourses projected no increase. In fact, when the projected increases in water-sensitive corps are averaged, the farmers on the head watercourses projected a slightly higher percent of change than did farmers on tail watercourses (Table 30).

Table 30. Comparison of cropping pattern changes under current and "adequate" water supply (*rabi*) (n=233).

	Crop and Moisture Sensitivity*							
	Veg. (6.55)	S/cane (2.70)	Oilseed (2.27)	Berseem (1.98)	Wheat (1.42)	Oats (1.00)	Fallow (0.00)	CMS**
	%							
Head								
Existing	6	1	1	19	58	7	8	1.71
With "adequate" supply	10	4	1	14	63	4	4	1.99
% change	167	400	0	-27	109	-43	-50	112
Tail								
Existing	1	1	14	10	55	2	17	1.42
With "adequate" supply	6	1	14	9	61	2	7	1.82
% change	600	0	0	-10	111	0	-59	128
Total								
Existing	3.5	1.0	7.5	14.5	56.5	4.5	12.5	1.57
With "adequate" supply	8.0	2.5	7.5	6.5	62.0	3.0	5.5	1.91
% change	229	250	0	-55	110	-33	-56	122

*() indicate moisture sensitivity for crop.
**CMS = Crop moisture sensitivity score.

The effect of obtaining "adequate" water would differ for different crops. Tables 28 and 30 indicate that head farmers with relatively good existing water control would choose to increase cultivation in sugarcane if they were to receive "adequate" water supply. Tail farmers whose existing water control is relatively poor would choose to increase rice cultivation in *kharif* and vegetables in *rabi*. These findings suggest that improved water control might lead to greater crop diversification.

Analysis of Water Control and Agricultural Production by Quadrant

The Niazbeg system was subdivided into quadrants. Quadrant 1 included the first 20 sample farmers on watercourses 1 through 3 (head of the head of the system); quadrant 2 included the tail 20 sample farmers on watercourses 1 through 3 (tail of the head); quadrant 3 was composed of the first 20 sample farmers at the head of each of watercourses 4 through 6 (head of the tail); and quadrant 4 consisted of the tail 20 sample farmers at each of the tail positions of watercourses 4 through 6 (tail of the tail). The quadrant groups were intended to disaggregate the sample farmers into units sufficiently large to permit multi-variate analysis, but leave the sample sufficiently disaggregated to perceive rough distributions by location (Tables 31 and 32).

Canal water control sustained a substantial and positive relationship with increased cropping intensities throughout the head of the system during both *kharif* and *rabi*. Farmers in quadrant 1 at the head of the system employed their greater canal water control to increase cropping intensity. Tubewell water control had almost no effect on cropping intensities at the head of the system. Rather, tubewell water control appeared to be strongly related to improving yields and to moving to higher-yielding, less drought-resistant crops. This tendency holds for both seasons, but the relationship is stronger in *kharif*.

In quadrants 3 and 4, the situation is reversed. Tubewell water supplies made irrigation possible over substantial reaches of the tail of the system. Farmers located on these watercourses use tubewell water to increase the amount of land cropped. Apparently, in *rabi* at least, the access to tubewell water provides enough security to increase cultivated acreage in

Table 31. Canal and tubewell water control, and agricultural production by quadrant for *kharif* (Pearson's r).

	Cropping Pattern							
	Cropping Intensity (n=234)		Drought Resistance (n=234)		ETA/day (n=234)		Crop Yields (n=89)	
Quadrant*	Canal	TW**	Canal	TW	Canal	TW	Canal	TW
1 (head/head)	.38	.07	.07	.38	.34	.22	-.48	.60
2 (tail/head)	.45	.12	.13	.12	.41	.17	.22	.49
3 (head/tail)	.07	.13	.01	.34	.00	.23	.00	.14
4	14	.31	.16	.14	.13	.29	***	***

*Head/head = head of distributary, head of watercourse; tail/tail = tail of distributary, tail of watercourse.
**TW = Tubewell.
***Quadrant 4 farmers did not grow rice due to lack of water supply and control.

Table 32. Canal and tubewell water control, and agricultural production by quadrant for *rabi* (Pearson's r).

	Cropping Pattern							
	Cropping Intensity (n=234)		Drought Resistance (n=234)		ETA/day (n=234)		Wheat Yields Maunds/Acre (n=222)	
Quadrant*	Canal	TW**	Canal	TW	Canal	TW	Canal	TW
1 (head/head)	.17	.12	.00	.38	.19	.27	.00	.28
2 (tail/head)	.40	.12	.64	.21	.46	.11	.11	.36
3 (head/tail)	.00	.30	.05	.25	-.13	.29	.00	.40
4 (tail/tail)	.05	.08	.00	.13	.00	.23	.26	.04

*Head/head = head of distributary, head of watercourse; tail/tail = tail of distributary, tail of watercourse.
**TW = Tubewell.

quadrant 3, but is insufficient in quadrant 4 to induce change in cropping patterns to more moisture-sensitive, but higher-yielding crops.

Table 31 reports that during *kharif*, canal water control had a negative relationship to yields at the head of the system (quadrant 1)--tubewell water control made up the difference even in this relatively favored sector of the system. However, except for farmers at the tail of the tail watercourses (quadrant 4), tubewell water control was positively related to increases in both rice (*kharif*) and wheat (*rabi*) yields.

The importance of enhancing farmer irrigation water control in order to improve agricultural productivity has been supported. Furthermore, the significant contribution of tubewell water to enhanced farmer water control is clearly indicated at all locations, and is especially apparent for Niazbeg farmers located at the tail of the system. Clearly, tubewell water is a strategic component of Niazbeg irrigation on the sample watercourses because it makes irrigation possible in reaches not well served by canal water and it improved production substantially, even in areas relatively well served by canal water. It is also clear that improvements in canal functioning, by way of improved organizational rules and tools for management of canal water, would do much to improve the conditions of irrigated agriculture.

Hypotheses regarding water control and the three agricultural production variables were supported, but with particular qualifications. Canal water control consistently contributed to increased cropping intensities and more water-sensitive cropping patterns at the head of the Niazbeg system, while it had, at best, only a weak relationship to crop yields. On tail watercourses 4 through 6, canal water control had little relationship to agricultural production, while tubewell water control had a strong positive effect on all agricultural production measures.

The greater the farmer water control, the greater is the cultivation of high-yielding, moisture-sensitive crops, and the greater is the cropping intensity. These hypotheses were examined in light of cropping patterns under existing water conditions, and cropping patterns under conditions of "adequate" water supply and control projected by sample farmers.

Variation in the locational pattern suggests that the additional flexibility of water supply and control afforded by tubewell water is essential to farmers on all watercourses, but especially for those at the tail of the system. The data also suggest that farmers with access to tubewell water are better able to meet the water demands of moisture-sensitive crops than are farmers who have relatively good canal water control, but little access to tubewell water.

The analysis indicates that Niazbeg farmers would shift to more moisture-sensitive crops and higher cropping intensities if they had more adequate water supply and control. The shift would be more dramatic in *kharif* when moisture stress becomes very high, due to extreme heat and high evapotranspiration rates. The shift in *rabi* would be substantial, but not as dramatic since *rabi* is a relatively mild season and wheat, a more drought-resistant crop, is the preferred crop.

The contrast between the water control provided by canal and tubewell water delivery systems is important for policy makers. The tubewell delivery system is able to provide increased water control and, hence, increased agricultural productivity because it is locally controlled and managed by water users. The flexibility necessary for farmers to apply water in sufficient quantity and in a timely manner is built into the tubewell system. Because of the enhanced water control provided by tubewells, farmers are willing to invest in tubewell construction and maintenance, to mobilize farmer resources, and to control "free riders." In short, farmers will organize themselves to collectively secure water control and therby increase their agricultural productivity.

If organizations adapted to the requirements of managing surface water flows can be built, a vastly improved irrigated agriculture is possible. Pakistani farmers on sample watercourses have already accomplished much local organization in the realm of groundwater.

Water Control and Organizational Support

What is the relationship between water control and farmer willingness to support the existing watercourse *warabandi* rules and private tubewell organizations?

Table 33 reports findings regarding farmer willingness to pay costs for a mutually operated watercourse or tubewell organization as an alternative to supporting private tubewell development. Costs of such an organization would be funded by allocating total costs to shares. Each share would allocate its

Table 33. Farmer willingness to invest in a tubewell organization (n=206).

Water-course	Not Willing Number	Not Willing % of Total	Somewhat Willing Number	Somewhat Willing % of Total	Very Willing Number	Very Willing % of Total	Combination of Somewhat and Very Willing (%)
1	13	6.3	19	9.2	7	3.4	
2	11	5.3	20	9.7	7	3.4	
3	9	4.4	8	3.9	11	5.3	
Subtotal	33	16.0	47	22.8	25	12.1	34.9
4	3	1.5	13	6.3	13	6.3	
5	20	9.7	16	7.8	4	1.9	
6	6	2.9	12	5.8	14	6.8	
Subtotal	29	14.1	41	19.9	31	15.0	34.9
Total	62	30.1	88	42.7	56	27.2	69.8

Table 34. Rejection of *warabandi* rules: a measure of organizational support (n=206).

Water-course	Allocation Rules: Allocation by weekly time period	Allocation Rules: Head to tail delivery	Maintenance Rule: Participate in maintenance	Assessment Rule: Assessment by Irrigation Dept.	Total
1	0	0	0	3	3
2	5	5	0	2	12
3	0	0	0	1	1
Subtotal	5	5	0	6	16
4	5	4	0	5	14
5	10	5	0	6	21
6	17	10	8	13	48
Subtotal	32	19	8	24	83
Total	37	24	8	30	99

fraction of total water just as each share would obligate its owner to pay its fraction of the organizational costs. The data indicate that there was a great deal of support for such organizational development throughout the system. Of the 206 respondents, 144 (70%) stated that they would be willing to invest in such a collective effort to enhance water control (Table 34). Table 33 indicates that head farmers and tail farmers are equally supportive of investing in a mutual tubewell organization.

While farmers were generally supportive of organizational development of mutually owned tubewells to supplement canal supplies, there were important watercourse differences (Table 33). Farmers on watercourse 5, where water control was the lowest of all sample watercourses, were the least willing to support such a collective effort. Fifty percent of watercourse 5 sample farmers stated they were unwilling to finance a mutually owned and operated tubewell, while only four (10%) stated that they would be very willing to support such an endeavor. One might speculate that the prolonged water difficulties may have split farmers on watercourse 5 to the point where they distrust collective efforts of any nature.

It was predicted that greater compliance with canal *warabandi* rules would be found among farmers along the head watercourses, where canal water supply and control is better, via water exchange. Recall that water exchange increased in the head reaches where canal water was more available and reliable. It was further predicted that there would be little locational difference found in compliance with tubewell organizational rules because it was expected that farmers would attempt to control any who would attempt to take water without payment. Therefore, compliance with organizational rules was expected to be much higher among farmers as members of tubewell organizations than among the same farmers as users of canal water. While farmer "X" might not comply with canal rules where free riding is easier and more difficult to sanction, the same farmer "X" could be expected to fulfill demands imposed by associates in an informal tubewell organization.

Table 34 reports the pattern of sample farmer compliance with canal *warabandi* rules pertaining to allocation, maintenance, and fee assessment. Compliance was measured by three indicators: agreement with the rule, judgment of the rule as a fair one, and obedience to the rule. Farmers were considered to have rejected a rule only if two of the three responses were negative. That is, if a farmer disagreed with a rule, and considered it unfair, but nevertheless obeyed the rule, the response of the farmer was still reported as a rejection. Because farmers were reluctant to candidly criticize the canal rotational (*warabandi*) system or to openly admit to breaches of official rules, it is likely that the values reported in Table 34 substantially underestimate rejection of rules.

Of the 206 farmers responding to questions regarding rejection of canal rotational (*warabandi*) rules, 99 rejected the rules (Table 34). Of these, 83 were located on tail watercourses. These figures strongly support the notion that the greater the farmer's canal water supply and control, the greater the farmer's compliance with canal *warabandi* allocation and maintenance rules. Responses reported in Table 34 also indicate that compliance with maintenance rules was not the primary basis for granting or withdrawing organizational support. The maintenance rule was the least problematic--all rejections of this rule came from farmers located on watercourse 6, where maintenance is relatively fruitless given the lack of canal water. Allocation and assessment rules were most likely to be rejected.

Table 35 Rejection of tubewell organization rules: a measure of organizational support (n=206).

Water-course	Allocation Rule: Water delivered upon request		Maintenance Rule: Those who use channels should maintain channels		Assessment Rule: Assessment set by owner bound by local market costs		Total	
	No.	% of Total	No.	% of Total	No.	% of Total	No.	%
1	0	0.0	0	0.0	4	1.9	4	1.9
2	1	0.5	1	0.5	3	1.5	5	2.4
3	0	0.0	0	0.0	0	0.0	0	0.0
Subtotal	1	0.5	1	0.5	7	3.4	9	4.4
4	0	0.0	0	0.0	0	0.0	0	0.0
5	0	0.0	0	0.0	0	0.0	0	0.0
6	4	1.9	6	2.9	0	0.0	10	4.9
Subtotal	4	1.9	6	2.9	0	0.0	10	4.9
Total	5	2.4	7	3.4	7	3.4	19	9.2

Table 35 indicates that farmers were more supportive of tubewell organizational rules than canal *warabandi* rules. Only 19 of 206 farmers rejected tubewell organizational rules. Furthermore, looking at locational differences, farmers on tail watercourses gave only one more rejection response than those at the head, indicating that tubewell organizational support was uniformly distributed.

However, note that more than half of the rejections (10) came from farmers on watercourse 6, and that six of the ten farmers rejected the maintenance rules and four farmers rejected the allocation rule. Half of the watercourse 6 farm units depended exclusively on tubewell water--the total lack of access to canal water may place additional stress on tubewell organizations. Furthermore, it may be speculated that tubewell owners, given their relatively greater monopoly over water on watercourse 6, have been more abusive of non-owners. Farmers located on watercourses 1 and 2, who enjoy relatively good canal water control, but who are faced with relatively steep tubewell water assessments, are more likely to reject the tubewell assessment rule, than the allocation and maintenance rules.

A comparison of Tables 34 and 35 indicates that there is much more sample farmer support for tubewell organizations than for the canal *warabandi* system. The greatest rejection of *warabandi* rules came from farmers located on tail watercourses, where canal water supply and control is extremely poor. Good canal delivery must be viewed as an important complement to tubewell water to strengthen the bargaining power of the most disadvantaged farmers.

Willingness to Support Water Users Associations

Table 36 reports sample farmer responses to questions regarding their willingness to support a water user association if increased water control were provided by that organization. The question included within it a designation of a share system which linked amount invested to amount of water received. Specifically, farmers were asked if they would be willing to contribute labor and funds, and provide land if the association could provide them with improved canal water supply and control. The categories of response were "not willing," "somewhat willing," and "very willing."

Table 36. Farmer willingness to support water users associations.

Water-course	Form a WUA (n=209) Willingness: Not	Some	Very	Contribute Labor (n=208) Willingness: Not	Some	Very	Contribute Funds (n=208) Willingness: Not	Some	Very	Provide Land n=(208) Willingness: Not	Some	Very
Head (1-3)	1	36	66	1	12	93	0	44	62	4	37	65
Tail (4-6)	0	7	96	1	6	95	4	20	76	3	14	82
Total	1	43	165	2	18	188	4	64	140	7	51	150

Virtually all sample farmers stated that they would be somewhat or very willing to support a canal WUA if such an organization could provide increased canal water control and if water delivered could be linked to organizational assessments paid. Of these, 79 percent stated they were "very willing." The sample farmers also indicated willingness to contribute labor, funds, and even land. Of these three support indicators, contributions of labor were most enthusiastically endorsed. However, farmers gave an overwhelmingly positive response to all three support indicators.

Table 36 also supports the anticipated relationship between existing canal water control and support for local water users associations. While a majority of farmers located on head watercourses were supportive of such an organization, they did not generate as a large a majority as did farmers located on tail watercourses.

Niazbeg farmers were willing to make significant investments in building an organization if such investments could be directly linked to increased water control. While farmers are unfamiliar with the strategies and techniques of building canal *warabandi* water user associations, some have already demonstrated a capacity for making organized joint agreements to manage tubewells.

Water Control and Organizational Support: The Control of "Free Riders"

The "free rider" problem centers on the systematic violation of share distribution arrangements, where one or more persons consume the collectively provided good (e.g., canal or tubewell water) without paying for their share of the cost. The problem of collective goods and "free riders" is discussed in some detail in Chapter 2. If a member of a watercourse or tubewell organization can violate allocation agreements without suffering any negative consequence, support for the organization will be quickly undermined. Others will join the ranks of "free riders" and take whatever benefits are available without paying the costs. Any individual who then continues to pay costs for benefits received is being exploited. The gulf between *de jure* rules and *de facto* behavior will widen. The capacity to enforce joint agreements through sanctions that restrict and punish "free rider" behavior is essential if members are to have confidence in organizational arrangements that are designed to match receipt of benefit with appropriate payment.

Tubewell organizations have the capacity to directly control water at the tubewell head. Water can be turned on or off by the operator, depending on the demand of the user and the agreements between owner(s), operators, and users. If a person does not pay his or her assessment, water delivery will be withheld. If an owner does not deliver the water, or does not otherwise fulfill the mutually established agreements, the user can withhold payment, seek another source of supply, or even take measures such as establishing another tubewell. In other words, sanctions for breaking tubewell organizational rules can be effectively implemented.

On the other hand, informal cooperative action on watercourses, such as it is, is primarily oriented toward mobilizing labor for periodic watercourse maintenance. Farmers have no direct control of the source of supply from the canal. Water flows continuously in the watercourse at whatever level is determined by distant authorities. Each farmer obtains an allocated share of watercourse time per week; when the farmer's time is up, the *warabandi* schedule requires that the next farmer take the allocated time-share. Water may or may not accompany this time-share and water cannot legally be turned on or off either at the *mogha* (watercourse inlet) or at the field outlet (*nukka*).

Because there are no watercourse organization employees on sample watercourses, to protect the organizational interest, each farmer is responsible for seeing that the flow of water to his field outlet is not disrupted. If another water user decides to divert some of the watercourse flow outside his scheduled time period--day or night--it is the responsibility of the offended shareholder to to decide whether or not to take action against the transgressor. If there are watercourse leaks during a farmer's *warabandi* turn, it is that farmer's responsibility to fix the leaks and restore a full flow. If a farmer chooses to take corrective action when another watercourse user is diverting his supply, destructive conflict may ensue. The matter can be brought to the attention of the local leaders for resolution, but this creates a social disturbance in the midst of people who must live together. Thus, appropriate sanctions for control of "free riding" behavior on canals have not been designed, and those which are available to farmers are not easily enforced.

Table 37 indicates that of the 212 respondents, 98 (46%) identified water theft, or taking water out of turn, as a major problem. The table also indicates that theft is as troublesome for farmers at the head of the head watercourses as for those at the tail. Twenty-five (63%) of the farmers on watercourse 2 identified water theft as a major problem--more than from any other single watercourse. Apparently, the relatively good canal water control enjoyed by the head watercourses does not deter theft. Given poor local organization, greater water availability simply provides more opportunity for "free riding."

Table 37. Lumber of sample farmers identifying water theft as a major problem (n=212).

Water-course	Watercourses					
	Head (1-3)		Tail (4-6)		Total (1-6)	
	No.	Total (%)	No.	Total (%)	No.	Total (%)
1	10	4.7	8	3.8	18	8.5
2	13	6.1	12	5.7	25	11.8
3	2	1.0	6	2.8	8	3.8
4	6	2.8	8	3.8	14	6.6
5	9	4.2	10	4.7	19	9.0
6	9	4.2	5	2.4	14	6.6
Total	49	23.1	49	23.1	98	46.2

Summary and Conclusion

In the absence of an effective local farmer organization to remove head-tail disparities, it was hypothesized that location would dictate the distribution of canal water to the farmers.

In short, the greater the distance from the source of water supply, the less would be farmer water supply and control. This hypothesis was tested against rival hypotheses to determine the effect that other farmer attributes might have in explaining variation in water supply and control. These included land owned, land operated, formal education, and caste. Analysis demonstrated that such individual attributes could not account for variation in water supply and control. That is, farmers located at the tail of the system received less water than their counterparts at the head of the system, and they did so without regard for land owned or cultivated, education, or caste affiliation. This locational bias was revealed among and within watercourses and it occurs because no effective local irrigation organization exists to overcome locational problems throughout the distributary or individual watercourses.

While the relationship between location and farmer water control was strong, the data also indicated that the *warabandi* distribution system provides poor water control for all farmers on the Niazbeg system. Although head watercourses received water in excess of their *de jure* allocations, the timing and reliability of water delivery was low. Even on relatively water-rich watercourses, farmers could not meet their varying crop water demands. Many farmers on the water-poor tail watercourses had dropped out of the *warabandi* system altogether, irrigating their crops exclusively with private tubewell water.

The analysis of water control and organizational effectiveness at the main system level indicated that there were inadequate measurement and regulation structures with which officials could gauge or alter water deliveries to the distributary or watercourses. Furthermore, the organizational structure for grievance procedures was cumbersome and ineffective. Watercourses at the head of the system received water supplies in excess of *de jure* allocations, while watercourses toward the tail of the system received less water than officially allocated.

The analysis of the relationship between water control and agricultural production (as measured by cropping intensities, cropping patterns, and crop yields) revealed the importance of private tubewell organizations within the Niazbeg system, as well as the degree to which tubewell water contributes to farmer productivity.

The analysis has indicated that the decrease in canal water control at the tail of the system was associated with an increase in groundwater development through tubewell technology and organization. Furthermore, the analysis revealed that tubewell water is a critically important source of irrigation water. Only slightly more than one-third of the water supply for the six sample watercourses was provided by canal water and almost two-thirds was supplied by tubewells. Even watercourses at the head of the system revealed a slight predominance of tubewell water over canal water supplies, while many farmers on tail watercourses relied exclusively on tubewell water.

The most significant relationship found was between water control and cropping patterns. Farmers with better water control were more likely to cultivate more moisture sensitive and potentially higher-yielding crops. Furthermore, the availability of tubewell water appeared to be the critical factor in determining farmer cropping patterns. Those farmers with high tubewell water control were more likely to cultivate higher-yielding moisture-sensitive crops than those with highest available canal water control, indicating that the flexibility of timing provided by tubewells is critically important.

Yields were considerably higher when farmers had better tubewell water control. This measure was at least partly a function of shifting cropping patterns to higher yielding varieties. Interestingly, cropping intensities were found to be little related to farmer water control. However, this finding is easily interpreted. Farmers with low water control are more reliant on drought-resistant, lower-yielding crops. They tend to compensate for lower yields by cultivating a larger percentage of their land in drought resistant crop varieties.

The guiding hypothesis for the relationship between farmer water control and organizational support was that the greater the farmer water control provided by an organization, the greater would be the farmer support for organizational arrangements and rules. The measures of organizational support were (1) farmer willingness to pay for water control, (2) farmer support of organizational rules, and (3) farmer willingness to control "free riders."

The analysis indicated that farmers throughout the Niazbeg system give little support to canal *warabandi* assessment, allocation, and maintenance rules. Also, the support was considerably weaker among farmers at the tail of the system than at the head. Thus, organizational support for *warabandi* rules paralleled the locational bias in water control. The greater the distance from the canal water source, the less was farmer water control, and the less was farmer support of *warabandi* rules.

The *warabandi* organizational rule which farmers were least likely to support was the assessment rule because they are charged according to units of time, regardless of whether or not water is delivered during their allocated time. The rule they found least problematic, and were most likely to support, was the maintenance rule.

Sample farmers indicated more support for tubewell assessment rules than for *warabandi* assessment rules. Even though the price per unit of tubewell water is considerably higher than that of *warabandi* water, farmers were supportive because they are relatively certain to receive the water for which they have paid. Seventy percent of farmers stated they were willing to invest in water control by financing a mutually owned tubewell. Consistent with the locational patterns of water delivery, farmers at the tail of the system were somewhat more willing to make such an investment than those at the head.

Problems stemming from the locational bias of the *warabandi* could be mitigated, if not eliminated, through effective local farmer organizations (see Chapters 2, 3, and 4). Through their cooperative efforts in developing tubewell technology and organizations, Niazbeg farmers have already demonstrated the will and capacity to develop viable local organizations, if those organizations can provide greater water control and the means to effectively sanction "free riders." Tubewell organizations have been sufficently effective such that a number of farmers at the tail of the system have been able to rely exclusively on tubewell water. However, the best water control was found on watercourse 3, where farmers have been able to build effective organizations around conjunctive use of tubewell and canal water.

It would appear that any organizational design will have to confront the problem of delivering water among watercourses along the Niazbeg distributary, as well as the problem of water control within watercourses. Failure to organize at the distributary level would make water supply delivery to watercourse inlets (*moghas*) erratic and deficient, which would doom watercourse organizational efforts.

If water control becomes a reality for farmers in an experimental subproject area such as the Niazbeg via effective local organizations, other local organizations designed to provide agricultural services other than water control may then become viable companions to further agricultural productivity. Without developing a viable organizational mechanism for improving farmer water control, however, other organizations are highly constrained in any attempt to improve agricultural productivity or well-being of farmers.

Farmer water control is a global issue, relevant to all farmers who rely on irrigated agriculture in more or less developed countries. This research lends empirical support to irrigation policy which sees water control as critical to enabling farmers to grow more moisture-sensitive crops to achieve greater yields, and which sees water control to be a function of the manner in which farmers are linked to main system management by effective, middle-level, water users organizations. Design of such organizations is addressed in Part One.

6

ORGANIZATION OF A SMALL RESERVOIR SYSTEM IN MADHYA PRADESH, INDIA

David M. Freeman and Vrinda Bhandarkar

Introduction

The objective of Indian irrigation development earlier in this century was to provide drought protection to agriculture (Abbie et al. 1982). That emphasis has changed. Growing population pressures and aspirations for a developed agricultural sector have shifted objectives to better fulfillment of crop water requirements in order to obtain higher productivity per unit of land and capital.

