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Linking Main and Farm Irrigation Systems in Order to Control Water

Volume 3:
A Tank System in Madhya Pradesh, India

Water Management Synthesis Project
WMS Report 69

LINKING MAIN AND FARM IRRIGATION SYSTEMS IN ORDER TO CONTROL WATER

VOLUME 3:

A TANK SYSTEM IN MADHYA PRADESH, INDIA

by

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WMS Report 69

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TABLE OF CONTENTS

Section		Page
	LIST OF TABLES	v
	ACKNOWLEDGMENTS	vii
	PREFACE	viii
	EXECUTIVE SUMMARY	ix
I.	INTRODUCTION	1
	A. Community Development Program	1
	B. Panchayat Raj	2
	C. The Green Revolution	3
	D. The Integrated Rural Development Program	3
	E. Central Bureaucracy	4
	F. The Village	4
II.	PROJECT DESCRIPTION	7
	A. Location	7
	B. Study Area	7
	1. Dam and tank	7
	2. Canals	10
	3. Villages	10
	4. Soils and crops	13
	C. Organization of the Main System	13
III.	STUDY DESIGN	16
	A. Problem	16
	1. The Main System	16
	2. The Farm Irrigation Analysis	16
	3. Intermediate Level Analysis	19
	B. Data Collection	19
IV.	RESEARCH FINDINGS FOR THE MAIN SYSTEM	22
	A. De Jure Operations	22
	B. Defacto Operations	23
V.	RESEARCH FINDINGS FOR THE FARM LEVEL	31
	A. General Information	31
	B. The Logic of the Analysis	35
	1. Water control and cropping intensity	36
	2. Water control and cropping patterns	38
VI.	CONCLUSIONS	43

TABLE OF CONTENTS (continued)

Section		Page
VII.	LITERATURE CITED	46
VIII.	APPENDICES	49
	A. Key Informant Interview Schedule	51
	B. Sample Farmer Interview Schedule	57
	C. Glossary of Abbreviations and Terms	62
	D. List of Water Management Synthesis Project Reports	63

LIST OF TABLES

Table		Page
1	Annual irrigated area for the tank project	8
2	Monthly rainfall at Bhopal from January 1977 to December 1983	8
3	Dam and tank features	9
4	Yearly opening and closing dates of canal for *rabi* irrigation, with reservoir water levels	9
5	Utilization of tank water for *rabi* crops	10
6	Location, capacity, and proposed area served by minors along the LBC	11
7	Original design features of the LBC	11
8	Distribution of sample respondents and fields	21
9	Irrigation water charges in Madhya Pradesh	23
10	Field channels in use by source of construction	24
11	Sample field irrigations, *rabi* 1983-84	31
12	Location of sample fields not receiving water during *rabi* 1983-84, relative to fields receiving water	32
13	Size of sample farming operations by village and canal location	33
14	Location of the largest field of each sample farmer in the command area	33
15	Location of sample farmers' fields	34
16	Location of unleveled fields as reported by sample farmers.	34
17	Number of sample fields which had contracted leveling, by size of the total farming operation	34
18	Percentage of fields fallow in *kharif* 1984	36

LIST OF TABLES (continued)

Table		Page
19	Sample fields fallow and planted in *kharif* crop	37
20	Number of fallow fields in *kharif* by the number of fields needing land leveling	37
21	Acreage of *kharif* crops on all minor canals in the command area in 1984	38
22	Distribution of crops on sample minors in *kharif* 1984	38
23	Crop varieties grown in the overall command area in *rabi* 1983-84	39
24	Varieties of wheat grown in different villages in the command area in *rabi* 1983-84	40
25	Crops planted in sample fields (by location) on command area during *rabi* 1983-84	41
26	Sample farmer area planted in different crop varieties in *rabi* 1983-84	41
27	Crops on sample fields by number of intervening outlets between the head of the minor and field or between the head of the minor and the field channel	41
28	*Rabi* crops in sample fields by the number of intervening irrigators	42
29	*Rabi* crop variety in sample fields by size of farming operation	42

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PREFACE

In recognition of the importance of water management for improving irrigated agricultural production, Water Management Synthesis II Project developed several activities related to irrigation system management. One such activity was the special studies research program initiated by Colorado State University. The program examined formal and informal organizational relationships between main system managers and farmers in their efforts to control water in four irrigation systems in Pakistan, India, Thailand, and Sri Lanka. The information that was obtained is presented in the following five volumes:

Linking Main and Farm Irrigation Systems in Order to Control Water. WMS Report 69. Water Management Synthesis Project, Colorado State University, Fort Collins.

- Volume 1: Problems of local organization for reconciling water supply and demand (D.M. Freeman).
- Volume 2: A case study of the Niazbeg distributary in Punjab, Pakistan (E. Shinn and D.M. Freeman).
- Volume 3: A tank system in Madhya Pradesh, India (V. Bhandarkar and D.M. Freeman).
- Volume 4: The case of Lam Chamuak, Thailand (K. Paranakian, W.R. Laitos, D.M. Freeman).
- Volume 5: Two tank systems in Polonnaruwa District, Sri Lanka (J. Wilkens-Wells, P. Wilkens-Wells, D.M. Freeman).

The reader is advised that reading Volume 1 will enhance his or her understanding of the significance of the information reported in volumes 2-5.

EXECUTIVE SUMMARY

This, the third volume in the Water Management Synthesis II special studies series, reports findings of a study of farmers and main irrigation system officials in a central Indian minor tank irrigation project. Farmers (n=42) representing six villages and working fields (n=138) on two head and two tail minor canal commands were studied during 1984 as they struggled to control irrigation water to produce crops.

Special attention was paid to the manner in which the state irrigation bureaucracy was linked to irrigators. The logic of inquiry was as follows: the adequacy of organizational mechanisms between main system civil service managers and irrigators was considered to affect farmer control over irrigation water. The farmers' degree of water control was seen to affect farmer choices regarding cropping intensities and cropping patterns. Greater water control encouraged farmers to grow higher yielding, water sensitive crops, while less water control encouraged farmers to grow lower yielding, but more drought-resistant, varieties. Therefore, the quality of organization (physical structures appropriately combined with enforcable social rules) between individual farmers and main system management was seen to be critical to irrigation water productivity.

What was found? The officially sanctioned de jure organizational arrangements for main system management do not operate as intended. The actual arrangements between farmers and state bureaucracy are far removed from those officially prescribed. The existing system is not capable of integrating farmer water demand with main system supply in a manner that supports announced goals of distributional equity and productivity. At the heart of the matter, no set of social rules supported by appropriate physical structures for water control exists to 1) allocate water, 2) connect water allocation with appropriate farmer obligations for system operation and maintenance, and 3) manage conflicts which arise regarding water allocation and maintenance.

Given the flawed de jure organizational design for matching farmer water demand to main system supplies, irrigators -- individually and in small groups -- have developed de facto arrangements to allocate water in a somewhat predictable, but still highly problematic, fashion. Some haphazard maintenance is performed, and conflicts are managed to the minimal satisfaction of at least a few, but all of this transpires within a network of arrangements which does not, and cannot, intrinsically control water in the interest of a potential irrigation community. Water allocation, maintenance, and conflict management are conducted disproportionately in the interests of a minority of irrigators who have been advantaged by history or geography. A rough equilibrium has emerged over the years which does not serve the best interests of main system management, who are beleaguered by impossible and organizationally undisciplined farmer demands; of farmers, whose water supply and control circumstances vary, but even the best situated

of whom work under significant constraints imposed by inadequate organizational design; or government, which realizes disappointing returns to its irrigation investment.

Since water productivity is diminished by inadequate organizational linkages between main and farm systems and poor maintenance of the physical system, crop production potentials are far from fulfilled. Water productivity is sacrificed because water is not delivered at the proper time in adequate quantities for most farmers in the system. Therefore, poor organizational design, which reduces potential control over water, has much diminished the value of water.

