Final Report

Program on Farmer-Managed Irrigation Systems and Support Services

Phase II

VOLUME 6

FARMER-MANAGED GROUNDWATER IRRIGATION WITHIN THE EASTERN GANDAK IRRIGATION SYSTEM IN BIHAR, INDIA

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FINAL REPORT

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Abbreviations

BSD	Bishunpur Sub-Distributary of the Vaishali Branch Canal
CAPART	Council for Application of People's Action in Rural Technology
CCA	Culturable command area
cumecs	Cubic meters per second
cusecs	Cubic feet per second
GCADA	Gandak Command Area Development Authority
GCA	Gross command area
IIMI	International Irrigation Management Institute
O&M	Operation and maintenance
PADI	Peoples' Action for Development India
PVC	Polyvinyl chloride
RD	Reduced distance = 1,000 feet
Rs	Rupees
TMC	Tirhut Main Canal of the Eastern Gandak System
VASFA	Vaishali Area Small Farmers' Association
VBC	Vaishali Branch Canal of the Eastern Gandak System
WALMI	Water and Land Management Institute
WRD	Water Resources Department

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Foreword

THIS STUDY IS an outgrowth of collaboration between the International Irrigation Management Institute's global study on Farmer-Managed Irrigation Systems (FMIS) and the Bihar portion of the IIMI-India Collaborative Study carried out by the International Irrigation Management Institute (IIMI) together with the Water and Land Management Institute (WALMI) in Patna and with the Centre for Water Resource Studies at Patna University.

The IIMI-India Study in Bihar was concerned with a macro understanding of the problem of conjunctive water use management within the Eastern Gandak Command in North Bihar. That study touched only peripherally on questions of how farmers actually managed the multiple sources of irrigation water available to them. Yet those questions were critical to understanding what was happening.

Therefore, as Project Leader for the FMIS Study, I suggested that the FMIS would be interested in funding a study of farmer-management of irrigation sources, particularly of groundwater irrigation, within the area of the IIMI-India Study. Dr. R. Sakthivadivel, IIMI's Project Leader for the IIMI-India Study, and Dr. Jeffrey D. Brewer, as the IIMI person most directly concerned with Bihar in the IIMI-India Study, felt it was an excellent idea and got the agreement of Mr. A. K. Verma, IIMI-India Project Coordinator for WALMI. Dr. K.V. Raju was recruited to head the study in the field.

Initially under my direction and later under Dr. Brewer's, Dr. Raju spent from August 1992 through April 1993 collecting data in the field. During that period, he had the assistance of a locally recruited team consisting of Dr. B.N. Singh, Mr. Ram Kumar Sinha, and Mr. Rajeshwar Dayal. Specific help with evaluating the performance of tubewells was provided by a consultant, Dr. David Purkey. Considerable assistance was given by WALMI. They provided Dr. Raju with a place to live, provided his team with office and computer facilities and helped with field arrangements, including permissions, introductions, and transport arrangements.

Dr. Raju prepared a draft report while in the field. This was circulated among various government officers in April 1993. A workshop was held at WALMI in April to discuss the officers' reactions to the report. Dr. Raju came to IIMI in May 1993 to prepare a draft of this study. Because of deficiencies in the canal management section, we arranged for him to return to Bihar to collect additional information in November 1993 under the guidance of Dr. Sakthivadivel. Since then, Dr. Brewer and Dr. Sakthivadivel rewrote the draft report and put it in the present form.

Douglas L. Vermillion
International Irrigation Management Institute
October 1994

Farmer-Managed Groundwater Irrigation within the Eastern Gandak Irrigation System in Bihar, India

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CHAPTER 1

Groundwater Development in Canal Commands in Eastern India

1.1 GROUNDWATER DEVELOPMENT IN CANAL COMMANDS IN INDIA

MANY OBSERVERS HAVE noted the phenomenon of the large-scale installation of wells in the command areas of canal irrigation systems in India. Although there have been government attempts to restrict such wells, researchers have pointed out several reasons why this development is to be welcomed. These reasons include:

* Introduction of irrigation water from canals has, in many areas, led to major rises in water tables and to waterlogging (Planning Commission 1993:64-65). The use of groundwater for irrigation can lower or maintain water tables (Vohra 1985).

* Many canal systems, particularly the very large systems of Northern India, are river diversion systems without storage. Canal water supply is dependent upon the flow in the river which can vary greatly. Often the largest demand for irrigation water comes when rains have ceased and the river is at its lowest. Use of groundwater to supplement the surface water supplies allows farmers to overcome this problem (Prasad and Sharma 1991).

* Indian canal systems are generally designed for extensive irrigation; that is, they have been designed to spread water thinly over a large area. One result is that even when water is available at the source, system managers may not be able to supply adequate and timely water supplies to all farmers in the command. Having access to groundwater gives farmers precise control over water supply so that management problems with the system need not lower yields. Since a large part of the groundwater recharge is likely to originate from the surface system, wells serve to make the irrigation system more efficient in delivering water as needed by farmers (Svendsen 1991).

* Economic analysis shows that investments in wells located in surface systems often have better returns than other wells because seepage from the canals and fields stabilizes the water table (Dhawan and Satya Sai 1991).

These reasons explain quite well why groundwater development is to be expected in canal commands in India.

The great majority of wells are owned and managed by farmers themselves. The Planning Commission (1993:61) says that "groundwater development is under private sector to the extent of 90 percent." In canal commands this fraction may be higher because most state governments have prohibited the development of state tubewells within canal commands.

Certain problems with groundwater development in canal commands have been noted, including the following:

* It has been argued that to help the surface system most and to prevent problems with the water table, wells should be located near the head of the canal system. However, since surface water is generally cheaper to farmers, just the opposite frequencies are found (Shah 1991).

* It has been suggested that the presence of extensive groundwater development can weaken the farmer and other institutions designed to control the surface systems since it weakens individual interests in the surface systems (Reddy 1992; Vaidyanathan 1991).

* Overuse of groundwater is possible even in canal commands, particularly in drier areas.

* Groundwater development may favor the wealthier farmers because of the capital needs, thus increasing inequity (Vaidyanathan 1991).

Despite these problems, the rapid development of groundwater in India in canal commands, particularly by farmers themselves, suggests that the advantages well outweigh the disadvantages. In particular, the advantage of having the system under direct control by farmers is likely to be found to be of utmost importance.

1.2 GROUNDWATER DEVELOPMENT IN EASTERN INDIA

The Gangetic plains of Eastern India—including major portions of Eastern Uttar Pradesh, Bihar, and West Bengal—have a very large groundwater potential. The plains consist of alluvial soils and are traversed by very large rivers, including the Ganga and its tributaries, the Brahmaputra, and others. Together with annual rainfall ranging from 1,000 mm in the west to well over 3,000 mm in the east, there is a great deal of easily accessible groundwater in the area. Also, the agricultural potential of the region is very high since the region has deep and productive soils and a generally good climate.

Eastern India is the poorest region in India; Bihar has by far the lowest per capita income in India and both Uttar Pradesh and West Bengal have below average per capita incomes (Tata Services 1992:16). Also the area is highly dependent upon agriculture; Bihar has the highest percentage of agricultural workers in the country and Uttar Pradesh also has a very high percentage (Tata Services 1992:7).

Although the annual rainfall is adequate, it is both highly seasonal—well over half falls during the months of June to September—and highly variable. Development of irrigation to stabilize water availability to allow use of modern agricultural technologies, including high-yield varieties, and to provide water for crops outside the rainy season and thus raise cropping intensities is a necessity for development in the area.

Because of the alluvial soils and abundant groundwater in the region, development of groundwater for irrigation is both cheaper and far faster than development of canal systems. There is ample reason for government and other support for the development of groundwater for irrigation in the area. Indeed, some have argued that the basic irrigation development strategy in the region should have focussed solely on groundwater development (Chaturvedi 1988; cf Kolavalli et al. nd:2).

It is not surprising therefore that virtually all irrigation in Bangladesh—at the extreme eastern end of the region—is from groundwater. There has also been important developments of groundwater resources for irrigation in Uttar Pradesh, Bihar, and West Bengal as well. Groundwater irrigation has been encouraged by the government through many programs, including the installation of state tubewells, and subsidy programs for privately owned or cooperative tubewells. In Bihar, for example, the area irrigated by tubewells has risen from under 100,000 hectares in 1950/51 to almost 1,300,000 hectares in 1984/85. Over the same period, the area under canal irrigation has doubled from 662,000 hectares to 1,370,000 hectares and the area under other sources, including tanks and dugwells, has significantly decreased (Prasad and Sharma 1991).

However, despite the high potential and government support, groundwater development in Eastern India is much less than expected. Only 31 percent of the groundwater potential in the Ganga Basin has been developed; less than 24 percent has been developed in Bihar; in contrast, 79 percent of the groundwater potential of the Indus Basin has been developed (CGWB 1991). Another source (World Bank 1991, Annex 2:10) gives the groundwater potential utilized in 1985 as only 26 percent as contrasted with 79 percent in the Indus Basin. Pant (1991) claims that "low use of available groundwater is the main cause of the eastern region's agricultural backwardness." Others (e.g., Kahnert and Levine 1993) have also recommended focussing on groundwater development to alleviate poverty in the region.

Why, when the benefits appear to be so obvious, has groundwater development lagged in Eastern India? One study (Kolavalli et al. 1989) suggests the following reasons:

* Lack of demand—farmers prefer to use cost-free rain and Eastern India has higher rainfall than much of the rest of the country.

* Lack of high-yield varieties—other varieties do not require well controlled irrigation.

* Easy availability of canal water.

* Low returns to irrigation.

* Adverse ecological effects.

* Limited electrical power—since electricity for agricultural uses is highly subsidized it is the preferred power source for pumps.

* Small landholdings—a farmer with very little land may not be able to justify the capital investment for a well and pumpset.

* Lack of credit to purchase wells and pumps.

A detailed study of groundwater irrigation in Eastern Uttar Pradesh (Kolavalli et al. nd) identified low returns to investment in wells on small holdings (1 hectare or less) as the major reason for the slow rate of groundwater development there. Most farmers have small holdings; the study sample showed that 75 percent had less than 0.5 hectare. Returns were low not only because of the size of the investment relative to the availability of land, but also because the small farms are often the most affected by waterlogging, soil salinity, and other adverse ecological problems thus lowering their value. Moreover, because of the relatively high rainfall, farmers can produce crops without irrigation, thus giving the small farmers an alternative. The study found, however, that access to markets that gave opportunities to produce high-value crops increased the relative value of investments in wells even for small farmers.

1.3 GROUNDWATER DEVELOPMENT IN CANAL COMMANDS IN EASTERN INDIA

As with groundwater development in general, development of groundwater in canal commands in the region has also lagged. There are very good reasons to develop the groundwater potential within canal commands in the Gangetic plains of Eastern India, including:

* Rainfall is relatively high, natural water tables can be high, and waterlogging in canal commands is a problem. The presence of tubewells can help.