This study examines the interplay between existing physical works and social irrigation behavior in a tank system in Madhya Pradesh, particularly the linkages between main system operators of the tank and main canals and farmers. Breakdowns in the organizational interface between farmers and main system managers account for a large portion of diminished productivity of irrigation water. Before proceeding with the analysis, the problem of local linkage between farmers and representatives of the government is placed in historical perspective.

History

Launched on October 2, 1952, India's community development program was intended to build local community self-reliance. Rural transformation was to be administered through the establishment of zones, called blocks, to coordinate rural socio-economic development efforts (Dantwala and Barmeda 1985). The block consisted of about 100 villages on average, covering

400-500 km^2 with populations in the range of 60,000-70,000 people (Panchanadikar and Panchanadikar 1978:191). The Community Development Program was not a "single, coherent, rationally conceived development program" (Nicholson 1973:10). Resources were scarce, priorities imposed from above often did not fit local needs, and personnel and materials were thinly spread. Many operational difficulties arose and the development effort was hobbled.

Organizations that linked rural people and state administrative organizations were deemed insufficient (Dantwala and Barmeda 1985). Community development analysts recognized that conflict existed between individual interests and the requirements of collective community development action (Nicholson 1973). Improved local organization was required to mobilize local resources, to galvanize local participation, and to provide a link to state administrative agencies.

The Balwantray Mehta Committee, appointed in 1957 to look into the problems of the Community Development Program, suggested a three-tier system of democratic decentralization known as Panchayat Raj. The purpose of *Panchayat Raj* was to involve affected people in planning and implementing programs (Panchanadikar and Panchanadikar 1978). "Public enthusiasm and cooperation, stimulated by government authority, were seen to be the answer to India's poverty" (Nicholson 1973:18). In short, it was recognized that local people had to be organized to conduct development programs, to distribute their benefits, and to link formal state bureaucracies to local people.

In the traditional village, a *panchayat* was a council of five elders. This council attended to collective community needs and maintained stability. The effective power of the *panchayat* --apart from authority gained by arranging consensus--was the power it drew from securing services of leading landlords (Nicholson 1973; Panchanadikar and Panchanadikar, 1978). After independence in 1947, *panchayats* were linked to the larger units of administration at the *taluka* and the district level. This three tier system was intended to provide the missing organizational interface between rural people and the agencies of state administration (Panchanadikar and Panchanadikar 1978; Franda 1979). *Panchayats* would facilitate planning from below by aggregating and channeling the needs of the people. However, decisions about physical targets and resource distribution continued to be made from above by administrators in the central state and federal bureaucracies (Jain et al. 1985).

While development bureaucracies addressed overall plans, *panchayats* became preoccupied with resource distribution. With few resources of their own, they became organizations through which state and central governments channeled material goods to local networks. Given the scarcity of those resources, *panchayats* were quickly dominated by rural elites. Therefore, they did not serve to organize the rural community at large in order to mobilize scarce development resources locally for collective community development (Jain et al. 1985).

There was another problem. In the struggle for control over resources, *panchayats* quickly became bogged down in factional politics. Development bureaucracies found it difficult to remain neutral. Representatives of government bureaucracies and local rural elites forged alliances. The conflicts and incongruities that resulted from this interaction considerably reduced the effectiveness of local *panchayats* as community entities. *Panchayats* were meant to increase the responsiveness of the bureaucracy by acting as an organizational interface between local people and civil service managers. To some unknown extent, this function may well have been served, but the politics of the local *panchayat* in the interface with central bureaucracy has "intensified the ambiguity and conflict in the authority relationship" (Heginbotham 1975:72).

In spite of the development efforts under the Panchayat Raj during the late 1950s and early 1960s, problems with agricultural productivity were not resolved. By the late 1960s, however, technological break-throughs associated with the "green revolution" offered hope, and emphasis shifted to increasing agricultural production by promoting high-yielding plant varieties. It was assumed that new technology would trickle down to the poorer sections of the agricultural sector. However, the green revolution did not spread its benefits as anticipated (Bhattacharya and Sharma 1979). Political and administrative officeholders were associated in the management of organizations created to provide access for the rural poor to credit, seeds, fertilizers, and water essential components of the new green revolution technology. However, organizational channels to reliably convey inputs to users were insufficient. Rural development efforts were constrained by the inadequate linkages between state bureaucracy and local communities (Jain et al. 1985).

In the 1970s, new programs specifically aimed at improving the condition of the rural poor were initiated (Sharma 1980). Previously, development administration was organized with functionally specific technical departments. The new approach required multipurpose field organizations, which were to consider the particular needs of specific localities. Staff were jointly supervised by several departments in order to promote a multidisciplinary approach to rural development. However, *panchayats* remained a major link between the state bureaucracies and rural people.

The Integrated Rural Development Program as implemented did not succeed in decentralizing authority (Jain et al. 1985). It continued to introduce programs from the top down. Over the years, bureaucratic personnel acquired tremendous power by directly controlling resource flows, and local leadership was bypassed (Sharma 1980; Jain et al. 1985).

Organizational Context

The Indian government bureaucracy is strong. It has held together an enormous and culturally diverse country by providing a "steel frame" (Rudolph and Rudolph 1987) capable of driving the nation to attain food self-sufficiency, considerable industrial muscle, and membership in the global nuclear club. The population (a total of 710 million) of many of its 23 states ranks with those of the largest European nations. Uttar Pradesh alone has a population in excess of 100 million people, which ranks it just behind Indonesia, the world's seventh largest sovereign state (by population).

To meet the needs of its people, a nation must create multiple levels of government to serve various sub-groups and units. In the United States (population 230 million), the nation is divided into 50 states, which are further divided into numerous county and city governments. India (population 800+ million) is served by 23 state governments only, 5 of which are marginal. In the absence of adequate local, state, parastatal, and quasi-public local organizations to connect the vast number of villages to the state ministries, the Indian state bureaucracies are only weakly linked to the population in general and to rural people in particular. The capacity of the state to contact the rural people--especially in the agricultural sector, which accounts for 67 percent of the Indian labor force and 39 percent of the gross national product--has remained seriously weak (Franda 1979; Jain et al. 1985; Rudolph and Rudolph 1987).

To further complicate matters, the structure of Indian bureaucracy was defined by the British colonial tradition of administration. British officials viewed their Indian subordinates as having "no moral scruples, [being] inveterate liars, and scheming incessantly among themselves" (Heginbotham 1975:34-36). This attitude had a number of consequences. For one, decisions were made at higher levels without considering particular requirements of local people. Higher officials were regularly rotated to prevent them from establishing circles of self-interest in their jurisdiction, a practice which kept officials from developing knowledge about local conditions. Delay tactics were employed to avoid making decisions. In their overall style of administration, British officials did not appeal to the self-esteem or the conscience of their subordinates, and did not emphasize the importance of including particular site-specific requirements of affected people in their decision making. Given this tradition, the leaders of independent India had to contemplate extensive structural change to implement anything approximating participatory community development. The necessary bureaucratic reorientation has only begun to take place (Nicholson 1973).

The traditional village had a more or less autonomous political structure with little direct linkage to state bureaucracy. "The most important local source of power was land, in the absence of alternative, externally supported power roles" (Nicholson 1973:20-21). The village was also a largely autonomous economic unit under the control of the landlord(s). In the context of static technology and a static economy, initiative, creativity and originality were not highly valued. New ideas and new ways threatened to disrupt the established balance and change the distribution of goods and, thus, threatened to create instability and conflict (Heginbotham 1975).

During the last century, however, the traditional village did not remain insulated. It has become part of a larger administrative system. Land reforms have had some effect on landholding patterns and land tenure relationships (Rudolph and Rudolph 1987). Though empirical evidence is lacking, many feel that with changes in the tenancy laws, an increased amount of land has come to be cultivated under the personal supervision of the owners (Sanyal 1972; Agrawal 1981) who employ new technology that requires inputs supplied by agencies outside the village. The village is no longer an autonomous, self-sufficient unit.

Elections in villages have improved local access to power and opened villages to greater political activity. National political parties have extended their linkages to constituencies in villages. Government development programs distribute valuable resources, and elections provide avenues to improve access to resources. Political alliance also provides an avenue for upward mobility beyond the confines of the village (Plunkett 1984). Awareness of this has increased factional competition for new opportunities. Village elites are competitors in this struggle, and smaller subsistence farmers can fulfill their demands by forming factional alliances with larger farmers even across caste lines (Nicholson 1973).

The power of local leadership now depends on the legitimacy commanded by status and the ability to mediate resource flows between the local faction and the state bureaucracy. An implication is that local leaders avoid programs that impose costs on their constituencies. Leaders are more interested in increasing their power base by controlling resource flows from the state than by organizing local people to mobilize local resources within their village or region. Rural development programs tended to be quickly reduced to subsidy distribution activities. It is no surprise that rural development analysts have judged the experience to be less than successful (Dantwala and Barmeda 1985).

In the absence of effective local organization for aggregating local demands and linking them with state bureaucracies, a dilemma emerges. On the one hand, if professionals in central bureaucracies involve local people, they are quickly confronted with conflicting and often exaggerated demands impossible to accommodate within the constraints of available resources and administration objectives. On the other hand, if professionals do not involve local people, they cannot configure their servies to local needs in a manner that supports sustainable local action. Caught between the rigidity of central administration and the rigidities of local village power constellations, rural development flounders.

Organization of the Main Irrigation System

The structure of bureaucratic authority in Madhya Pradesh is similar to other Indian states, with minor differences. The Chief Minister appoints ministers--elected state legislators--who are assigned portfolios and are responsible for daily administration of their respective departments. Madhya Pradesh is governed by uniform rules and regulations. The structure of the Department of Irrigation in Madhya Pradesh is presented in Figure 1.

The Secretary of Irrigation, not shown on Figure 1, administers his domain through the Chief Engineer. The jurisdiction of the Chief Engineer is divided into circles, each headed by a superintending engineer. The superintending engineer is assisted by a team of executive engineers. Each executive engineer is in charge of one or more divisions, each of which typically comprises 30 to 40 reservoirs. Four or five assistant engineers aid each executive engineer, and each assistant engineer is in charge of a subdivision, which usually contains six or more irrigation schemes. Each subdivision employs five sub-engineers, each in charge of about 7,200 hectares.

Sub-engineers are directly responsible for operating and maintaining canals. Sub-engineers check irrigation measurements and enforce the Irrigation Act. Furthermore, sub-engineers are responsible for assessing and collecting revenue. Each sub-engineer is assisted by at least one *amin* or revenue official, one of whom is provided for approximately every 1,000 ha. *Amins* are supervised by irrigation inspectors; normally, one inspector supervises eight *amins*. A canal deputy collector frequently oversees revenue collection on specific command areas.

A timekeeper, a lineman, and several casual laborers are usually employed to carry out sub-engineer and *amin* instructions regarding the operation and maintenance of the system. Labor is employed as demand dictates. Farmers are not officially involved in operating and maintaining the main system--individually or collectively. However, alteration and even destruction of main system structures, the installation of "unauthorized" outlets, and the use of temporary checks to raise water levels reveals that farmers are centrally involved in *de facto* operation of the main system.

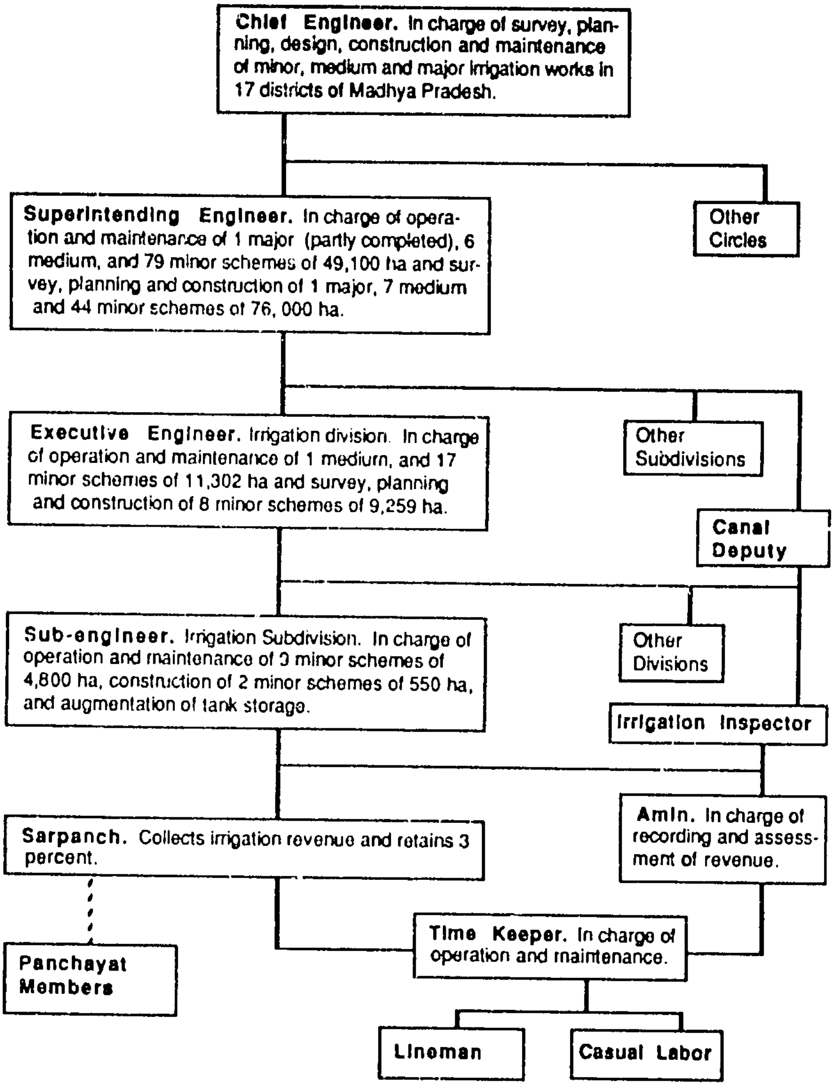


Figure 1. Irrigation Department--Madhya Pradesh

It is in this context that the study reported here examined the organization of the Minor Tank Project. A causal chain was posited and examined with available data: inadequate local organizations operating between main system managers and farmers reduce farmer control over water. With less water control, farmers adapt by reducing cropping intensities and by shifting away from more productive cropping patterns which greatly depend on having reliable and controllable water supplies. The discussion turns now to a description of the minor irrigation system selected as the site of the case study.

Geography

This study was conducted in the central state of Madhya Pradesh, which has the largest area in the Indian union, but a relatively low population density. Madhya Pradesh is well endowed with agricultural resources, but it has not yet mobilized them to significantly reduce rural poverty. A substantial potential exists for increasing both irrigated acreage and output per acre.

The irrigation project studied lies about a half-day journey by road from Bhopal, the state capital. The total project cultivable command area is 4,609 acres. Rainwater flows to a catchment area created by an earthen dam. Two canals on the left and right banks command the irrigated area (Figure 2).

The head village nearest the tank (reservoir) is connected to a nearby industrial town by a fair weather road that is unusable during the monsoon season. Another unpaved road maintained by the Department of Irrigation joins this village to the national highway. No public transportation exists in the irrigation command area.

Started in 1953 and completed in 1958, the Tank Irrigation Project was designed to serve about 2,430 hectares (6,000 acres). The actual annual irrigated area is reported in Table 1. The project was conceived by a landlord living in a village near the system's head. He put forth the proposal and gained approval in 1953. The Department of Irrigation usually contracts with private construction companies to build main system facilities. The landowner who initiated the project was granted the construction bid.

The tank provides water to the system primarily during *rabi* season (October through March). From June to September,

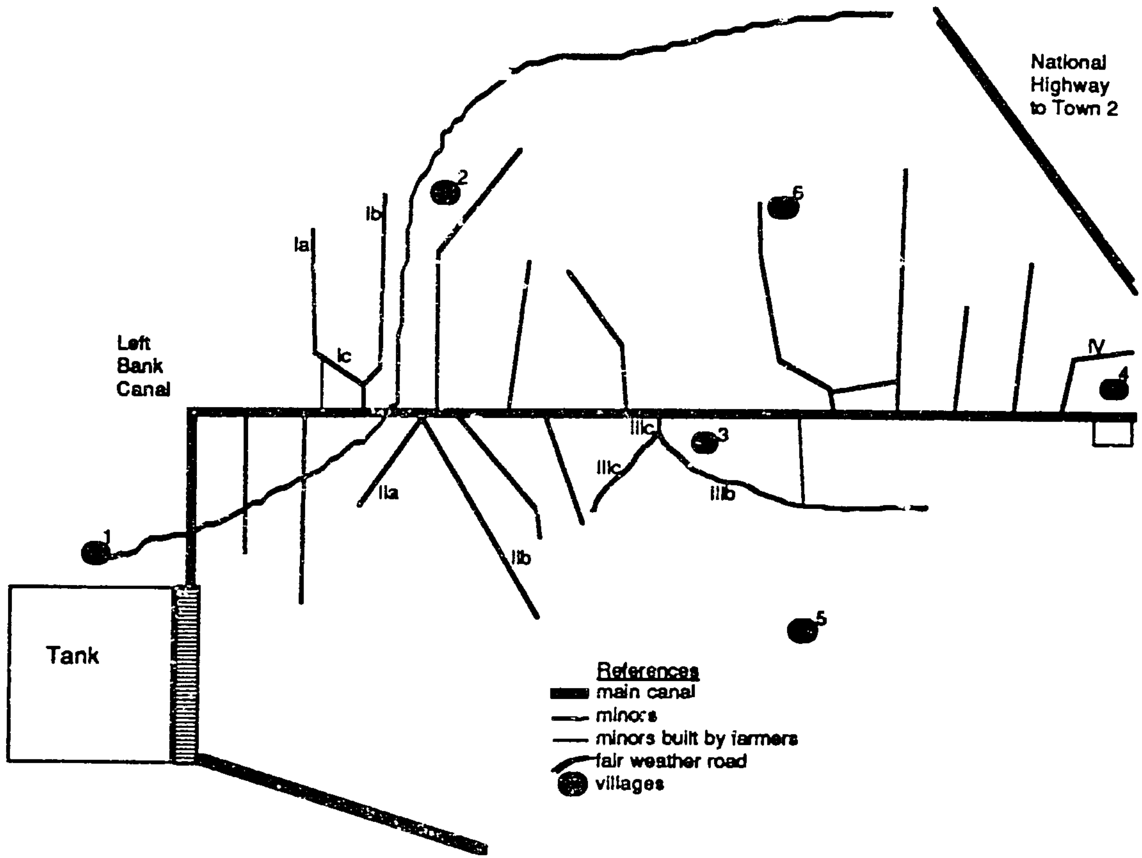


Figure 2. Schematic diagram--left bank layout

Table 1. Annual irrigated area for the tank project (acres).

Year	Kharif	Rabi	Perennial	Total
1959-60		179		179
1960-61	100	179		279
1961-62	122	344		466
1962-63	248	139	110	597
1963-64	248	139	110	597
1964-65	150	685	125	960
1965-66	210	780	293	1293
1966-67	312	202	57	571
1967-68	247	638	2	887
1968-69	325	823	5	1153
1969-70	704	997	27	1728
1970-71				2548
1971-72				3631
1972-73				3039
1973-74	150	1793		1943
1974-75	221	1834		2055
1975-76	212	3155	3	3370
1976-77	211	3183		3394
1977-78	275	1008		1284
1978-79	404	2339		2743
1979-80	607	876		1483
1980-81	466	2408		2874
1981-82	597	2601		3199
1982-83	760	3321		4082

Source: Venkatraman et al. 1984:Appendix D.

monsoon rains are the primary water source. Average annual rainfall for the area is 125.3 cm (49.3 in), with most coming during the summer (*kharif*) monsoon period. Table 2 reports monthly precipitation at Bhopal. Note the substantial variation in rainfall. The highest amount, in 1978, was 146 percent of the average; while the lowest, in 1979, was 38 percent of average.

The dam is an earthen structure 2,600 ft long originally intended to serve irrigation. Its capacity was recently increased to supply water to a nearby industrial complex. Flood water previously flowing over the waste weir is now stored for an industrial demand of 300 million ft^3 (8.50 million m^3) without diminishing irrigation supplies. The original and present features of the dam and tank are summarized in Table 3.

Observations of the tank gauge register (Table 4) reveal that the tank filled almost to full reservoir level in all years except 1979-80, a drought year. By comparing capacity available at the beginning of the irrigation season to that at the end

Table 2. Monthly rainfall at Bhopal from January 1977 to December 1983 (in centimeters).

Month	1977	1978	1979	1980	1981	1982	1983	Average
Jan	0.8	1.5	4.9	0.0	1.4	7.1	1.0	1.7
Feb	4.2	4.4	3.8	0.5	0.0	0.9	0.0	0.5
Mar	1.8	0.6	0.2	0.0	0.4	0.0	0.0	0.9
Apr	1.3	2.0	0.0	0.0	0.1	0.3	0.1	0.4
May	1.0	0.0	2.1	0.0	2.6	0.6	2.0	1.0
Jun	26.0	22.6	7.7	30.1	16.8	13.9	10.1	14.0
Jul	30.9	82.2	15.8	16.0	28.2	32.2	22.3	49.1
Aug	52.2	56.6	18.6	42.2	33.5	52.4	49.1	27.8
Sep	22.3	6.4	1.2	2.3	7.2	10.1	54.4	24.0
Oct	2.3	0.0	0.1	0.3	3.7	1.9	6.4	3.2
Nov	3.7	1.3	11.6	0.0	1.0	6.9	0.0	2.1
Dec	0.3	6.4	0.9	4.4	5.0	2.0	0.0	0.6
Jun-Sep	131.4	167.8	43.3	90.6	85.7	108.6	135.9	114.9

Source: Venkatraman et al. 1984:Appendix D.

Table 3. Dam and tank features.

Feature	Original	1984
Top of bund	R.L.* 1514 ft	R.L. 1515 ft
Maximum water level	R.L. 1509 ft	R.L. 1509 ft
Full tank level	R.L. 1505 ft	R.L. 1509 ft
Sill level of sluice	R.L. 1487 ft	R.L. 1489 ft
Gross storage capacity	684 million ft^3	984 million ft^3
Live storage capacity	624 million ft^3	924 million ft^3
Dead storage capacity	60 million ft^3	37 million ft^3

*Reservoir level.

Table 4. Yearly opening and closing dates of canal for *rabi* irrigation, with reservoir water levels (in feet).

Year	Opening Date	Water Level (ft)	Closing Date	Water Level (ft)
1973-74	10/25	1504.5	3/31	1496.4
1974-75	11/15	1502.5	4/5	1495.3
1975-76	10/4	1504.9	4/5	1493.5
1976-77	10/1	1504.4	3/18	1494.8
1977-78	10/9	1504.5	3/29	1498.1
1978-79	10/1	1504.1	3/21	1494.5
1979-80	10/3	1495.0	2/20	1487.0
1980-81	10/1	1500.0	2/20	1492.3
1981-82	10/3	1501.8	4/17	1494.8
1982-83	10/15	1500.8	3/17	1487.0

Source: Venkatraman et al. 1984:Appendix D.

Table 5. Utilization of tank water for *rabi* crops.

Year	Capacity (mft³)			Area (mft³)			Evap. Losses (mft³)	Net Capacity (mft³)	Use (mft³/acre)
	At Start	At End	Used	At Start	At End	On Avg.			
73-74	651.7	246.7	405.0	63.3	38.1	50.7	130.8	274.2	0.153
74-75	532.0	206.4	325.6	56.4	35.0	45.7	118.0	207.6	0.113
75-76	677.1	146.2	530.9	64.7	28.0	46.4	119.6	411.3	0.130
76-77	645.4	189.2	456.2	63.0	33.4	48.2	124.3	331.9	0.104
77-78	651.7	315.3	336.4	63.3	42.7	53.0	136.8	199.6	0.198
78-79	626.4	179.5	446.9	61.9	32.3	47.1	121.5	325.4	0.139
79-80	195.7	36.6	159.1	34.2	9.9	22.0	56.8	102.3	0.117
80-81	416.1	117.7	298.4	48.9	23.7	36.3	93.6	204.8	0.085
81-82	493.2	189.2	304.0	54.0	33.4	43.7	112.8	191.2	0.074
82-83	450.8	36.6	414.2	51.3	9.9	30.6	78.9	335.3	0.101

*mft³ - million cubic feet.
Source: Venkatraman et al. 1984:Appendix D.

of the season, the quantity utilized for irrigation can be determined (Table 5). Dividing the net capacity used (Table 5) by the *rabi* acreage reported in Table 1 gives a rough estimate of consumptive use in million ft per acre (Table 5). Consumptive use of water varied from 0.074 million ft³/ac to 0.198 million ft/ac.

In addition to the dam and tank, main system facilities consist of right and left bank canals. The system was designed to operate continuously day and night for the full irrigation period with all minors and outlets functioning simultaneously. The left bank canal (LBC), which was the focus of this study, is 7.65 km long (Table 6). Originally, the first 1.35 km of the LBC consisted of an earthen bank on the uphill side and a single masonry wall on the downhill side. Later, a masonry wall was added on the uphill side, and the downhill side was raised and strengthened. Concrete fillets were introduced at the inner edges to reduce leakage, and three reaches were lined with flagstone. The remainder consisted of double-banked earthen channels (Venkatraman et al., 1984).

Six villages are located along the left bank canal. The head village, Village 1, with a population of 1,700 is the largest (Figure 2). At the time of this study in October-March (*rabi*) 1984, the total command area of the left bank was 2,400 acres.

Industrial Town is the closest urban area to the command area. It has attracted a large labor force. Many farmers have taken full-time jobs in Industrial Town and farm part-time

Table 6. Location, capacity, and proposed area served by minors along the LBC.