During the summer (kharif) season, cropping intensities were found to be quite low (about 40%), and cropped fields were largely devoted to lower yielding crop varieties than the system is potentially capable of serving. In winter (rabi), cropping intensities were uniformly at 100 percent, but most farmers were compelled to grow lower yielding, more drought-resistant, crops due to lack of water supply and control. They lacked organization for properly maintaining the system and enforcing water allocations.

The researchers had expected to find dramatic shifts in cropping patterns and intensities from the head to the tail of the system. However, given the poor performance at all locations, the strength of relationships between location and the two cropping variables was limited. Even in fields where high yielding crop varieties were planted, reported yields were far below the potential for the area.

The costs of inadequate organizational design have been considerable. Much potential exists for irrigation development in minor irrigation schemes such as the ono reported here. However, that potential will be realized only if an appropriate organizational design is implemented. An appropriate design is one that involves farmers and main system managers in a mutually satisfactory system of organizational linkages which serve to properly operate and maintain the water delivery system. Concepts and procedures for such an organizational design are addressed in Volume 1 of this series of reports: **Linking Main and Farm Irrigation Systems in Order to Control Water: Problems of Local Organization for Reconciling Water Supply and Demand.**

I. INTRODUCTION

Increases in agricultural productivity have been essential to any vision of viable rural development. Given that irrigated agriculture in India is disproportionately productive -- 37 million irrigated hectares of a total of 127 million ha account for half of the grain production in India (Keller et al., 1981) -- the Government of India has strongly emphasized irrigation development.

The objective of irrigation development earlier in this century was to provide drought protection to agriculture (Abbie et al., 1982, p. 1). The 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.

Major increases in crop yields can be achieved by quantitative expansion of the areas served by systems or by qualitative improvements in existing irrigation networks. The costs of expansion rise rapidly as works are undertaken in less naturally suitable physical settings. Increases in acreage accounted for only 25 percent of food production growth in third world nations during this century (Svendsen et al., 1983, p. 18). Improving existing projects, however, offers prospects of high returns to investment (Abbie et al., 1982). Yet, deferred maintenance and declining performance in many projects are of serious concern. Even so, attention has been shifting to rehabilitation of existing projects. When rehabilitation includes redesigning existing organizational arrangements as well as improving physical structures, and when qualitative improvement includes fitting together the newly refurbished "tools" with supportable social rules for irrigation water management, a rupee invested in rehabilitating an existing system promises most productive returns. Rehabilitation that improves physical works with little regard to the social nexus within which the physical structures function, seriously compromises the likelihood of receiving an adequate economic return to investment.

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. Before proceeding with the analysis, the problem of local linkage between farmers and representatives of the government is placed in historical perspective. Breakdowns in the organizational interface between farmers and main system managers account for a large portion of diminished productivity of irrigation water.

A. COMMUNITY DEVELOPMENT PROGRAM

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, p. 52). 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, p. 191). The Community Development Program was not a "single, coherent, rationally conceived development program" (Nicholson, 1973, p. 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, p. 52-53). Community development analysts recognized that conflict existed between individual interests and the requirements of collective community development action (Nicholson, 1973, p. 19). 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, p. 191). "Public enthusiasm and cooperation, stimulated by government authority, were seen to be the answer to India's poverty" (Nicholson, 1973, p. 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.

B. PANCHAYAT RAJ

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, p. 25; Panchanadikar and Panchanadikar, 1978, p. 53). 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, p. 193-194; Franda, 1979, p. 116-146). 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, p. 72).

C. THE GREEN REVOLUTION

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 breakthroughs 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).

D. THE INTEGRATED RURAL DEVELOPMENT PROGRAM

In the 1970s, new programs specifically aimed at improving the condition of the rural poor were initiated (Sharma, 1980, p. 5). 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, p. 7; Jain et al., 1985).

E. CENTRAL BUREAUCRACY

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, p. 2) 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's much larger population 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 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, p. 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, p. 12).

F. THE VILLAGE

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, p. 20-21). The

village was also a largely autonomous economic unit under the control of the landlord(s) (Nicholson, 1973, p. 21). 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, p. 33).

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, p. 109-110, 314-319). 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 across caste lines (Nicholson, 1973, p. 36).

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 without an effective approach to rural development. It is no surprise that analysts have judged the experience to be less than positive (Dantwala and Barmeda, 1985, p. 59-60).

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.

It is in this socio-historical 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 organizational mechanisms between main and farm systems 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.

II. PROJECT DESCRIPTION

A. LOCATION

This study was conducted in the central state of Madhya Pradesh, which has the largest area in the union, but a relatively low population density. Madhya Pradesh is well endowed with agricultural resources, but it has not yet mobilized them to eradicate rural poverty. A substantial potential exists for increasing 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 ac. Rainwater flows to a catchment area created by an earthen dam. Two canals on the left and right banks command the irrigated area.

B. STUDY AREA

The head village nearest the tank 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 command area.

Started in 1953 and completed in 1958, the Tank Irrigation Project was designed to serve about 2,430 ha (6,000 ac). 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 the main system of an irrigation project. The landowner who initiated the project was granted the construction bid.

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

1. Dam and Tank

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.

Table 1. Annual irrigated area for the tank project (in 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.

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.

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.

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 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^3 per acre (Table 5). Consumptive use varied from 0.074 million ft^3/ac to 0.198 million ft^3/ac.

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.

Table 5. Utilization of tank water for rabi crops.

Year	Capacity (mft^3) At Start	At End	Used	Area (mft^3) At Start	At End	On Avg.	Evap. Losses (mft^3)	Net Capacity (mft^3)	Use (mft^3/acre)
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

*mft^3 = million cubic feet.
Source: Venkatraman et al., 1984.

2. Canals

In addition to the dam and tank, the main system consists of the 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 (255 chains) 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 (from 1.32 km to 2.55 km, 3.69 km to 4.41 km, and 4.80 km to 5.40 km) were lined with flagstone. The remainder consisted of double-banked earthen channels (Venkatraman et al., 1984). The location of original minor offtake points along the left bank canal are indicated in Table 6. The design features of the LBC are shown in Table 7.

3. Villages

Six villages are located along the left bank canal. The head village, Village 1, with a population of 1,700 is the largest (Figure 1). At the time of this study in rabi 1984, the total command area of the left bank was 2,400 ac. The area irrigated was 2,024 ac.

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 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.

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

Section Number	Location (chains)	Location (mi)	Location (km)	Capacity (cfs)	Proposed Area for Irrigation (ac)
1	67	1.27	2.04	1.27	125
2	97	1.84	2.96	0.78	75
3	108	2.04	3.29	2.97	280
4	123	2.33	3.75	3.85	337
5	142	2.68	4.32	0.62	60
6	145	2.75	4.42	1.50	145
7	156	2.95	4.75	1.03	100
8	176	3.33	5.36	1.10	100
9	183	3.47	5.58	2.83	263
10	196	3.71	5.97	3.79	355
11	215	4.07	6.55	0.85	80
12	230	4.36	7.01	4.30	430

Table 7. Original design features of the LBC.

Chainage	Bed Width (ft)	Full Supply Depth (ft)	Side Slopes	Bed Slope	Velocity (ft/s)	Free-board (ft)
0-67*	6.0	2.50	Vertical	0.0004	2.51	1.50
67-97	5.5	2.50	1.5H:1V	0.0004	1.55	1.50
97-122	4.0	2.50	1.5H:1V	0.0004	1.55	1.50
122-145	3.5	2.50	1.5H:1V	0.0004	1.55	1.50
145-183	3.0	2.25	1.5H:1V	0.0004	1.40	1.50
183-196	3.0	2.00	1.5H:1V	0.0004	1.20	1.50
196-215	2.0	1.75	1.5H:1V	0.0004	1.20	1.50
215-230	2.0	1.50	1.5H:1V	0.0004	1.10	1.50

*This section was lined.
Source: Venkatraman et al., 1984.