* All of the surface systems are run-of-the-river systems subject to variation in canal supplies. Having tubewells can help compensate for the variations.

* All of the surface systems are large and are subject to major management problems making canal deliveries unsure. Having tubewells can help compensate for delivery problems.

From Das Gupta et al. (1979) through CWRS (1993), groundwater development in the canal commands in the region has been recommended to help solve these problems. Yet there appears to be relatively little development in some canal commands, even in the tails of the commands.

Unfortunately, there is a significant problem in actually estimating the areas irrigated by groundwater in canal commands. Since data on areas irrigated by groundwater and by canals is collected or estimated by different departments, there may well be significant overcounting of both areas wherever the land is irrigated from both sources (cf Vaidyanathan 1991).

Depending from the starting point, the questions that can be asked about groundwater development in canal commands differ. Someone interested in the canal system usually wants to know how to make the canal system work well so that groundwater use is unnecessary. Someone interested in groundwater is interested in knowing why there has been relatively little development of groundwater in canal commands in Eastern India. Those interested in conjunctive management of surface and groundwater want to know to what extent it is occurring and how to manage the two sources as a single resource.

These questions can only be answered by investigating the use and management of all water resources by the farmers and government agencies involved. The key nexus are the farmers. They are the persons who actually use the water provided by canals and tubewells. However, there have been few studies focussing specifically on farmer interests and farmer institutions for management of multiple sources of irrigation water in canal commands. Of course, farmer actions will be based on how they understand and perceive their environment. With regard to irrigation, the environment is created, in part, by the agencies responsible for the sustainable development and management of water resources.

The key issues are:

* What are the different sources of irrigation water and the extent of their use within a canal command area?

* In a canal command area laced with rich groundwater resources, how do farmers evaluate and manage multiple sources of irrigation water?

* What are the institutions developed by farmers to manage groundwater resources and under what circumstances are the different institutions most advantageous?

* What features of the canal management systems determine its performance relative to groundwater extraction?

* What features of the government programs determine farmers' attitudes toward use of canal water and groundwater development?

The present study is aimed at answering these questions in order to throw more light on the overall problem of underdevelopment of irrigation resources, especially groundwater resources, in Eastern India.

1.4 THE PRESENT STUDY

As part of the IIMI-India Collaborative Research Project, a study of conjunctive management of surface water and groundwater resources was undertaken in the Eastern Gandak Command in Bihar by the Centre for Water Resources at Patna University, the Bihar Water and Land Management Institute, and the International Irrigation Management Institute (IIMI). The project was funded by the Ford Foundation and by the United States Agency for International Development through the Water Resources Management and Training Project. The study (CWRS 1993) focussed primarily on macro level management of the surface and ground water within the tail area of the Gandak Command. One finding was the relative lack of groundwater development in the Gandak Command.

The present study was developed to supplement the larger study described above by focussing specifically on micro level (farmer) management of multiple sources of irrigation water within the tail of the Gandak command in order to understand why farmers have not made more use of groundwater. The present study was funded by the German Government through the Farmer-Managed Irrigation Systems Project at IIMI. Fieldwork was carried out by IIMI personnel with the collaboration of the Water and Land Management Institute (WALMI), Patna.

The basic approach was to study (a) the development and management of tubewells and river lift pumps in detail within specific sub-areas of the Gandak Command, and (b) the key aspects of the management of the canal system and on the management of irrigation as a whole in the area.

1.5 METHODOLOGY

The area selected for study is the same as that selected for the IIMI-India Collaborative Research Project—the command of the Vaishali Branch Canal (VBC) in the Eastern Gandak Command Area in North Bihar.

The following steps were taken:

1. A map of the command area of the VBC was obtained from the Executive Engineer's Office, Gandak Project, of the Water Resources Department. Based on this map, official data was collected both for hydrologic areas and for villages which are partly or fully irrigated by the VBC.

   * The VBC has 32 hydrologic sub-areas, including minor canal commands, and 208 villages supposedly, partly or fully irrigated from the VBC. For each village, the area irrigated was listed by source, based on the 1981 demographic census and the 1986-87 groundwater census.

   * Based on the area irrigated in kharif 1992 as reported and verified in the field, three minor canals—Chakwa Minor in head area, Madan Chapra Minor in the middle area, and Shampur Minor in the tail end of VBC—were selected for detailed study. For each minor, the actual command area (much smaller than the designed command area) was defined and used as the study area.

2. Initially, key informants were selected from each village. These were persons who had knowledge of the whereabouts of all or most irrigated village plots, who knew the crops and irrigation sources (by current and previous seasons) for different plots, who could make village-level maps, and who could move easily with all categories of farmers of the village. Later, more direct contacts with the farmers became more important.

3. Study team members walked through the sample minor commands with village-level maps and informants and located each tubewell and identified its location on the map.

4. A systematic survey of farmers in the study area was carried out. The survey covered the last four crop seasons: kharif 1991, rabi 1991-92, hot weather 1992, and kharif 1992. The data collected from each farmer included owner's name, crop grown, and source of irrigation for each irrigation.

5. A systematic survey of well owners and operators in the study area was also carried out. The survey covered the location of each tubewell, status (functioning or not) of the tubewell, fields irrigated from each tubewell, and specifics on diesel pumpsets installed.

6. A detailed study of a sample of tubewell was carried out.

   * The water table at the well location spot was measured by allowing an ordinary thread with a small stone tied at one end to drop slowly in the tubewell till it reached water. After removal, the string was measured with tape. For cross checking, the water table was also measured in nearby open wells.

* The owner was requested to operate the tubewell. While operating the following measurements were taken: diesel consumption, water discharge, and position of engine. Discharge measurements were made by measuring the time taken to fill a 165 liter drum.

* The owner was also questioned about repairs, spare parts replacement and availability in local markets, previous and present diesel and oil prices, water selling rates and the justifications for the present water selling rate, fields irrigated by the tubewell, the buyers of water and their field locations.

* The field channels used for conveyance of tubewell water were mapped by walking them with the well owner or water buyer.

7. The surveys were supplemented by participant observation and informal interviews with selected informants on issues dealing with the role of agencies, technical details of groundwater extraction mechanisms, spatial pattern of tubewell location, number of plots and area irrigated across the irrigations within a season and across the seasons.

8. The results were written up into a single report. This report was then discussed with officers from various irrigation agencies in a workshop. Modifications were introduced in response to comments at the workshop and to some written reactions. In addition, various portions of the report were discussed with farmers in the field to check the accuracy of the facts and conclusions. The present report is an extensively modified version of the draft report discussed with officers and farmers.

1.6 ORGANIZATION OF THE STUDY

The objectives of this report are:

* To describe how farmers evaluate and use different sources of irrigation water in the tail of the Gandak Canal Command Area, including describing the farmers' institutional arrangements for management of irrigation water.

* To describe the various features of canal management and other governmental actions that help define the environment that farmers respond to when evaluating and managing irrigation water.

* To identify the implications of these micro-level findings for the major questions about groundwater usage identified earlier.

* To identify actions that can be taken to improve the existing situation.

The report is organized as follows:

* Chapter 2 provides a general description of the study area.

* Chapter 3 describes the management of the Eastern Gandak Canal System to show just what the problems and limitations of canal water delivery are.

* Chapter 4 describes tubewell installation and management by farmers in detail.

* Chapter 5 describes the use of farmer-owned river lift pumps.

* Chapter 6 describes the groundwater market in the study area.

* Chapter 7 discusses how farmers actually choose among the multiple sources of water available to them.

* Chapter 8 summarizes the findings and considers their implications for irrigation development in the area.

CHAPTER 2

Description of the Study Area

2.1 THE STUDY AREA

THE STUDY AREA consists of areas commanded by three minor canals of the Vaishali Branch Canal (VBC) in the Eastern Gandak Canal System in North Bihar. The VBC is a direct offtake from the Tirhut Main Canal—the main canal of the Eastern Gandak System—and is located in the tail reach of the system.

The three sample minor canals are:

* Chakwa Minor in the head reach of the VBC.
* Madan Chapra Minor in middle reach of the VBC.
* Shampur Minor in the tail reach.

Chakwa Minor is located in Sahebganj Block of Muzaffarpur District; Madan Chapra Minor is located in Paroo Block of Muzaffarpur District; Shampur Minor is located in Vaishali Block of Vaishali District.

As used in this study, the term "designed area" refers to the area planned for irrigation from the canal system. This is the area defined in all official documents and field office records of the Gandak Project. The designed area was the basis on which the original expenditure plans were drawn. In addition, irrigation staff have been assigned to field offices and fund allocations are made on the basis of the designed area. The VBC has a designed area of 64,289 hectares. However, because construction has not been completed, the potential so far created is only 17,250 hectares.

However, after walking the command areas of the selected minor channels with the relevant *Amins* (officials responsible for assessing irrigated areas for revenue purposes), we found a significant difference between the designed area and the area supposedly irrigated by canal water. To help us, the Amins demarcated the area getting canal water on the village maps. The demarcated area is substantially less than the designed area for these minor channels. The area demarcated by the Amins is called the "Study Area." Our surveys were conducted within the "Study Area."

Further, we found that within the Study Area not all fields are irrigated with canal water. The area where fields actually get canal water is called the "actual irrigated area."

This chapter provides background data on the area and its population. Details of the irrigation in the Study Area are given in the following chapters.

2.2 PHYSIOGRAPHY, AND CLIMATE OF THE GANDAK COMMAND

The Eastern Gandak Command (see Figure 3.1, page 16) is located in the Gangetic plains of North Bihar. The Gandak Command lies between longitudes 83°15' and 85°15' east and between latitudes

Table 2.1. Rainfall in the study area (mm).

Month	Sahebganj Block (Muz. Dist.)		Paroo Block (Muz. Dist.)		Vaishali Block (Vaishali Dist.)		Muzaffarpur District	Vaishali District
	1991	1992	1991	1992	1991	1992	(average)	(average)
January	11.8	-	29.8	6.8			13.8	12.2
February	-	-	2.0	-			19.7	18.3
March	1.4	-	10.4	-			7.0	9.5
April	-	-	-	-			15.8	7.7
May	44.6	49.9	16.4	33.2	32.6		47.8	28.4
June	119.2	49.2	105.4	107.0	69.2	38.0	172.7	152.1
July	65.0	287.9	306.2	228.2	162.4	263.2	301.1	256.5
August	355.6	224.6	637.0	323.2	436.8	169.2	297.0	294.5
September	165.7	91.5	325.8	58.0	92.5	117.2	241.2	294.0
October	-	88.8	-	38.0	-	17.0	57.5	47.7
November	-	-	-	-			5.1	7.8
December	0.6	-	16.4	-			2.6	3.6
Total rainfall from June-Sept	705.5	653.2	1,374.4	716.4	760.9	587.6	1,074.6	1,052.6

Sources: The figures for the blocks come from the respective block offices. The district figures are from CWRS (1993:42).

25°40' and 27°25' north. In the north, the Gandak Command is bounded by Nepal, in the west by Uttar Pradesh, in the south by the river Ganga, and by the districts of Sitamarhi, Darbhanga and Begusarai in the east.