Section Number	Location (mi)	(km)	Capacity (cfs)	Proposed Area for Irrigation (ac)
1	1.27	2.04	1.27	125
2	1.84	2.96	0.78	75
3	2.04	3.29	2.97	280
4	2.33	3.75	3.85	337
5	2.68	4.32	0.62	60
6	2.75	4.42	1.50	145
7	2.95	4.75	1.03	100
8	3.33	5.36	1.10	100
9	3.47	5.58	2.83	263
10	3.71	5.97	3.79	355
11	4.07	6.55	0.85	80
12	4.36	7.01	4.30	430

with the help of family members. Because of the development of the industrial complex, farmers complain about labor shortages and high costs of labor, especially in the harvesting season. To overcome this shortage and the resulting high labor costs, many farmers have bought tractors. Tractors have become easier to purchase due to the availability of institutional credit. They are also rented by smaller farmers.

The command area of the left bank canal is characterized by heavy clay soils that are difficult to work when wet. Farmers traditionally ploughed the land before the monsoons to capture moisture for growing *rabi* crops. The main traditional *rabi* crop grown was a tall variety of wheat. Others were lentils, chick-peas, and *arhar* (a legume). A few rain showers during *rabi* were usually sufficient to grow these traditional varieties given the moisture retention properties of the soils.

With the advent of irrigation, farmers started growing paddy (rice) during *kharif* and in fields assured of sufficient irrigation water during *rabi*. Soybeans are also cultivated in areas assured of sufficient water in *rabi*. If a *kharif* -op is cultivated, it is followed by a fast-growing dw variety of wheat--if a reliable and sufficient supply of water is available. The traditional, tall, drought-resistant variety of wheat is grown in areas that receive an insufficient and unreliable supply of water. It is common to find farmers irrigating the tall variety of wheat during *rabi*. In unirrigated or unreliably irrigated fields, lentils, *arhar*, and garbanzo beans are grown.

Study Design

Main system water supply and individual farmer crop demands must be matched. To make this match, effective organized action between farmers and the main system is necessary to acquire and deliver water to farmers' fields productively and reliably. Effective action requires appropriate organizational rules and tools for water control. It can be hypothesized that in the absence of adequate local organization for matching main system water supply to local farmer demand, geographic or locational characteristics will largely dictate water availability and control. Water availability and control will be associated, in turn, with cropping intensities, crop varieties, and crop yields. In the absence of adequate local irrigation organization to overcome effects of location, an irrigator's position along the "head" or "tail" of a canal necessarily creates inherent advantage or disadvantage. This section presents the study design used to systematically investigate the impact of farmer location on two important variables cropping intensity and cropping patterns.

Given the lack of organizational agreements among farmers and main system managers, and the absence of water control and measurement structures in the system, it was posited that location of the farm would largely determine water availability and control. The effect of location (independent variable), therefore, was investigated as it affected cropping intensities and patterns (dependent variables).

The main system organization investigated was that of the Department of Irrigation as described in the preceeding section. The department's operation was examined to determine how it allocated water, maintained the system and resolved conflict.

Dependent and independent variables employed in the farm-level analysis are presented in Figure 3. Sample farmers were interviewed to determine cropping patterns, intensities, and yields for 1983-84. The reliability and, therefore, the validity of yield data was questionable for the following reasons:

1. Farmers did not keep records of yields.
2. Sample farmers who were leasing lands had an incentive to report less than they produced because of their tenancy agreements.
3. Some farmers failed to report yields reserved for home consumption or local barter.

4. Sample farmers may have underestimated their yields to emphasize their water problems.
5. Many farmers who owned more then one field reported yields aggregated over fields with different water control situations.

Such problems can be overcome given sufficient research resources, but such resources were not available. Therefore, it was not possible to examine the effect of varying water control on crop yields.

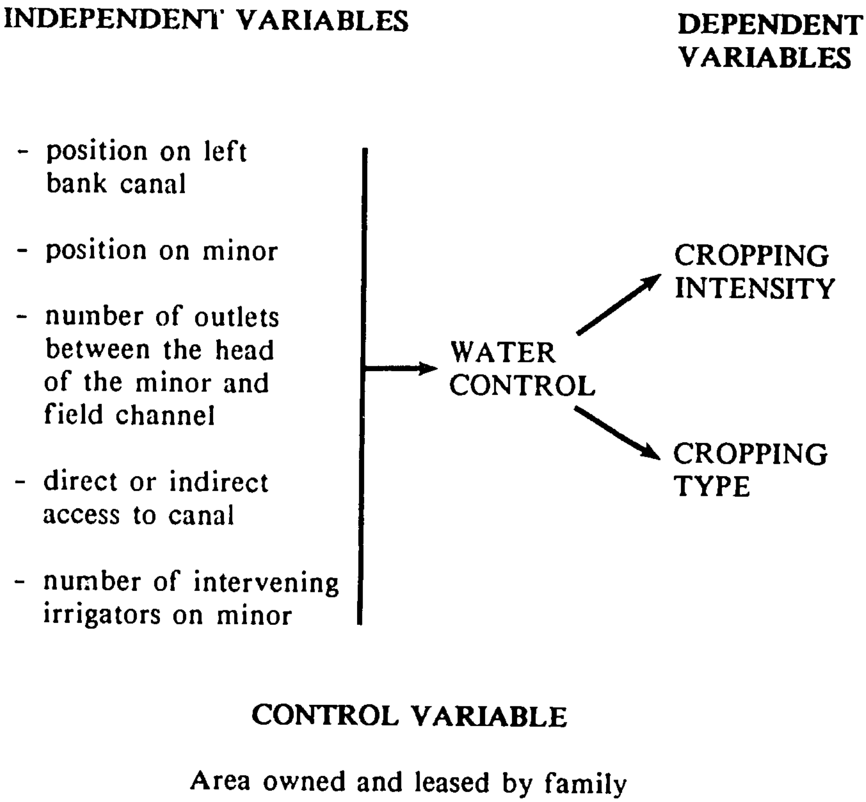


Figure 3. Design for investigation of a farm level irrigation.

Cropping patterns were defined by varieties of crops sown in *kharif* and *rabi*. Farmers categorized their crops as follows: (1) the crop type sown (e.g., soybeans, paddy, lentils, or wheat) and (2) seed variety (lower yielding, but drought-resistant, or higher yielding, but more water demanding). Because market demand for a crop was expected to uniformly affect this small irrigation system, one could expect farmers to shift to higher yielding varieties--if all other things were equal. Of course, if all other factors were not equal, if a key factor of production--irrigation water--for the more water sensitive, high-yielding varieties was not sufficiently available, one could expect a shift to less water demanding, but lower yielding crops. Therefore, adjustment of cropping patterns represents a central farmer strategy for responding to water supply situations and reflect farmer judgments of water availability and control.

Cropping intensities were measured by determining the percentage of land under cultivation in *kharif* and *rabi*. Farmers attempt to cultivate two crops annually. Intensity expresses the proportion of the potentially cultivable land actually placed in production for both seasons of the year. A cropping intensity of 200 percent would indicate that all potential cultivable land was placed in production during both *kharif* and *rabi*.

Farmer water control is affected by farm location in the command area (the independent variable) in at least three ways:

1. Position on the main canal; i.e., head, middle, and tail. These designations were determined by dividing the left bank canal study area into thirds by measuring distance from the headmost water user.
2. Position on the minor. Minor canals were segmented into thirds (head, middle, and tail). Also, the number of outlets between the head of a minor and the farmer's field outlet were also recorded to provide another measure of location.
3. Field location. Field location was identified by its connection to, or its distance from, the minor supply canal. A farmer whose field was not directly served by a minor (i.e., the field received water through intervening fields) was dependent on other farmers for water.

The most advantageous location was one directly served at the head of a head minor and without one or more intervening fields. Data were also gathered on whether water was obtained directly from the left bank main canal or from a minor.

Irrigation in fields was recorded in hours of water application. However, sample farmers originally responded by giving days of water application. A "day" was never sufficiently defined by the farmers, despite probing. Therefore, for purposes of the study a "day" was considered to equal 9 hours. Since day length could only be estimated, hours of water application are approximate values.

Size of a farming operation might affect farmer ability to construct water control structures at the main system and farm levels, and it might affect capacity to gain control over water in other ways. Therefore, the size of a farming operation was viewed as a control variable. Size of the farming area was measured by calculating the area (in acres) of sample fields (bunded units), the area owned personally by the individual irrigator, and the land owned by the family. Many farmers managed and cultivated land owned by different members of their family. For study purposes, farm size was determined to be the amount of land owned and leased by the family.

In gravity-fed irrigated basins, land leveling is important because it assures even distribution of water to plant root zones, although some minimal gradient may be required for drainage. Data on land leveling was elicited from irrigators in interviews that revealed whether or not, in the sample farmer's judgment, a given field had been properly leveled and remained level at the time of the interview.

Tenancy agreements can also affect an operator's incentive to construct local water control structures and one's standing in the irrigation community. Tenancy agreements were found to be of two types: (1) Cost and yield sharing agreements between owners and tenants and (2) A fixed cash rental arrangement in rupees per acre.

This particular tank irrigation project in Madhya Pradesh was chosen for two reasons. The Madhya Pradesh Department of Irrigation had selected the command area for rehabilitation, and the system was identified by authorities as "typical" for that region.

Because key informants had diverse backgrounds, the interview schedule was tailored to their specific backgrounds and was wide ranging and unstructured in nature. The information proved valuable in gaining an understanding of the command area, farming practices, and organizational patterns. Reliability was established by counter-checking data during interviews. Key informants represented: (1) Department of Irrigation, Department of Agriculture, and social welfare agencies (seven); (2) political leaders occupying village administrative positions (four); and (3) farmers, ranging across a spectrum of farming situations and locations in the area (ten).

The sample of farmer respondents and fields was designed to maximize variance on the dependent variables--cropping intensity and cropping patterns. Two minors at the head and two minors at the tail of the left bank canal system were chosen for intensive study. Since the number of farmers on each minor was small, the sample included all farmers working fields on each selected minor. The sample consisted of forty-two irrigators who farmed a total of 138 fields. All of the sample farmers (27 farmers at the head and 15 farmers at the tail) operated fields on more than one minor. Sample respondent distribution and their field locations are reported in Table 7.

Table 7. Distribution of sample respondents (n=42) and fields (N=138)

Minor	Fields	Number of Respondents* with Field(s) on Minor
Ia	13	5
Ib	21	14
Ic	2	2
IIa	18	11
IIb	18	8
IIIa	3	3
IIIb	42	26
IIIc	1	1
IV	20	10
Total	138	80*

*Greater than 42 because all 42 respondents operated on multiple minor canals.

Findings--Main System

In Madhya Pradesh, water charges are collected by the Department of Irrigation and not as a part of land revenue, as is the case in other Indian states. The *amin* keeps records of area irrigated and crops grown, and is to draw up agreements for water allocation between the Department of Irrigation and individual farmers. Prior to the organization of water *panchayat*, *amins* also collected water charges. The subengineer's duty is to examine all records kept by the *amin*. The subdivisional engineer checks about half of these records, and the executive engineer verifies a small percentage of them.

At the beginning of each irrigation season, the executive engineer is supposed to call a meeting of all irrigators to arrange a water schedule. Agreements are to be made with each individual farmer, and main system management is to deliver water to the field outlet in accordance with each agreement. Such agreements are based upon projections of available water in the tank and crop water demands. Farmers not drafting agreements cannot be refused water; rather they are assessed at one and one-half times the regular rate. Farmers with agreements, but who do not receive water because of a system malfunction, can appeal to the executive engineer for a refund. After a review, the water charge may then be adjusted. When farmers default on their payment a new agreement cannot be drafted until outstanding charges are paid. If charges mount across seasons, the sub-engineer has the judicial power to auction the farmer's land to recover the money, but this has not happened. Conflicts over water in the command area are to be settled by the sub-engineer. Conflicts not resolved at this level are referred to higher authorities.

Madhya Pradesh employs one state-wide tariff structure for irrigation water without respect to actual local costs. Water revenue is expected to cover only a portion of the costs of irrigation operation and maintenance. A yearly flat rate of Rs. 10/acre is charged for all cultivable lands in the command areas whether farmers use water or not. An additional seasonal charge of Rs. 12/acre is levied for using water in field preparation. Additional water charges depend on crop type and are levied regardless of quantity used. The water charge structure is presented in Table 8.

In March 1984, two irrigation *panchayat* were introduced to the command area. Only those irrigators who had fully paid

Table 8. Irrigation water charges in Madhya Pradesh.

Name of Crop	Water Charge (Rs./ac)
Rice	24.0
Wheat	
High-yielding varieties	37.5
Local varieties	25.0
Soybean	18.0
Arhar, garbanzo, lentils, peas	17.0

their water charges could contest and vote in the irrigation *panchayat* elections. For every 500 irrigators, one five-member irrigation *panchayat* was to be elected to represent the irrigators' interests. *Panchayat* members then chose a *sarpanch.* Beginning with *rabi* 1984, the *sarpanch* was given the responsibility for collecting water charges. The *sarpanch* is authorized to retain 3 percent of the revenue collected; the rest goes to the Department of Irrigation. Apart from revenue collection, *panchayat* are advisory bodies with little power to manage irrigation systems. They are expected, in an ambiguously defined manner, to assist in resolving water conflicts and to decide water rotation schedules. However, no powers have been specified for them that have been given legitimacy by agreement among local irrigators or main system managers.

Assessment of water availability is made about two months prior to sowing for *rabi.* The executive engineer, the Deputy Director of Agriculture, and influential cultivators are to participate in this assessment. Time tables are then to be set for *rabi* crops, along with tentative schedules for water releases.

Despite the claim of 24-hr operation, night irrigation is rarely practiced. The canal is opened each day between 3 a.m. and 8 a.m. and is usually closed between 4 p.m. and 6 p.m. Opening and closing times have varied by season and demand. Since, the main canal was designed to serve all 11 minor canals simultaneously, no gates or other control structures, and no measurement devices, were incorporated into the design. Lack of control and measurement structures means that no assembly of organizational rules can be devised to match main system supply to farmer demand in a manner that serves the *de jure* conceptions. Without control structures, in low demand periods much water flows past fields, while during high demand periods, many farmers obtain insufficient supplies or go entirely without irrigation water.

In actuality, heavy conveyance losses prevent all minors from operating simultaneously. To allocate water to the lowest four minors, the first four minors must be blocked. Because water is more readily available nearest the tank, farmers at the head are more willing to make contractual agreements with main system managers. Farmers located toward the tail are reluctant to make contracts, for to do so would obligate them to pay a fee for water supplies that are deficient in quantity and timing. At times, tail farmers reported that they wait for water up to 10 days after their requests because farmers all along the canal take water as it flows by.

Few farm field ditches exist in the command area. Those that do typically do not function because their bed levels are higher than the minor canal supply level. Farmers improvise by using pipes to construct outlets and waterways not authorized by the original design, and by building stone check structures to elevate flows. Many farmers criticized the government for incompetence in surveying and constructing minors, watercourses, and the few farm field ditches. Farmers are rarely involved in locating or constructing waterways.

A number of watercourses have been dismantled by farmers. Table 9 compares field channels in use by source of construction. Note that slightly over one-third of the field ditches built by the main system management were no longer in use by the time of the study.

Table 9. Field channels in use by source of construction.

Field Channels Built By	Not in Use	In Use	Total
Individual Farmers	1	35	36
Groups of Farmers	0	23	23
Government	7	13	20
Total	8	71	79

Flagstone linings had been installed in some canal reaches, but many farmers had removed the stones to use elsewhere as check structures to divert water to minors. Farmers claimed that such effort has been necessary due to poor alignment of main and minor canal beds. Land ceilings in Madhya Pradesh limit a person to owning not more than 75 irrigated acres, or 125 unirrigated acres. When minors were built, they were deliberately designed to bypass certain lands, technically preserving them with unirrigated status. However, their proximity to the minor allows water to be "lifted" by landlords for irrigation.

Poor canal alignment and the system's inability to simultaneously operate all minor canals led farmers to build many unauthorized outlets. Forty-two outlets on the main canal exist that are not part of the original design. These outlets, which were poorly designed and aligned, are a source of leaks; they diminish canal delivery efficiency. Furthermore, when farmers install checks to direct water into their outlets, they impede downstream water flow in ways not originally intended by the designers.

The Irrigation Department did not distribute water along minors. Once water entered the minors, farmers allocated it among their outlets and diverted it to their fields using temporary earthen, wooden, and stone checks. Given the lack of organization to make and enforce cooperative agreements, it was not surprising to learn that minimally necessary flows of water were reported to be rarely observed by farmers in tail reaches of the command area.

Revenue to fund continued operation and management of Madhya Pradesh irrigation projects comes from local farmers via water charges. However, financial allocation decisions are made by the state government with no local input. Farmers, therefore, displayed little interest in the allocation of main system revenue. Laborers hired by the Department of Irrigation worked under the direction of main system management which operated with little sensitivity to local farmers' definitions of priority.

Despite the apparent calm displayed by main system management and farmers, water allocation and facilities maintenance proceeds as an intensely political process. The command area has become highly politicized as irrigation officers tend to act on behalf of local, powerful factional leaders. Most officials are transferable employees. If they fail to fulfill the demands of influential farmers, they typically find themselves threatened with relocation to more remote and less desirable projects. Promoting a conception of "equity" in water distribution could be expected to disrupt standing agreements among factional groups.

Job placement of main system officials was an issue of great importance. Executive engineers, divisional engineers, and sub-engineers reported frequent interaction with local politicians to seek career advantages or to protect themselves from adverse moves. Powerful farmer leaders reported taking personal grievances directly to the executive engineer, who could threaten to transfer the targeted individual. In fact, a sub-engineer was recalled during the research period because he failed to satisfy the expectations of a faction in Village 4.

Sub-engineers, who represent important potential links between irrigators and the main system administration, were placed in a difficult position. On one hand, involvement with factional farmer leaders threatened to compromise main system operational standards. To respond to local requirements, engineers had to become involved in administering local inequities endorsed by local factions. On the other hand, to look to main system expectations was to cut off linkage to local realities and needs. Key informants conveyed the message that it was safer to reduce involvement in local irrigation problems as much as possible and look toward higher ranks in the main system for approval.

The *amin* was hard pressed to serve 500 farmers. Traveling by bicycle, he attempted to record and enforce agreements. Delinquent farmers were charged one and one-half times the regular water rate, but although such assessments were easily recorded, they were not so easily collected. In addition, nobody was denied water, despite accrued unpaid fees. Though land can be auctioned off to recover delinquent accounts, this is perceived as extreme and has not occurred in the study area. In fact, it was estimated that 150 farmers in Village 1 owed about 80,000 rupees, a substantial sum compared to the annual maintenance grant of Rs. 83,000 received from the government. No informant or sample farmer advanced the view that defaulters would be penalized. Officials reported that small farmers paid more routinely than large landholders. Although interviews revealed substantial numbers of farmers in both categories who were in default, an exact number could not be determined.

Until recently, land could be bought and sold without collecting overdue revenue. The new owner could not be charged, and former owners refused to pay. In cases of land dispute when proprietorship was in question, assessments were simply not made. In 1984, a new regulation was implemented which levied a 150 percent charge to defaulters. A few farmers responded and paid past dues. Further incentive to pay dues came in political form. Farmers in default were deprived of participation in local *panchayat* elections. *Sarpanches*, working on behalf of the water *panchayat*, were motivated to maximize fee recovery since they retained 3 percent of collected irrigation revenues. Yet, by the summer of 1984, only a small portion of past due revenue had been collected--probably less than 15 percent.

Irrigators were to request water by filling out and submitting a form to the sub-engineer. However, farmers in Village 1, located near the sub-engineer's office, bypassed this process and directly petitioned the *amin* and even casual labors. Those in the other villages felt compelled to send their written request forms with a security guard (*chowkidar*) to ensure delivery.

When an "adequate" demand for water accumulated, the sub-engineer released water. To be defined as adequate, requests were to equal 100 acres or 10 to 15 farmers. However, during *kharif* 1984, it was observed that water releases for 10 to 15 acres would occur in the head reaches. To elicit actions, tail farmers had to wait for aggregation of demands from large acreages--due to greater canal losses. Demands from all farmers on all minors tended to peak together, which exacerbated conflict. In 1984 *kharif*, monsoons were late, resulting in severe water shortages. Supplying household water--especially in Village 1--became a significant problem. During this time, water released specifically for tail farms failed to arrive in sufficient quantities or on time due to diversions by intervening irrigators.

All sample farmers expressed dislike for night irrigation. Those at the head refused to irrigate at night. During peak irrigation season, the tank sluice was open 24 hours a day, with night irrigation at the tail reaches. The rules stated that water should be issued from tail to head. However, in the absence of organizationally enforceable schedules and the lack of command area meetings between irrigators and officials to ensure implementation of such a procedure, distribution actually occurred from head to tail.

An illustration of allocation problems is in order. During *rabi* 1983-84, farmers at the head of a minor canal (approximately 2 miles from the tank) who needed to irrigate fields at elevations higher than the minor, installed small, crude check structures to elevate water for diversion. This 100-acre area required 15 days to irrigate, after which time the farmers removed the check structure. During this period, hired labor unplugged outlets to the head minors at about 5:00 p.m. each day to allow water to flow downstream to the tail of the main canal. Farmers at the tail, 4.6 miles from the tank would begin to receive water by about 11:00 p.m. However, head farmers rechecked the channel and reopened their minors by 8:00 a.m. each day, again depriving the tail of all flow. Only when irrigators at the head stopped irrigating did tail farmers receive water, and then the supply was reduced due to conveyance losses and diversion by intervening irrigators.

A topographical survey in May, 1984, revealed that substantial undocumented acreage owned by large landowners was being served by the irrigation system. The landowners had arranged to have such acreage removed from official records. Such lands were served by unauthorized outlets, but in reality no operational distinction existed between authorized and unauthorized outlets. In fact, the Department of Irrigation had installed pipes at some illegal outlets--evidence that farmers working in small networks with main system officials informally modified the system. Factions, with and without the assistance of main system management, optimized the situation as best they could, but the individual and small group approaches, while rational, came at the expense of wider system performance, downstream irrigators, and any sense of common irrigation community enforced by viable organization.

Irrigation officials reported feeling helpless in the face of seriously inadequate physical structures for water control, factional farmer alliances in defense of existing allocations, and a lack of organized linkage to farmers. Water allocation had become a function of tank proximity and political influence. A small sub-set of farmers advantaged by location, land endowments, and political strength were able to take what they wanted, when they wanted it.

The Irrigation Department maintained the dam, canals, minors, and roadways. Hired labor was usually drawn from Village 1 during April, May, and June. The road through the command area was kept solely for Irrigation Department vehicles, and road repairs consumed a large portion of the annual maintenance budget. Unfortunately, the route was not an adequate path for inspecting main or minor canals. Canal inspection was performed on foot or bicycle, but only rarely by irrigation officials. Untrained hired labor generally inspected the canal. News of breaches was almost always brought to main system managers by messengers sent by farmers.

Annual canal cleanings have been required to remove silt and other material produced largely by monsoon flooding. However, lack of funding has reduced the frequency and quality of cleaning. Hired labor suffers no direct repercussions for failure to maintain high standards. They are not directly accountable to farmers, nor are their superiors. Laborers, hired *ad hoc* on an hourly wage, possessed little technical knowledge. Cleaning and repairs seldom followed systematic procedures.

No fixed cleaning schedule existed for minors, although cleaning them has generally been performed when labor has been available after *kharif* harvesting and before *rabi* ploughing. Availability of time between seasons, financial resources, and the factional leaders' relationship to main system managers directly determined how often a minor is serviced. There was tremendous variability in cleaning practices--minors were cleaned yearly, bi-annually or never. Key informants reported that minors serving more powerful irrigation factions obtained attention proportionate to their capacity to direct main system laborers to their channels.

It appeared that no standard procedures were followed to resolve or manage irrigation conflicts. Existing regulations--written, but unduly complicated and largely unenforced--have been open to dispute and varying interpretation. Furthermore, any given interpretation is likely to offend a farmer faction. Hence, officials in the Department of Irrigation have attempted to stay out of local disputes. They reported that when they have intervened, they have sought solutions by manipulating water flows in the few ways available to them. Some influential farmers regularly petitioned the Department, especially to request repeal of water charges. The executive engineer used "discretion" in responding to such requests.

No formal farmer organization has existed that was capable of supporting a collective irrigation agenda for the community of irrigators. The absence of an appropriately designed local organization, consisting of legitimate social rules for use of physical tools, has left a partial socio-political vacuum into which opportunistic individuals and groups have stepped to determine how water should be distributed, facilities should be maintained, and conflicts should be resolved. Representatives of powerful local factions manipulated officials for immediate gain. The combined effects of arbitrary treatment of protested water fees, unauthorized irrigation of lands, capricious water schedules, and inadequate water supplies in terms of timing and quantity have meant that at least some farmers in all reaches of the command area experienced problematic service.

Sample farmer interviews revealed that minor command areas were not perceived by farmers as a social unit. Irrigators made water demands, asserted grievances, and discussed allocation strategies and maintenance needs in the villages. Key informants and sample respondents revealed that farmers at the canal head (Village 1) take conflicts to the *sarpanch* of the village *panchayat*. Tail villagers have resorted to depending on the wisdom and influence of their village elders, one major reason being that elected members of "their" *panchayat* live in another village. Any organization to construct field channels is done within villages rather than between villages.

Village solidarity varied. For example, Village 4 (population 467) was relatively cohesive. Farmers there had no intra-village court litigation cases, and disputes were managed internally at the village level. Village 1 (population 1,700) was factionalized by both religion and caste. Disputes frequently have been violent, and many have ended in court. Respondents reported that the power of a faction is measured by the extent to which public officials could be influenced to dispense resources. Faction "A", a dominant group in Village 1, had strong ties to political leaders in the irrigation bureaucracy. Informants identified Village 1's faction in power as consisting of one extended family. This family faction monopolized links to main system management during the study. However, in specific irrigation disputes beyond the kinship circle of Village 1, the faction was ascribed little legitimacy by other disputants. Faction A was perceived by others as simply furthering its own interests.