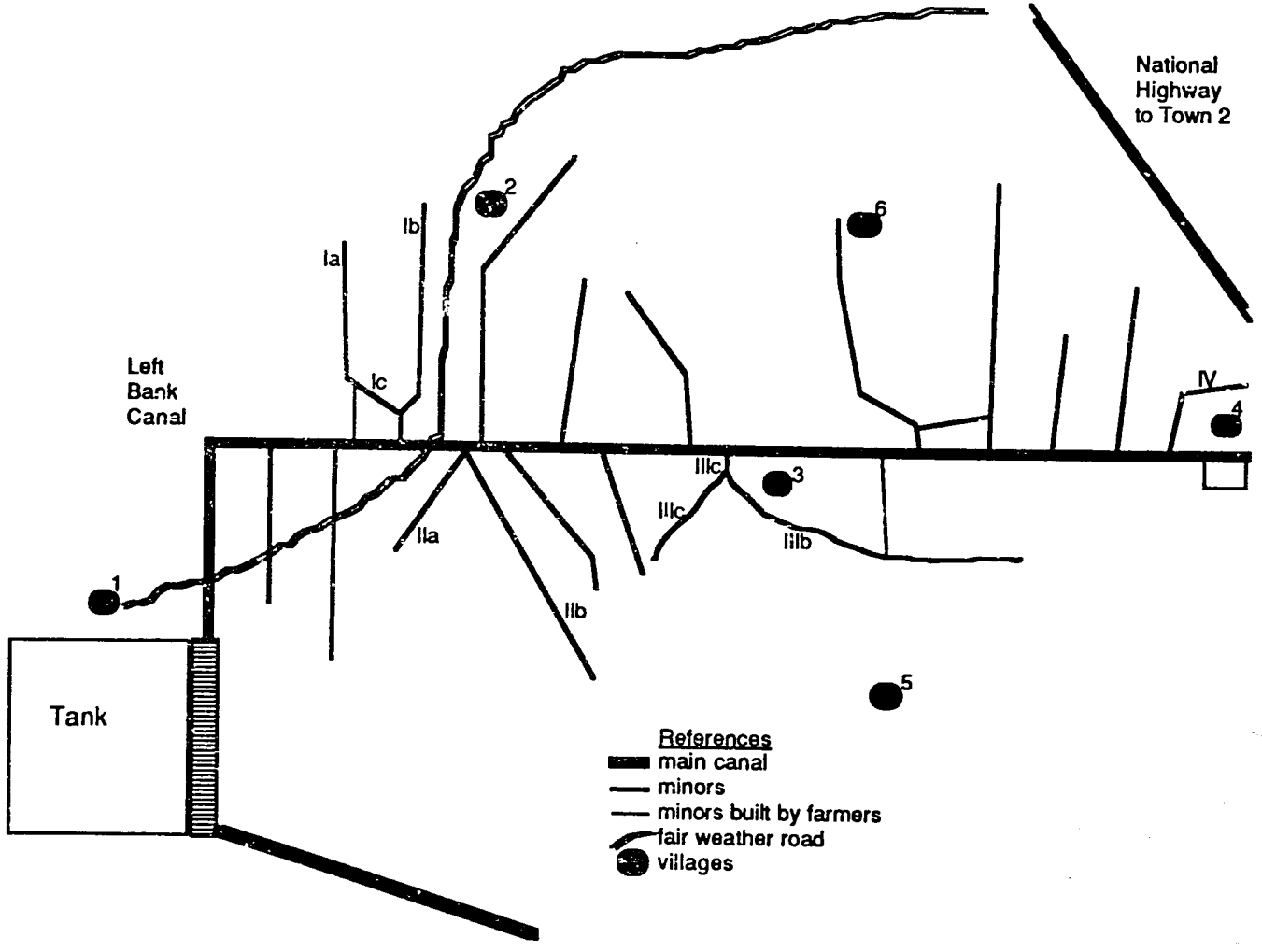

Figure 1. Schematic of study area.

4. Soils and Crops

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, chickpeas, and arhar (a legume). A few rain showers in 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 crop is cultivated, it is followed by a fast-growing dwarf 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.

C. ORGANIZATION OF THE MAIN 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 2.

The Secretary of Irrigation, not shown on Figure 2, 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 tanks. 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 ha.

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.

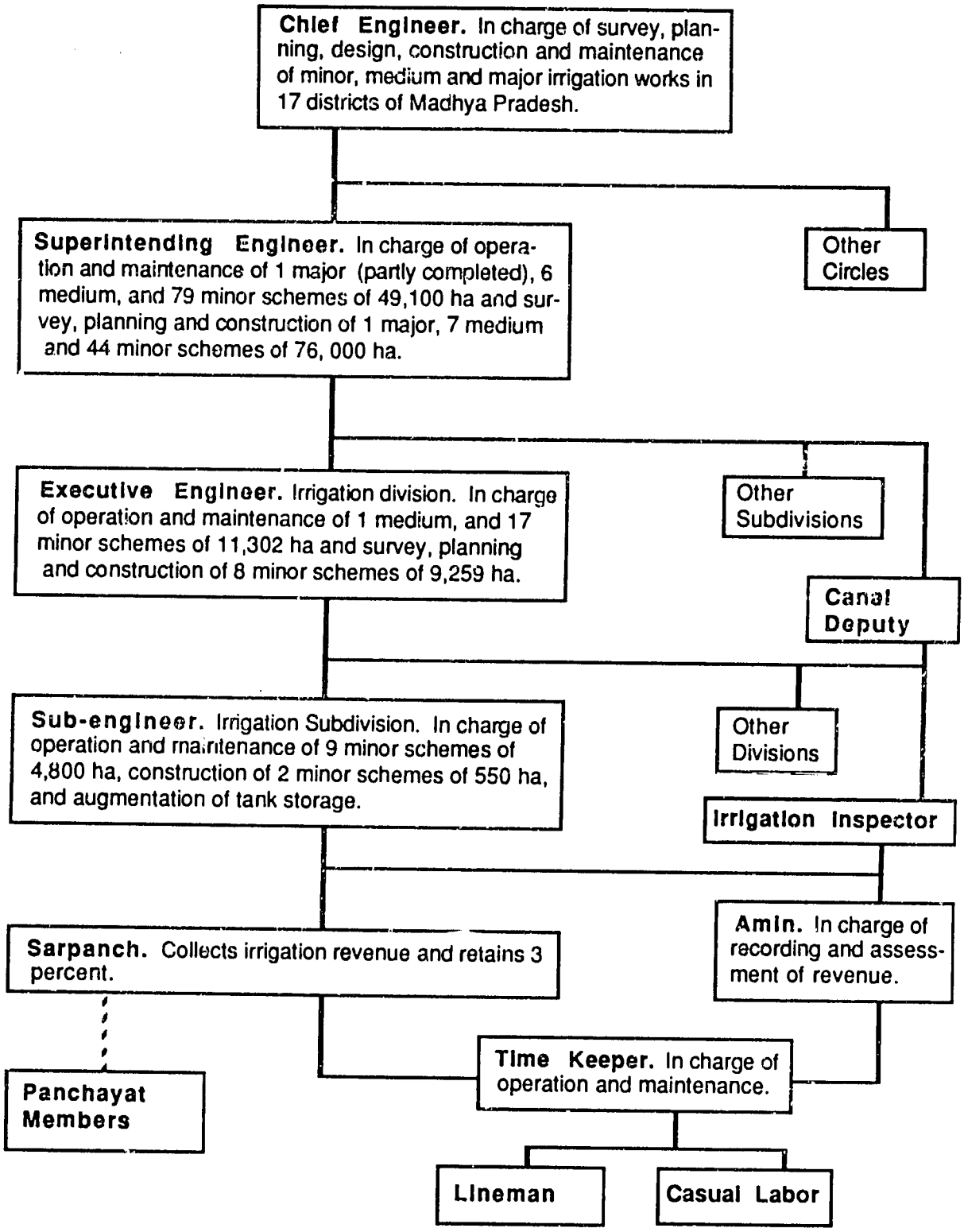

Figure 2. Organizational structure of the Department of Irrigation in Madhya Pradesh, India.