The Gandak Command area is flat except for the hilly tracts of West Champaran District. The slope of the command in West Champaran is about 1 in 1,500 which flattens to 1 to 3,500 in East Champaran. Further, east in the districts of Muzaffarpur, Vaishali, and Samastipur the slope further flattens from 1 in 5,000 to 1 in 20,000.

North Bihar as a whole may be treated as a vast inland delta; all the principal rivers emerging from the Himalayas enter the plains of North Bihar and ultimately flow to the Ganga. The process of delta formation has been in progress from thousands of years by the heavy silt and detritus load brought by the rivers from the Himalayas. The principal rivers that pass through Bihar are the Gogra, the Gandak, the Bagamati, the Kamala and the Kosi. In the process of land building the rivers shift channels. It is likely that the Burhi Gandak River was once the bed of the Gandak but the latter moved westwards. This movement of rivers leaves depressed areas, now known locally as *mauns* or *chaurs*. These areas are generally flooded seasonally by the rains.

The Gandak Command Area lies in the monsoon subtropical zone. It is characterized by a wet monsoon season from June through September, followed by cooler and drier weather from October through February, and then followed by a hot summer season with occasional thundershowers and dust storms from March to the middle of June.

Temperatures vary from highs of 41° C in May or early June to lows of around freezing in January. The Gandak Command area is one of the humid areas of the state. Humidity is lowest (52%) in the months of March and April and highest (83%) during the rainy months of July and September.

As shown in Table 2.1, rainfall in the area shows a markedly skewed seasonal pattern. As shown by the district averages, over 80 percent of the rainfall falls from June through September. However, as shown by the values for 1991 and 1992 in the respective blocks, rainfall can vary markedly from year to year and from location to location.

During the 1992 rainy season, the Government of Bihar declared drought in most districts, including all three of the blocks listed in Table 2.1. However, as shown in the table, both Paroo and Vaishali blocks suffered a severe drop in rainfall but the drop for Sahebganj Block was rather small.

2.3 DEMOGRAPHIC CHARACTERISTICS OF THE SAMPLE AREA

Table 2.2 shows some selected demographic features of the state of Bihar and of the Muzaffarpur and Vaishali districts taken from the 1991 Census. Table 2.3 shows changes in selected demographic indices over time for the three sample minors. These figures give some idea of the problems faced by the people in Bihar and in the study area.

First, the population density in the study area is very high and is almost double the statewide population density. This is a general characteristic of North Bihar.

Agriculture is the main occupation in the area. In Bihar as a whole, about 80 percent of the working population is involved in agriculture (Tata Services 1993:7). Table 2.2 shows that, as in the rest of Bihar, more than a third of the men working in agriculture do not work their own farms.

The sex ratio (the number of males per one thousand females) in the study districts is similar to that for the whole state. However, in the area of selected minors, the sex ratio was very high during 1961 and has gradually dropped over the years. Given the preference for male children, this change seems to reflect increasing seasonal or permanent outmigration from the area. During the study, we found that seasonal migration in search of employment, mainly to Punjab, Assam and metropolitan cities like Delhi and Calcutta, is common.

The literacy rate is low in the area. For the three minors, the literacy rate in 1991 varied from 21.38 percent to 29.64 percent while the literacy rate for Bihar as a whole is 52.63 percent (Tata Services 1993:7). Overall, these figures indicate low levels of social services and social development in the area.

The population in the area is overwhelmingly Hindu and consists of a variety of castes, including Harijans. Multiple castes are found in all villages in the area. Caste membership remains very important for social relations in the area.

Table 2.2. Selected demographic features of the study districts, 1991.

		Muzaffarpur district	Vaishali district	Bihar
Total population		2,946,000 persons	2,144,000 persons	86,338,000 persons
Population density		928 persons/sq km	1,053 persons/sq km	497 persons/sq km
Literacy rate				38.5 %
Population working in agriculture:	Male	39.63 %	33.97 %	33.02 %
	Female	65.87 %	66.90 %	57.92 %
Revenue villages		1,813	1,569	

Sources: District Census Handbook 1991, Muzaffarpur District; District Census Handbook 1991, Vaishali District.

2.4 AGRICULTURE IN THE GANDAK COMMAND

Three agricultural seasons are recognized. The agricultural year begins with the *kharif* (rainy) season from mid-June through mid-November, followed by the *rabi* (cool) season from mid-November through the end of February or mid-March, and then followed by the summer, also called the hot season, from mid-March until the monsoon rains come in mid-June.

Table 2.3. Selected demographic features of the sample minors.

Year	Total population			Sex ratio			Literacy rate		
	Chawa	Madan Chapra	Shampur	Chakwa	Madan Chapra	Shampur	Chakwa	Madan Chapra	Shampur
1961	4,363	1,938	2,281	1,190	1,108	1,088	15.15%	13.05%	12.89%
1971	5,622	2,210	3,615	1,000	997	1,077	15.67%	16.33%	18.06%
1981	6,479	2,627	4,127	na	na	na	na	na	na
1991	8,852	3,417	5,163	928	920	998	23.17%	29.64%	21.38%

Notes: Data for each minor is derived from all the villages partly or fully irrigated by the concerned minor. In Shampur Minor, literacy percentages are from 2 villages in 1961, 4 villages in 1971 and 3 villages in 1991.
Sex ratio = The number of males per one thousand families.
na = Not available.

Sources: District Census Handbook 1961, Muzaffarpur District; District Census Handbook Part X 'A and B', Muzaffarpur District.

The Gandak Command is primarily a kharif rice growing area. Wheat, maize and barley are the principal rabi crops. Mustard is the major oilseed crop and sugarcane, jute, mesta and tobacco are the most important cash crops. A wide variety of other crops are also grown, including some perennial crops.

Canal irrigation has not brought major changes to the area. As shown in Table 2.4, the cropping intensity in the tail reach of the Gandak Command was 155 percent during 1984-85, only 5 percent more than the cropping intensity in 1966-67 before canal irrigation began and only a little more than the cropping intensity outside the command. Gandak Project planners, however, had projected a cropping intensity of 180 percent within the command after completion of the irrigation project.

Table 2.4. Change in cropping intensities in Gandak Command.

Location on the Tirhut Main Canal	Cropping intensity in command area		Cropping intensity outside command area
	1966-67	1984-85	
Head reach	161 %	163 %	149 %
Middle reach	160 %	172 %	153 %
Tail reach	150 %	155 %	149 %

Source: AFC (1986).

Table 2.5 shows the change in crops over the same period for the whole Gandak Command. Over the period, the total annual cropped area increased about 6 percent. There were significant changes only in a few crops. One major change was a doubling of the area under wheat (during rabi) largely replacing coarse grains. The areas under tobacco and vegetables, although only small portions of the total, also went up a great deal. However, our surveys in the study area indicate that trends may have changed since 1985; and the areas under oilseeds and fruit and other trees have been increasing.

Table 2.5. Cropping patterns and canal irrigation in Gandak Command.

Crop	1966-67		1984-85	
	Area ('000 ha)	Percentage of GCA	Area ('000 ha)	Percentage of GCA
Rice	871.42	40.57	955.81	41.71
Maize	228.85	10.66	252.83	11.03
Wheat	231.13	10.76	529.60	23.11
Other cereals	245.14	11.41	68.44	2.99
Total, cereals	1,576.54	73.40	1,806.68	78.84
Arhar	55.30	2.57	28.10	1.23
Gram	40.69	1.89	10.85	0.47
Other pulses	161.23	7.51	129.00	5.63
Total, pulses	257.22	11.97	167.95	7.33
Rape/mustard	17.00	0.79	18.83	0.82
Other oilseeds	25.29	1.18	15.19	0.66
Total, oilseeds	42.29	1.97	34.02	1.48
Potatoes	23.36	1.09	40.17	1.75
Other vegetables	19.97	0.70	33.46	1.46
Total, vegetables	38.33	1.79	73.63	3.21
Fruits	58.85	2.74	60.09	2.62
Other foods/spices	59.27	2.76	34.51	1.51
Total, other food crops	118.12	5.50	94.60	4.13
Total, food crops	2,032.40	94.63	2,176.92	95.99
Sugarcane	89.33	4.16	87.41	3.81
Jute/mesta	17.29	0.81	7.04	0.32
Tobacco	8.57	0.40	20.07	0.88
Total, industrial crops	115.19	5.37	114.52	5.01
Grand total	2,147.69	100.00	2,291.44	100.00

Source: AFC (1986).
Note: GCA = Gross Command Area.

CHAPTER 3

Sources of Irrigation Water: The Gandak Canal System

3.1 THE EASTERN GANDAK CANAL SYSTEM

THE GANDAK RIVER flows from the Himalayas in Nepal into the western side of Bihar, then flows southeastward through North Bihar until it joins the Ganga near Patna. Diversion of the Gandak River for irrigation in Bihar was first considered in the 1870s. Two diversion systems were constructed before although planning had begun much earlier.

After independence, a large project to use the waters of the Gandak, incorporating most of the two existing systems, was developed and taken up as a joint project among Bihar, Uttar Pradesh, and Nepal. Initial planning was completed in 1959 and work began in 1961. The project included construction of a new barrage on the Gandak at Valmikinagar, right on the international border. A 200 kilometer right bank canal running through Nepal and Uttar Pradesh before reentering Bihar was constructed and came to be known as the Western Gandak Canal System. The portion of the Main Western Canal in Bihar—the lower portion of the canal—is called the Saran Main Canal. The Western Gandak System was designed to irrigate a gross command area (GCA) of 563,000 hectares in Bihar and 533,000 hectares in Uttar Pradesh. Also a 34 kilometer canal from the Gandak's right bank known as the Nepal Western Canal was constructed to irrigate an area of 16,200 hectares in Nepal. These two systems have been completed.

Construction also began in 1961 on the left bank canal system serving North Bihar. This system came to be known as the Eastern Gandak Canal System shown in Figure 3.1. Work on the Eastern Gandak System continued through 1985 when Phase I was declared finished although the system was not complete.

The Main Eastern Canal takes off from the left bank of the river. The Don Branch Canal takes off from the Main Eastern Canal at about 3 kilometers and runs about 99 kilometers before entering Nepal where it is known as the Nepal Eastern Canal. The Nepal Eastern Canal runs for a further 85 kilometers. The Don and Nepal Eastern Canals irrigate some 23,600 hectares in Bihar and 46,000 hectares in Nepal. At RD 9.05, the Tribeni Branch Canal takes off from the Eastern Main Canal, runs for about 150 kilometers, and irrigates a GCA of 215,000 hectares. Beyond the Tribeni Canal Offtake, the main canal is called the Tirhut Main Canal (TMC). The Don and Tribeni Canals and their distribution systems had been completed by 1985.

In Bihar, canal lengths are generally measured in Reduced Distance (RD): 1 RD equals 1,000 feet. The Tirhut Main Canal was designed to extend to 909 RD (about 226 kilometers). A schematic diagram of the Tirhut Main Canal as planned is given in Figure 3.2.