Village 2 (population 133) is virtually a suburb of an industrial town. Its inhabitants possessed little land in the command area, and the few farmers resident there operated individually. Irrigators of Village 3 (population 178) were primarily small farmers. The large landholders were absentee and did not participate in local politics. Farmers of Village 3 had no factional leaders in contact with state administrators.

Village 1 irrigators unconnected to faction A acted individually when requesting water. At the tail, however, 10 of 16 sample farmer respondents in Village 4 reported that they jointly sent water requests to main system management with their *chowkidar*.

Minor IIIb served Villages 3 and 4 (Figure 1), but ran uphill from Village 3 to Village 4. With farmers attempting to run water uphill toward Village 4, fields in Village 3 were easily flooded. Consequently, farmers of Village 3 reduced the size of the minor inlet to reduce flooding. In response, large landowners in Village 4 constructed their own minor downstream of Minor IV, at a level slightly higher than the canal bed. They usually wait for tail farmers on Minor IV to finish irrigating before diverting water to their minor. Despite collective action by villagers in Village 4 to overcome the inadequacy of Minor IIIb, flooding still occurred regularly, and conflicts with irrigators in Village 3 and Village 4 have continued.

Unresolved water conflicts fetter local organization. Disputes at the village level were, of necessity, negotiated within and between factions without the aid of legitimate organizational leadership representing the community of irrigators as a whole. In the situation under study, a leader affiliated with one faction had no necessary standing with another. Festering water conflicts have compelled individual farmers to adapt to circumstances, but they have not tried to resolve conflict by developing representative local organization.

During *rabi* 1983-84, irrigation *panchayat* elections were held during the peak irrigation period. The elections mobilized farmer involvement in state government policy. Voting required paid accounts. However, the election process was not straightforward since elders representing existing village factions had met and negotiated membership composition of *panchayats*. The five farmers selected by the elders for each of the irrigation *panchayats* then elected one member of each *panchayat* as the *sarpanch*. Since each *sarpanch* retains three percent of irrigation revenue, there is incentive for influential irrigators to aspire to this office.

For example, two *panchayats* represented the left bank canal command area. Leaders of villages 1 and 2 together selected members for one irrigation *panchayat*, while leaders in the remaining four villages identified members for the other *panchayat*. Key informants reported that most irrigators did not participate in the election because they were uninformed about it. Furthermore, the many revenue defaulters could neither contest nor vote. In the head reaches, only 10 to 15 votes were cast, with about the same number of votes reported in the tail reaches. One person was selected to a *panchayat* who was not consulted on his nomination. He was unaware of the proceedings until he was informed that he had been elected. The impact of voting on the selection of *panchayat* members was negligible.

Panchayats, as designed and operated, did not provide a well-organized interface between farmers and bureaucracy. They were controlled by small, closely-knit groups, usually bonded by kinship affiliations. *Panchayats* had neither authority nor widespread legitimacy to act as a mediating force to match water supplies to demands, to make and enforce rules on behalf of the community of irrigators, to resolve conflicts, or to undertake sustained programs of maintenance on behalf of the system. Farmers had no recourse but to rely on themselves and their factions to gain whatever water control could be had under the circumstances.

Findings--Farm Level

General Context

Wild flooding of basins is the only irrigation technique employed in the command area. This practice does not allow for precise water application in each portion of a field. Unleveled fields make water application uneven. Furrow irrigation has been tried in the past, but farmers reported that it was too labor intensive and made it difficult to operate their implements.

Table 10 reports the number of *rabi* irrigations applied to sample fields. The first irrigation was almost always for field preparation. Ten fields at the head were irrigated 21 days after sowing high-yielding varieties of wheat. When drought-resistant wheat was planted, a 40-day irrigation interval was usually observed.

Note that 21 percent of the fields received no irrigation water, but most fields that received water were irrigated two or three times. The distribution (by location) of fields not

Table 10. Sample field irrigations, *rabi* 1983-1984.

Number of Irrigations	Number of Fields
0	29
1	9
2	51
3	44
waterlogged*	5
TOTAL	138

*Fields seriously waterlogged by canal seepage; no irrigation was applied.

Table 11. Location of sample fields not receiving water during *rabi* 1983-1984, relative to fields receiving water (number and percentage of the total number of fields in category).

Location on the Canal	Location on the Minor (n=29)					
	Head		Middle		Tail	
	No Water	%	No Water	%	No Water	%
Head	3	20	5	16	10	40
Tail	3	19	3	18	5	28

obtaining irrigation water is reported in Table 11. Even in head reaches some fields failed to receive water due to high field elevation or poor minor canal alignment. Overall, some fields in all locations failed to receive water. However, unirrigated fields tended to be located in the tail reaches of both head and tail minors.

Problems associated with sharing outlets arose when a canal outlet served several fields owned by different farmers, the case in 63 of the 138 sample fields. According to farmers, no rules existed for sharing outlets. Farmers with fields separated from a canal by intervening irrigators were totally dependent for service on the good will of upstream neighbors. Where field channels were absent, basins were used to convey water from one field to the next. Conflict of interest arose between farmers lower in the system and those above who were requested to allow prolonged flooding of their fields to permit irrigation below. Farmers closer to the outlet objected that water stood in the upper fields too long and damaged crops. Yet, to allow field channels to run through upper fields would diminish cropping area. Since there were no rules to define rights of way for ditches or basin conveyance rights, farmers in the lower regions reported that they were often denied water.

In general, sample farmers reported that the smaller the basin and the less variance in elevation, the faster the water saturated the area and the fewer were farmer complaints. However, tail fields, which were more poorly served by the system, were larger in size and exhibited greater variance in elevation. Irrigators, equipped with no formal organization which could collectively act to create the conditions to control water, were compelled to adapt to constraints rather than collectively re-shape them. To adapt, farmers constructed unauthorized outlets, took water from neighbors, and shifted to drought-resistant, lower-yielding crop varieties.

Logic of the Analysis

If the *de jure* system of water contracts between main system management and farmers made water equally accessible to farmers throughout the command area, one would expect no substantially different cropping intensities or patterns given that soil types, climate, and market forces were uniform. If, however, cropping intensities and patterns were observed to shift markedly from head to tail reaches, then it would be possible to suggest that the shift in intensities and crop patterns is a direct function of access to water.

In the absence of effective irrigation organization, location is viewed as critical to gaining access to water. Access, in turn, is hypothesized to be a critical determinant of cropping intensities and patterns. One ventures the hypothesis, therefore, that farmers located in head and middle regions, having better access to water, will tend to cultivate more high-yielding varieties and sustain higher cropping intensities. Conversely, tail farmers are expected to adapt to scarce and unreliable water by choosing lower yielding, but more reliable drought-resistant plant varieties and by lowering their cropping intensities.

Before proceeding, a note about crop yields is in order. Yield data gathered during the course of research were found to be suspect for several reasons. However, in aggregate the yield data sustain one illuminating comparison. Maximum reported yields for the local high-yielding variety of wheat were 970 kg/acre, and the average reported yield of this strain was 639 kg/acre. Yet, the potential yield for this variety was determined by local seed suppliers to be about 1,700 kg/acre. The average reported yield on sample fields for the drought-resistant variety of wheat was 461 kg/acre compared to a potential of 485 to 566 kg/acres. Whereas farmers in the command area had been able to achieve near-potential yields for drought-resistant varieties, yields for water-sensitive, high-yielding varieties were far below potential.

Water Control and Cropping Intensity

Cropping intensity was analyzed during *kharif* only; *rabi* intensity showed no variation as it was 100 percent throughout the command area. Heavy soils make cultivation difficult during the monsoons of *kharif*. Therefore, *rabi* has traditionally been the main cropping season. Furthermore, *rabi* wheat is a much less labor-intensive than *kharif* rice. Labor is relatively expensive in the command area because of its proximity to Industrial Town and the capacity to pay wages for the labor required for *kharif* rice limits the acreage planted. Of the 138 sampled fields, 54 (299 acre) were fallow during the 1984 *kharif*, giving a cropping intensity of 60 percent for the sample area.

Locations of fallow sample fields in *kharif*, 1984, are presented in Table 12. Because each sample field was either fully cropped or was left totally barren, cropping intensities are reported in terms of fallow field units as well as in acres. Examination of Table 12 reveals that numbers of fields left fallow during

Table 12. Percentage of fields fallow in kharif 1984, by location (n=128).

Position on the Canal	Position on Minor*		
	Head	Middle	Tail
Head	7 (1/15)	41 (13/32)	64 (16/25)
Tail	44 (7/16)	29 (5/17)	52 (12/23)

*() = number of fields fallow/total number fields in category.

the *kharif* was high in five of six locations in the command area. The proportion of fallow fields distinctly increased as one moves from head to the tail reaches of both head and tail minors.

Fields left fallow during *kharif* were substantially larger at the tail than the many smaller fallow plots located in the head reaches. Size of farm operation, measured by summing acres of land owned and acres leased-in, was only slightly related to the tendency of farmers to leave land fallow (Table 13).

Table 13. Sample fields fallow and planted in kharif crop, 1984, by farm size (n=138).

Farm Size Area Owned and Leased in acres	Number of Fields Fallow	Planted	Total
0-5	35	49	84
5.1-10	3	10	13
10.1-25	2	8	10
25.1-200	14	17	31
Total	54	84	

X^2 = 3.64* d.f. = 3 p=.303 C = .160

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical value occurred by chance; p values should be discounted because values in the Table were drawn from a purposive, not random, sample.

Table 14. Number of fallow fields in kharif by the number of fields needing land leveling.

Land Leveling Needed	Fallow	Cropped	Total
No	26	66	92
Yes	28	18	46
Total	54	84	138

X^2 = 13.67* d.f. = 1 p = <.001 Cramer's V = .315 Phi = .315

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical value occurred by chance; p values should be discounted because values in the Table were drawn from a purposive, not random, sample.

In essence, farmers decided to leave fields fallow for a variety of reasons, especially water supply, intervening irrigator problems, and capacity to fulfill crop labor requirements. At least the first two factors operate on farm operations falling into all size categories.

Levelness of fields is associated with tendency to crop them (Table 14). Since land leveling affects water control, it is not surprising that it is significantly associated with cropping intensity.

Overall, what does the analysis of cropping intensities reveal? The effects of an unmeasured variable--cost of labor--made analyzing cropping intensity during *kharif* problematic. Location may, in fact, be critical to having access to water, but only if canals are properly aligned and if constraints on labor supply do not intervene. Misalignment of minor canals relative to fields and the main canal may overwhelm the effect of farmer location in the command area when some farmers cannot get water to their fields even in head and middle reaches.

Water Control and *Rabi* Cropping Patterns

Three varieties of wheat were planted in the area during *rabi*--C-306 (a lower-yielding drought-resistant variety), WH-147 and Sujata (both high-yielding varieties). The most common wheat varieties are C-306 and WH-147. C-306 is a tall hybrid, developed for dryland areas. It was introduced to the area in the mid-1960s. Although it is a drought-resistant crop, farmers in this area irrigate C-306 wheat where possible. This variety should yield 485 to 566 kg/acre, with a growth period of 130-135 days. Locals report a strong preference for C-306 as food for personal consumption.

WH-147 is a dwarf, fast-growing variety developed for irrigated areas. Its growing period is 120-125 days, and it promises yields of 1,619 to 1,822 kg/acre--if timely and appropriate applications of water and fertilizer are made. Local people prefer to exchange WH-147 for C-306 for personal consumption. Sujata was planted by only one sample farmer. It was reported to yield less than WH-147, but it is valued for its rich luster. About 125 days are needed for Sujata to mature, and it is highly sensitive to any deficiency in quantity of water applications.

Despite easy availability of hybrids in most local markets, many farmers chose to cultivate drought-resistant wheat. Although farmers prefer eating C-306, they reported that they prefer to grow WH-147 because of its higher yield, its and its shorter growing season. Their practice of growing low-yield, drought-resistant varieties is a rational adaptation to their irrigation constraints. Thus, varieties of wheat sown are a means to gain insight into the performance of the irrigation system.

Table 15 shows distribution of wheat varieties by village location, and Table 16 reports these varieties by canal command area location. Farmers of Village 1 (head) are clearly the most devoted to cultivating high-yielding varieties (Table 15).

Farmers in all other villages overwhelmingly selected drought-resistant varieties. Yet, even in the head reaches serving Village 1 farmers grew almost as much C-306 as WH-147 wheat variety. Poor canal alignment at the head of the head minor compels the use of traditional varieties. Irrigation officials expressed concern about this fact since Village 1 is located in the section with supposedly better water availability.

Because sample farmers at all locations tended to select drought-resistant varieties, crop type and location along the canal were associated only at a very low level (Table 16). One would expect more water sensitive crops near head reaches. This is revealed to be the case to a very small extent, but the relationship is weak due to the effect of poor water supply and control caused misaligned minors and intervening irrigators throughout the system.

Table 15. Varieties of wheat grown by village location in *rabi* 1983-1984.

Village	Acres: Area Under C-306	Acres: Area Under WH-147
1 (head)	250	300
2 (tail of the head minor)	170	16
3 (middle minor)	162	66
4 (tail minor)	260	124

Table 16. Crops planted in sample fields (by location) during *rabi* 1983-1984 (n=136).

Location on Main Canal Commands	High-Yield Wheat WH-147	Lower-Yield Wheat C-306	Drought-Resistant Beans, Peas, *Arhar*, Lentils, Garbanzo	Total
	---------------number of fields---------------			
Head	25	12	3	40
Middle	26	17	6	49
Tail	16	22	9	47
Total	67	51	18	

X^2 = 7.837* d.f. = 4 p = .0977 C = .233 Cramer's V = .169

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical value occurred by chance; p values should be discounted because values in the Table were drawn from a purposive, not random, sample.

Inspection of Table 16 reveals that the number of sample fields planted in high yielding wheat drops somewhat as one moves from head to tail reaches of the main canal command areas. Conversely, the number of sample fields devoted to the lower yielding C-306 variety increases modestly toward the tail of the main canal. Drought-resistant lentils also appear more frequently in tail areas as compared to the head, but both C-306 wheat and lentils are found to a significant extent in the upper middle and head reaches, a distribution which keeps the chi-square and contingency coefficient values at a low level.

Table 17 reports the association between cropping pattern and location on the left bank canal by acreage. The acreage of water-sensitive crops is substantially greater in head reaches than in the tail portions, but the relationship between location and crop type remains modest.

Because outlets are sometimes shared by irrigators, the relationship between the actual number of irrigators operating between a canal outlet and fields and the cropping type was examined. *Rabi* crops and their relationship to the number of intervening irrigators is displayed in Table 18. As expected, high-yielding varieties tended to be sown where fewer intervening irrigators were present. However, this was true for all crops. Intervening irrigators are avoided as much as possible in a system without viable local organization to allocate water and manage conflict.

Table 17. Sample farmer area planted (acres) in different crop varieties in *rabi* 1983-84, by location.

Location on Main Canal	WH-147	C-306	Others (garbanzo, peas, lentils)
Head	246.90	151.62	33.79
Tail	90.18	179.22	39.21
TOTAL	337.08	330.84	73.0

X^2 = 89.025* d.f. = 2 p = <.001 C = .328 Cramer's V = .347

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical value occurred by chance; p values should be discounted because values in the Table were drawn from a purposive, not random, sample.

Table 18. *Rabi* crops in sample fields by the number of intervening irrigators (n=138).

Number of Intervening Irrigators	Rabi Crop Sown			
	WH-147	C-306	Others	Total
	number of fields			
0-1	62	42	17	121
2-3	6	5	1	12
4-5	0	4	1	5

Table 19. *Rabi* crop variety in sample fields by size of farming operation (total area owned by family, plus area leased in, minus area leased out).

Size (ac)	WH-147	C-306	Others
	number of sample fields		
0-5	3	3	0
5-10	11	10	4
10-20	12	7	1
20-40	14	10	9
+ 40	28	21	5

X^2 = 9.011* d.f. = 8 p = <.50 C = .247 Cramer's V = .181

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical value occurred by chance; p values should be discounted because values in the Table were drawn from a purposive, not random, sample.

The size of farm operation might also affect farmer cropping decisions. Table 19 reports the relationship between crop type and farm size. Examination of Table 19 reveals that the number of sample fields devoted to different crop varieties shows little tendency to vary with farm size. Data reported in Table 19 reveal a slight tendency for larger farms to plant drought-resistant legumes and lentils. Most of the chi-square value can be attributed to this tendency. This is because larger farms tended to be located toward the tail reaches of the command area. Size of farming operation cannot be said to affect the choice to grow high-yielding varieties.

Conclusions

This case study has focused on organizational arrangements, or lack thereof, at the main system level, the farm level, and in the linkages between the two in a small tank system in Madhya Pradesh. What has been found?

First and foremost, *de jure* organizational arrangements were observed to not function in actuality. Joint agreements among farmers, and between farmers and main system managers, that were reported by sample farmers and key informants were far removed from those officially prescribed. It is debatable as to whether or not the *de jure* rules should be implemented. The authors, persuaded by the logic of irrigation organization advanced in Part One, contend that the *de jure* system as observed in this case was seriously flawed. This system did not promise a viable organizational design for this cultivation site. Most importantly, the *de jure* system did not integrate local farmer demands with main system management supply. Nor did it take into account the different kinds of knowledge, skill, and interest brought to the irrigation system by main system managers and farmers. Furthermore, there was no adequate share system capable of stitching together benefit (receipt of adequate and timely water supply) and obligation (contribution of resources to system operation and maintenance); nor was there a viable method for controlling "free riders" in the interest of the entire irrigation community.

Given the flawed *de jure* organizational design, irrigators--individually and in small groups--have developed a reasonably stable set of arrangements which allocate water in a predictable, though problematic manner. In addition, some haphazard maintenance is performed and conflicts are managed, but all of this transpires within a system which does not, and cannot, control water in the interest of a potential irrigation community sharing responsibility for a common system. A rough equilibrium has emerged over the years, but it is in the best interest of no party--not the main system management beleaguered by impossible demands, lack of clearly organized guidelines, and grossly inadequate water control tools; not farmers disadvantaged by location who fail to receive sufficient or timely water; not farmers advantaged by geography and somewhat better canal performance, but whose constraints on water productivity remain severe; not the government which finds disappointing returns to investment; and not international donor agencies who see their periodic support of irrigation rehabilitation emerge as a substitute for continuous and proper operation and maintenance.

Secondly, irrigation potentials were far from fulfilled. Given the lack of irrigation organization for matching main system supplies with farmer demands, water productivity is sacrificed. Water does not come at the right time and in the proper amount for most farmers in the system. Therefore, its value is much diminished.

During the summer (*kharif*), cropping intensities were quite low (about 40%) and cropped fields were largely devoted to lower yielding varieties than the system is potentially capable of serving. In winter (*rabi*), cropping intensities were uniformly at 100 percent, but most farmers--faced with problems caused by poor physical system maintenance and misalignment of canals, and by the actions of intervening irrigators--were compelled to shift their cropping patterns in the direction of lower yielding, but more drought-resistant. varieties. Even in the minority of fields where high yielding varieties were planted, reported yields were found to be far below potential for the area. The costs of inadequate local organization, with which to link farmer water demands and main system supply, have been considerable.

Data about relationships between command area location, cropping intensities, and cropping varieties consistently revealed that tail farms were relatively disadvantaged. However, poor access to and control over water in all portions of the command area hold down the strength of the observed head-to-tail relationships.

Is the problem rooted in behavior of farmers who have refused to cooperate with main system management? Clearly not. Farmers have simply adapted to a system designed and built by others. They have actively modified that system individually and in small groups as they have sought to increase their access to and control over water flows. However, farmers do not have organizational tools to establish legitimate leaderships charged with acting in the interest of the larger irrigation system so as to assure farmers that their contributions will be fairly matched by all others. Therefore, farmers have struggled to obtain whatever water control the system has permitted at their particular location.

Is blame to be laid upon main system managers? No In the absence of clearly defined, enforceable, and locally appropriate organized systems of joint agreements, main system managers have been faced with (1) becoming involved with particular factions of farmers to the detriment of *de jure* job performance and with the likelihood of generating opposition from other factions; or (2) pursuing a policy of minimal involvement such that they are unable to respond to local realities. Main system managers have been as much victims of poor organizational design as have farmers.

One might contend that blame should be placed upon the physical system since it does not have adequate water control and measurement devices or proper canal and field alignments. The solution would then be to properly rehabilitate the physical works. There is no question that physical rehabilitation will be essential to irrigation development at this site. However, any attempt to bring the system back to a former design standard without addressing the issues of organizational design (advanced in Part One), will be unable to sustain successful operation.

Physical rehabilitation must serve some coherent conception of irrigation organization to make water controllable and productive. In 1908, when Mohandas K. Gandhi published *Hind Swaraj* (Indian Self-Rule), he linked local people,--self-reliant, decentralized, democratic, organized appropriately to provide necessary local services--to self-mastery and progress for the nation. We recall this when we conclude that physical structures and tools for water control must be developed to fit a socially appropriate set of joint agreements to which irrigators and officials subscribe and can mutually enforce. Authentic irrigation development must necessarily translate into viable local organizational development. The development of viable local organizations that combine appropriate social rules and technical tools to produce collective goods making possible better utilization of private goods, and authentic participation in local civic life, is what development in irrigated agriculture is all about.

7

TWO RESERVOIR SYSTEMS IN SRI LANKA

David M. Freeman, John Wilkins-Wells, and Patricia Wilkins-Wells

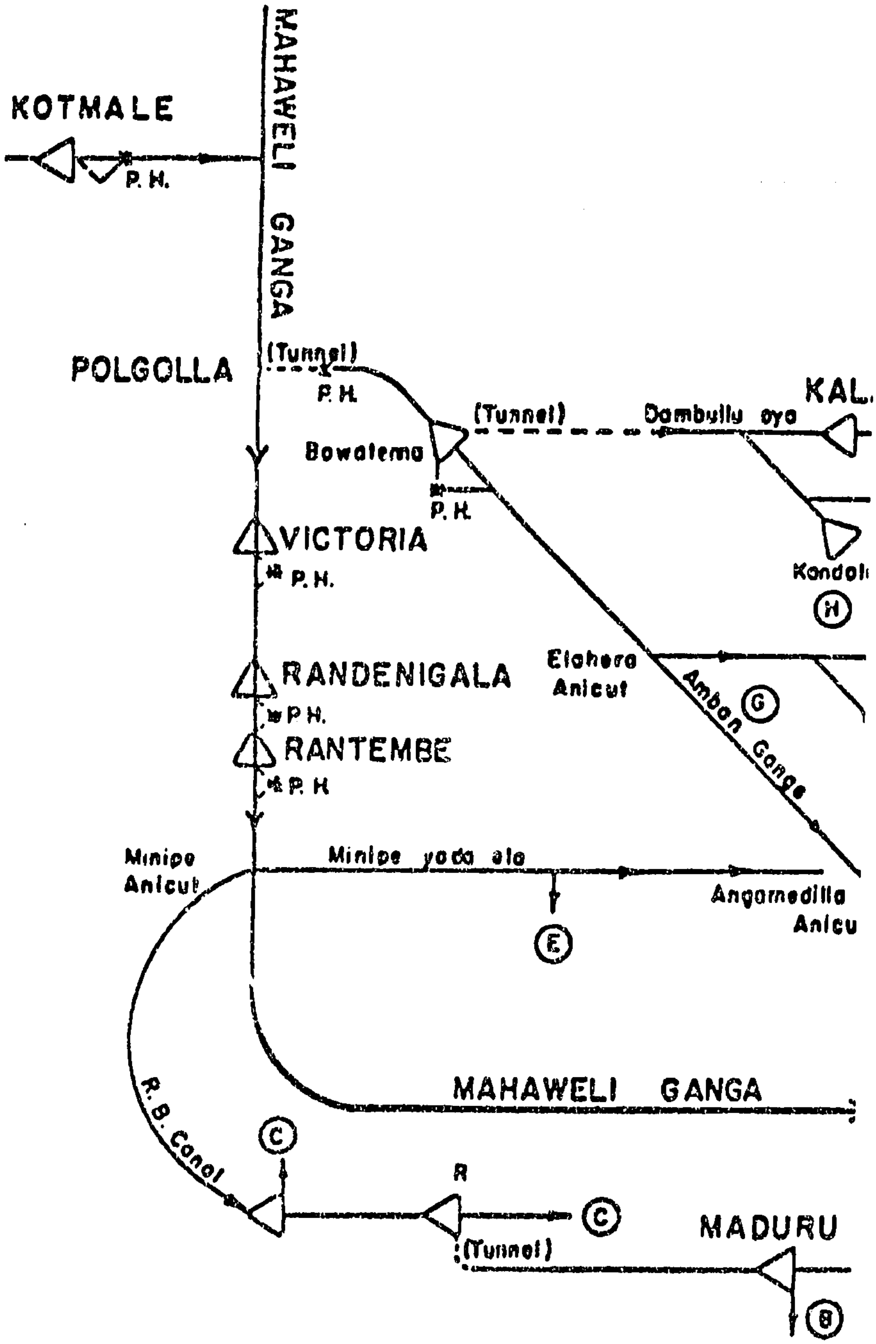
Introduction

Researchers examined the availability and timing of water deliveries to farms served by two centrally managed tank (reservoir) irrigation systems--Parakrama Samudra and Giritale schemes in Polonnaruwa District--in the Dry Zone of Sri Lanka (see Figure 1). The study was designed to investigate the effect of local organizational linkages between central administration and farmers on water availability and control at the farm level. Water control was viewed as an important determinant of crop yields and of farmers' willingness to collectively act to more equitably allocate water and maintain the irrigation system. Data were collected in Parakrama Samudra and Giritale schemes during *maha* season (Sept.-Feb.) 1985-86 and *yala* (Mar.-Aug.) 1986. However, only data gathered during *yala* 1986 are presented.