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.

III. STUDY DESIGN

A. PROBLEM

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 and disadvantage. This chapter presents the study design used to systematically investigate the impact of farmer location on two important variables -- cropping intensity and cropping patterns.

This study examined, in an exploratory manner, the Tank Irrigation Project's operation at three levels: the farm, local collective activity between the farm and the main system, and the main system.

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).

1. The Main System

The main system organization investigated was that of the Department of Irrigation as described in Chapter II. The department's operation was examined to determine how it allocated water, maintained the system and resolved conflict. The results of the investigation at this level are reported in Chapter IV.

2. The Farm Irrigation Analysis

Dependent Variables. 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.

Thus, it was not possible to examine the effect of varying water control on crop yields in this study.

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

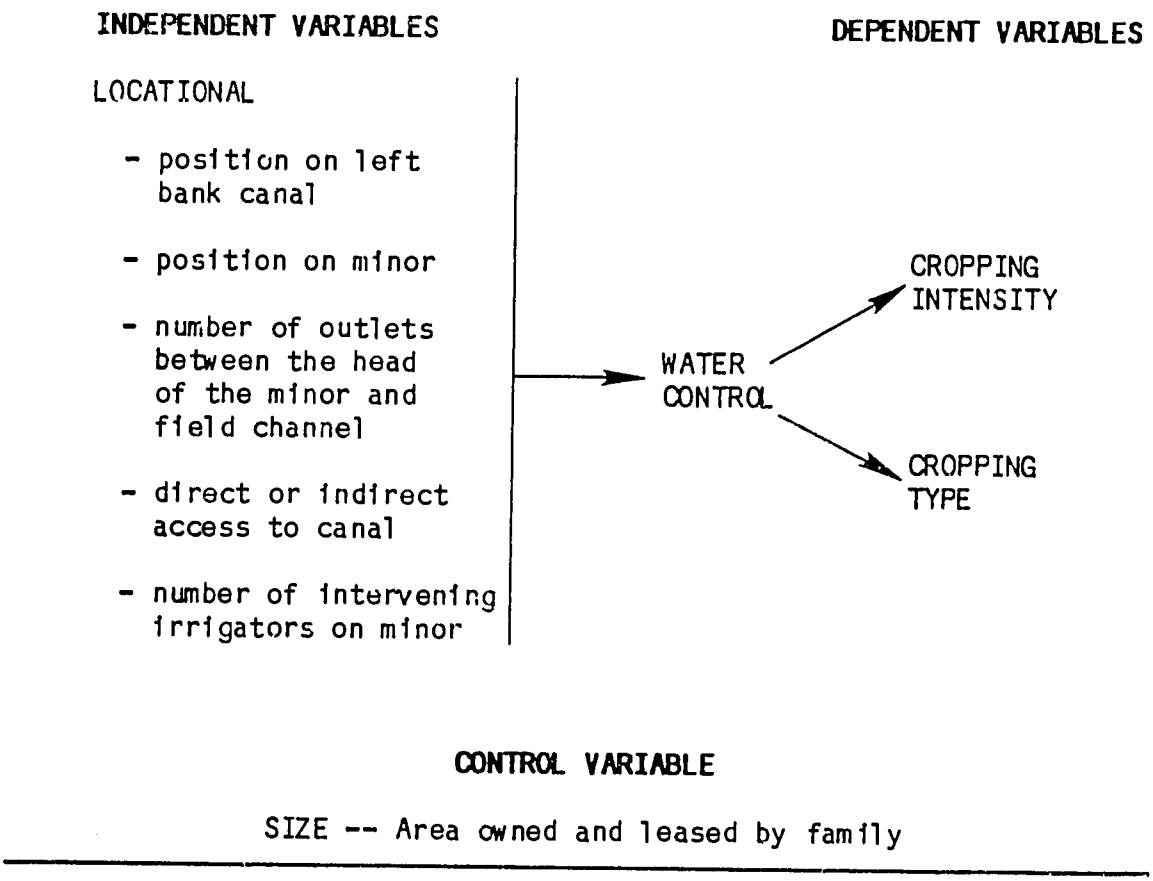

Figure 3. Design for investigation of a farm level irrigation.

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, cropping patterns represent a central farmer strategy for responding to water supply situations and represent 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.

Independent Variables. Farmer water control is affected by farm location in the command area 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 head.

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 considered to be 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.

Two types of water access became apparent during the study:

1. Some water originated from minors with multiple outlets -- indicating a need to share water with other irrigators.

2. Direct access to the main canal.

Fields were categorized accordingly, indicating relative dependence of farmers on others for water and the locational advantage of having an outlet on the main canal.

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 we estimated day length, we consider the hours of water application to be approximate.

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.
2. A fixed cash rental arrangement in rupees per acre.

3. Intermediate Level Analysis

This study specifically investigated interaction between farmers and main system managers regarding water allocation, maintenance, and conflict resolution. Information was gathered by asking sample farmers open-ended questions. This was supplemented by conducting extended interviews with key informants -- officials and farmers.

B. DATA COLLECTION

The 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. Field work was conducted in three stages:

1. The senior author became familiar with the setting and people. Since she did not speak the particular dialect of the region, this period was also spent learning the local dialect. Key informants were identified during this stage, and the logistics of data gathering were

established. (The key informant interview schedule is presented in Appendix A.)

2. Contact was made with representatives of the irrigation bureaucracy. An overview of the system was obtained at the departments of Irrigation and Agriculture. Social welfare and agricultural officials aided in drafting key informant schedules. Key informants were interviewed, sometimes more than once. Based on the information gathered, a sample of farmers was drawn.

3. Sample farmers were interviewed, sometimes more than once. (The sample farmer questionnaire is presented in Appendix B.)

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 were of three categories:

1. Department of Irrigation, Department of Agriculture, and social welfare officials (seven).

2. Political leaders occupying village administrative positions (four).

3. Farmers, representing a spectrum of farming situations and locations in the area (ten).

The sample 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. Forty-two sample irrigators were available 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. Respondent distribution and their field locations are reported in Table 8.

Data were gathered during June and July, 1984. Most interviews were conducted in farmers' homes, although a few farmers were interviewed at a common village meeting place. Interviews were conducted in the local Hindi dialect without the aid of an interpreter. When necessary, as many as three interviews with respondents were conducted.

Department of Irrigation officials who were responsible for the Tank Irrigation Project offered a jeep to the senior author, who took up residence in village. The offer was politely refused to avoid raising farmer suspicions that she was allied with the main system operators. The senior author traveled in the command area by foot. After an initial visit to the command area, the senior author decided to reside at a local doctor's house, a residence perceived to be neutral by various factions in the area.

Table 8. Distribution of sample respondents (n=42) and fields.

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.

IV. RESEARCH FINDINGS FOR THE MAIN SYSTEM

A. DE JURE OPERATIONS

Madhya Pradesh has a large Irrigation Department as evidenced by its 13 chief engineers. Officials up to the level of executive engineer in the project area selected for this study operated from offices in Bhopal. The subdivisional office is in Town 2 (Figure 1), about 4 km from Village 4, at the tail of the system. The sub-engineer's office is in Village 1, at a resthouse on the tank.

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 panchayats, amins also collected water charges. The sub-engineer'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 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 9.