When work stopped in 1985, the main canal had been completed to RD 790. The distribution system had been completed only to the offtake for the Vaishali Branch Canal (VBC) at RD 554, but some parts of the distribution system had been developed from RD 554 to RD 704. Overall, about 70 percent of the planned Eastern Gandak System has been completed. The total planned command area for the Tirhut Main Canal is over 600,000 hectares in eight districts comprising West Champaran, East Champaran, Muzaffarpur, Vaishali, Samastipur, Gopalganj, Siwan and Saran.

Figure 3.1. The Eastern Gandak Irrigation System.

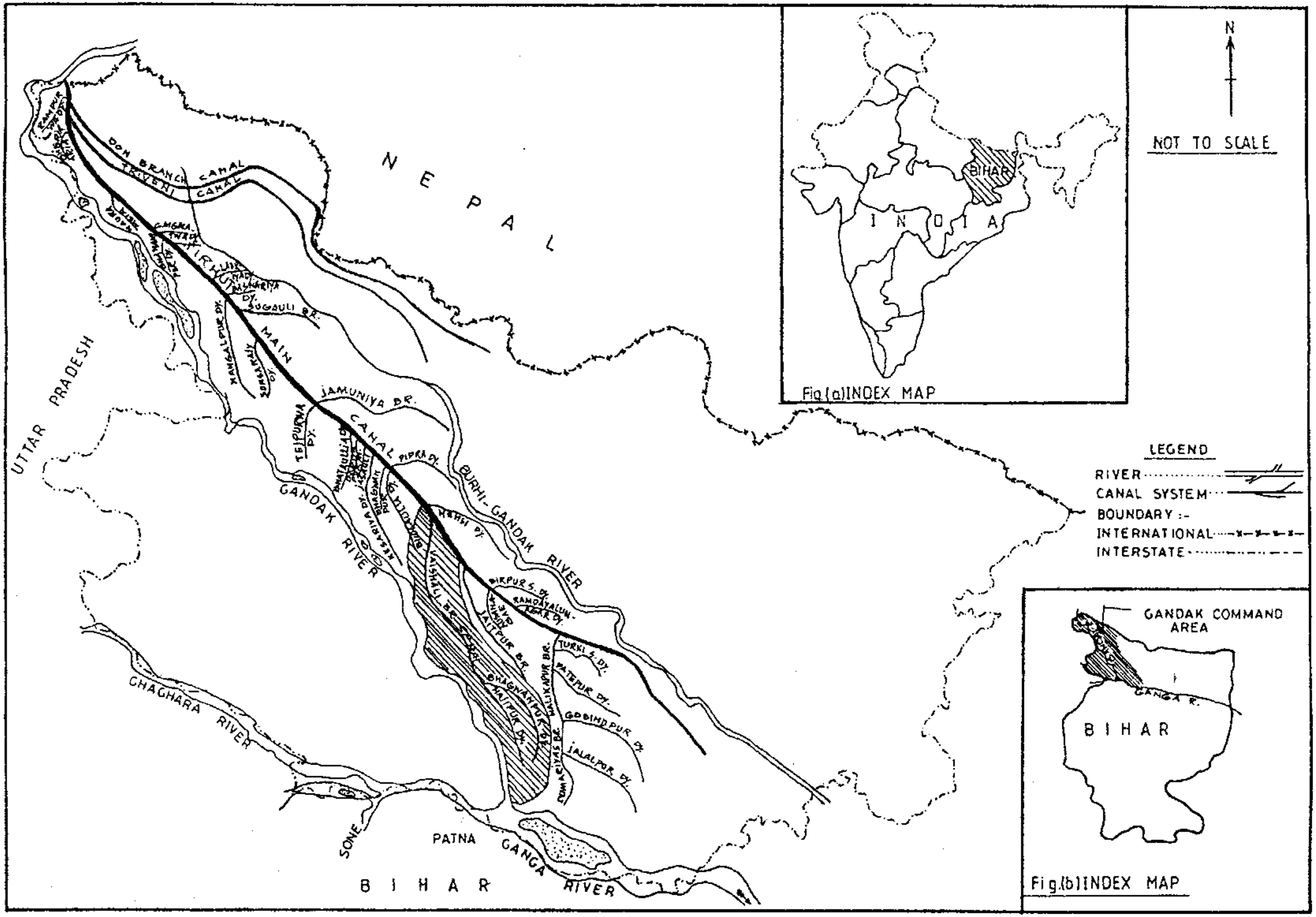
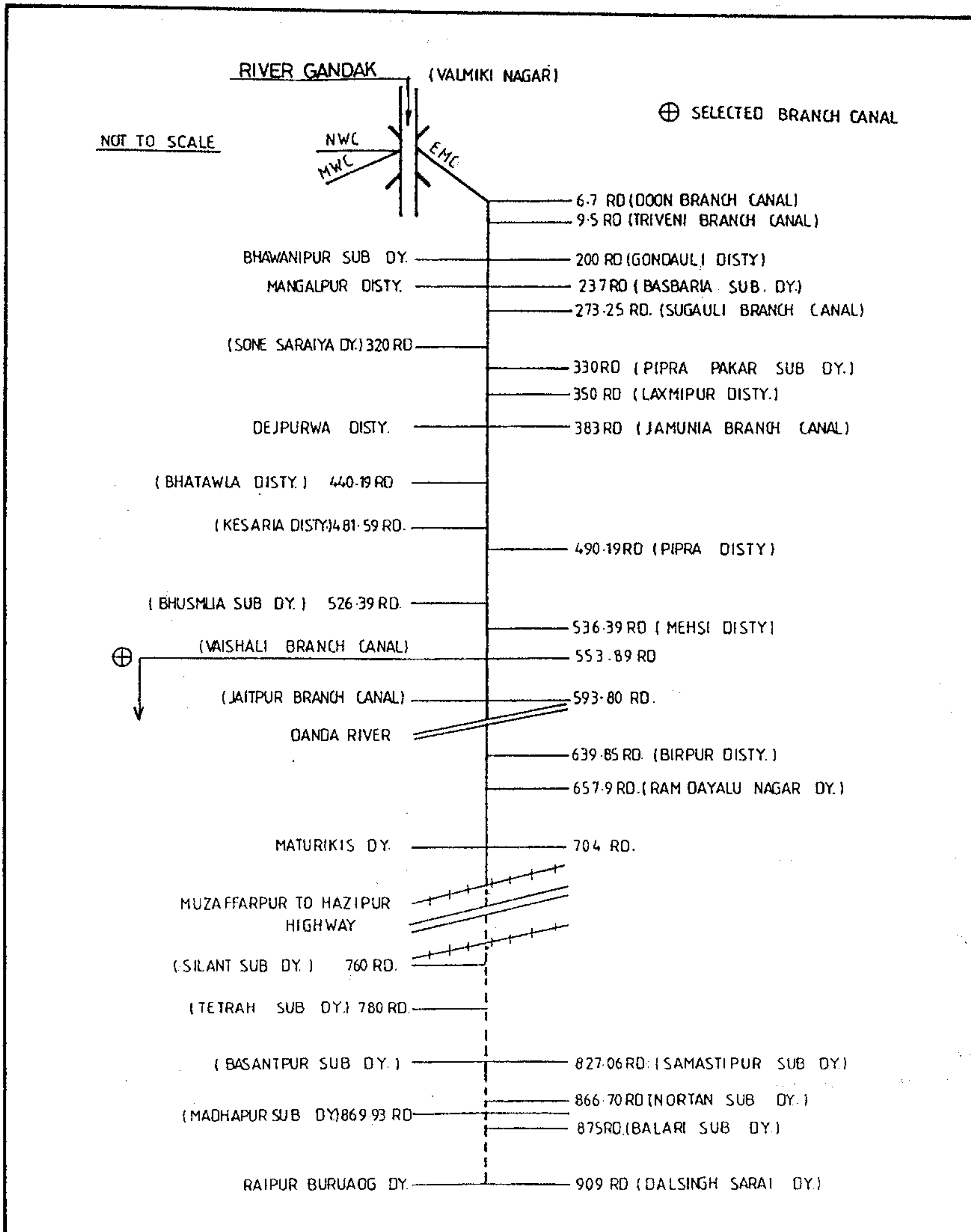


Figure 3.2. Schematic diagram of the Tirhut Main Canal.



Consideration has been given to completing the development of the Tirhut Main Canal Command beyond RD 704. A committee constituted by the Government of Bihar—generally called the Ghosh Committee after its chairman—looked into the matter. Their report (WRD 1985) pointed out some problems created by the canals and recommended that drainage problems be solved first. The Government of Bihar, however, has submitted a proposal to the Government of India to fund Gandak Project Phase II to complete the system. This proposal has not been funded.

3.2 IRRIGATION MANAGEMENT POLICIES AND AGENCIES

3.2.1 Changes in Policy

The British colonial authorities constructed irrigation projects on a commercial basis. To make these projects economically and financially viable, they not only framed appropriate rules and regulations but also empowered officers to manage the systems efficiently. Prior to 1974, the Eastern Gandak Canal System was managed under the Bengal Irrigation Act of 1876 through a system popularly known as the "satta system."

Under the satta system, canal officers issued permits to take water, called *satta*, on farmers' written requests. Double water rates were charged for unauthorized irrigation. One farmer per outlet was appointed as *sattadar* to oversee water distribution. He was paid 2 percent of the canal revenue collected in his area. The canal authorities were responsible for getting the water to the outlet and the sattadar managed distribution below the outlet. Village channels were constructed and maintained by villagers. Informants claim that water would be denied to a village if the village channels were not maintained properly. Alternatively, the canal authorities might carry out necessary repairs and charge the costs to the villagers. Assessment and collection of water rates was done by the revenue wing of the Irrigation Department with help from the sattadar.

After India's independence in 1947, water came to be regarded as common property which every individual had a natural right to use (MOWR 1987). The independent government came to view irrigation not as a commercial venture but as a form of welfare. This had three consequences:

* The government made an effort to spread irrigation to as many farmers as possible leading to heavy demands on the systems.

* Water rates were kept low, leading to inadequate revenues for operation and maintenance.

* Power to manage irrigation became more centralized in the state-level bureaucracies and political entities. The powers of the field level officers were gradually reduced making it more difficult for the officers to control the system well and to punish farmers who abused the system.

Consequently, farmers began paying less attention to filing the applications for water knowing that if the monsoon failed they could always pressure the government to supply water. To do their jobs without appropriate powers, field staff, including the sattadars, started harassing farmers. The situation eventually became unmanageable and the government abolished the satta system in 1974.

Next >>

Under the system introduced in 1974, farmers were not required to make applications for water. Instead they were given the right to take water from canals whenever it was available. Canal officers were made responsible for preparing water schedules and informing farmers which canals would be open and for what duration. Water distribution below the outlet remained the responsibility of the farmers. Assessment of water rates was based on a register of land actually irrigated. The position of the sattadar was abolished.