Background

History

The Parakrama Samudra and Giritale irrigation schemes represented an effort by the Government of Sri Lanka to develop irrigated agriculture in the North Central Province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KOTMALE
P. H.
POLGOLLA
(Tunnel)
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Bowatenna
(Tunnel)
Dambulu oya
KAL
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Kandal
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VICTORIA
P. H.
RANDENIGALA
Elahera
Anicut
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Amban Ganga
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RANTEMBE
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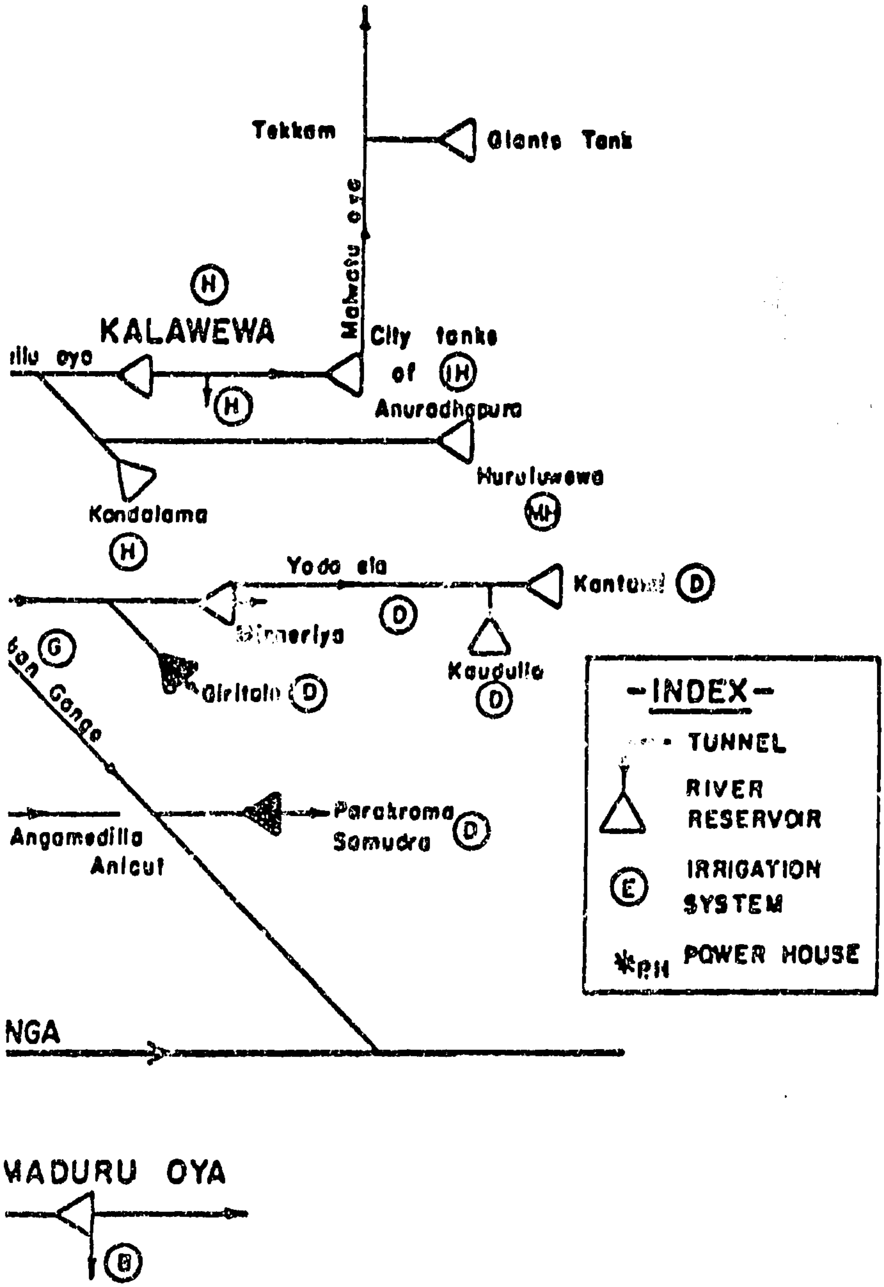


Figure 1. Schematic of Giritale and Parakrama Samudra water distribution systems.

prior to independence. This province was a major center of agricultural production and cultural life in the 12th and 13th centuries, but the district was uninhabited from the fall of the medieval capital at Polonnaruwa to the beginning of the 20th century, except for a few small hamlets located immediately below the ancient tank bunds of Minneriya, Giritale, and Parakrama Samudra. Early British explorers reported only small paddy fields along local streams, fed by breaches in the old bunds. There were probably no more than 500 acres cultivated under all three tanks.

In tracts below the Parakrama Samudra Tank, remnants of at least 200 small, village tank bunds are spread across an area of 20,000 acres. These bunds are still visible and are identifiable on the engineering sheets used to lay out the Parakrama Samudra Scheme. Many bunds are aligned in a complex cascade system, suggesting an extensive use of drainage water by the ancients.

Evidence at Giritale Tank strongly suggests that in ancient times water was dumped from the main canal into a complex network of smaller tanks. Today, modern distributaries accept water from the ancient main canal and convey it along crown ridges scattered throughout the paddy tracts. Field channels run perpendicular from the distributaries down these ridges. This is the same basic hydrological design found in the Parakrama Samudra Scheme.

In the early 1890s, plans were initiated by the Central Irrigation Board for restoring the tanks. Major restoration work on the Giritale Tank was completed in 1905. However, little land was brought into paddy production for another 15 years.

Restoration work was not begun on the larger Parakrama Samudra Tank until 1939. Private companies, usually European-managed, financed most of these early settlement schemes. The Parakrama Samudra Scheme was initiated during World War II, although most of the settlers arrived after the war. As with other schemes, the Irrigation Department and the Survey Department designed and constructed the Parakrama Samudra works using settler labor and hired laborers. Each settler and his family were given 8 acres--5 acres for paddy cultivation and 3 acres of unirrigated highland. In Giritale, each allottee was given 5 acres--3 acres for paddy cultivation and 2 acres for unirrigated tree crops.

Land fragmentation is more prevalent in the Parakrama Samudra Scheme than in Giritale. The average farm size in the study area was unknown, but probably ranged from 2 to 4 acres. For the sample of 82 farms, the average size of the paddy landholding was 2.8 acres (1.13 hectares).

Land tenure in the settlement schemes is semi-private. Original settlers were selected from different parts of the island and received deeds to land. About one-quarter of the settlers were veterans of World War II who received an allotment of land in compensation for military service. The transfer of these deeds through open market sales is not authorized. However, an unofficial land market exists.

The Polonnaruwa District exhibits a generally homogeneous population; there are no major ethnic cleavages. The population is 91 percent Sinhalese and 7 percent Moor. Six percent of the population in the district speaks Tamil as their first language, and nearly 90 percent of the Tamil-speaking population are Muslim.

The Polonnaruwa area is noted for its relatively high agricultural yields. Sunlight and rainfall in *yala* (dry season) are determined by the southwest monsoons. Usually some rain falls early and late in *yala*, and throughout most of the season the skies are partly cloudy and the days are 12 hours long. Sunlight is ample for vigorous plant growth. Wind velocity is light early in *yala* (about 2 to 5 km/hour), but it increases gradually up to 10 to 12 kph toward the end of the season. Hot, strong winds can considerably reduce yields if they occur during flowering. About 95 percent of the irrigated land is cultivated with rice (paddy), while the remaining area is under chili, green gram, and tobacco.

Generally, *yala* is viewed by local farmers as an excellent season for plant growth, whereas during *maha* (wet season), flooding, poor drainage, and less sunlight are common, and all contribute to plant disease. However, *maha* yields are generally higher because water supplies are more reliable.

The schedule of water delivery during *maha* traditionally has not been a problem because water supply from storage tanks is supplemented by the northeast monsoons. During *yala*, however, farmers rely almost entirely on the tank storage and the surface irrigation systems.

Until the early 1980s, the Amban Ganga (river) was the major source of water supply during *yala*. Now storage and conveyance structures on the upper reaches of the Mahaweli River drainage basin provide additional water. For instance, the two settlement schemes are hydrologically connected to the Mahaweli River by a large feeder canal that conveys water to the Amban Ganga above the storage tank diversions (Figure 1).

General Organization

The Irrigation Department is responsible for allocating water from reservoirs (tanks) to main canals and through branch canals and distributaries to field channels. Farm turnouts typically obtain water directly from field channels, but some fields obtain water directly from distributaries. The Irrigation Department is the custodian of all irrigation structures--reservoirs, canals, irrigation structures, farm turnouts, and lands reserved for canals and channels (see Figure 1).

Main canals in the study area have capacities ranging from 100 to 300 cubic feet per second (cusecs) and each runs about 12 miles. Branch canals have smaller capacities. Distributaries carry from 4 to 10 cusecs depending on the size of the distributary, and serve 75 to 350 acres. Distributaries are clearly defined hydrological units, and farmers along each distributary have traditionally viewed themselves as a "community of irrigators." Field channels are served by pipes of 6 to 9 inches in diameter and deliver water to 4 to 20 farmers.

An irrigation plan is formulated by the Irrigation Department before each cultivation season. This plan analyzes the water balance at the beginning of the season, anticipated catchment flow, acres to be cultivated, first and last dates of water issue, and the proposed rotation schedule. *Kanna* (cultivation) meetings are held to inform farmers about the amount of water available in the reservoir and the distribution schedule. Rotation schedules indicate pre-set times for proposed water issues to distributaries from the main or branch canals. The Irrigation Department determines the amount of water to release to meet crop requirements and whether or not sufficient water has been delivered to distributaries. These procedures are viewed as being guidelines and are altered from time to time.

The Resident Deputy Director of Irrigation is responsible for overall supervision and management of district irrigation work. There are three to five field divisions under him, each managed by a resident divisional irrigation engineer, whose staff consists of a deputy irrigation engineer, technical assistants, work

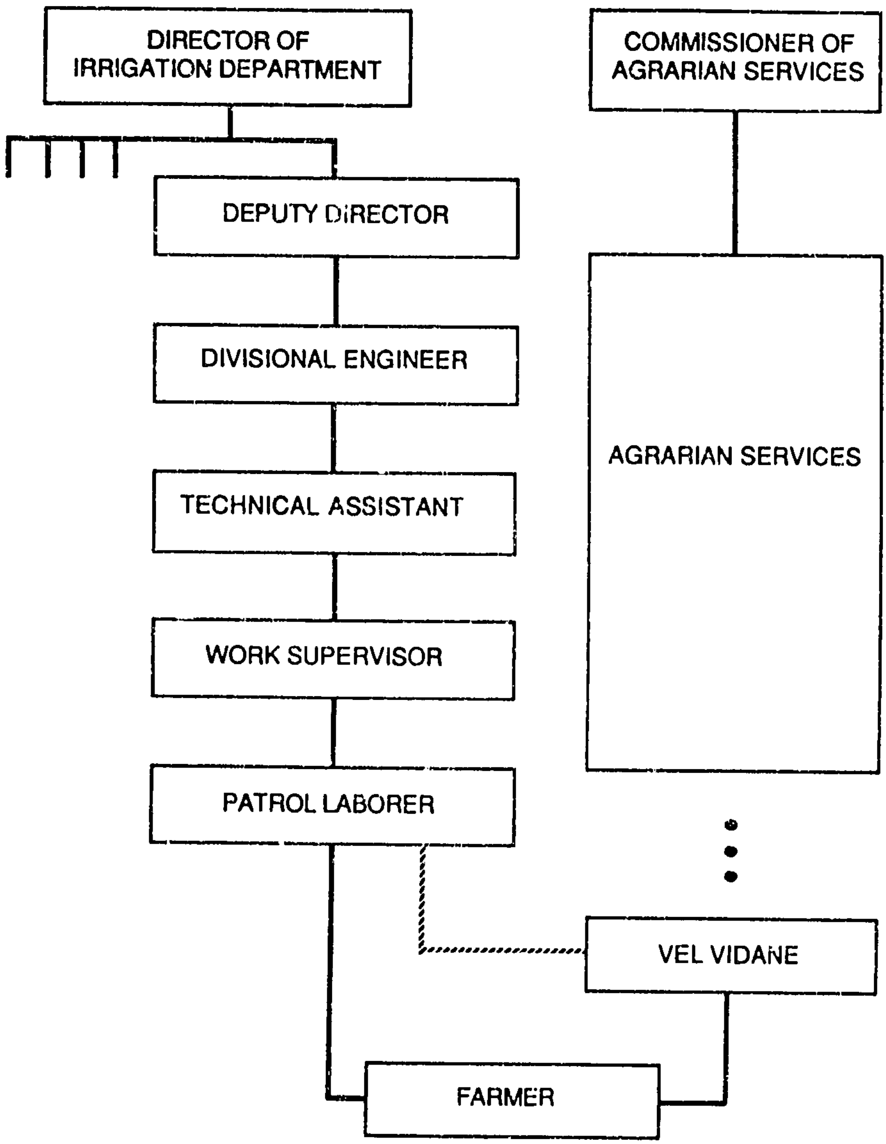


Figure 2. Irrigation Organization

supervisors, patrol laborers, and a few administrative support personnel (Figure 2).

The divisional irrigation engineer is in charge of the administration, financial, and technical aspects of managing one or more storage tanks, river diversion structures, sluices, spillways, service bridges, and roads. This officer supervises the technical assistants, who allocate water from the tanks through main canals, branch canals, and distributaries.

Irrigation engineers furnish information about water requirements in their divisions to the Deputy Director of Irrigation for preparing the annual implementation plan and budget. They also specify requirements for structural improvements, in *yaya* tracts based on information relayed by technical assistants.

Farmers and farmer representatives are informed about methods of water allocation at cultivation meetings and district agricultural committee meetings. Technical assistants, work supervisors, and patrol laborers distribute water from one area to another by opening and closing headgates. In addition, these junior officers supervise maintenance work, control water flows, and attempt to manage disputes.

No organized procedures for water allocation have been agreed to by all parties. Procedures are often altered by the irrigation engineer and technical assistants according to site-specific problems encountered in managing water throughout the season, and as local opportunity permits. The technical assistant is generally responsible for supervising water distribution and maintenance work within an area of 4 to 8 square miles commanded by several distributaries. He has no authority over *vel vidanes*. Therefore, technical assistants tend to avoid distributing water below the distributary headgates, and consider this to be the responsibility of *vel vidanes*.

There are instances when technical assistants become involved in problems of local water distribution--especially when alterations occur at turnouts or drop structures. The rotation schedule also can be changed by the technical assistant when water shortages are reported or when there is a request for an extension of water deliveries to irrigators.

Work supervisors are assigned to several distributaries. They report water shortages, forward written complaints from farmers to technical assistants, read water flows at tank sluices, record changes of water volumes from distributary headgates, and adjust distributary headgates. The work supervisor is not authorized to increase the number of days in a rotation schedule, but he can block a head field channel in order to divert more water to the tail. Work supervisors also assess costs of broken structures and cleaning up trash in distributies.

Patrol laborers are primarily responsible for adjusting distributary headgates according to rotation schedules and monitoring water flows in the main canals running through their areas of responsibility. They usually supervise the headgates of 3 to 5 distributaries and report violations of rotation schedules. Patrol laborers keep headgate keys during working hours and then return them to their work supervisor. They are authorized to open and close field channel gates and to check for obstructions along the main canal.

The major responsibility of the *vel vidane* is to ensure equitable distribution of water among farmers along the distributary after the water has been issued from the distributary headgate. In addition, the *vel vidane* is also expected to settle water disputes and report any damage done to turnout structures. As a farmer representative, the *vel vidane* attends cultivation meetings and passes information to farmers about dates of water issues and dates for initial land preparation. *Vel vidanes* also mobilize farmers for cleaning distributary canals and field channels. The total distance of a distributary or a field channel is divided among the number of farmers, and a portion of each channel is assigned to each farmer. A fine of up to Rs. 25 may be assessed for each 6 ft of a field channel that is not cleaned. The *vel vidane* is also given the responsibility to monitor water flows along 6 to 10 field channels. The *vel vidane* may close field channel headgates in the upper reaches of a distributary if tail farmers are short of water.

Officially, junior officials in the Irrigation Department are responsible for distributing water along main canals, through distributary headgates to field channel headgates. Actually, farmers and their *vel vidanes* allocate water among themselves below the distributary headgate and irrigation officers are called upon only in instances of severe disputes or emergencies.

The lack of equitable and reliable distribution and allocation of water below tank sluices remains a persistent problem. Recognizing this, the Government of Sri Lanka has elsewhere initiated an institutional development program to address issues related to water allocation, maintenance, and dispute resolution at the organizational level between tank sluices and individual farm turnouts. This program allows farmers to form field channel turnout groups and to appoint field channel representatives to a committee at the distributary level. Farmers elect representatives from distributary committees to represent farmers' interests on a project committee at the settlement scheme level. This program is supervised by the Irrigation Management Division (IMD) of the Irrigation Department.

The Irrigation Department controls water distribution along the main canals. No provision exists for farmer organizations to participate directly in managing storage tanks. These tanks have traditionally been supervised by the Irrigation Department.

The Irrigation Department does not supervise the *vel vidanes*, who distribute water at the distributary level and who once worked under the Commissioner of Agrarian Services (Figure 2). As a result of this divided authority and responsibility for water allocation, disputes between these two government agencies over water allocation have erupted occasionally.

Property Rights

From the beginning, the central government's control over settlement schemes extended to property rights, procurement of agricultural inputs, and financing. Of these, a major issue, especially in the 1930s, was land entitlement.

The Crown Lands Ordinance (1840) designated all unoccupied land throughout Sri Lanka as Crown land. This ordinance was eventually followed by a declaration of the Land Commission (1927) specifying that all Crown land would be held in public trust "according to the interest of the community" as defined by the national government. The Land Development Ordinance (1935) provided for leasing lands to settlers, who were given the right to designate a family successor. This lease arrangement was eventually revoked in favor of a 99-year lease after recommendations of the World Bank in 1952 (Gunawardena 1981).

Ultimate ownership of the land is retained by the government. This reflects a general concern for administrative justice prevalent among settlement planners and administrators, which has frequently led to policies that doggedly attempt to control land transfers and traditional moneylending practices. The government has always subscribed to the policy that public control of lands prevents their takeover by urban absentee landlords, shop owners, and moneylenders. This assumption has carried over in paternalistic attitudes of settlement administrators toward settlers.

In settlement schemes, landholders are referred to as "allottees" and must carry an identity card when applying for government agricultural services. Allotment holders legally cannot sell or mortgage their land, but transfers of land do occur regularly. Land fragmentation, population increase, and the mortgaging of land to local credit sources have created a complex pattern of extra-legal land ownership. Farmers who wish to sell or lease land for credit frequently record these transfers in official registers by paying unofficial "service" fees.

Tenancy is widespread. Although legislation has been enacted over the years to strengthen and secure tenancy rights and to prevent moneylenders from taking land as collateral, most attempts to do so have failed. Furthermore, the threat of eviction and use of other forms of leverage by landowners on tenants have consistently dampened tenant interest in filing grievances (Herring 1981). Thirty percent of the food producers along sample distributaries were tenants. Key informants reported that land is illegally secured, even coerced, from allottees by individuals residing outside the settlement schemes. In the absence of an official land market, such transactions occur without legal sanction.

Attempts of government planners to restrict land exchanges in order to contain the power of local credit sources have been thwarted by the development of illegal land and credit markets. In such markets neither indebted farmers nor lenders have legal protection. Farmers reported violent incidents over land, especially when attempts were made to reclaim land mortgaged to moneylenders. Neither an allottee nor a moneylender can legitimately call on government agents for support, since both have engaged in an illegal transaction.

An ideology of distributive justice, and the strong paternalistic attitude toward settlement schemes, has clouded the government's ability to evaluate the role of traditional credit sources for farmers. Farmers face difficulties in obtaining credit to purchase agricultural inputs at the beginning of each season. In the absence of an effective credit system through the government, or sufficient availability of commercial credit in the private sector, traditional sources of rural credit play an important role, even though interest rates are frequently usurious.

Farmers were also insecure regarding local property rights pertaining to irrigation structures, canals, and water. The Irrigation Department, as a public agency, claims ownership of, and responsibility for, all irrigation canals and structures to the lowest level of the system. Farmers are not authorized to alter, rebuild, or remove any structure, or to change canal or channel features. Farmers sometimes work as laborers for the Irrigation Department in maintenance activities, and allottees are required to contribute labor for maintenance organized by the local *vel vidane*, a traditional water manager on distributaries. Such labor mobilization is difficult to enforce and has been highly variable in effectiveness.

Water is supposed to be distributed to farmers according to a standardized plan specifying the amount of water required per acre to cultivate a crop. A field officer in the Irrigation Department determines whether or not a sufficient amount of water has been delivered in aggregate to an area of a distributary. If a farmer or group of farmers request additional water, or complains that someone else receives more water than they should rightfully obtain, junior irrigation officers personally assess the situation and intervene according to the dictates of their best judgment. No organized legitimate set of joint agreements exists between farmers and officials to address such matters.

The implications of this management situation are many. Farmers do not have a legally recognized definition of "fair share" of water that they may use as a basis for complaint; neither does the Irrigation Department have a definition to use in settling disputes. Farmers may agree on the amount of water each should receive, but they must rely on the final judgment of an outside official who is not bound by any organized set of expectations. This provides a few farmers, who have disproportionate access to resources, with an opportunity to influence the judgment of the officers.

Farmers must make formal complaints or requests for change to the Irrigation Department. Since all repairs and alterations to irrigation structures must be authorized and directed by the Irrigation Department, farmers interpret these restrictions to mean that the Irrigation Department bears full responsibility for system performance and maintenance.

Cultivation Committees

The Paddy Lands Act (1958) was initially a response to tenant insecurity and it authorized the formation of cultivation committees. Each cultivation committee consisted of an elected body of farmers in a *yaya* tract (150 to 350 acres) irrigated by a single distributary. The committee was given responsibility for adjudicating land disputes, coordinating land preparation for paddy cultivation, and distributing water. Herring (1981:152) observed that the formation of these committees was "in part a [government] response to the absence of village-level democratic institutions or associations of cultivators" to manage such affairs.

Each committee was supervised by a local colonization officer from the Land Development Office. When problems occurred, the colonization officer was to be the final arbitrator.

In Polonnaruwa District, the cultivation committee was responsible for collecting an acreage tax. Collection of this tax was conducted under the supervision of the colonization officer, whose close ties to the revenue officers at the Government Agent's office was distrusted by farmers. Between 1942 and 1958, these government civil servants were able to punish offenders of the Irrigation Ordinance by confiscating seed paddy or by withholding water.

In 1952, *vel vidanes* were elected in the study area, and were officially under the supervision of colonization officers. Although the Paddy Lands Act (1958) later gave the traditional *vel vidane* water management role to the cultivation committees, the *vel vidane* role persisted. Today, irrigators are represented by a paddy tract manager called *yaya palaka.* These tract managers are usually former *vel vidanes*, and they continue to carry out all of the supplementary activities of the traditional *vel vidane*. In addition, farmers refer to them as *vel vidanes*.

Pieris (1976) and Inayatullah (1972) have contended that the cultivation committee was not effective in implementing land reform policies, but it was successful in coordinating paddy production and helped settle water disputes. The most probable reason for the failure of the cultivation committee was the multiplicity of tasks imposed upon it. In addition to adjudication disputes and collection of acreage taxes, cultivation committees were responsible for issuing identity cards to farmers. These cards were required to obtain agricultural inputs provided by the government, to rent agricultural equipment, and to maintain land ownership and cultivation records in the Land Development Office (Moore 1979).

In 1972, the Agricultural Productivity Law placed cultivation committees under the supervision of the Agricultural Productivity Committee (APC). APC officers were selected by political appointment, but these appointments were terminated by the UNP (United National Party) government in 1977. These events, together with the abolishment of the traditional village headman position in 1963, and its replacement by a government officer (*grama sevaka*), clearly demonstrated the increasing role of the central government in the economic and social life of the settlement schemes.

Production and Marketing Organization

K.M. De Silva (1981) indicated that about 50 percent of the gross national product of Sri Lanka was allocated to welfare programs in 1947, and settlement schemes were a large part of this expenditure. The government attempted to initiate settlement cooperatives to provide credit and marketing facilities to settlers. Brohier (1941:36) reported that the government goal, by way of the Registrar of Cooperative Societies, was to see all future agricultural activities conducted through cooperatives:

> The object of the cooperative effort at Minneriya [in the Polonnaruwa District] is to work towards the day when it will be possible to conduct all activities in the colony on cooperative lines. The colonist will then buy his goods from his cooperative store, sell his produce through his marketing society, and bank his money through his credit society.

Farmer (1957) noted that the government was energetic in its efforts to form cooperatives as organizations of production and distribution in settlement schemes, although their early function was limited to administering the guaranteed price program for commodities (excluding vegetables, plantains, and coconuts).

Government officers were appointed as ex-officio presidents of cooperative associations, while settlers performed routine secretarial duties. In addition, the cooperatives worked under the guidance and patronage of the local Government Agent. This policy has remained basically unchanged to the present day, with the exception that local politicians now recommend appointment of association board members. In recent years, multipurpose cooperatives have been organized for supplying a variety of consumer goods. Cooperative managers are politically appointed.

In reviewing the history of the cooperative movement in Sri Lanka, Inayatullah (1972) notes that since its inception in 1912, cooperative administration has gradually moved away from the goal of relying on widespread local participation to achieve local autonomy and to build democratic institutions in the rural sector. Instead, the central government has increasingly moved toward greater control of cooperatives.