Table 9. 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

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

B. DEFACTO OPERATIONS

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 10 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 10. 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

Large water losses occur in the initial reaches of the left bank canal where water flows over porous, stratified, sandy rock. Total canal losses are unknown. However, a loss of 25 percent was measured by the diagnostic analysis team (Venkatraman et al., 1984) in the first kilometer and a loss of 16 percent was measured in the second kilometer (lined with flagstone). During kharif irrigation 1984, substantial seepage occurred along canal walls. Uneven canal beds exacerbate seepage and silting, and crab holes in the banks are abundant. The lack of roads in the area means that canal banks function as walkways. Bank erosion results with consequent water overflows. During the study, in one month alone, the canal breached three times. Breaks were repaired by mobilizing mass labor. However, crab holes -- one source of the problem -- were left unattended.

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 user fees. 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, but with few systematic means to be sensitive to local farmers' definitions of priority, except as defined by complaining sub-groups.

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 could find themselves relocated 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 de jure standards since no legitimate agreements existed to define and enforce some concept of distributional equity, maintenance obligations, and conflict management procedures. 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 600 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 panchayats, 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.

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 plugged outlets to the head minors at about 5:00 p.m. each day to divert water 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 reopened their minors by 8:00 a.m., 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 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, were 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. The earthen dam required yearly maintenance and routine work. 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 suffer 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 done 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 power.

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 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 beyond 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. Therefore, 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.

V. RESEARCH FINDINGS AT THE FARM LEVEL

This chapter reports an analysis of the effect of existing arrangements between main system operators and farmers at the farm level. The question posed is: How are cropping intensities and patterns affected by existing arrangements, or lack thereof, for water control? Before examining this question, some general findings are reported.

A. GENERAL INFORMATION

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. Unlevel fields make water application uneven. Furrow irrigation has been tried in the past, but farmers reported that it was too labor intensive and was not conducive to operating their implements in the field.

When asked how they determine when to start irrigating, farmers reported that 42 of the 138 sample fields were irrigated as soon as water was available in the minor. Of those 42 fields, 38 were located in one of the two tail minors. Farmers cultivating another 38 fields in the head and middle reaches reported that they begin to irrigate when the soil begins to crack. One of the 42 sample farmers looked for moisture 5 to 6 inches below the surface to determine soil moisture availability.

Table 11 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.

Table 11. 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.

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 obtaining irrigation water

is reported in Table 12. Even in head reaches some fields failed to receive water due to high field elevation or poor minor 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.

Table 12. 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

Only one farmer in the command area tested soils. This farmer, not included in the sample, cultivated 75 to 100 acres and had completed a college education in agriculture. He reported sending soil samples for testing to a laboratory and employing results to determine choice of seed and fertilizers. He also was unique in the command area for continuing to update his knowledge about agricultural techniques by staying in regular communication with the regional agricultural university. Whereas the average reported yield for high-yielding varieties of wheat among sample farmers was 639 kg/acre, this farmer regularly obtained yields in the range of 1,200 to 1,300 kg/acre. Sample farmers relied on their experience when applying fertilizer, and many had reduced their fertilizer use due to its cost and lack of water. Farmers said that crops "burn" when fertilized without sufficient water, and that unreliable water supplies made investing in fertilizer a risky proposition.

While gramsevaks (agricultural advisors) are to be provided by the government of Madhya Pradesh at the ratio of one to 100 farm families, no gramsevak served the 600 families in the command area. The last such advisor served the area in 1981-82.

Table 13 reports the distribution of farmers on minor canals in the command area by village of residence. The greater number of farmers representing Village 1 reflects the generally smaller, more intensive cultivation pattern in the head reaches. Only one individual from Village 2 was included in the sample because other residents of Village 2 were employed in Industrial Town. Overall, farms tended to be larger in the middle and tail reaches of the command area where cultivation was more extensive (Table 13).

Table 13. Size of the sample farming operations by village and canal location.

Area of Land Owned and Leased (ac)	Sample Number of Farmers Villages and Approximate Location in Command Area (n=42)			
	1* (head minor)	2* (tail of head minor)	3* (middle) minor	4* (tail minor)
0 - 5	4	-	-	1
5 - 10	6	-	3	1
10 - 20	8	-	-	-
20 - 40	3	-	4	1
+40	5	1	-	5
TOTAL	26	1	7	8

*Village.

Of the 42 sample farmers, 13 (31%) leased all or part of their land. Five leased all their land: two in Village 1 and three in Village 4. Two types of tenancy predominated: 1) sharing costs and outputs between owner and tenant in 1:1 or 2:1 ratios, and 2) tenant payment of a fixed rent in cash or in kind.

One method used to determine a farmer's position relative to the canal and minor, was by assigning the farmer's position according to the location of his largest field (Table 14). Most farmers had their largest field in the middle areas of the command. Table 15 displays the distribution of all 138 sample fields across the command area. Sample fields were evenly divided across head, middle, and tail sections of the main and minor canal commands. Of the 138 fields, 19 fields were directly irrigated by the main canal, 76 fields by a minor, and 26 fields were separated from a minor by one intervening field.

Table 14. Location of the largest field of each sample farmer in the command area.

Location on the Main Canal	Location on the Minor			
	Head	Middle	Tail	Total
	number of fields			
Head	5	15	7	27
Tail	5	5	5	15
TOTAL	10	20	12	42

Table 15. Location of sample farmers' fields.

Location on the Main Canal	Location on the Minor			
	Head	Middle	Tail	Total
	----------number of fields----------			
Head	15	32	25	72
Tail	16	17	23	66
TOTAL	41	49	48	138

Land leveling was a problem. Of the 138 fields, farmers judged that one-third required leveling (Table 16). Unleveled fields were distributed across sample minor canal commands, but the larger farms located toward the tail tended to be judged by farmer respondents to be more in need of leveling than smaller fields toward the head. Lack of leveling was reported to be associated with the poor alignment of minors, which adversely affected water supply.

An important consideration is that farmers can cope better with land leveling in smaller basins. As field size increases, leveling becomes more difficult, given the equipment available to farmers. Therefore, farmers with larger plots must contract for land leveling services. The propensity to contract leveling is clearly associated with farm size (Table 17).

Table 16. Location of unleveled fields as reported by sample farmers.

Position on the Canal	Number and Percent* of Sample Fields Reported to Require Leveling		
	Head	Middle	Tail
Head	5 (33)	10 (31)	21 (84)
Tail	0 (10)	3 (18)	7 (30)

*() = % of sample fields in category.

Table 17. Number of sample fields which had contracted leveling, by size of the total farming operation.

Sizes (ac)	Number of Fields Leveled
0- 5	0
5-10	2
10-20	3
20-40	2
+ 40	21

Head minor Ib served an especially large number of fields in need of leveling. The minor was not properly aligned in its head reaches. Furthermore, farmers on branch Ia (Figure 1) routinely refused to release water into minor Ib during periods of high demand. With such a poor water supply, farmers of minor Ib reported that they lacked incentive to incur land leveling expenses.

Problems associated with sharing costs arose when a canal outlet served fields owned by different farmers, the case [redacted] 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 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 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.

B. THE 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/ac, and the average reported yield of this strain was 639 kg/ac. Yet, the potential yield for this variety was determined [redacted] 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.

1. 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 in kharif. 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.

The locations of fallow sample fields in kharif 1984 are presented in Table 18. 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 18 reveals that numbers of fields left fallow during the kharif was high in five of six locations in the command area. The proportion of fallow fields distinctly increased moving from the head to the tail reaches of both head and tail minors.

Table 18. 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.

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 19). 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.

Table 19. Sample fields fallow and planted in kharif crop, 1984 (n=138).