This system was not a success. Since permits were not required, there was no definition of unauthorized irrigation. Thus farmers in the upper areas could take as much water as they wanted irrespective of the needs of farmers lower down the system. Also, it was assumed that all farmers within the command would take water and all were assessed water rates. In addition, the weak financial and managerial powers of the canal officers encouraged abuse of water by farmers and reluctance by officers to visit the canals.

In 1988, the government reintroduced the satta system and sattadars were appointed by the canal authorities. However, the root causes of the problems—increased demands on the system and inadequate government finances and powers to operate and maintain the system—remained. Thus the reintroduced satta system is not working effectively.

3.2.2 Agencies Responsible for System Management

Presently, management of the Gandak Command is in the hands of two agencies: the Water Resources Department (WRD), formerly the Irrigation Department, and the Gandak Command Area Development Authority (GCADA).

Gandak Command Area Development Authority

The Gandak Command Area Development Authority was established in 1975 as the nodal agency for the integrated rural and agricultural development of the Gandak Command Area. The Authority's 1991/92 Annual Report states that it has been engaged in activities designed to promote coordination among the different departments involved in rural and agricultural development. The Report also states that it has endeavored to facilitate maximum utilization of available irrigation facilities by implementing on-farm development programs in the Project. In reality, GCADA's only major activities are the construction of lined and unlined field channels and on-farm development. Field enquiries indicate that financial and administrative constraints have prevented GCADA from effectively fulfilling its functions. GCADA has also suffered from a lack of efficient leadership.

Water Resources Department

The irrigation wing of the Water Resources Department is responsible for management of the canals down to the outlets. Initially, one Chief Engineer was appointed to be in charge of operation and maintenance for the whole Eastern Gandak Command. Currently, there are three Chief Engineers: two Chief Engineers in charge of operation and maintenance of the Eastern Gandak System, one headquartered at Motihari in charge of the main canal from RD 0 to RD 537, and the other stationed at Muzaffarpur in charge of the canal from RD 537 to RD 790. Operation and maintenance of the Saran Main Canal—the portion of the Western Gandak System in Bihar—is the responsibility of a Chief

Engineer headquartered at Siwan. These Chief Engineers have nine, four and eight divisions, respectively, under their jurisdictions. For every four divisions one Superintending Engineer has been appointed. Each division is headed by an Executive Engineer, who has four sub-divisions under his jurisdiction.

The sub-divisional office is the lowest administrative level of the Water Resources Department in the Gandak Project. The sub-divisional office is generally located at block headquarters and is headed by a Sub-Divisional Officer who is an Assistant Engineer. This officer is generally in charge of an area of 15,000 to 20,000 ha and has four Junior Engineers to assist him, each in charge of 4,000 to 5,000 ha. Besides their other functions, Junior Engineers keep track of water discharges in distributaries and minors and irrigated area in the minors. They are also expected to regularly check the physical condition of the distribution network.

Junior Engineers are assisted by Amins, whose main responsibility is to ensure timely supply and distribution of canal water below the minors. At the end of the season, Amins make a record of fields irrigated by canal water with their relevant revenue survey numbers and send these records to the revenue office at the block level, which in turn prepares the water revenue report based on the fields irrigated.

WRD personnel responsible for canal operations are not perceived to be efficient and effective (cf Srivastava and Brewer 1994). One problem is that neither Executive Engineers nor Assistant Engineers are provided with work charts or operational guidelines to enable them to discharge their duties efficiently. In the absence of well-defined operational rules and guidelines, officers have to depend on oral and written instructions from higher-level officers. Proper in-service training aimed at improving skills and enhancing capabilities is not available. Transfers within the Department from one area of responsibility to another, for example from construction to operation or from groundwater to design, frequently take place without the benefit of prior familiarization training. This too tends to reduce the efficiency of the officers. Other reasons are given in Section 3.2 above.

3.2.3 Area Irrigated and Canal Revenues

The area irrigated by canal water as reported at the end of a season is considered the "achieved area" for the season. This is measured against the "target area" fixed at the beginning of the season. Invariably, the achieved area is much less than the target area. Both target area and achieved area are listed minor by minor.

Area irrigated is linked to revenue collection. Revenue assessment is supposed to be made by the Amin in the field. Every Amin is expected to assess an average of 500 ha. However, the jobs are temporary and salaries are not paid regularly, the work of the Amins is generally unsatisfactory.

In Bihar, there are normally two water rates: one charged if the farmer takes only one watering during the season, and a higher rate if he takes more than one watering. Canal water rates, as shown in Table 3.1, are low. Water rates for rice were increased to Rs 56 per acre in 1992, but this rate has not been officially implemented yet. According to the present water rate structure, full irrigation of rice per season costs Rs 36.20 per acre. For wheat, full irrigation costs Rs 20.70 per acre.

Table 3.1. Canal water rates (Rs/acre).

Season and crop	1981-84	1984-92
Kharif (rice)		
- one irrigation	18.00	20.70
- more than one irrigation	31.50	36.20
Rabi (wheat)		
- one irrigation	*	*
- more than one irrigation	18.00	20.70

**Note:* Rabi crops do not have single water rates.
Source: Irrigation Revenue Circle Office, Saraya 1992.

Despite low water charges, collection rates are also low because:

* Eye measurements are used to assess actual area irrigated both for a single irrigation and for more than one irrigation. Eye measurements are not accepted by farmers as accurate.

* The number of revenue staff members is not adequate to make field assessments, calculate water rates and collect revenues.

* Village maps are often not available. Where village maps are available, they indicate only survey numbers of plots. No information is given on the boundaries of the canal command area, or fields with waterlogging or other problems. Land ownership titles are not updated and new survey numbers are not given to fragmented landholdings.

* Support systems are inadequate. Transport, in particular, either in the form of vehicles or travel allowances, is not provided.

* *Chaur* areas (low lying areas flooded during the rainy season) are listed as canal irrigated and counted as irrigated areas for revenue purposes.

* Records on the number of irrigations provided for each crop during the season are not maintained by the WRD divisional or the sub-divisional offices. Given the prevalence of other sources of irrigation water in some areas, it is often difficult for Amins to correctly note how many irrigations are supplied by the canal.

Only 25 percent of the total irrigation dues are being collected. Also, of total revenues collected at the end of the year, the amount collected as dues from previous years is not reported separately from current dues. Farmers often contest dues because of the various sources of error noted above.

Monitoring cells have been established at Superintending Engineer and Chief Engineer levels, with Executive Engineers as heads, and at state level to assess irrigated area for revenue purposes. Daily, weekly, fortnightly and monthly progress reports of irrigated area in a prescribed format are submitted by Executive Engineers to these monitoring cells which gather data on volume of water received and distributed in the command area and extent of irrigated area assessed. These cells have yet to have much influence on either revenue assessment and collection or on performance of the system.

3.3 MANAGEMENT OF THE HEADWORKS AND MAIN CANAL

3.3.1 Water Availability in the Gandak River

Data on the availability of water in the Gandak River at the barrage at Valmikinagar is given in Table 3.2. These data clearly show the large variation in flow between the rainy and dry seasons. The capacity of the Main Eastern Canal is 443.4 cumecs and that of the Main Western Canal is 367.9 cumecs. The total is 811.3 cumecs. Table 3.2 shows that the combined capacity of these two canals is exceeded, with 75 percent dependability, from June through November every year.

Table 3.2. Seventy-five percent dependable flow in the Gandak River at Valmikinagar.

Month	Flow (cumecs)
June	1,324.60
July	4,568.62
August	4,622.00
September	4,005.39
October	1,911.53
November	966.89
December	575.64
January	372.83
February	311.74
March	293.74
April	294.74
May	546.06

Source: CWRS 1993.

Canal water needed to meet crop requirements was assessed in 1982/83 by the Ghosh Committee while examining the possibility of extending the Tirhut Main Canal from RD 704 to 909. Findings reveal that if crop water requirements as per specifications in the original design are to be fully met, then the Tirhut Main Canal and the Saran Main Canal would probably suffer water shortages between February and March every year assuming that all irrigation needs are met from the canal system. At the present level of development of the system, the river flow is adequate to serve the whole system.

3.3.2 Operation of the Gandak Barrage

The barrage office at Valmikinagar is headed by a Superintending Engineer who oversees the operation and maintenance of the barrage and canal headworks. His responsibilities include not only the civil engineering aspects but also the mechanical and electrical engineering aspects as well. A manual for the operation and maintenance of the barrage and canal headworks gates serves as the primary guide for staff. Other guidelines are issued periodically.

Monitoring of silt load and rainfall and analysis of river behavior is undertaken by the Quality Control Division under the oversight of the Superintending Engineer. A wing of the Central Ganga Flood Control Office, an agency of the Government of India, regularly studies hydrological parameters of the river and makes its findings available to the Superintending Engineer.

The head regulators for the canals are located downstream of the barrage. Water releases for irrigation are made by releasing water to the river which is then picked up at the canal headworks. When water is to be discharged into the river to be picked up at the canal head regulators, the under sluice gates on both sides of the barrage are opened first. If there is a further need to allow water to flow downriver, the center gates are also opened. The side gates are the last to be opened.

Flow in the river is measured continuously to aid in operations and to protect the system. The barrage gates are supposed to be operated to allow excess water to flow downriver without damaging the barrage or interfering with canal operations. As an emergency measure, the canal headgates are closed whenever river flow exceeds 450,000 cusecs (about 12,740 cumecs).

Silt load in the Gandak River is a problem. To provide an accurate assessment of the silt load factor there is a standing order to record measurements of silt load at three hourly intervals. Samples are collected by the Barrage Division and tested by the Quality Control wing. Results are to be communicated to Operations within two hours for action. If the silt load is high, canal headgates are supposed to be closed to prevent excess silt from entering the canals. Unfortunately, this system does not work because:

* The instrument used to collect samples is not functioning effectively and samples cannot be taken at the desired depth.

* Samples are neither sent speedily to the laboratory nor are they attended to quickly when they are received, resulting in test results not being taken into consideration in canal gate operations.

* Supervision is inadequate.

Although silt from the pond area is meant to be propelled into the river by silt excluders, improper detection and handling of silt has resulted in canal water becoming heavily silt-laden. There is no provision for a silt ejector in the Eastern Main Canal and this has caused heavy siltation of the canal bed and has considerably reduced canal capacity.

Also a heavy deposit of river boulders and concrete debris is evident for a considerable length along the head reach of the Eastern Main Canal, having found its way into the canal through ineffective control at regulation points. The concrete debris comes from damaged canal lining and from rubble left behind by the contractors.

3.3.3 Operation of the Tirhut Main Canal

Operation of the Tirhut Main Canal includes (a) water allocation to the different parts of the canal system, (b) overseeing distribution of the allocated water.