Rural Development Societies

One of the major goals of the central government since independence in 1948 has been to develop rural integrative institutions to coordinate government departments, and to coordinate planning and implementation of community development projects (roads, schools, public health, and irrigation works). The Rural Development Department was formed to coordinate the activities of village-based rural development societies in 1948. District agricultural committees established after independence were responsible for coordinating agricultural production at the district level and for acting as advisory councils for government agents on development matters. The Rural Development Department appoints a Rural Development Officer at the divisional (village headman) level to coordinate the activities of the village-based societies.

Societies have always depended on funds from the government for their continued existence. Uphoff and Wanigaratne (1982) have noted that locally elected leaders frequently have been displaced after national elections. Many settlers believe that rural development societies are of little use. One reason might be the early attempt to impose upon them responsibility for dispute resolution (Tiruchelvam 1984a). Uphoff and Wanigaratne (1982), however, reported that of all associations, rural development societies have shown the highest level of participation and the greatest amount of project activity. Yet, these societies have been plagued by political manipulation and rely heavily on central government direction.

Production and Distribution of Agricultural Inputs

The national government plays a dominant role in agriculture by stabilizing commodity prices and heavily subsidizing the production of fertilizer and agro-chemicals. Pieris (1976) refers to these policies as "welfare-statism," which is characterized by the production and distribution of agricultural resources through a state-financed and managed agro-chemical industry. Production and distribution systems employ a large cadre of government officials responsible for distributing agricultural inputs to farmers at numerous local agricultural service centers.

Agricultural inputs are allocated primarily by the Department of Agrarian Services under supervision of a local divisional officer. Divisional officers in and near the study area were frequently nominated by the local Member of Parliament.

Given high demand for agricultural inputs, in insufficient supply, tenants must make special arrangements with their landlords or seek alternative, but expensive, methods of resource acquisition. Farmers reported that officials and field officers engage in favoritism in input distribution. They are aware, however, that in the absence of other viable options for procuring resources they must maintain satisfactory relations with local field officers. Observations of farmers and officers indicated an overwhelming propensity for farmers to exhibit outward compliance in relationships with officers.

During the final months of field work in *yala* 1986, there were indications that this situation was changing somewhat because farmers were increasingly obtaining agro-chemicals and seed paddy from the commercial private sector. There two explanations. First, government agents had difficulty delivering inputs on time and storing adequate stocks of inputs. Secondly, the UNP government began to encourage the private sector to become more involved in supplying farmer demand for inputs.

District Agricultural Committees

District agricultural committees have played an important role in coordinating agricultural activities. They were designed to coordinate the agendas of the Departments of Agriculture, Agrarian Services, and Irrigation. These committees are concerned with broad agricultural policy at the district level.

The Government Agent, as the chairman of the district agricultural committee, is responsible for coordinating local activities of these agencies, but has neither the power or staff to perform this function.

The district agricultural committee comprises the chief district officers (or their appointees) of the three agricultural departments. The Government Agent receives recommendations from the district officers regarding the seasonal agricultural calendar. He then presents the calendar to farmers, or their representative irrigation headmen, at a cultivation meeting at the beginning of each cultivation season.

Farmers are expected to make suggestions at district agricultural committee meetings, but this rarely occurs. Agrarian Service committees which operate at a sub-district level, are more closely linked to farmers. The Agrarian Service committee consists of field officers from the same agencies of agricultural development represented on the district agricultural committees. Each local Agrarian Service committee is responsible for carrying out policies made by the district agricultural committee, including collecting crop statistics, distributing agricultural inputs, supervising water deliveries, and delivering extension services.

Capacity of committees to coordinate line agencies has been limited. Wanasinghe (1985:244) stated:

> The technical departmental cadres [agencies] continued to maintain their allegiance to their departments rather than to the "district organization" [District Agricultural Committee]. They viewed the district as a "temporary place of work"--not as a locale of development commitment. Their commitment was to the development program of their own department as a whole--whether it was the agricultural extension programme, or the irrigation program. This was but natural in a context wherein career advancement depended entirely on the parent department, and not on the Government Agent at the district level, and wherein the majority of the technical cadres belonged to transferable services and not to the district.

Wanasinghe (1985) further stated that the most prominent feature of the organizational structure was the absence of farmer involvement in, and commitment to, planning and implementation of agricultural policy. Murray-Rust and Moore

(1983) stated that the Government Agent frequently suspends the legally required meetings simply because he cannot realistically communicate to farmers. Furthermore, the seasonal agricultural plan is so general in nature that most of farmers have little interest in it.

The District Development Council and Members of Parliament

Several changes in district administration have affected the roles of the District Minister, District Members of Parliament and, to a lesser extent, the Government Agent. These public officials are linked to one another by the District Development Council (Tiruchelvam 1984a, 1984b), which is responsible for allocating funds in an annual block grant (district budget) from the central government.

The position of District Minister was established in 1978 and the occupant is accountable directly to the President of Sri Lanka. The District Minister, with the assistance of district Members of Parliament, is responsible for coordinating district development projects and allocating the block grant. Leaders of political party units and other voluntary organizations provide information to members of Parliament on requirements for developing paddy tracts.

The Government Agent is designated the permanent secretary to the District Minister (Oberst 1986). This has reduced the status of the Government Agent significantly. Furthermore, block grant funds are allocated on an electoral basis. In this way, all members of Parliament, along with the District Minister, receive a grant that fuels the patronage structure in the rural sector. This patronage system has become an important link between the state and local communities. The role-status position of Parliament Members has become, therefore, strengthened locally.

Agricultural development agencies receive a portion of the budget for development projects identified by the Government Agent's planning unit. These projects are forwarded to the District Minister and Members of Parliament for evaluation.

The District Development Council, which presently oversees all district rural development projects, is structured along the lines of a miniature parliament. The council consists of people elected proportionally for four years, who are responsible for debating and voting on development plans or projects formulated by the district executive committee.

"Grass roots" involvement is promoted by the appointment of *gramodaya mandalaya* (village development councils). A *gramodaya mandalaya* exists for each *grama sevaka* division in the district. The council consists of representatives from cooperatives, rural development societies, temple committees, and death benefit societies. The *gramodaya mandalaya* is responsible for formulating and submitting local projects to the *pradeshiya mandalaya* (regional development council), which then passes them on to the District Development Council.

Political party penetration into the rural sector typically takes the form of overlapping leadership in these community-level organizations (Oberst 1986). Elected officials in these organizations are frequently the local party representatives who dominate direct linkages to the District Development Council. Members of the local community make their political demands through local elites to Members of Parliament.

Conflict Management

Organizations for conflict management at the village level have been controlled by the central government. Tiruchelvam (1984a) has summarized the historical accounts of the traditional *gamsabhava*, or village tribunal, in the central provinces. The *gamsabhava* was an *ad hoc* tribunal consisting of village elders responsible for handling administrative and adjudication matters in the village, such as arbitrating breaches in caste rules, mediating land disputes, sanctioning property theft, and regulating village irrigation water and structures according to traditional procedures and standards. Village tribunals were overseen by a *rata sabhava*, a council summoned by important citizens and officials in the Kandy-kingdom district when a local *gamsabhava* could not come to a resolution.

In 1924, the Village Community Ordinance formalized village councils, which then possessed powers to issue licenses and make bylaws. Village tribunals were established as rural courts under the Rural Courts Ordinance of 1945, and were presided over by the Judicial Service Commission (Pieris 1976). Village tribunals held jurisdiction over all breaches of bylaws and criminal offenses under the Village Communities Ordinance of

1871 and the Rural Courts Ordinance of 1945. However, these rural courts were abolished in 1977, and the District Court became the only remaining adjudicating body for farmers and other community residents.

Uphoff and Wanigaratne (1982:511) advanced the view that village councils lacked sufficient economic resources, authority, and local autonomy.

> The calibre of persons who were elected to such quasi-autonomous bodies, or who were recruited for staff positions in the netherworld between patronage and merit appointments, left much to be desired. Add to this the effects of party competition and resource constraints already mentioned, and one can see why such institutions' performance was frequently stalemated.

Farmers are concerned about the absence of local, rural adjudication bodies. Property damage and minor civil disturbances frequently go unpunished, and irrigation offenses have increased. Farmers express a feeling of helplessness about property damage and theft. Many farmers reported that the increase of irrigation violations in recent years is due to the delays in hearing offenses by the district court system.

Irrigation offenses are reported to the local divisional engineer, who reports to the Additional Government Agent at the *kachcheri*. The Additional Government Agent then forwards the complaint to a court coordinator (a paralegal) who then writes a legal brief and consults with a lawyer if necessary. The divisional engineer is then requested to produce witnesses, along with the plaintiff. Irrigation violations are brought before the court only on Fridays. Since a judge can hear on the average only two cases per day, it typically takes months for a case to come before the court. Frequently, by the time the case comes to court, the problem has been negotiated locally and witnesses express reluctance to come forward. Influential people often become involved in a case, either directly or indirectly, in support of one of the litigants, and farmers see the process as being so capricious, slow, and risky that they tend to withdraw.

Research Design

Research proceeded at three levels:

1. The technologies, procedures, and management roles involved in managing water flow from main canals to the headgates of local distributaries (reported above).
2. The management of the distributaries, which deliver water to individual farms by way of farm field channels.
3. Individual farmer response to the irrigation system.

The distributary headgate was viewed as being the major organizational dividing point between the higher (main system) and lower (local) organizational levels.

Collective management capacity at the distributary level was considered to be a local organizational attribute affecting water control at the individual farm headgate. Water control at the farm headgate was, in turn, hypothesized to explain a portion of variance in farm yields. Similarly, the degree of management capacity along the distributary was expected to explain a significant portion of farmer willingness to support water user associations. Variables were defined as follows:

1. Management Capacity--above the distributary headgate, was defined primarily in terms of the water management procedures and roles of Irrigation Department personnel. The predominance of government control and ownership of the irrigation system means that management at this level is characterized by standardized central planning, modified at the discretion of individual officers operating in the field. Below the distributary headgate, management capacity was defined primarily in terms of the supervision and authority of the *vel vidane* and the informally organized support he receives from local farmers. This cooperation was seen to be a function of informal agreements among farmers for water allocation and distributary maintenance rules which the *vel vidane* should employ.

2. Distributary Problems--The severity of water distribution problems as reported by sample farmers.
3. Water control--the degree to which the timing and quantity of water deliveries to sample farms met minimal water requirements of paddy cultivation at each growth stage.
4. Yield--Sample farm paddy yields computed in bushels per acre.
5. Relative Water Supply--the total water supply at a distributary headgate released to the distributary command area over the season. It is considered an important intervening or control variable. It was thought that increased availability of water to the distributary might affect the need or desire to develop management capacity at the local level. Varying water availability, in other words, might create a varying organizational environment within a distributary.
6. Tenancy--the percent of tenant irrigators along the distributary as reported by the *vel vidane* in his personal ledger. A tenant farmer is defined as one who is not an original allottee along the distributary, nor an offspring of an original allottee, nor one who has been irrigating under the distributary headgate for more than two years. Tenant farmers are not considered by *vel vidanes* as a part of the community of irrigators.
7. Density--the number of farmers per acre irrigating within the distributary command area. It was viewed as being an indirect measure of land fragmentation.
8. Investment--the total rupee value of investment in fertilizer and other chemical applications per acre by each sample farmer. Computations included costs for weed and pest chemicals, and fertilizer costs for the common fertilizer applications. Labor costs were not included.
9. Farm Size--total acreage under paddy for each of the sample farmers.
10. Hydrological Location--the location of sample farmers in respect to position at head or tail in the distributary and the research block.

11. Willingness to support water users associations --the degree of sample farmer support along each sample distributary, for the idea of local farmer controlled water users associations at the distributary level.

Hypotheses are diagrammed in Figure 3. Model 1 posits relationships between distributary characteristics (management capacity and distributary problems), water control, and yield. Model 2 posits a simple bivariate relationship between management capacity and willingness to support water users' associations at the distributary level. Model 1 raises two questions: How does management capacity of a distributary affect water control at the farm turnout, and what is the effect of distributary water control on crop yield. Model 2 addresses the question: How does management capacity of a distributary affect farmer willingness to support local water users associations?

Data were collected in 30 sample areas representing 15 distributaries in the two settlement schemes. These distributaries varied in length from 1 to 2 miles and served from 40 to 150 farmers. On each sample distributary, a *vel vidane* supervised water allocation.

Six distributaries were selected from Parakrama Samudra system, nine from the Giritale Scheme. Distributaries were purposively selected to obtain substantial variance in the conditions of water distribution by securing variance in the source of water and farm location--head, middle, or tail--(Figure 4). Characteristics of sample distributaries are listed in Tables 1 and 2. Table 1 reports the number of original allotments in distributaries, acreages of distributary command areas, and the seasonal relative water supply. Table 2 presents tenancy status and total numbers of farmers on distributaries.

Measuring Management Capacity and Distributary Problems

Sample farmers evaluated the management capacity of each distributary. They were asked to respond to a questionnaire administered in a group session, which protected respondent anonymity. The questionnaire elicited information about procedures and practices for water allocation to field channels,

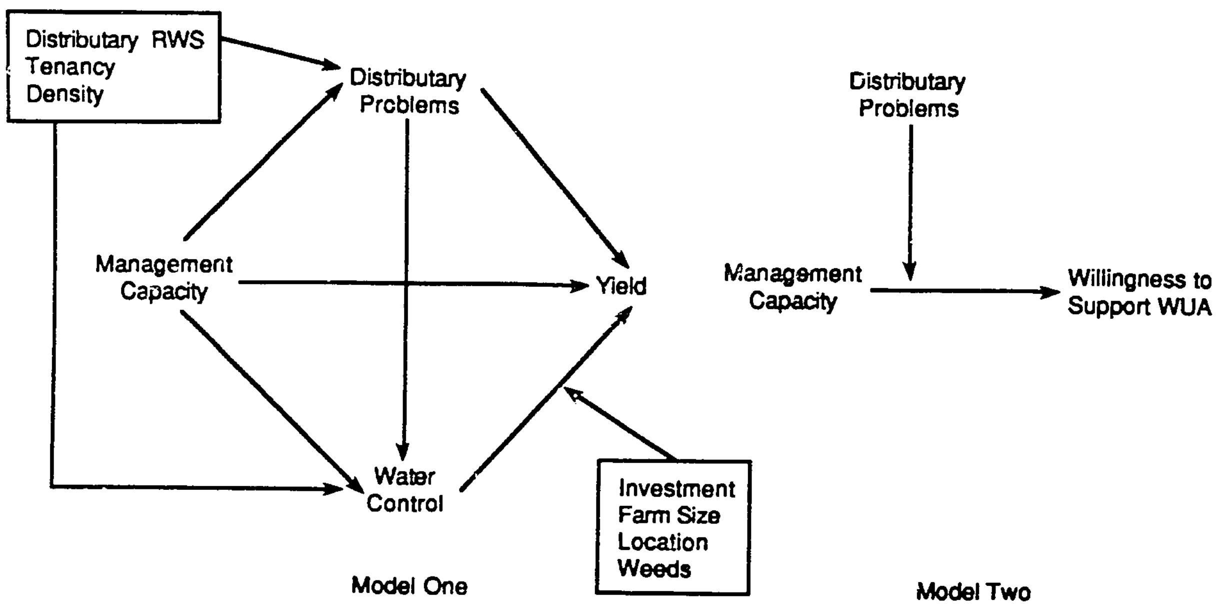


Figure 3. Models of relationships between variables.

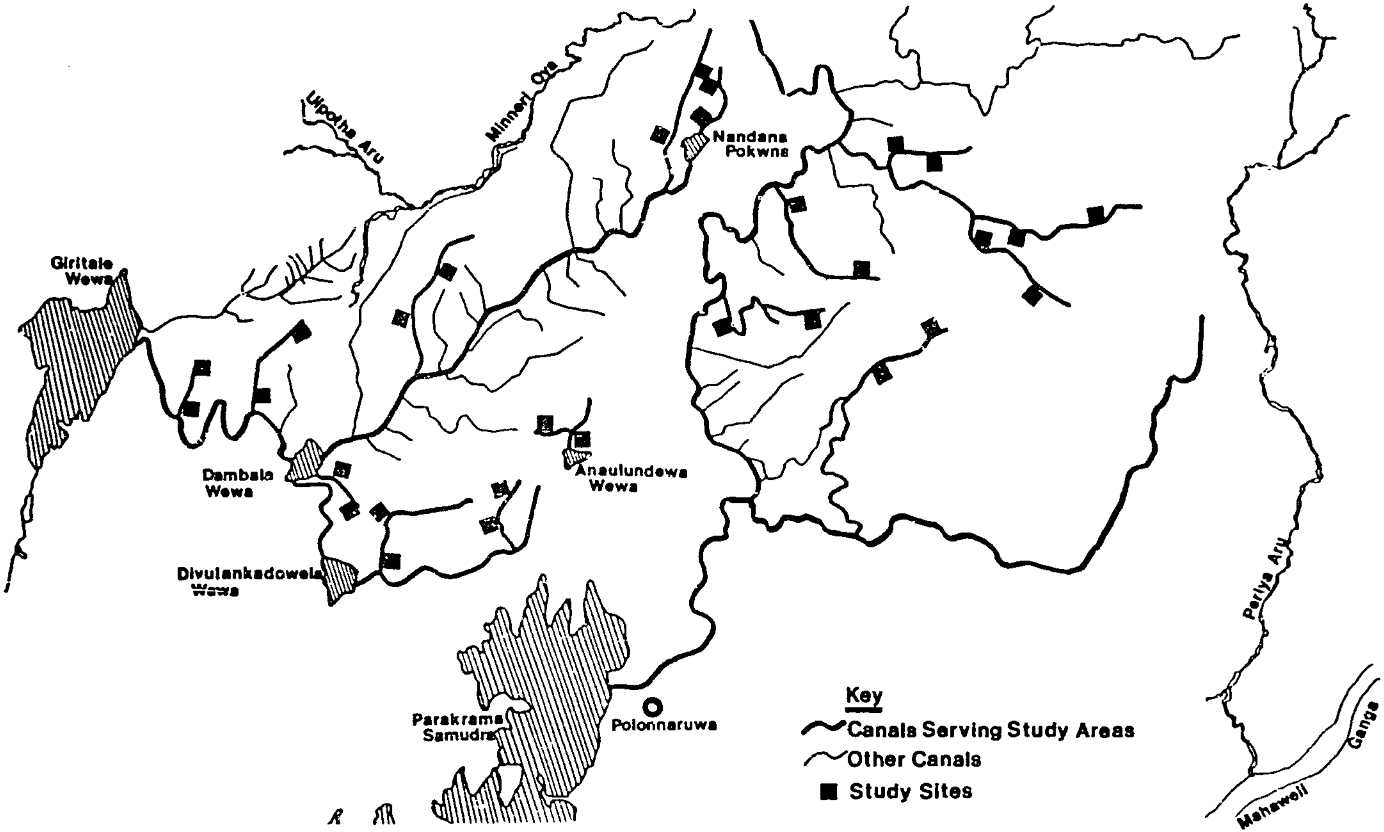


Figure 4. Research blocks (study sites) and sample distributaries.

Table 1. Physical characteristics of sample distributaries.

Distributary	No. of Original Allotments	Irrigated Acreage	Relative Water Supply
1	27	76.75	4.26
2	59	183.75	1.07
3	67	200.75	2.83
4	110	360.50	1.43
5	26	84.00	1.72
6	38	124.00	1.37
7	126	254.50	2.67
8	45	93.25	1.96
9	40	129.75	1.06
10	51	252.50	1.55
11	67	319.75	1.38
12	20	98.00	3.13
13	46	258.00	1.82
14	40	189.25	1.45
15	35	123.00	1.53

Table 2. Tenancy status of farmers on sample distributaries.

Distributary	Percent Original Allottees	Percent Offspring of Original Allottees	Percent Tenants	Total No. of Farmers
1	25	58	17	73
2	35	50	15	125
3	63	26	11	76
4	48	26	26	135
5	63	17	20	30
6	32	19	49	65
7	71	13	16	131
8	39	22	39	51
9	46	18	36	49
10	22	34	44	77
11	44	27	29	91
12	20	32	48	44
13	40	27	33	78
14	19	34	47	79
15	52	29	19	31

canal maintenance, resolution of water disputes, and willingness to support water user associations in the future.

Measuring Water Control and Yield

A sample of 82 farm households was drawn from predesignated research blocks (study sites) at the head and tail of each distributary (Figure 4). These 30 blocks ranged from 15 to 20 acres in size, and researchers conducted surveys of soils, cropping pattern, and yields in each block.

Designating research blocks was essential. The land irrigated by field channels ranged from 30 to 50 acres, an area too large for careful surveys of soil conditions and cropping patterns, and comprehensive monitoring of water flows. Consequently, a portion of each sample distributary was demarcated for the study and labeled a "block". Water flows were measured in each block throughout *yala*. Soil conditions, cropping patterns, and water supplies in each block were monitored regularly.

Research blocks were chosen to represent types of soils, cropping patterns, and slope in the larger irrigated area. Socioeconomic information was also collected from sample farmers irrigating within each block. Depending upon the acreage of individual blocks, two or three sample farm households were chosen to represent each block's water control situation at the farm headgate and crop yields.

The farm household comprised those family members who shared the income from one or more fields in the designated research block. If family members separately cultivated a portion of a land allotment and did not share the generated income, they were considered separate households. Land fragmentation resulted in a rich array of cultivation groups among parents, siblings, and children.

Analysis and Results

Data are reported in Figures 5 and 6. Values on key variables, disaggregated by distributary, are provided in Table 3. Detailed explanations of data analysis procedures are available in the Technical report referenced in the Preface.

Regression analysis was employeed to evaluate relationships in Model 1. The yield variable was well suited to regression analysis, and independent and intervening variables did not violate the assumptions needed to conduct a defensible regression analysis (Lewis-Beck 1980; Asher 1983; Davis 1986). Furthermore, multicollinearity among variables was low, and the analysis of residuals (error terms) showed no violations of normality in the distribution of index scores, or in the values of the water control, weed, or yield variables. There was

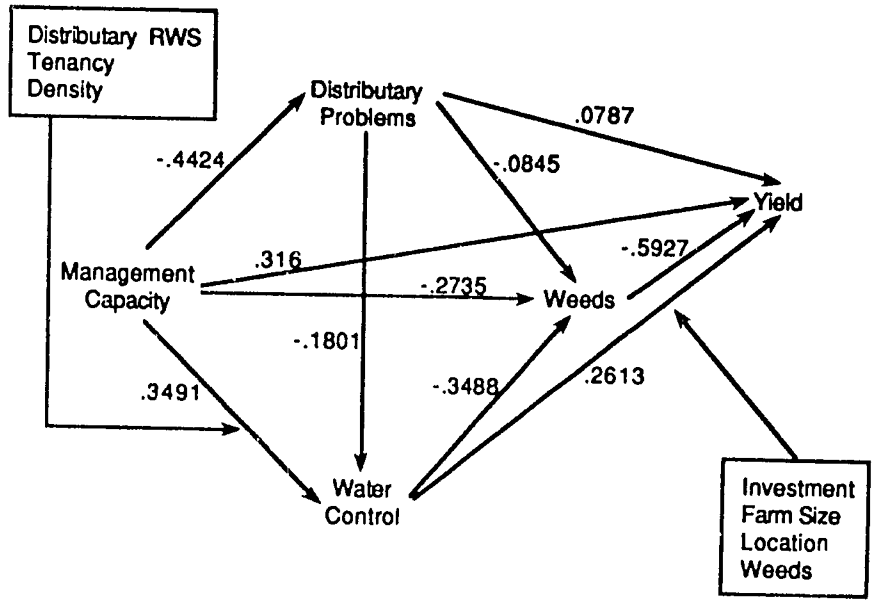


Figure 5. Assessment of research hypothesis--Model 1.

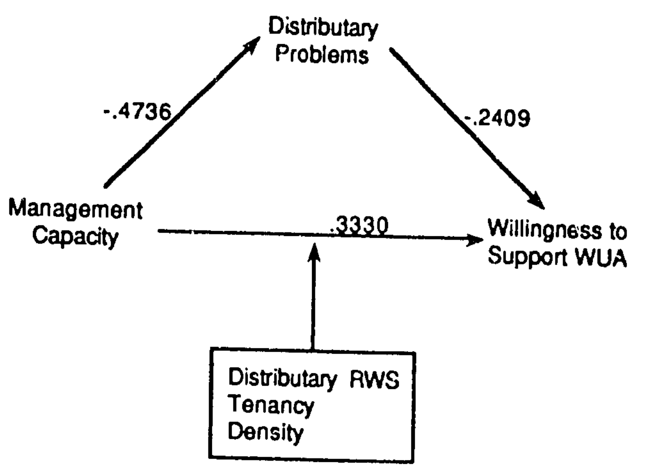


Figure 6. Assessment of research hypotheses--Model 2.

Table 3. Summed index values of indicators for management capacity, distributary problems, and willingness to support water user associations.

Distributary	Management Capacity	Distributary Problems	Willingness to Support WUA
1	538	624	723
2	615	651	754
3	610	628	712
4	431	701	783
5	526	719	708
6	712	581	845
7	382	722	752
8	505	672	693
9	389	636	750
10	622	649	810
11	540	669	827
12	537	610	692
13	456	582	813
14	588	604	740
15	452	560	654

no indication of clustering or any other abnormality in the distributary index scores.

Since a purposive non-random sample was used, it is problematic to make statistical statements about the error terms, and therefore, about the degree of homoskedasticity and autocorrelation of error terms. However, there was no evidence of abnormality in the distribution of any of the variables in the model. Furthermore, given a non-random sample, there is to basis for making inferences from sample distributaries to any larger population of distributaries. Therefore, statistical tests of significance, therefore, are not reported.

Analysis of Model 1

Each bivariate relationship in Model 1 was evaluated separately by examining the Pearson "r" correlation coefficient and the partial correlation coefficient for each relationship which permits examination of changes when the effects of control variables were statistically removed. This analysis provides an evaluation of the overall strength of each relationship in the model. Table 4 provides zero-order correlation coefficients among all variables employed in the models.