Farm Size (Area Owned & Leased in ac)	Fallow	Planted	Total
	----------number of fields----------		
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*

Levelness of fields is associated with tendency to crop them (Table 20). Since land leveling affects water control, it is not surprising that it is significantly associated with cropping intensity.

Table 20. 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*

Overall, what does the analysis of cropping intensities reveal? The effects of an unmeasured variable -- cost of labor -- made analyzing cropping intensity during kharif difficult. Location may, in fact, be

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical value occurred by chance.

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 at portions of head and middle reaches.

2. Water Control and Cropping Patterns

During kharif, a highly labor-intensive crop (paddy), tends to be sown by smaller operators whose labor supply is relatively great in proportion to the area they cultivate. However, if water is available, but not labor, farmers prefer soybeans. Acreage under paddy and soybean in the entire command area for kharif is presented in Table 21. Soybeans are planted on more than eight times the acreage of rice. Table 22 reports crop distribution among fields on the sample minors.

Table 21. Acreage of kharif crops on all minor canals in the command area in 1984.

Crop	Acreage
Paddy	123
Soybeans	1000 to 1500

Source: Sub-engineer's office.

Table 22. Distribution of crops on sample minors in kharif 1984.

Crop	Location on the Main Canal	Area Cultivated (ac)	Number of Fields
Soybeans	Head	148.22	32
	Tail	101.54	25
TOTAL		249.76	57
Paddy	Head	9.18	2
	Tail	21.02	23
TOTAL		30.20	25

The relationship between irrigation water accessibility and cropping patterns is not as strong in kharif as compared to rabi because the sample does not represent the actual distribution of paddy fields at the head of the canal. Kharif crops are also chosen according to labor availability. Furthermore, the monsoons suppress the impact of irrigation or the lack thereof. Therefore, cropping decisions in rabi are viewed as better indicators of irrigation system performance.

Three varieties of wheat were planted in the area during rabi (Table 23) -- C-306 (a lower yielding variety) and WH-147 and Sujata (two 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 potential 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 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 and higher unit price. About 125 days are needed for Sujata to mature, and it is highly sensitive to properly timed water applications.

Table 23. Crop varieties grown in the overall command area in rabi 1983-1984.

Crop Variety	Acres Cropped
Wheat	
C-306	1,367
WH-147 and Sujata	532
Lentils, garbanzo, peas, or arhar	376

Despite availability of hybrids, many farmers chose to cultivate drought-resistant wheat. Although farmers prefer eating C-306, they reported that they grow WH-147 because of its higher yield, its higher exchange value, 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 24 shows distribution of wheat varieties by village location, and Table 25 reports these varieties by canal command area location. Farmers of Village 1 (head) are clearly the most devoted to cultivating high-yielding varieties (Table 24).

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.

Table 24. Varieties of wheat grown in different villages in the command area in rabi 1983-1984.

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

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 25). 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 misaligned minors and problems posed by intervening irrigators throughout the system.

Inspection of Table 25 reveals that the number of sample fields planted in high yielding wheat drops 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 somewhat toward the tail of the main canal. The 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, which keeps the chi-square and contingency coefficient values at a low level. Again, sample farmers reported that they rely on alternatives to high-yielding wheat varieties because the water supply is not assured due to a combination of the behavior of the intervening irrigators and misaligned minors.

Table 26 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.

Position, as measured by the number of intervening irrigators on a given minor canal outlet, also might affect crop type. Of the 19 fields irrigated directly by the main canal, 16 were sown with WH-147. Therefore, access to the main canal partly accounts for the presence of high-yielding varieties lower in the system. Direct access to main canal flows creates a condition favorable to growing high-yielding wheat varieties.

In a system without effective joint agreements among farmers and main system operators for securing water from the main system and allocating it equitably along the major and minor canals, one might suspect that the greater the number of outlets between the head of the minor and the field, the less the access to water and control over water a farmer would have. In turn, one would expect to find a shift to lower yielding, less water-sensitive crops. Table 27 reports data which modestly support this hypothesis.

Table 25. Crops planted in sample fields (by location) on command area 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*

Table 26. 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 C = .328 Cramer's V = .347 p = <.001*

Table 27. Crops on sample fields by number of intervening outlets between the head of the minor and field or between the head of the minor and the field channel (n=138).

	Rabi Crop Sown on Fields		
Number of Outlets	WH-147	C-306	Other (lentils)
0- 3	33	12	2
4- 8	11	17	6
9-13	18	14	7
14+	6	8	4
Total	68	51	19

X^2 = 15.567 d.f. = 6 p = <.025 C = .318 Cramer's V = .237*

*X^2 = chi-square, d.f. = degrees of freedom, C = contingency coefficient, p = probability that statistical values occurred by chance.

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 28. 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.

Table 28. 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

X^2 = 6.043 d.f. = 4 p = <.25 C = .205 Cramer's V = .148*

The size of farm operation might also affect farmer cropping decisions. Table 29 reports the relationship between crop type and farm size. Examination of Table 29 reveals that the number of sample fields devoted to different crop varieties shows little tendency to vary with farm size. A statistical analysis of the data reported in Table 29 revealed 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 areas. Size of farming operation cannot be said to affect the choice to grow high-yielding varieties.

Table 29. 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.

VI. CONCLUSIONS

Irrigation systems are designed to reduce uncertainty about the adequacy and timing of water deliveries to crop root zones. To effectively reduce uncertainty, joint agreements must be made and enforced between farmers and main system management regarding the use and maintenance of physical works. Making and keeping joint agreements is the essence of irrigation organization. Irrigation organization allows people to do things collectively that cannot be accomplished individually. Since no farmer can individually purchase a unit of water supply and control on the private marketplace, they and main system managers must organize to operate and maintain system works and to divide main system flows into units useable by individual farmers. Specifically, if water is to be more productive, main system supplies must be better matched with individual farm demands. Furthermore, individual interests in minimizing costs and maximizing benefit must be harnessed to cooperative effort to allocate water, share water losses among all irrigators so as to create common interest in system performance, maintain the collectively owned apparatus, and manage conflicts which inevitably arise around issues of allocation and maintenance.

This case study focused on the de jure and de facto organizational arrangements at the main system level, the farm level, and in the linkages between the two in a small tank system in Madhya Pradesh. Data about the nature and effects of the joint agreements were gathered from main system officials and irrigators. In addition to repeated in-depth interviews with key informants drawn from the ranks of main system officals and farmers, 42 farmers were studied who had irrigable land (138 fields) on four minor canal commands which represented the range of head and tail locations on the main left bank canal. What was found?

First and foremost, de jure organizational arrangements were observed to not function in actuality. The 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 Volume 1 of this series, 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 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 organizational design 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 the de jure design? 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 Volume 1), will be unable to sustain successful operation.

Physical rehabilitation must serve some coherent conception of integrated organizational design -- including viable staffing patterns and productive, locally enforceable water share systems linked closely to technically appropriate maintenance -- to make water controllable and productive. In 1908, when Mohandas K. Gandhi published Hind Swaraj (Indian Self-Rule), he linked local, self-reliant, decentralized, democratic people, 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 is what development in society is all about.

VII. LITERATURE CITED

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VIII. APPENDICES

APPENDIX A

KEY INFORMANT INTERVIEW SCHEDULE

NOTE: For key informant farmers start with Section B. For key informant officials, Section B is not applicable. Section C is common to both officials and farmers.

SECTION A

Name: Age:
Religion: Caste:
Official Position:
Where is your office?
Where do you live?
How long have you been in this place at this position?
[Reason for choosing the official]:

What are your responsibilities?

[Trace the map of the organization and role of the people in the organization.]

Non-routine construction and rehabilitation:

Allocation and drainage:
Maintenance:
Conflict resolution:

Under full canal flow:

Minor No.	Prescribed Size of Outlet	Command Area

What was the frequency of water release in the rabi season of 1983-84?

Can you give me the water release schedule for rabi of 1983-84?