Water Allocation

The WRD O&M officers strive to determine water demand and allocate water every 10 days during an irrigation season. The basic pattern is as follows:

* Each Junior Engineer attached to a sub-divisional office determines the demand in his area.
* The Junior Engineer forwards this demand to the Sub-Divisional Officer, who consolidates the demands from his Junior Engineers.
* The Sub-Divisional Officer forwards the consolidated demand to the Executive Engineer in charge of the division who consolidates demands from his sub-divisions.
* The Divisional Executive Engineers send the consolidated demand to their respective Chief Engineer's office—in Motihari for the upper portions of the Eastern Gandak System or in Muzaffarpur for the lower portions—where the divisional demands are consolidated.
* The Chief Engineers' offices send these consolidated demands to an Executive Engineer located in Betiah who prepares a consolidated demand for the whole Eastern System.
* This Executive Engineer then sends the final consolidated demand to the headworks of the Eastern Main Canal at Valmikinagar.

Indents for water have to be made 13 to 15 days in advance by the Junior Engineers in the field due to communication and transportation problems. The Executive Engineers prepare demand estimates 10 to 12 days in advance and the Chief Engineer's offices eight to 10 days in advance. The consolidated demand reaches the headworks six to eight days in advance of actual releases into the canal.

Because the demands have to be prepared so far ahead of time, there is no possibility of taking rainfall or field conditions into account. Rainfall data is collected and maintained by the Block Development Office but not used for planning irrigation. There is also a general feeling that rainfall predictions are misleading. Rainfall does affect operations; some gates are closed when there is excess rain.

Water Distribution

Water distribution differs greatly depending upon water availability in the canal, the lower portions get far less water than the upper portions. For operational purposes, the Tirhut Main Canal is divided into an upper portion from RD 0 to 537, and a lower portion from RD 537 to 790. This section focusses on the area below RD 537.

Under the standing orders of the system, the Tirhut Main Canal is to be opened on the following schedule:

Kharif	-	20 May to 20 October
Rabi	-	1 December to 10 March
Hot Weather	-	10 April to 19 May

Headwork canal gates are operated on the basis of demand placed by the Executive Engineer, Tirhut Canal Division, Betiah. As water flows down the head reach, Executive Engineers there take water as per their needs irrespective of the amount they requested. If there is rainfall in the head reach and water is not required, then it is allowed to flow down the canal but if demand exceeds the amount indented, it is taken without regard to needs downstream.

Water is made available to the Executive Engineer, Muzaffarpur, at the cross regulator at RD 537, just below the turnout to the Mehsi Distributary. The cross regulator comes under the jurisdiction of the Tirhut Canal Division at Betiah. The Executive Engineer, Muzaffarpur, generally makes a request to the Executive Engineer at Betiah to release water as per demand plus 10 percent, but this is seldom done. The Executive Engineer, Muzaffarpur, has to take whatever water is made available at RD 537.

Though water is abundant at the headworks during kharif, tail end farmers nevertheless suffer due to defects in the water distribution network. The Tirhut Main Canal from 0 to 537 RD has a low carrying capacity; the canal is unable to carry simultaneously the indents of the upper reach and the lower reach. The result is the upper reach receives most of the canal water during the day and the reach below 537 RD receives water during the night. Most farmers are not used to night irrigation so most of the water either goes waste or floods the fields.

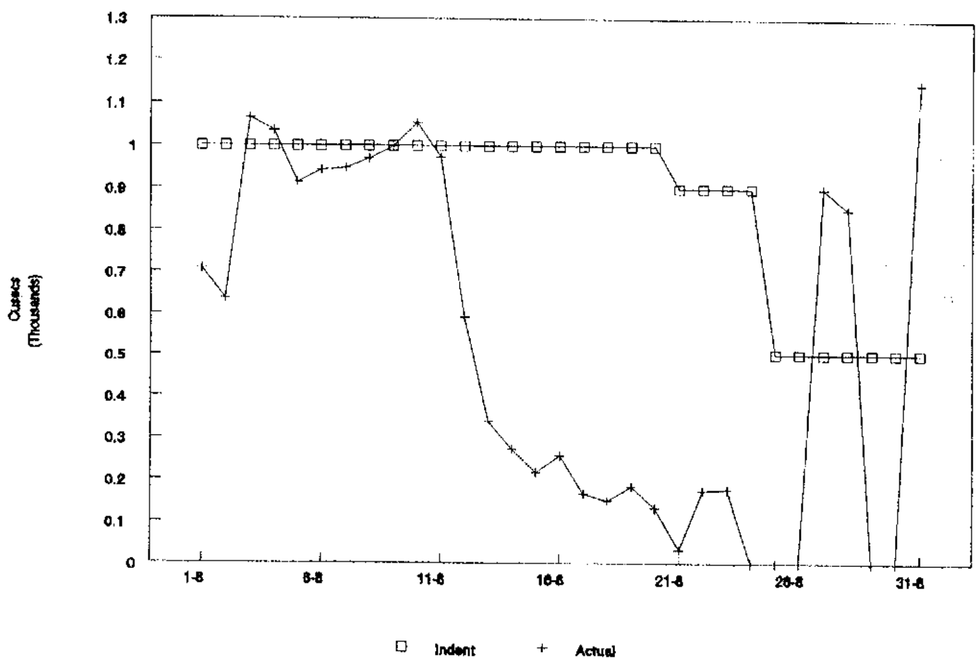
Table 3.3 shows indents versus actual amounts delivered at RD 537 during kharif 1993. This table shows that the overall amount of water supplied is well under the amount requested. The difference is small during June when demands are still small. However, in August when demands of flowering rice are the highest, the Muzaffarpur Division is getting less than 60 percent of the requirement. Yet in September, when demand drops sharply as the rice crop ripens, the lower reach gets over 150 percent of requirements.

Table 3.3. Indents and amounts supplied at Tirhut Main Canal RD 537, kharif 1993 (acre-feet).

Month	Indent	Amount supplied	Percent supplied
June	15,000	12,490	83 %
July	51,600	38,508	75 %
August	54,200	31,766	59 %
01-23 Sept	12,700	19,186	151 %
Total	133,500	101,950	76 %

Figure 3.3 shows the indent and actual discharges at RD 537 of Tirhut Main Canal (TMC) for August 1993. As can be seen, there is only the vaguest relation between indent and actual discharge. Most importantly, the actual discharge is well below the indent at the middle of the month when demand is very high but when demand dies down near the end of the month, actual discharges are well above indent. In other words, users upstream get the water when farmers want water while downstream users get it when they do not want it.

Figure 3.3. Indent and actual discharge at TMC RD 537, August 1992.



Discharge through head regulators, cross-regulators, and escape regulators is recorded through regular gauge readings. At control points, gauge scales have been painted on the walls. For each control point, a calibration chart has been prepared with regard to extent of opening of gates and corresponding discharge. Gauge readings are recorded by a gauge reader at each structure and are taken at four hourly intervals, usually 8 am, 12 noon and 4 pm. Generally gates are adjusted during the night so that they do not have an adverse effect on the system during periods when no readings are made. Due to inadequate maintenance, many gates of minors and outlets are missing and quite a few control structures leak, with the result that readings are not reliable for discharge computation and performance evaluation.

Below RD 537, the Vaishali Branch Canal takes off at RS 554, the Jaitpur Branch Canal at RD 594, the Birpur Sub-Distributary at RD 639, the Barkagoan and the Ram Dayalu Nagar distributaries at RD 658 and the Mallickpur Distributary at RD 704. Between RD 704 and RD 790, the Tirhut Main Canal functions as an escape channel to the Burhi Gandak River (cf Figure 3.2). There is a cross-regulator across the canal just below each offtake.

Normally water is allowed to flow from the Tirhut Main Canal simultaneously into these distributaries, from them into the minor canals, and from the minor canals into the outlets. Only in drought periods are attempts made to rotate distribution among the canals.

Though the Tirhut Main Canal from RD 537 to RD 704 was planned to irrigate a cultivable command area of 154,000 ha, irrigation facilities have been provided only for 40,412 ha because of the halt of ongoing construction in 1985. As a result, the maximum possible demand at RD 537 is around 1,420 cusecs or 26 percent of designed capacity. The maximum discharge recorded at RD 537 was 1,569 cusecs during the 1992 kharif season.

In many places canals and outlets have not been constructed. Where there are no distributaries or minors, farmers cut the canal bunds to obtain water, especially during kharif, weakening the canal bunds. Also, canal alignment in many places was altered under public pressure towards natural depressions (chaurs) and has resulted in heavy fillings. Since soil in these areas is mostly sandy loam, when there is water in the canal the saturated soil mass becomes unstable and can breach easily if not managed properly. To overcome this problem, it has been proposed that canals be lined but this has not been done for want of funds. Crops are occasionally damaged from floods from breaches because neither the WRD nor the farmers maintain the canals in good repair. Fear of breaches causes the system managers to limit the flow in many canals, including the Tirhut Main Canal.

Another problem is that along certain reaches of the canal, earth was removed from the canal bed to form bunds. It was presumed that during the initial stages of canal run these depressions would be filled with silt. Since the Tirhut Main Canal has not been operated at full design discharge, cross-regulators have to be operated in the head reach to raise water levels to meet outlet requirements, most of the silt has been deposited in the head reach and only silt free water has been carried below RD 537. This has left the excavated pockets unfilled.

The government allocates funds for maintenance based on the irrigated extent of the division. Because the Muzaffarpur Division has a long length of canal (537 RD to 704 RD) from which no direct irrigation is done, the canal is deprived of much needed maintenance funds.

Thus, although water is available in the Gandak River, these factors, coupled with the unpredictability of water available in the Tirhut Main Canal at RD 537, make it impossible to deliver water in the tail of the Gandak System in the planned amounts and with any degree of reliability.

3.4 OPERATION OF THE VAISHALI BRANCH CANAL

3.4.1 The Vaishali Branch Canal

The Tirhut Main Canal runs idle from RD 537 to RD 554 where the Vaishali Branch Canal (VBC) takes off. At this point, there is a cross regulator across the main canal and a head regulator in the offtaking canal.

Basic Features of the VBC

The command area of the Vaishali Branch Canal is bounded by Baya River and Bhushali Distributary Canal on the west and Jaitpur Branch Canal on the east. The designed gross command area (GCA) of the VBC is 90,413 hectares; the designed culturable command area (CCA) is 63,289 hectares. The VBC command lies in Vaishali and Muzaffarpur Districts.

The VBC runs for 155 RD (about 47 kilometers). Beyond that point, it is named Bhagwanpur Distributary whose length is 107 RD (about 33 kilometers). The alignment of canal follows the ridge line between the Baya River and Gandak River. The designed canal network for the VBC includes two distributaries, 14 sub-distributaries, and 45 minor canals having a total length of 296 km. All canals are designed on the ridges. Figure 3.4 gives a map of the VBC area and Figure 3.5 gives a schematic diagram of the canals as designed.

The VBC is designed to carry a discharge of 1,304 cusecs at the head of the canal for a total annual irrigation of 75,946 ha divided as shown in Table 3.4.

Table 3.4. Planned annual surface irrigation for the Vaishali Branch Canal.