Table [illegible]. Zero-order correlations between variables.

	Management Capacity	Water Control	Distributary Problems	Weeds	Yield	Distri-butary	Tenancy	Density	Invest-ment	Size
Model Variables										
Water control	.3491	-	-	-	-	-	-	-	-	-
Distributary problems	-.4424	-.1801	-	-	-	-	-	-	-	-
Weeds	-.2735	-.3488	-.0845	-	-	-	-	-	-	-
Yield	.3160	.2613	.0787	-.5927	-	-	-	-	-	-
Control Variables										
Distributary RWS	-.0771	.1570	-.0526	-.1992	.1711	-	-	-	-	-
Tenancy	.2878	.1366	-.5383	.0499	-.2052	-.2778	-	-	-	-
Density	.1525	-.0282	-.0783	.0022	.1035	.5606	-.2524	-	-	-
Investment	.2139	-.0061	.0163	-.1143	.0771	-.0187	.0943	-.0579	-	-
Size	-.0154	.1790	-.0307	-.1827	.1173	-.2043	.1277	-.4609	-.2725	-
Location	.1799	-.0468	.0001	-.0540	.0158	-.0601	-.1150	-.0421	.2656	-.1165

Management Capacity and Distributary Problems

Table 5 displays the zero-order relationship between management capacity and distributary problems (-.4424), and the change in this relationship when controlling for sample distributary relative water supply, the number of irrigators in the distributary command area, and the proportion of tenants on the distributary.

The relationship between management capacity and distributary problems is quite strong and negative. Increased management capacity at the distributary level does reduce distributary problems, although the number of tenants irrigating within the distributary command area seems to have a mild positive effect on this relationship. Distributary problems decrease as tenancy increases--an interesting but unexpected finding.

Table 4 shows that the relationship between tenancy and distributary problems is rather strong (-.5383). The negative relationship between tenancy and distributary problems is believed to hold because distributaries with high management capacity attract tenant cultivators. During the field work, it was noticed that tenant farmers frequently cultivated high value cash crops, such as tobacco and chilies, which require high levels of investment.

Table 5. Partial correlation analysis of the effects of selected control variables on the bivariate correlation between management capacity and distributary problems.

		Independent Variable Management Capacity	
Dependent Variable	Control Variable	Zero-Order Correlation	Partial Correlation
Distributary problems		-.4424	-
Distributary problems	Distributary RWS	-	-.4484
Distributary problems	Density	-	-.4369
Distributary problems	Tenancy	-	-.3562

It is argued that tenant farmers tend to favor irrigating along distributaries where management capacity and water control at the farm level are high. The bivariate zero-order relationship between management capacity and tenancy is .2878 (Table 4).

It is somewhat surprising that the number of irrigators in the distributary command area (density) and the seasonal-relative water supply for the distributary command area (distributary RWS) do not appreciably affect the relationship between management capacity and distributary problems (Figure 6). Management capacity of sample distributaries simply overcomes the impact of farmer numbers and relative water supply. Development of organized management capacity is a way of coping with variation in local water supplies and farmer numbers.

Management Capacity and Water Control

Table 6 reports the zero-order coefficient between management capacity and water control (.3491), and the change in this relationship under the impact of control variables.

Table 6. Partial correlation analysis of the effects of selected control and intervening variables on the bivariate correlation between management capacity and water control.

Dependent Variable	Intervening Variable	Control Variable	Independent Variable Management Capacity Zero Order Correlation	Partial Correlation
Water control			.3491	-
Water control	Distributary problems			.3054
Water control		Distributary RWS	-	.3668
Water control		Density	-	.3577
Water control		Tenancy	-	.3265
Water control		Location	-	.3638
Water control		Farm Size	-	.3576

The relationship between management capacity and water control is affected somewhat by the other temporally relevant variable in the model (distributary problems). An effect of the "distributary problems" on water control would be expected.

It is again surprising that none of the control variables had any substantial effect on the relationship between management capacity and water control. One might have predicted that either relative water supply in the distributary (distributary RWS) or percent of tenant farmers (tenancy) would have affected this relationship. For instance, one could argue that poor relative water supply would affect the ability of the *vel vidane* to perform his water allocation duties. Likewise, one could predict that the greater the number of tenants, the greater would be disagreement over water allocation, since tenants might be more unwilling to follow "the rules of the game" established by the local community of irrigators. However, a strong argument can be made that tenant farmers want good water supplies and are reluctant to cause problems along distributaries.

Again, management capacity along a distributary tends to limit the effects of other physical and social conditions. If a distributary has a good *vel vidane*, if the services of locally influential people can be called on from time to time to assist the *vel vidane* in resolving water disputes, and if irrigators along the distributary have developed workable agreements about placing check dams in the distributary and field channels when water is flowing, then there is a greater likelihood of individual farmers having relatively better water control at the farm turnout. In sum, when the *vel vidane* secures informal organized support from farmers at this middle level of management, there is a positive effect on water control.

Distributary Problems and Water Control

Table 7 presents data regarding the relationship between distributary problems and water control (-.1801) and the change in this relationship when the impact of each control variable is statistically removed. The effect of distributary problems on water control becomes negligible when controlling for management capacity. Management capacity sustains its relationship with water control when the effects of distributary problems are held aside.

Table 7. Partial correlation analysis of the effects of selected control and intervening variables on the bivariate correlation between distributary problems and water control.

Dependent Variable	Intervening Variable	Control Variable	Independent Variable Distributary Problems Zero Order Correlation	Partial Correlation
Water control			-.1801	-
Water control	Management capacity			-.0305
Water control		Distributary RWS	-	-.1742
Water control		Density	-	-.1829
Water control		Tenancy	-	-.1276
Water control		Location	-	-.1803
Water control		Farm Size		-.1775

Table 8. Partial correlation analysis of the effects of selected control and intervening variables on the bivariate correlation between management capacity and weed problems.

Dependent Variable	Intervening Variable	Control Variable	Independent Variable Management Capacity Zero-Order Correlation	Partial Correlation
Weeds			-.2735	-
Weeds	Distributary problems		-	-.3479
Weeds	Water Control			-.1728
Weeds		Distributary RWS	-	-.2957
Weeds		Density	-	-.2771
Weeds		Tenancy	-	-.3010
Weeds		Location	-	-.2686
Weeds		Farm size	-	-.2810
Weeds		Investment	-	-.2567

Management Capacity and Weeds

The zero-order correlation between management capacity and the extent to which farm fields are affected by the presence of weeds is -.2735 (Table 8). Two important partial correlations stand out. The first is the effect of water control on this relationship. The weed problem at the farm level is substantially reduced as water control at the farm turnout increases. Water control, in turn, is a function of management capacity at the distributary level. The second partial coefficient of special interest in Table 8 is the logical, although small, effect of the investment variable on weeds.

Management Capacity and Yield

Table 9 reports the relationship between management capacity and yield (.3160), and the change in this relationship when effects of the control variables are statistically removed.

Table 9. Partial correlation analysis of the effects of selected control and intervening variables on the bivariate correlation between management capacity and yield.

			Independent Variable Management Capacity	
Dependent Variable	Intervening Variable	Control Variable	Zero-Order Correlation	Partial Correlation
Yield			.3160	-
Yield	Distributary Problems			.3924
Yield	Water Control			.2485
Yield	Weeds			.1986
Yield		Distributary RWS	-	.3351
Yield		Density	-	.3054
Yield		Tenancy	-	.4001
Yield		Location	-	.3183
Yield		Farm size	-	.3200
Yield		Investment		.3075

None of the control variables--particularly location, farm size, and investment--have any appreciable effect on this relationship. However, it would be predicted that water control and a reduced weed population would influence yield. The model temporally specifies that this would be the case, and it is a logical interpretation to make. Water control, weed problems, and yield are closely interrelated, and their sequential relationship is strong. The effect of weeds is the most notable in the relationship between management capacity and yield, and reveals a rather significant "causal" relationship; namely, as management capacity increases, weed problems decrease.

Farm size and location produce a negligible effect on the relationship between management capacity and yield. One could predict that larger farms would have greater problems managing the water they receive, and that unfavorable hydrological location of sample farms would further add to problems with water control and yield. Yet it seems that management capacity tends to compensate for such problems. For the present, it appears that management capacity not only affects yield directly, but also affects yield by reducing distributary problems and improving water control.

Water Control and Weeds

Table 10 displays the bivariate relationship between water control and weeds--namely the greater the water control, the less the weed problem (-.3488). This is a noteworthy relationship, one which is expected under the environmental conditions of the Dry Zone. Of greater importance is that none of the control variables, particularly investment, seems to markedly change this relationship. However, it is known (Table 4) that sample farmer willingness to undertake investment does slightly increase with better distributary management capacity ($r = -.2139$), and that investment is affected by the quality of management capacity at the distributary level. The greater the management capacity at the distributary level, the greater the willingness of farmers to invest in agricultural inputs.

Water Control and Yield

The bivariate relationship between water control and yield (.2613) is positive (Table 11), as are the partial coefficients when the effects of control variables (location, farm size, and

Table 10. Partial correlation analysis of the effects of selected control variables on the bivariate correlation between water control and weed problems.

Dependent Variable	Control Variable	Independent Variable Water Control Zero-Order Correlation	Partial Correlation
Weeds		-.3488	-
Weeds	Location	-	-.3522
Weeds	Farm size	-	-.3268
Weeds	Investment	-	-.3518

Table 11. Partial correlation analysis of the effects of selected control and intervening variables on the bivariate correlation between water control and yield.

Dependent Variable	Intervening Variable	Control Variable	Independent Variable Water Control Zero-Order Correlation	Partial Correlation
Yield			.2613	-
Yield	Weeds			.0723
Yield		Location	-	.2624
Yield		Farm size	-	.2460
Yield		Investment	-	.2626

investment) are partialled out. There is no significant change in this relationship when effects of the control variables are removed. However, as noted earlier, the effect of the weeds variable is dramatic.

Weeds and Yield

Table 12 reports the bivariate relationship between weeds and yield (-.5927) and the partial coefficients remain about the same after having controlled for the effects of location, farm size, and investment. Yield appears to be heavily a function

Table 12. Partial correlation analysis of the effects of selected control variables on the bivariate correlation between weed problems and yield.

Dependent Variable	Control Variable	Independent Variable Weed Problem Zero-Order Correlation	Independent Variable Weed Problem Partial Correlation
Yield		-.5927	-
Yield	Location	-	-.5928
Yield	Farm size		-.5851
Yield	Investment		-.5895

of weed control at the farm level, while presence of weeds is clearly a function of degraded water control at the farm turnout (Tables 4 and 10).

Direct, Indirect, and Spurious Influences in Model I

The partial correlation analyses have supported the major research hypotheses. One way to evaluate the potential direct influence of management capacity on the yield is to subtract from this direct influence the indirect influence of the intervening variables in the model and the spurious influences of selected control variables. Direct influence gives a slightly more realistic picture of the potential power of organizational management capacity in explaining variance in yield. Davis (1986) has discussed the importance of such an evaluation in better understanding the nature of relationships in a multiple variable model, and suggests some simple and useful techniques for conducting such an evaluation. One technique proposed by Davis was applied to the model and is reported in Table 13.

Tenancy and investment were chosen as control variables in this analysis. Both variables show modest correlation with management capacity and, therefore, may be expected to affect the relationships between management capacity and other variables in the model.

Table 13. Effects of management capacity and yield, controlling for significant potentially confounding variables.

(A)	**Bivariate** relationship between management capacity and yield	= .3160
(B)	**Direct** influence of management capacity on yield, controlling for tenancy, investment, distributary problems, water control, and weeds	= .2557
(C)	**Indirect** influence of management capacity on yield caused by (the intervening variables) distributary problems, water control, and weeds (D - B)	= .1345
(D)	**Causal** influence of management capacity on yield, controlling for both tenancy and investment	= .3902
(E)	**Spurious** influence between management capacity and yield caused specifically by tenancy and investment (A - D)	= .0000

Direct influence is that portion of the bivariate relationship that does not include any indirect influence from intervening variables inside the model, or any spurious influence from control variables outside the model. Indirect influence is that portion of the bivariate relationship explained by other variables in the model that intervene between management capacity and yield.

Causal influence is the combination of the direct influence of the independent variable on the dependent variable, as well as its indirect influence through all of the intervening variables in the model. Causal influence is usually a little less than the bivariate correlation because it is a product of the interaction of all of the variables in the model, and the coefficient typically suffers slightly from this interaction. Notice, however, that this is not the case in Table 13. The causal coefficient is higher than the bivariate coefficient.

Spurious influence is that portion of the bivariate correlation contributed by variables not specified by the model. It is always assumed that there are unspecified variables, and that one or more of these explain a portion of a given bivariate correlation and, therefore, a portion of the variance in the dependent variable.

Computations (Table 13) show the direct influence of management capacity on yield is .2557. There is virtually no spurious influence from the control variables chosen for this analysis. However, this means that there are other unknown, unspecified, and unmeasured variables "out there" beyond the model which contribute to the relationship between management capacity and yield.

The causal influence of management capacity on yield (Table 13) is slightly higher than the bivariate relationship between these two variables, presumably because management capacity has some effect on the control variables of tenancy and investment as well. That is, one could speculate that tenancy rates increase with greater management capacity (Table 4) because tenants perceive a distributary command area with good management capacity as a good investment locality. Likewise, investments in fertilizer, herbicides, and pesticides tend to increase (Table 4) in distributary command areas with relatively better management capacity. The control variables chosen to present rival hypotheses in the model do not seem to greatly affect the hypothesized relationships.

In any event, the causal influence of management capacity on yield reveals the importance of informal organizational arrangements at the distributary level on water control and yield for sample farmers. Middle-level distributary organization does make a considerable difference in local rice production despite the problems with management capacity above the distributary headgate in the main irrigation system.

Path Analysis of Model 1

A path analysis of Model 1 provides similar results; the focus now shifts to identify which particular path from management capacity through the intervening variables explains most of the variance in yield (Figure 7).

When employing path analysis, there are three effects on the dependent variable, yield, that can be evaluated:

1. The direct path effect of the independent variable on the dependent variable. This is the bivariate relationship between these two variables.

2. The indirect path effect of the independent variable along all of the intervening variable paths leading to the dependent variable.
3. The total path effect of the independent variable, which is the sum of the direct and indirect path effects.

Figure 7 displays the standardized regression coefficients (beta coefficients) between model variables. A comparison of the analyses in Table 13 and Figure 7 show the results to be very similar, if not identical, as Davis (1986) predicted should be the case. What is different is the additional information provided in Figure 7 about individual path effects.

The path (Figure 7) with the most explanatory power is that directly from "management capacity" to "yield," while the second most useful path for explaining the relationship is through the "weeds" variable. Water control at the farm turnout has a direct and important effect on weed problems. Water control is sustained as providing a critical path between management capacity and yield.

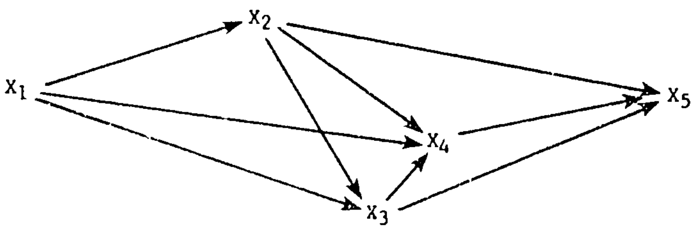
Management Capacity and Farmer Willingness To Support Water User Associations (Model 2)

Farmers were twice presented with questions measuring their willingness to support the development of local distributary water users' associations in the near future. Taking a larger sample of 304 farmers from the 15 distributaries as a whole, 65 percent expressed either "strong support" or "support" of water user associations.

The question to which farmers responded posited a water users association which would make decisions regarding water rotation schedules between field channels on the distributary, as well as making decisions concerning the use of locally collected maintenance fees. Government officers were involved only as nonvoting advisors.

What is the relationship between various aspects of the distributary environment and farmer willingness to support water user associations? The relationship of primary interest was that between management capacity and willingness to support

PATH			
X_1 X_2 X_5	-.3402 * .0221	=	-.0007
X_1 X_2 X_3 X_4 X_5	-.3402 * .0002 * -.3027 * -.4985	=	-.0000
X_1 X_2 X_4 X_5	-.3402 * -.2311 * -.4985	=	-.0392
X_1 X_3 X_5	-.3560 * .0379	=	.0135
X_1 X_3 X_4 X_5	-.3560 * -.3027 * -.4985	=	.0537
X_1 X_4 X_5	-.2721 * -.4985	=	.1356
X_1 X_2 X_3	-.3402 * .0002 * .0379	=	-.0000
Subtotal of indirect effect		=	.1629
Subtotal of direct effect		=	.2487
Total effect of management capacity on yield		=	.4116



X_1 = Management capacity
X_2 = Distributary problems
X_3 = Water control
X_4 = Weeds
X_5 = Yield

Figure 7. Path analysis of the relationships in Model 1, including beta values, summed path effects, and total causal influence of management capacity on yield, controlling for tenants and investment in all paths.

Table 14. Zero-order correlations between variables related to willingness to support water users associations.

	WUA*	Management Capacity	Distributary Problems	Distributary RWS	Tenants
Management capacity	.3330	-	-	-	-
Distributary problems	-.2409	-.4736	-	-	-
Distributary RWS	-.3733	-.0445	-.0864	-	-
Tenants	.3247	.2583	-.5032	-.2673	-
Density	-.1296	.1825	-.1078	.5701	-.2145

*WUA - Willingness to support water users associations.

water users associations, controlling for effects of several other variables.

Intercorrelations for this set of variables are provided in Table 14. Some of these coefficients are slightly different from those reported in Table 4 because they are based on composite index scores derived from all participating farmers in the 15 sample distributary cases, rather than on the 82 sample farmer cases reported in Table 4. What is important is that the signs and relative strength of relationships remained unchanged.

Table 14 reports that management capacity and willingness to support water users associations are positively related to each other (r = .3330). Table 15 reveals that the relationship between management capacity and sample farmer support for water user associations decreased with rising distributary problems. These relationships are not inconsistent with earlier discussion. It has already been shown that distributary problems are a partial function of management capacity and tend to minimally affect other variables as management capacity increases. It was also shown that tenancy tends to occur in command areas where management capacity is relatively better, rather than in command areas with better relative water supply. In fact, Table 14 reports that the relationship between tenancy and relative water supply is negative (r = -.2673). The issue for tenants, as for farmers in general, is less how much water

Table 15. Partial correlation analysis of the effects of selected control variables on the bivariate correlation between management capacity and willingness to support water user associations.

Dependent Variable	Intervening Variable	Control Variable	Independent Variable Management Capacity Zero-Order Correlation	Partial Correlation
WUA*			.3330	-
WUA	Distributary problems		-	.2561
WUA		Distributary RWS		.3413
WUA		Tenants		.2726
WUA		Density		.3658

*WUA - Willingness to support water users associations.

comes through the distributary headgate (although this is undoubtedly important), but what management capacity is available at the distributary level to allocate the given water supply.

Since management capacity and distributary relative water supply do not appear to be much related to each other (r = -.0445), they operate independently on farmers support for water users associations. This is also suggested by the partial correlation analysis presented in Table 15.

There is virtually no difference between the zero-order bivariate correlation between management capacity and willingness to support water users associations and the partial coefficient obtained when controlling for distributary relative water supply (RWS). It is likely that management capacity and distributary relative water supply are two distinct options available to local farmers for improving irrigated agriculture at the distributary level. (At the farm level, management is considerably more important for water control and yield.) Nevertheless, distributary RWS and organized management capacity have dramatically different effects on the willingness to support water user associations in the future, as seen in Table 14. Namely, as relative water supply worsens, support for water user associations increases, whereas, distributary management capacity is positively associated with support for farmer controlled local organizations.

Table 14 reported that there is little or no relationship between management capacity and distributary relative water supply. Yet, sample farmer support for water user associations increases on distributaries with more management capacity--i.e., with active *vel vidanes*, with higher degrees of concensus on the placement of check dams during the day and night, and with more normative control over serious destructive actions such as bathing cattle and washing farm equipment in the distributary. High support or appreciation for water users associations under conditions of strong management capacity may come out of the everyday struggle for better water availability and control.

Management capacity has a dramatic effect on both rice yields and the willingness of farmers to support water users associations. Management capacity overcomes the effects of a number of significant socio-technical variables to insure better water control at the farm turnout, which in turn reduces weed problems and insures higher yield. Despite the low level of management capacity above the distributary headgate, informal organizational arrangements below the headgate demonstrate the importance of local organization in improving agricultural production.

Discussion

Ownership of canals and other irrigation structures by the government, and the government's policy of centrally administering the system, have generally prevented farmers from assuming the initiative in maintenance activities along distributaries. This legal and administrative framework creates little incentive for local farmer participation. In addition, the lack of local and effective enforcement mechanisms to control "free riders" further contributes to the problem of inferior water control by undermining the community's sense of identity and its ability to enforce essential standards of behavior on its members. Attempts to initiate farmer-sponsored organizational and physical improvements along distributaries often meet with reluctance on the part of government officers and some community residents for fear that influential farmers will object to any changes in flow rates.

In Chapter 3, the following questions were posed: Are middle managers accountable to the local irrigation community? Were middle managers recruited from local labor markets? Does a workable water share system unite maintenance obligation with water service? Except for the *vel vidane*, middle management roles were found to be accountable to the Irrigation Department almost exclusively, and most personnel recruited have a "cosmopolitan" background. Local farmer resources were not effectively mobilized for maintenance. No concept of a water share was recognized by main system management that defined an irrigator's right to use water in return for an obligation to contribute to local maintenance and other costs of controlling water.

It is argued that a clear concept of property rights to water and to physical structures provide an important basis for collective action in water management. Water exchange--whether between individuals, within an organization, or between organizations--provides irrigators with a means of moving water to areas within the irrigation community where it can be used more beneficially. Water measurements are crucial to effective local organization, and the concept of organized water shares helps determine eligibility requirements for irrigation community membership. Organized water shares can also stitch together water allocation and maintenance. These organizational features were found to be absent in the two settlement schemes.

Water user associations are viewed as necessary to improved managment of water and increased yields. Many farmers are receptive to water user associations. Distributaries characterized by higher management capacity tended to favor water users associations more than distributaries with lower management capacity. Farmers on distributaries with higher management capacity look for ways to better resolve maintenance and adjudication problems through locally organized action.

Distributaries with lower management capacity have broken into more atomized dyadic relations of power and coercion where might is right. In such social webs, great skepticism exists about organizations in general, especially given past failures at creating organized agreements capable of controlling the more powerful.

Introductory sections of this case study painted a troubling picture of social life in the settlement schemes. An unstable situation obtains with regard to land and water property rights.

This has created feelings of investment insecurity within the irrigation community. In addition, the lack of control over the operation and maintenance of irrigation structures has reduced incentives for farmers to participate in maintenance. The weakness of current farmer organizations has led to feelings of vulnerability and ineffectiveness. The loss of local institutions of adjudication and the general absence of redress for property damage have led to fear of reprisals by government officers, and pervading sense of helplessness. Village elites are viewed by farmers as the primary means available to the local community to get things done in the wider political environment. It is in this context that the majority of farmers indicated a preference for farmer controlled distributary water users' associations. Many sample farmers interviewed had been thinking about such organizations for many years.

Sample farmers were asked why there had been a lack of farmer effort to develop such organizations. Many reasoned as follows: if a farmer has no ownership rights to the land he or she cultivates, if the public agency responsible for the irrigation system discourages maintenance and repairs not authorized by the agency, and if repairs made cannot be protected as a property investment by the local irrigation community, then there is little incentive to develop an organization for collective action. Previous organizational attempts, such as the cultivation committees, were really only efforts to increase participation without connecting that participation to control over a real resource. Farmers frequently stated that such participation was an attempt to make farmers think they had power and influence in the system when they did not, in fact, have such power or influence.

Furthermore, it had become clear to farmers that the public main system irrigation department could not allocate water, maintain the system, or resolve conflicts successfully with available resources. Farmers reported that they did not expect this situation to improve in the foreseeable future.

Farmers expressed willingness to assume responsibility for water management at an appropriate hydrological level, while acknowledging that the irrigation department had special skills that were obviously needed to manage the large storage tanks and main canals. Farmers, for the most part, did not want to be involved in the financial matters of the main system, although they wanted to have some influence over how it was managed. In interviews, farmers seemed to voice the need for developing a mixture of centrally managed and locally managed (i.e., water users' association) irrigation property in such systems.

Long experience has provided farmers with a wealth of ideas about how not to organize. Experience with poor record-keeping, the absconding of organization funds, and other problems have alerted farmers to the care with which such organizations must be designed. Farmers expressed a strong interest in organizational design and an eagerness to participate in constructing their own organizations. They did not feel they needed someone in a public agency designing organizations for them, although they were not opposed to taking suggestions.

World War II veterans, in particular, seemed to have a keen understanding of what makes a good organization. They appeared to be particularly aware of how authority to enforce organizational rules is ultimately based on some power to make participants regularly comply, irrespective of the social rank they hold in the community. Organizations need leverage to secure compliance, and they can get such leverage through the local collective control of water and irrigation structures. They understand that the power of a local organization fundamentally rests on its capacity to deliver water to members who fulfill their obligations, and on its ability to deny water to transgressors.

Farmers favor water users' associations for a third reason --the inadequacy of current arrangements for dispute adjudication. Farmers do not like to bear witness against neighbors in police court, and they are afraid to face lawyers. They fear that such actions damage the reputation of their community, and there are real financial costs involved. Yet, *vel vidanes* are reluctant to face more powerful farmers about repeated offenses because they have no organizational leverage to exert.

Fear is experienced by public agency people as well. Irrigation Department personnel do not involve themselves at the community level in disputes; rather they prefer to wait until the paperwork on a complaint enters the "safety zone" of their office. Police do not like to respond to water disputes. They feel they have no practical authority to deal with such offenses. Certainly, no official wants to go out at night to respond to a complaint.