Time & date of releasing	Time and date of stopping water	How much was the sluice opened

SECTION B

Name: Age:
Religion: Caste:
[Reason for choosing]:

Lands managed by the respondent:

Minor No.	Position on the Minor	Away or on the Minor	Area in Acres

Area of land leased in _____ acres
leased out _____ acres

Tenancy agreement: crop share Rs. _____ per acre

What are other kinds of tenancy agreements in this command area?

What are the cropping types on this minor?

Position on the Minor	Kharif	Rabi

How do farmers decide on cropping intensities and cropping types?

Number of waterings in the last season (1983-84)?

Date	Duration	Minor Number	Position

SECTION C

Who makes the decisions regarding release of water from Dahod Tank?

How is it decided to open the gate?

How is it decided to close the gate?

How is water rotated among the minors?

Who makes the decision of rotating the water among minors?

How is the decision to close a minor made?

Who monitors the flow of water in the main LBC?

Who monitors the flow of water in the minors?

Is there a time keeper(s)? _____ yes _____ no

If yes, name(s):

Religion/caste:

What does a time keeper do?

Salary in cash Rs.: in kind:

Who supervises his work?

Comments:

How long does it take for the water to reach the tail?

How is the water charge set?

Who sets it?

Who keeps the records?

Who collects it?

What happens if an irrigator does not pay his/her dues? (Talk about particular cases.)

Are there any farmers outside the command area receiving water?
_____ yes _____ no

If yes, how?

There is always both support and opposition to any method of doing things.

Who supports the present arrangement of releasing water?

Where are they located?

Who opposes this most?

Where are they located?

What in your opinion are the top three priority problems with the present arrangements of allocation of water? Explain each priority problem.

Please tell me about the most important dispute which has occurred among irrigators between laterals?

Who represented the respective sides?

What are the most important problems faced on the minors?

To whom do farmers go to if they are not happy with the way in which water is rotated between minors?

Maintenance

Whose responsibility is it to maintain LBC:

Minor:

What is involved in cleaning the LBC?

Who does it?

When was it done last?

What is involved in cleaning of the minors?

Who does it?

When was it done last?

What are the key important problems in cleaning LBC?

Cleaning minors:

Who takes care of broken and leaky structures on LBC?

On minors:

How does information about maintenance problems get from farmers to the officials?

How long does it take to repair broken and leaky structures?

On what does it depend?

Are there any problems of seepage in LBC? _____ Yes _____ No

If yes, where?

What is to be done about it?

When was it last done?

Are there any problems of spillover? _____ Yes _____ No

If yes, where?

Intralateral Level

How is the water rotated within minors?

Do all minors have the same system? ____ Yes _____ No

If no, which are the different systems?

How do irrigators who share the same outlet from the minor share the water?

Who is responsible for putting field channels?

How is the cost covered?

Who monitors the field outlets?

What kinds of conflicts occur over sharing the water within a minor?

How are they resolved?

What are the key problems of sharing water from the same outlet?

What problems do farmers face in the design of the farm outlets?

Do you think this is a problem?

How do the farmers resolve the problem with the design of an outlet?

Does that affect other farmers? (Probe for unauthorized outlets.)

Water Panchayats

Are there any water or irrigation panchayats? ____ Yes ____ No

If no, go to the next section.

If yes, what administrative unit do they address?

...for each village, minor or the whole LBC?

How are the panchayat members chosen?

If they are elected, who elects them? (Probe for how particular people got elected.)

Name of the panchayat members	Religion/Caste	Comments

What are the duties of panchayat members?

allocation:

maintenance:

conflict resolution:

Distribution of Farmers in Minors

(Using the map of LBC, ask for rough distribution of farmers in different minors.)

Head/Tail	Minor No.	Size of Farms	Predominant Religion/Caste

APPENDIX B

SAMPLE FARMER INTERVIEW SCHEDULE

I. Date of interview:
Sample farm Khasera No.:
Revenue record:
Village:
Minor No.:
Position on the minor: ___ Head ___ Middle ___ Tail
Farm is ____ on the minor, or _____ away from the minor

II. Respondent No.: Age:
Religion/Caste:
Area owned by the respondent on this minor:

Total area owned by the respondent:

Total area owned by the family of the respondent:

	Minor No.	Position on Minor	Revenue Record No.
Area leased in: Where:			
Area leased out: Where:			
Tenancy arrangement:			
Crop share:			
	Rs. _____ per acre		

No. of fields:

Revenue Record No.	Kharif	Intensity of Cultivation	Rabi	Intensity of Cultivation

III. No. of Irrigations in the Last Rabi Season:

Field Khasera Number	Preparation of Field Irrigation	Time Required for Irrigation Qt.	Why

IV. How do you decide when to start irrigating?

How do you decide when to stop irrigating?

V. When you need water, how do you ask for it?

By filling in demand forms and taking them to the tank yourself?
By filling in a demand form and giving it to _____.
Who takes it to the tank?
By telling one of the irrigation staff?
Waiting for others to make applications?
Other?

Amongst irrigators, who takes the initiative in collecting demand applications for water?

Where do you get the agreement forms?

To whom do you give the agreement forms?

VI. After giving the applications, how long does it take to release water in LBC?

After the water is released into LBC, how long does it take to reach the head of the minor if all irrigators before you decide to irrigate?

How is the water rotated within the minor?

How many outlets are open on this minor at a time?

Does that affect the time taken for irrigating your field?
___ Yes ___No

If yes, how?

VII. Do you share the outlets on the minor or LBC with anyone else?

If yes, with whom do you share?

Khasera number(s):

On what terms do you share it?

What are the problems of sharing the same outlet? Explain each one,

If the water is being prevented from coming into your field, what is the reason for it?

If there are conflicts about sharing water from the same outlet, how are they resolved?

Who resolves these conflicts?

VIII. When LBC is flowing at full capacity at the head of the minor and when minor outlet is open, what is the level of water in the minor at the farm outlet if all other outlets on the minor are closed?

_____ full _____ partially full or _____ spills over

Why?

IX. Do you have field channels in your field? ____ Yes ____ No

If yes, who built them?

How was the cost covered?

Is the design of the field channels satisfactory? ___ Yes ___ No

If no, what is wrong with them?

X. Do you think the design of this minor is satisfactory? __ Yes __ No

If no, what is wrong with it?

How is the problem of wrong design being resolved?

XI. When was the last time the minor/LBC was cleaned at the farm outlet?

Who cleaned it?

How satisfied were you with the job?

___ not at all satisfied
___ satisfied
___ very satisfied

Comments:

XII. Do you have problems of

___ seepage
___ spillover
___ leaks
___ broken structures

Explain:

What is to be done about it?

What are you doing about it?

Is your land levelled? ___ Yes ___ No
If no, does it need leveling now? ___ Yes ___ No
If yes, what are the problems that you face now because your land is not leveled?

Explain:

XIII. How much did you produce on this farm (sample farm) last year?

	Crop	Quantity
Kharif		
Rabi		

XIV. Who checks the area irrigated on your field for levying the water charge?

Who keeps the records?

How is the water charge set for your field?

Who collected the water charge last year?

Who is collecting this year?

XV. What are the functions of irrigation panchayat?

Who elected them?

Do you know the names of the panchayat members in your area?

XVI. To whom would you go if you do not get your share of water on this minor?

In the village?

To whom do people go to if fights emerge in the village?

On this minor:

In the village:

To whom do people go to act as an intermediary between them and the irrigation department?

On this minor:

In the village:

XVII. There are many possible ways to improve the irrigation system. I would like your judgment as to what would be best for you. Please rate:

-2 highly unfavorable
-1 unfavorable
0 indifferent
1 favorable
2 very favorable

Allocation of water should be done in rotation by location and by time; and money paid by acreage.

The irrigation staff should be responsible to be hired and paid by Irrigation Department.