Season	Area (ha)	Percent of CCA
Kharif	44,302	70 %
Rabi	22,151	35 %
Summer	5,063	8 %
Perennial	4,430	7 %
Total	75,946	120 %

However, when construction stopped in 1985, irrigation facilities had been completed only for 17,250 hectares. Thus actual irrigated area is much less than the designed.

Steel gates, lifted by screws or hoists, have been provided to control water in the canal. Cross regulators are located at RD 37, 53, 78, 102, 138, and 155 as shown in Figure 3.5. All offtakes have gates.

The overall condition of the canals and control structures is not good. As described below, many of the gates are broken and have not been repaired for many years. While the VBC itself and most of the distributaries are still in relatively good condition, many of the minor canals have been damaged by farmers cutting the banks and by other changes. To a large extent, the poor condition of the canals and control structures is due to a lack of funds for maintenance.

Irrigation Facilities below the Outlet: Field Channels

The Water Resources Department is responsible for making water available at the "outlets" from the minor canals. Each outlet is designed to serve about 40-300 acres. Outlets are ungated. Watercourses or field channels below the outlet are needed to deliver the water from the outlet to individual farmers' fields. Watercourses above one cusec discharge were to be constructed by the Water Resources Department.

It was originally felt that farmers would be willing to develop the system below the outlet, including field channels below 1 cusec discharge. When they failed to do so the Gandak Command Area Development Authority (GCADA) was made responsible for constructing field channels. However, GCADA has only constructed about 10 percent of the needed field channels; field channels are yet to be constructed in many places.

Figure 3.4. Vaishali Branch Canal Command.

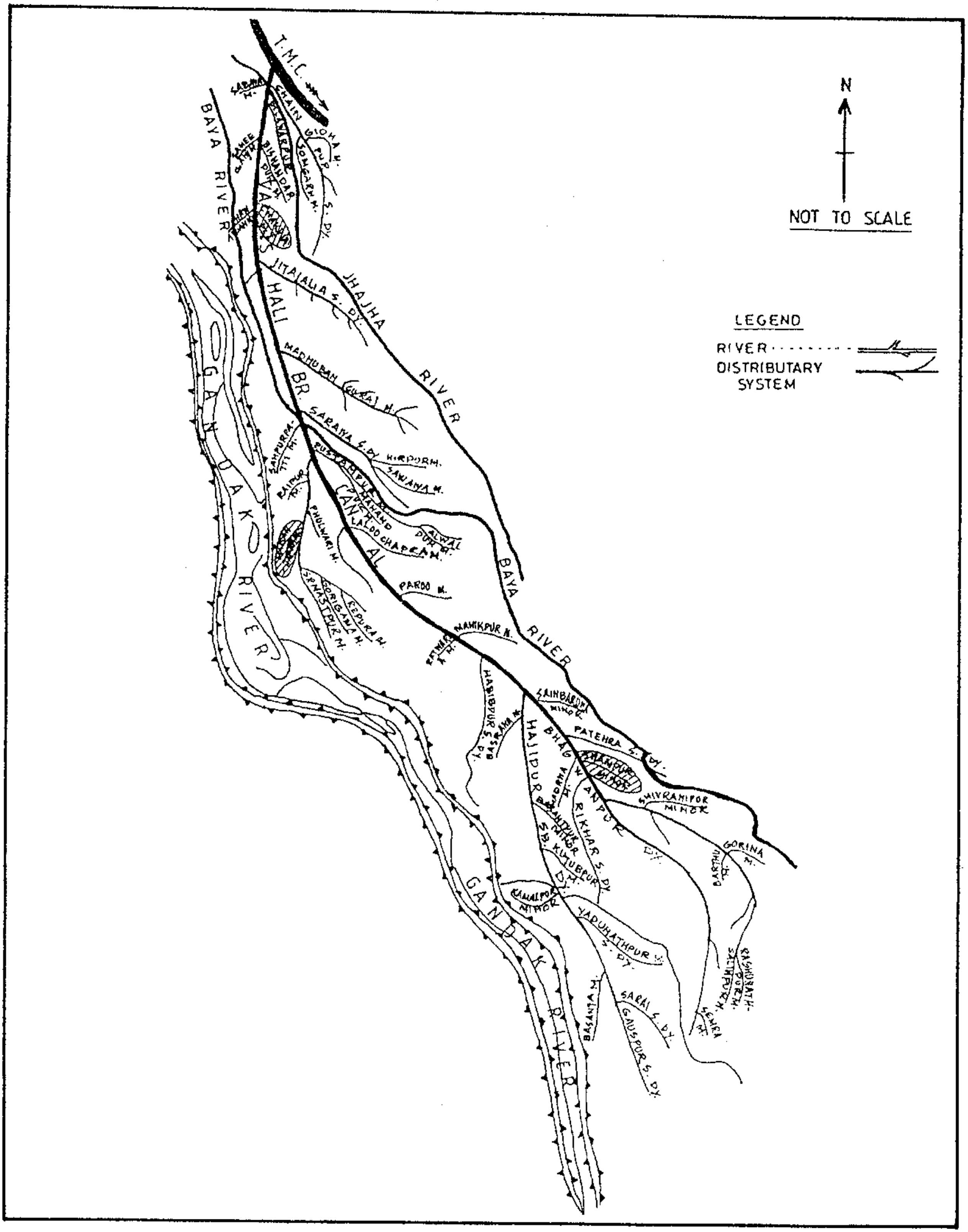
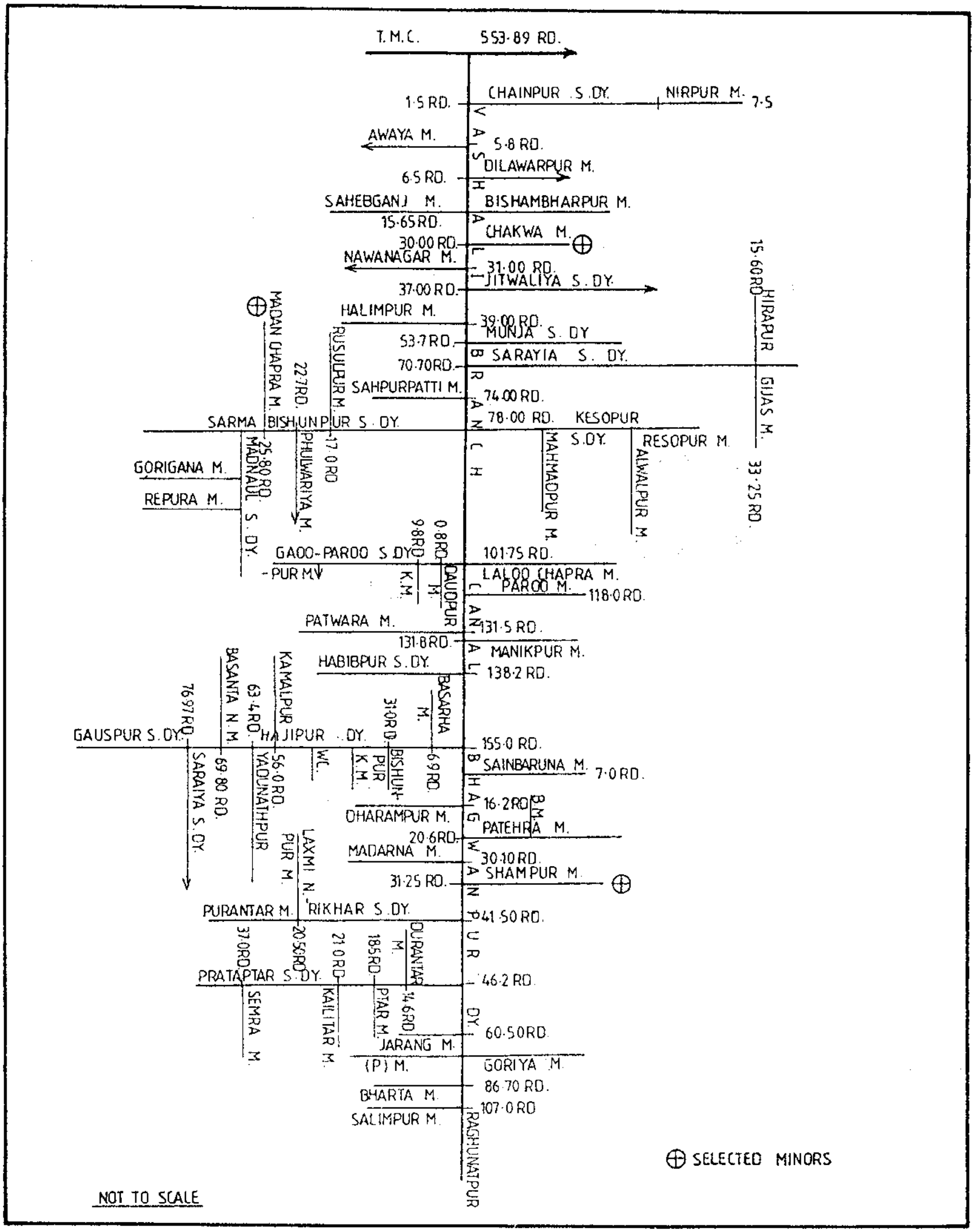


Figure 3.5. Schematic diagram of the Vaishali Branch Canal.



Many watercourses and field channels constructed earlier have become inoperative because of non-use or poor maintenance. Many field channels are not in use for want of proper linking arrangement between outlets and channels constructed by GCADA. In addition, field drainage and land levelling have not been completed in the command. These were also held to be the responsibility of the farmers. In the absence of proper on-farm development, there is considerable wastage of water.