The feeling of helplessness on the part of farmers and officials is a product of the incapacity of current organizational arrangements to punish offenders swiftly, predictably, and fairly withers the context of a socially legitimate local organization. Given the existing lack of organized and enforceable joint agreements, nobody wants to press charges on individuals for irrigation violations, not the *vel vidane*, not the technical assistant, not the police, and not other government officers in the area. Nobody has confidence in the institutional arrangements currently available.

Given this organizational context, the majority of farmers favor creating local water users associations which would allocate water and maintain the system. At the same time, they desire to form local water organizations to resolve water disputes. Since water is a major cause of conflict in the community, they feel that if water disputes can be resolved predictably, fairly, quickly, and inexpensively, the overall social climate of the settlement schemes will improve. Ability to resolve disputes over water will help restore confidence in the ability of local communities to solve many other kinds of economic and social problems.

Conclusion

The central thesis has been that variation in middle-level organizational capacity affects water control. In turn, water control affects crop yields and the willingness of farmers to support local water user associations at the distributary level.

Irrigation management has been viewed as being divided into two levels. The highest was the hydrological and organizational domain between the storage tank sluices and the many distributary headgates. This level is supervised by Irrigation Department personnel. The lower organizational level is that domain between distributary headgates and individual farm turnouts. This level is supervised by locally elected irrigation headmen (*vel vidanes*), who represent the community of irrigators along each distributary. The distributary headgate defines the point at which the public agency managing the schemes turns water management, in a *de facto* sense, over to the local community of irrigators and their *vel vidanes*.

Qualitative information regarding procedures and roles at the higher level under control of main system management revealed little variance in main system management capacity. The organizational and institutional arrangements for water allocation, system maintenance, and dispute resolution were found to be uniformly weak. All distributary communities of irrigators appeared to be negatively affected by problematic management capacity at this level. Quantitative data gathered at the lower level revealed considerable variation in local farmer and *vel vidane* management capacity observed from one distributary to another.

Both settlement schemes exhibited weak organizational arrangements for basically the same reasons. First, no adequate accountability procedures exist for specifying the rights and obligations of Irrigation Department personnel and farmers. Second, even junior personnel are recruited mainly from non-local "cosmopolitan" backgrounds. This kind of recruitment results in considerable social distance between agency personnel and farmers. Third, no adequate means of mobilizing resources for maintenance exist that permit local irrigators to define a relationship between individual water use and maintenance obligations. Finally, no adequately recognized concept exists which defines an individual irrigator's right to use water (water share) and connects that use right to an obligation to pay costs of local water management.

However, in the absence of viable formal water user associations, local distributary irrigation communities have developed informal arrangements (of variable capacity) for water management. Management capacity was determined by the supervision and authority of the local *vel vidane*, the degree of consensus among farmers over the rules of water allocation along the distributary, and the availability of one or more locally influential people to assist the *vel vidane* in managing water disputes. Distributary communities that revealed a higher degree of management capacity exhibited better water availability and control at the farm level, higher yields, and a greater willingness of farmers to support water user associations in the future.

These findings suggests three points. First, yield was demonstrated to be a direct and indirect function of local distributary management. Low water productivity and poor crop production is really an organizational issue. This is not to say that part of the variance in yield cannot be explained by the on-farm water management practices of individual farmers or by upstream problems in the main system. However, data presented in this study show that production levels vary with the degree of water control at the farm turnout, and that water control is greatly influenced by how the distributary is managed. Distributary management, in turn, is constrained by inadequacies of main system upstream organization.

Second, the traditional role of the *vel vidane*. It was officially introduced in the early years of settlement to facilitate water distribution. This role-status position was officially eliminated with the passing of the Paddy Lands Act (1958). Yet, the role of the *vel vidane* continues to be acknowledged and supported by farmers. Although considerably weakened by legislation and larger socio-economic forces, the traditional role of the *vel vidane* is viable and active, at least in some communities.

Third, most of the problems faced by *vel vidanes* have to do with their ability to enforce agreements between farmers along the distributary. *Vel vidanes* everywhere lack formal organization that gives legitimacy to their authority and that can provide resources for regularly maintaining the distributary. *Vel vidanes* face the community alone and must rely on persuasion and good humor to convince unwilling farmers to play by the traditional informal "rules of the game." They are, as local farmers say, a management "cup" without support of an organizational "saucer."

If water user associations are to be developed, they should be built to support the traditional *vel vidane* water management role. This role does not need to be replaced so much as it need strengthening. This can be accomplished by incorporating the role of the *vel vidane* into appropriate local organization as a manager responsible to farmer members who will employ resources mobilized by farmers within the terms of a viable water share distributional system.

Irrigation water control and crop yields are organizational issues and are functions of organizational capacity. The organization of water management requires accountability, local knowledge, maintenance obligations tied to water rights, and use rights linked to the concept of a water share. The concept of property, the ability to exchange water, effective measurement techniques, and local autonomy are basic requirements. Appropriately designed, local water user associations can do much to reduce problems of both farmers and main system managers and to increase the productivity of water.

PART THREE

Conclusion

8

DISCUSSION AND IMPLICATIONS

"One of the great challenges for policy analysis is the design of organizational structures which can mobilize local experience and integrate it with improved expertise....We recognize...that organizational resources are at least as scarce and valuable as capital, land, and technical knowledge."

Bruce F. Johnston and
William C. Clark 1982:34.

Much ink as been spilled on matters of development administration. Questions have centered on how to mobilize resources, insure accountability, link center and field, secure involvement and participation of affected parties, hold to responsible performance standards while at the same time provide for flexibility and productivity (Bryant and White 1982; Gable and Springer 1976; Montgomery 1974; Moris 1981). The lessons advanced here have been generated in one specific domain--the social organization of irrigated agriculture--and have implications for the development enterprize.

Local grass-roots development, without local control over resources and appropriate linkages to large state bureaucracies, is likely to be inconsequential; but state bureaucracy cannot properly administer resource streams down to the individual users in highly varied social-ecological niches. Only government has the resources and authority to create conditions within which local organization can thrive, but only local organizations can disaggregate centrally provided supplies and control them to productively mesh with site-specific needs.

Rural resource productivity, specifically irrigation water productivity, is low. A diagnosis of the problem suggests that productivity problems can be directly traced to lack of appropriate control over the resource. Lack of control, in turn, has been seen to be a function of organizational arrangements between central bureaucracies and local people. The thesis has been advanced that main system bulk resource deliveries must be disaggregated by intermediate organizations into smaller supplies which can be productively applied to fulfill rapidly changing consumptive demands. Effective organizational arrangements, suitable to this task, must integrate local site-specific idiographic knowledge with generalizable nomothetic scientific ways of knowing, and predictable organizational arrangements must provide a zone of investment security within which those who sacrifice to provide a public good--e.g., water resource control--can protect themselves from the depredations of would-be "free riders."

A solution has been put forth and investigated. Large bureaucracies, effective in maintaining relatively rigid routines, and capable of mobilizing resources for undertaking large scale public works programs, must be interfaced with individual resource users through the device of one or more layers of intermediate organizations. The design of local organizations as linkages has much to do with the productivity of local resource mobilization and use.

This general solution is the one adopted in industrial sectors of all industrialized and industrializing countries--socialist or capitalist. Irrespective of cultural or ideological orientation, factories are interfaced with customers by one or more intermediating wholesale and retail organizations. In no industrial society is it imaginable that factory managements would start and stop their assembly lines according to the daily demand dictates of individual customers. Main system requirements for handling large volumes of product in smooth and predictable ways are meshed with individual customer demands for a particular product configuration via the functioning of intermediate organizations which match factory supply to individual demand.

It is not too venturesome to suggest that, in the world of state supplied public goods, something similar must take place. Anytime an outside altruist--e.g., an irrigation bureaucracy--invests in supplying a resource with the characteristics of a public good (e.g., irrigation works, schools, sewage systems, trees for reforestation), provision must be made for an appropriately designed organization to accept local responsibility for that good, to operate it, maintain it, and manage conflicts which arise in the course of creating and distributing its stream of benefits. Failure to build appropriate local organizations, in any cultural setting, invites individual self-interested rationality to consume whatever benefits are made available in the short-run; individually rational people will jockey for position in the benefit stream, but they are without organizational means to do anything other than appropriate the benefits to their narrow purposes. Since, in the absence of effective local organization, the logic of the individually rational free-rider becomes dominant in the public good situation, choices made possible by the collective good are quickly eroded to the disadvantage of all parties.

In the history of industrialization, when workers migrated from farm to factory they moved, not just across space to cities, but from traditional social networks to new industrial organizations which would greatly enhance the productivity of their labor. Likewise, if rural people are to produce more food and fiber with properly controlled irrigation water, to protect hillsides from erosion by protecting flora and fauna, to reverse desertification, to provide drinking water and sewage treatment, they must also make organizational leaps empowering them to provide to themselves services necessary to any viable conception of social development. Armed with local organizational capacity, rural people can produce public goods, allocate them, maintain the necessary commonly held property, and manage the inevitable conflicts. Such organizational capacity is an essential engine of social development.

One does not induce attributes of a viable house from examination of the properties of individual bricks; likewise, one does not induce properties of effective local organization capable of developmentally expanding choices to control irrigation water by examining farmer and main system management behavior on any particular set of case study sites, especially when those sites are characterized by seriously problematic local organizational arrangements. The concepts advanced in Part One of this volume, defining attributes of effective local irrigation organizations, have emerged from many experiences in irrigation and agricultural development, from discussion and reflection with thoughtful observers in several countries, and from dissection of literature.

Hypotheses have been advanced to the effect that local level organizations must possess particular structural attributes if they are to succeed. Authority relationships must insure that local organizational leaders are responsible to definitions of success and failure advanced by local people as distinguished from upstream main system management (an attribute necessary to create space for local idiographic knowledge). Local people, hired on the local labor market and ambitious for a lifetime in the local area, must be recruited (an attribute necessary to insert local knowledge into the organizational space). Distributional share systems must be devised which connect delivery of organizational benefit to fulfillment of organizational obligations (an attribute necessary to control "free riding"), and which eliminate head-tail problems associated with queuing (an attribute necessary to create a common organizational agenda for all members regardless of queue position). Furthermore, it was postulated that organizations which can mobilize local resources, possibly supplemented by centrally provided subsidies, to hire staff for continuous maintenance will obtain greater resource control than those which rely solely on periodic mobilizations of memberships. It was, finally, hypothesized that to the extent that local organizations possess these attributes, the more effective the control of the local resource, the more productive the application of the resource, and the greater the local individual user-member support of such organizations. The reasoning is advanced as being cross-culturally applicable. The argument has been cast in terms of organizational forms capable of being adapted to an array of local cultural settings.

Case studies presented in Part Two were unable to present tests of all of the above hypotheses because the host sites were devoid of the necessary local organizational richness. Formally recognized local irrigation organizations were conspicuous by their absence at the Pakistan, Indian, and Sri Lankan sites. This is not surprising given the histories of many third world nations including the three represented here. Traditional local organizations were disrupted by colonial administration leaving partial organizational vacuums at the grassroots (Durning 1989; Esman and Uphoff 1984; Jain 1985). Furthermore, post-independence urban elites have tended to view traditional agriculture, and its social organization, more as an unpleasant reminder of the past and less as a source of insight into a productive future (Dahlberg 1979:Ch. 4). Working with Western development models which center upon aggregate economic growth, and which cast local organizational phenomena into the theoretical shadows, policy elites have tended to view local farmers as obstacles rather than as essential allies. Of course poorly organized farmers do pose problems for central administrators, but attempts to foster improved local organization have suffered a high failure rate (Gow et al. 1979; Esman and Uphoff 1984). All too often, they have been crude in conception, clumsily top-down in implementation and thereby insensitive to local realities or naively bottom-up without appropriate bureaucratic linkage and support.

However, farmers do organize as opportunity permits. The case studies present a picture of inadequate organizational arrangements serving no party's best interest--neither that of most farmer water users nor that of main system management. The case studies did provide opportunity for preliminary testing of the strategic local organizational hypothesis--that quality of local organization affects irrigation water control and thereby agricultural production, and that farmers do express willingness to support improved versions of local organizations.

At each study site, local organizational linkages between main system suppliers and local water users lack the design characteristics advanced in Part One. Nowhere is water sufficiently controlled, and everywhere lack of adequate water supply and control in lower reaches of the irrigation systems is directly connected to loss of agricultural production. Existing water management organization sacrifices agricultural productivity and, thereby, rural well-being. Limited variation in local informal organized action permitted glimpses of hypothesized effects--namely that the quality of locally organized action affects productivity of resource use.

Informal local organizational arrangements are constructed among irrigators and between them and main system management in all instances. This, in itself, is not remarkable. A valued resource flows from the main system organization; local action is required to take delivery of it, divide it, and at least minimally maintain certain physical facilities. However, the local organizational arrangements typically reflect the interests of the few, not the many. The question is not: will farmers organize to attempt to control water? The question is: will irrigators organize according to some defensible conception which will sustain productive control over resources in the service of social development?

Farmer participation is typically opportunistic in an administrative environment devoid of effective support for appropriately designed local organizations; it does not integrate local and main system knowledge and satisfactorily discipline "free riders" so as to generate the necessary local public good--water control and productivity. This does not mean, however, that farmers are not capable of effective local organization. In the Pakistan case, they have effectively organized around tubewells, and in Sri Lanka they succeed, at least to a limited degree on some distributaries, in informally cooperating to increase their management capacity and water control.

If all parties are hurt by poor organizational design, and if farmers are capable of organizing, why has there not been organizational improvement? A dynamic emerges in the interaction between farmers and central authority, a cycle of organizational breakdown (Figure 1). Given poorly designed organizational arrangements between the main system bureaucratic management and water users, farmers obtain insufficient water control. Irrigation water arrives too soon, too late, rarely in amounts too much, frequently in amounts too little. Poorly controlled water, supplied at considerable cost by the main system, is much less productive than it could be. Crop consumptive demands are insufficiently fulfilled necessitating shift to draught-resistant lower-yielding crops, sacrifice of yields, and reduction of cropped acreage. Farmers who, at sometime or another, made initial agreements with main system management to repay some portion of project costs, and to perform local maintenance tasks, become reluctant to pay for such a low value resource and they quickly lose enthusiasm for contributing toward maintenance of local facilities. They are constrained by the logic of collective goods. Why should any one irrigator sacrifice for the system, if all others will not? A contribution from one farmer makes sense only if a "fair share" contribution is forthcoming from all others. Only a viable local organization can insure that one's contribution to water control shall be matched and thereby made worthwhile.

Reduced willingness of irrigators to fulfill project repayment and maintenance obligations is typically taken by main system management as indicating farmer incompetence and perversity. Upstream managers tend to conclude that irrigators require more control from the center. Central management, then,

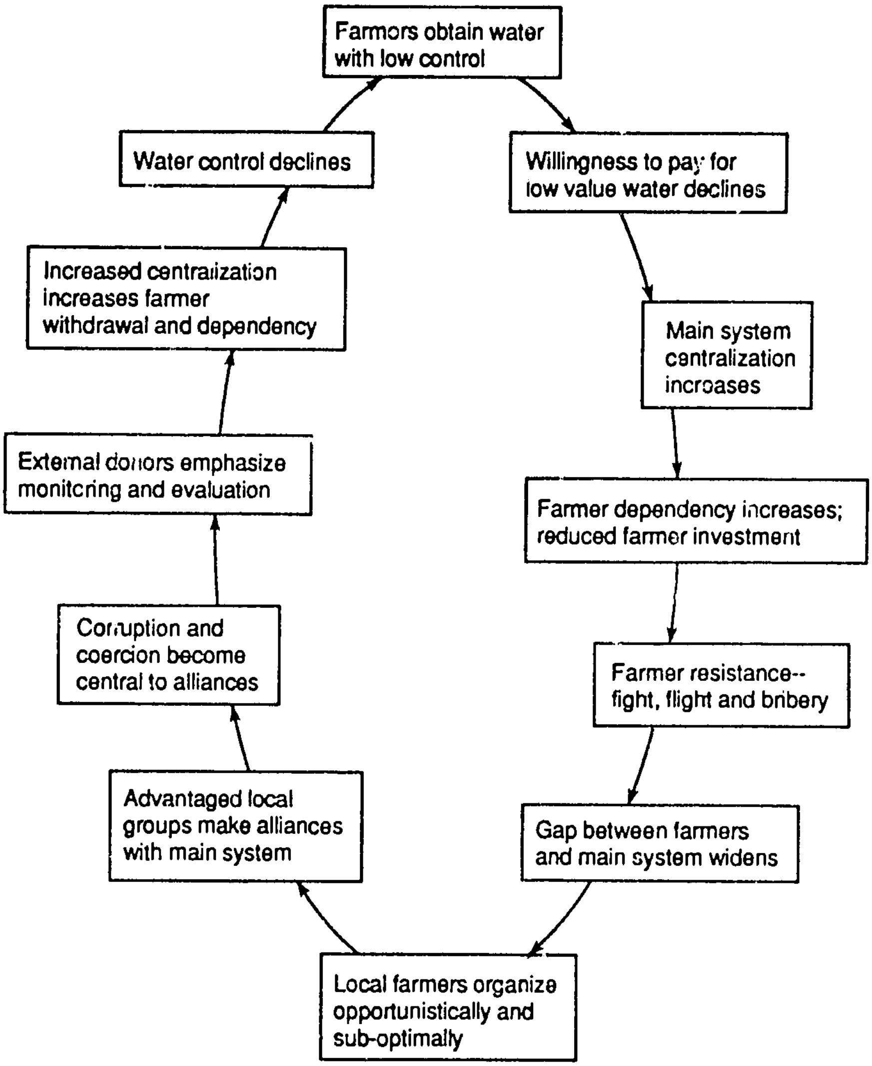


Figure 1. Cycle of Organizational Breakdown.

assumes greater responsibility by taking further initiatives in water allocation and facilities maintenance. Farmers, bearing witness to the fact that main system managers penetrate farther into lower reaches, and without sufficient organizational capacity of their own, conclude that: (a) any investment of effort on their part will be subject to the whims of remote bureaucrats undisciplined in their relationship to the work of farmers by effective organizational agreements; and (b) local irrigators have less and less of a legitimate role to play in local water matters. As local farmer investment diminishes, main system management finds re-confirmation of their initial negative assessment of farmer capabilities and good will.

Yet, farmers require timely and adequate water supplies. In order to secure as much water supply and control as possible, they resist centralized management in several, not mutually exclusive, ways. At times some will fight. Caught by a main system manager or another farmer in the act of taking water in an unauthorized manner, the deviant(s) will take up shovels, knives, clubs, and guns to protect water flow to a crop which would otherwise be moving rapidly to the permanent wilting point. Hostile encounters between irrigators, and between farmers and main system management, are the stuff of much local storytelling.

Some irrigators, disadvantaged by social and geographical position in the system, simply withdraw. Water supply and control is simply so poor that they circumvent the system either by employing groundwater or by shifting to unirrigated crops. A third option is to make special arrangements for water supply with representatives of main system management who are surreptitiously paid amounts sufficient to insure water deliveries to specific points in the canal network. As has been long recognized (Scott 1969), corruption is not a moral problem, but comes as a structural feature of social organization. Corruption represents, not an individual or a cultural aberration, but a product of the fact that people must jockey for control of a scarce resource in an organizational environment not properly designed to provide the necessary discipline for collective joint action on behalf of all irrigators.

Some farmers may primarily opt for one particular mode of response to main system management's operation of the system, but all three kinds of response may be employed simultaneously by farmers depending upon season and circumstance. A farmer who withdraws a given field from irrigated production may well also organize a small group to dig an unauthorized outlet, defend it, and participate in raising money with still other irrigators for illicit supply considerations.

Central system managers cannot be expected to adequately comprehend the myriad factors affecting consumptive crop demands in specific fields; furthermore, they have no adequate physical means to flexibly deliver water to various crop demands even if they did possess comprehensive knowledge of them. Therefore, farmers have no real alternative than to react to main system management with some combination of physical resistance, withdrawal, and bribery. Irrigation projects, when characterized by deficient organizational linkage between main system supply and individual farmer demand, become massive producers of social deviance. In all of this, some farmers gain relative advantage as compared to others, but the system remains severely dysfunctional for all.

As irrigators maneuver for water supply and control advantages, within their individual and factional constraints, there is less and less incentive to share information about their needs, intentions, and capabilities with opposing factions and with main system management. Full sharing of accurate information and data might well jeopardize one's position relative to competitors and central authorities. Information is, therefore, withheld and distorted. Communication gaps widen. Main system management operates with incomplete and erroneous information about patterns of water demand and consumption. For their part, farmers typically report that they are uninformed of central management plans.

Within deficiently organized systems characterized by poorly designed and enforced joint agreements and highly compromised information flows, farmer factions mobilize available social, economic, and political resources with which to make quiet alliances with upstream managers in the water bureaucracy. Managers are not to be condemned; their positions are untenable. If they refuse to make illicit agreements with factional influentials emerging out of the demand side of the system, they accomplish little except to make life personally difficult. In a system without effective local organization to take control of the water supply on behalf of all irrigators, the central system manager has little alternative but to respond to those who are sufficiently organized and aggressive to effectively assert demands. To refuse the proffered bargains, and to stand firm on principle in behalf of the less influential farmer(s) about to be denied water, is to invite complaint from the sub-optimally organized few. Continued resistance to hard-pressed demands by local influentials may lead to a variety of punishments including eventual transfer to worse work situations. Yet, to yield and accept illicit bargains is to acquiesce to situations known to be in violation of formal but impracticable rules drawn up to ostensibly serve some conception of common well-being. Poor design of local organizations traps central management into individually rational but collectively destructive behavior just as it does farmers.

As some local factions obtain water at the expense of others, those who have been denied all or a part of their share must be controlled. Corruption of formal rules for water allocation, system maintenance, and conflict management necessarily translates into gentle, or not-so-gentle, forms of coercion as members of winning alliances suppress demands of losers. When a reasonable cross-section of farmers is given an opportunity to express discontent without fear of retribution, litanies of complaint emanate from the deprived.

Because irrigated agricultural projects promise production and economic returns well above those actually realized, because substantial public investment has been sunk into them, and because persistent lack of routine maintenance necessitates substantial periodic rehabilitation, international donor agencies have been drawn to irrigation projects as foci for their development assistance. International donors, however, insist upon careful monitoring and evaluation of project work. Central irrigation ministries are held responsible for conduct of monitoring and evaluation functions. However necessary as part of a responsible plan, they are conducted within a context of inadequate linkages to local areas. Such efforts cannot repair the deficient organizational situation between main and farm systems, but they may increase the tendency of central bureaucracy to reach further downstream and thereby exacerbate the downward spiral of manager-farmer relationships which comes with over-reaching on the part of main system management, farmer withdrawal of information and other resources, and widening communication gaps.

Effective rehabilitation of irrigation systems must not aim simply at restoring physical works to original design specifications; it must address the organizational reasons which account for the fact that the systems require substantial and all-too-frequent rehabilitation as a substitute for routine maintenance. Much of the cause for inadequate routine operation and maintenance can be traced to poorly designed and implemented organizational arrangements intermediating central water supply and farmer demand. Organizational re-design and rehabilitation must go hand-in-hand with restoration of physical works.

In the absence of local organization, managers in central bureaucracies must either:

a. withdraw from countless resource draining local problems, demands, and conflicts, and thereby leave local people to the whims of local power constellations accountable to no legitimate public authority. Governments, feeling the limits to their capacity to intervene and sensitive to their fragile legitimacy, are in no position to make specific allocational and maintenance demands on the locally emergent alliances and cannot enforce social discipline in the use of state provided infrastructure. This phenomenon has long been recognized and has a name--the "soft state" (Myrdal 1970:237); or
b. attempt to intervene in the affairs of local communities without sufficient local knowledge or resources. One often noted paradox of social development (Bryant and White 1982) is that in poor nations where skilled administrative talent is most scarce, public agencies are highly centralized and require the presence of great supplies of such talent.

Overburdened central ministries, in effect, operate to further weaken whatever residue of local organization has survived colonial experience and neglect from urban elites. Rural development programs involving local public goods--health clinics, schools, rural drinking water supply and sewage systems, reforestation and soil erosion control programs--require creative, flexible, and innovative management. But, the limited administrative resources of state bureaucracies cannot be expected to be fitted to all the variety of special conditions in the countryside. Hope must lay in effective self-sustaining autonomous local organizations productively linked to state bureaucracies.

The cycle of organizational breakdown lays at the center of poor irrigation performance and productivity. There is reason to believe that other rural development programs are also held hostage to inadequate local organization insofar as they involve linking local people and central bureaucratic managements in the realm of public goods. A reforestation program to increase the viability of a population of trees and associated flora and fauna on the hills surrounding a village in Nepal produces a range of valuable services--protecting soils, controlling erosion, reducing downstream siltation and flooding, recycling wastes, providing habitat for valuable plant and animal species. Sustenance of such a forest is the best and cheapest way to insure the continued supply of essential services to sustainable local, national and international development, but it must be protected from the ravages of individual rationality. A social organization must be designed and energized which will effectively sustain collective well-being by virtue of its capacity to control the forest resource, to allocate its fuelwood and other resources according to a viable distributional share system designed to insure sustained yields, to connect delivery of the forest benefits with fulfillment of organizational obligation to the forest, and prevent individual free-riding.

It may be misguided to suggest that the particular forms of organizational design advanced in this work for the world of irrigation water management would apply to other public resource domains in any kind of simple one-to-one manner. Yet, it is suggested that design of local organizations is not only critical for the development of irrigated agriculture, but lessons learned here are relevant to social development in domains other than irrigation water. In the name of progress and development, precious local organizational resources have been neglected, circumvented, weakened, and destroyed. They have been in the shadows of planners' consciousness. It is past time, in the name of progress and development, to strengthen local collective capacities to produce and sustain essential choices that are produced by productive management of public goods.

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