The irrigation staff should be responsible to be hired and paid by local body of irrigators.

APPENDIX C

GLOSSARY OF ABBREVIATIONS AND TERMS

ad hoc	for the particular purpose at hand, without reference to wider application
amin	a revenue official who assists sub-engineers and is supervised by the irrigation inspector
arhar	a legume grown in the study area
cm	centimeter
de facto	actual observed behavior
de jure	officially prescribed action
free rider	individual or group who takes benefit from system without fulfilling obligation to system
ft	feet
gram sevak	agricultural advisor
ha	hectare
in	inch
kg	kilogram
kharif	summer monsoon season; June-September
km	kilometer
LBC	left bank canal
m	meter
panchayat	traditional council of elders in a village
rabi	winter dry season; October-March
Rs.	rupees
Sarpanch	responsible for collecting water charges

APPENDIX D

LIST OF WATER MANAGEMENT SYNTHESIS PROJECT REPORTS

WMS 1 Irrigation Projects Document Review

Executive Summary
Appendix A: The Indian Subcontinent
Appendix B: East Asia
Appendix C: Near East and Africa
Appendix D: Central and South America

WMS 2 Nepal/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 3 Bangladesh/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 4 Pakistan/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 5 Thailand/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 6 India/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 7 General Asian Overview

WMS 8 Command Area Development Authorities for Improved Water Management

WMS 9 Senegal/USAID: Project Review for Bakel Small Irrigated Perimeters Project No. 685-0208.

WMS 10 Sri Lanka/USAID: Evaluation Review of the Water Management Project No. 383-0057.

WMS 11 Sri Lanka/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 12 Ecuador/USAID: Irrigation Sector Review

WMS 13 Maintenance Plan for the Lam Nam Oon Irrigation System in Northeast Thailand

WMS 14 Peru/USAID: Irrigation Development Options and Investment Strategies for the 1980s

WMS 15 Diagnostic Analysis of Five Deep Tubewell Irrigation Systems in Joydebpur, Bangladesh

WMS 16 System H of the Mahaweli Development Project, Sri Lanka: 1982 Diagnostic Analysis

WMS 17 Diagnostic Analysis of Farm Irrigation Systems on the Gambhiri Irrigation Project, Rajasthan, India: Volumes I-V

WMS 18 Diagnostic Analysis of Farm Irrigation in the Mahi-Kadana Irrigation Project, Gujarat, India

WMS 19 The Rajangana Irrigation Scheme, Sri Lanka: 1982 Diagnostic Analysis

WMS 20 System H of the Mahaweli Development Project, Sri Lanka: 1983 Diagnostic Analysis

WMS 21 Haiti/USAID: Evaluation of the Irrigation Component of the Integrated Agricultural Development Project No. 521-0078.

WMS 22 Synthesis of Lessons Learned for Rapid Appraisal of Irrigation Strategies

WMS 23 Tanzania/USAID: Rapid Mini Appraisal of Irrigation Development Options and Investment Strategies

WMS 24 Tanzania/USAID: Assessment of Rift Valley Pilot Rice Project and Recommendations for Follow-On Activities

WMS 25 Interdisciplinary Diagnostic Analysis of and Workplan for the Dahod Tank Irrigation Project, Madhya Pradesh, India

WMS 26 Prospects for Small-Scale Irrigation Development in the Sahel

WMS 27 Improving Policies and Programs for the Development of Small-Scale Irrigation Systems

WMS 28 Selected Alternatives for Irrigated Agricultural Development in Azua Valley, Dominican Republic

WMS 29 Evaluation of Project No. 519-0184, USAID/El Salvador, Office of Small-Scale Irrigation -- Small Farm Irrigation Systems Project

WMS 30 Review of Irrigation Facilities, Operation and Maintenance for Jordan Valley Authority

WMS 31 Training Consultancy Report: Irrigation Management and Training Program

WMS 32 Small-Scale Development: Indonesia/USAID

WMS 33	Irrigation Systems Management Project Design Report: Sri Lanka
WMS 34	Community Participation and Local Organization for Small-Scale Irrigation
WMS 35	Irrigation Sector Strategy Review: USAID/India; with Appendices, Volumes I and II (3 volumes)
WMS 36	Irrigation Sector Assessment: USAID/Haiti
WMS 37	African Irrigation Overview: Summary; Main Report; An Annotated Bibliography (3 volumes)
WMS 38	Diagnostic Analysis of Sirsia Irrigation System, Nepal
WMS 39	Small-Scale Irrigation: Design Issues and Government-Assisted Systems
WMS 40	Watering the Shamba: Current Public and Private Sector Activities for Small-Scale Irrigation Development
WMS 41	Strategies for Irrigation Development: Chad/USAID
WMS 42	Strategies for Irrigation Development: Egypt/USAID
WMS 43	Rapid Appraisal of Nepal Irrigation Systems
WMS 44	Direction, Inducement, and Schemes: Investment Strategies for Small-Scale Irrigation Systems
WMS 45	Post 1987 Strategy for Irrigation: Pakistan/USAID
WMS 46	Irrigation Rehab: User's Manual
WMS 47	Relay Adapter Card: User's Manual
WMS 48	Small-Scale and Smallholder Irrigation in Zimbabwe: Analysis of Opportunities for Improvement
WMS 49	Design Guidance for Shebelli Water Management Project (USAID Project No. 649-0129) Somalia/USAID
WMS 50	Farmer Irrigation Participation Project in Lam Chamuak, Thailand: Initiation Report
WMS 51	Pre-Feasibility Study of Irrigation Development in Mauritania: Mauritania/USAID
WMS 52	Command Water Management -- Punjab Pre-Rehabilitation Diagnostic Analysis of the Niazbeg Subproject

WMS 53 Pre-Rehabilitation Diagnostic Study of Sehra Irrigation System, Sind, Pakistan

WMS 54 Framework for the Management Plan: Niazbeg Subproject Area

WMS 55 Framework for the Management Plan: Sehra Subproject Area

WMS 56 Review of Jordan Valley Authority Irrigation Facilities

WMS 57 Diagnostic Analysis of Parakrama Samudra Scheme, Sri Lanka: 1985 Yala Discipline Report

WMS 58 Diagnostic Analysis of Giritale Scheme, Sri Lanka: 1985 Yala Discipline Report

WMS 59 Diagnostic Analysis of Minneriya Scheme, Sri Lanka: 1986 Yala Discipline Report

WMS 60 Diagnostic Analysis of Kaudulla Scheme, Sri Lanka: 1986 Yala Discipline Report

WMS 61 Diagnostic Analysis of Four Irrigation Schemes in Polonnaruwa District, Sri Lanka: Interdisciplinary Analysis

WMS 62 Workshops for Developing Policy and Strategy for Nationwide Irrigation and Management Training. USAID/India

WMS 63 Research on Irrigation in Africa

WMS 64 Irrigation Rehab: Africa Version

WMS 65 Revised Management Plan for the Warsak Lift Canal, Command Water Management Project, Northwest Frontier Province, Pakistan

WMS 66 Small-Scale Irrigation -- A Foundation for Rural Growth in Zimbabwe

WMS 67 Variations in Irrigation Management Intensity: Farmer-Managed Hill Irrigation Systems in Nepal

WMS 68 Experience with Small-Scale Sprinkler System Development in Guatemala: An Evaluation of Program Benefits

WMS 69 Linking Main and Farm Irrigation Systems in Order to Control Water

Volume 1: Problems of Local Organization for Reconciling Supply and Demand
Volume 2: A Case Study of the Niazbeg Distributary in Punjab, Pakistan
Volume 3: A Tank System in Madhya Pradesh, India
Volume 4: The Case of Lam Chamuak, Thailand
Volume 5: Two Tank Systems in Polonnaruwa District, Sri Lanka