Management Organization for the VBC

The Executive Engineer, Saraya Division, is the WRD officer in charge of the VBC. For operation and maintenance of the system, there are six sub-divisional officers as listed below:

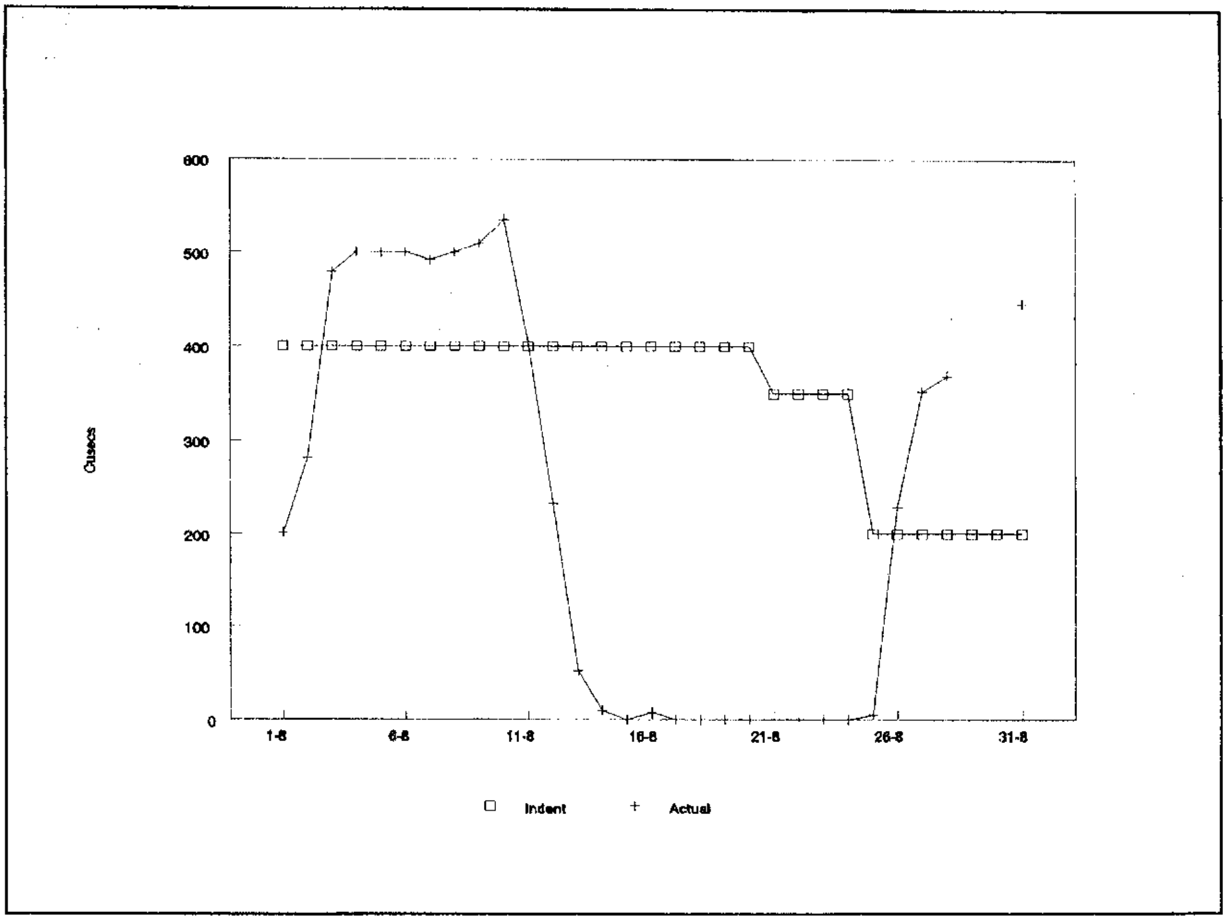
* Sahebganj
  a. VBC RD 0-37
  b. Chainpur Sub-Distributary
* Deoria
  a. VBC RD 39 to 78.30
  b. Mija Sub-Distributary
  c. Saraya Sub-Distributary
  d. Keshopur Sub-Distributary
* Paroo
  a. VBC RD 78.3 to 138.2
  b. Bishunpur Sub-Distributary
  c. Laloo Chapra Minor
  d. Paroo Sub-Distributary
* Saraya
  a. VBC RD 138.2 to 155
  b. Habibpur Sub-Distributary
  c. Hazipur Sub-Distributary
* Vaishali
  a. Bhagwanpur Distributary, RD 0 to 41.50
* Lalganj
  a. Bhagwanpur Distributary, RD 41.50 to 107
  b. Prataptar Sub-Distributary

The Executive Engineer and the Sub-Divisional Officers in charge of Saraya and Vaishali live at the Divisional Colony in Saraya whereas other Sub-Divisional Officers live at the headquarters in Muzaffarpur.

3.4.2 Performance of the Vaishali Branch Canal

When there is insufficient water available at RD 537 of the Tirhut Main Canal, the Vaishali Branch Canal's share of water is proportionately reduced, making flow as unpredictable at the head of the VBC as it is at RD 537. Figure 3.6 shows the indent and actual discharge at the head of VBC for August 1992. If this graph is compared to Figure 3.3, it can be seen that the flow patterns are similar. Flow is

Figure 3.6. Indent and actual discharge at VBC head, August 1992.



above indent in the early part of the month, but far below in the middle of the month and then far above the indent at the end of the month.

Table 3.5 shows the volumes of water delivered into the VBC during kharif 1993. The pattern is similar to that shown in Table 3.4 for volumes delivered at RD 537 of the main canal. The difference is that the percent supplied is lower during the months of heavy demand but far higher during September when demand is very low.

The VBC's design discharge is 1,304 cusecs. However, the VBC has been running at 30 to 32 percent of design discharge. During the last several years, maximum discharge during the kharif season has ranged between 400 and 450 cusecs. During the rabi season, it ranged between 250 and 300 cusecs. The highest discharge recorded at this regulator has been 978 cusecs during the 1978 kharif season.

At present, because of deterioration, the carrying capacity of the canal is 500 cusecs, which though capable of irrigating 14,000 ha in actuality only irrigates at most 10,000 ha during kharif. A former Executive Engineer of the Vaishali Branch Canal and later Chief Engineer of the Gandak Project said that during his tenure between 1975 and 1978, canal discharge was 600 to 900 cusecs. It is evident that the system has deteriorated considerably through the lack of proper and adequate maintenance.

Table 3.5. Indents and amounts supplied at head of Vaishali Branch (acre-feet).

Month	Indent	Amount supplied	Percent supplied
June	9,000	5,566	62 %
July	23,400	16,556	71 %
August	21,600	13,212	61 %
01-23 Sept	3,000	9,248	308 %
Total	57,000	44,582	78 %

Table 3.6 shows the target irrigated areas and the "achieved areas" for the VBC from 1978-79 through 1992-93. In this table, achieved areas from 1981-82 to 83-84 were based on eye estimates; those from 1984-85 onwards were based on field assessment (see below). Achieved areas are the areas that the WRD officers claim have been irrigated. If these are compared with the target areas, achievements range from 2 percent to 111 percent of target areas. The overall average for the 13 years for which the data is complete is 58 percent. Performance is bad even by the WRD's own standards.

3.4.3 Canal Operations on the Vaishali Branch Canal

There are some problems with the operation of the VBC and the subsidiary canals.

Making Indents for Delivery

Every ten days, the Junior Engineers are supposed to determine the demand for their areas and notify the Sub-Divisional Officers of the water needed. To do so, they need accurate data on the area to be irrigated.

* Engineers who operated the system in the early 1970s say that they used to maintain outlet registers and benefitted from the practice. The register would list each outlet and its command area. These registers have not been maintained so that now the Junior Engineers in charge of sections lack up-to-date information on the area they are supposed to irrigate. It is felt that Amins are not sufficiently disciplined to maintain these records nor would they agree to the Junior Engineers taking over their functions. The Junior Engineers seem to have lost the ability to control their subordinates.

* The Gandak Project design assumes that in the Gandak Command the only irrigation source will be canals. However, many farmers have installed tubewells. Therefore, it is essential to demarcate the area irrigated by tubewells for correct assessment of irrigated area by canals. The Minor Irrigation Division within the Water Resources Department attempts to keep track of groundwater development in the state. However, there is no communication in the field between

Table 3.6. Target and achieved irrigated areas in Vaishali Branch Canal (ha).

Year	Kharif		Rabi		Percent Target Achieved
	Target	Achieved	Target	Achieved	
1978-79	9,775	185	1,360	32	2 %
1979-80	12,826	3,590	800	956	33 %
1980-81	13,600	8,900	2,700	1,800	66 %
1981-82	11,800	12,980	3,780	2,860	97 %
1982-83	14,500	15,790	4,300	3,960	102 %
1983-84	16,500	18,795	4,990	2,279	111 %
1984-85	19,000	15,096	na	na	-
1985-86	16,290	na	2,700	442	-
1986-87	22,000	6,628	3,810	3,390	39 %
1987-88	15,000	6,625	7,500	2,975	43 %
1988-89	14,000	6,993	7,000	2,514	45 %
1989-90	14,000	6,313	6,212	2,591	44 %
1990-91	16,720	9,097	7,700	1,217	42 %
1991-92	16,720	9,490	2,500	2,271	61 %
1992-93	15,000	10,005	2,500	2,010	71 %

Note: na = Not available.
Source: Office of the Executive Engineer, Saraya, 1992.

the officers of the Minor Irrigation Division and officers of the canal division, although they both are in the same department.

Water demand also depends upon the crops planted and the growth stage of the crops. The WRD does not collect data on crops. They are supposed to coordinate with the Agriculture Department officers in the area.

* State government standing orders require the Water Resources Department to coordinate activities with the Agriculture Department at the highest level. Until 1989, Coordination Meetings were conveyed by the Chairman of the Gandak Command Area Development Authority before every crop season. At these meetings Agriculture officers would explain cropping patterns and describe the required inputs. The WRD would in turn provide information on targets. Cultivation plans would then be adjusted accordingly. Unfortunately these efforts have seldom been implemented efficiently.

* One problem in cooperation with the Agriculture Department is that the WRD keeps its records arranged on the basis of canal commands whereas the Agriculture Department and all other agencies keep records on the basis of administrative units, including the Blocks and Districts. Since the boundaries of these areas are different from the canal commands, there are real problems in working together.

At the moment, the Junior Engineers do not consult with Agriculture Department officers when preparing indents for water deliveries. Also, they do not consult farmers on the targets. Crop and growth stage are estimated by the Junior Engineer based solely on his own observations. When the Junior Engineer reckons that water is needed, he tends to fix the indent as high as possible depending upon the carrying capacity of the canals. The fear of breaches thus limits the amounts requested, generally to amounts less than needed by the farmers.

Once area targets are fixed, they are communicated to the Sub-Divisional Officer, Block Development Officers, District Magistrate and other Officers concerned with irrigated agriculture. No attempt is made to tell the farmers.

Operations

When adequate water is available in the Tirhut Main Canal, it is let into the VBC; the VBC runs continuously throughout the season whenever there is water barring canal breaches, excess rainfall, or severe drought. Normally, water is allowed to flow continuously from the VBC into the subsidiary canals down to the outlets. However, because the flow in the VBC is less than the design discharge, the cross-regulators have to be used to head up the water for proper flow into the distributaries. Therefore, even in normal continuous flow conditions there is a need to operate the gates.

Farmers do not generally interfere with canal operations but during droughts they will take action such as closing gates or blocking canals to get water. These actions sometimes lead to disputes and violence. To overcome these problems, the WRD attempts to deliver water on rotation. In Bihar, rotational deliveries are called the *tatil* system.

The tatil system is practiced in the Gandak Command during some droughts. For tatil, the VBC is divided into two sections: (a) RD 0 to 101.75, and (b) RD 101.75 to 155.00. At first, the full available water is allowed to go to the tail reach (RD 102 to 155) for four or six days, depending upon the degree of drought. Care is taken to ensure that cross-regulators above RD 101.75 are not closed by farmers during this period. During the following four or six days, the cross-regulator at RD 101.75 is closed to allow water in the first reach. One constraint of the system is that rotations are not effectively communicated to farmers, because of the inadequacy of the local newspaper distribution network, low literacy levels, lack of radio and television, and lack of funds for communication.

During droughts, when farmers are desperate for water, every farmer tries to get water first and the authorities have to take great pains in regulating water. Sometimes, canal authorities are compelled to call in the local police to maintain law and order. The present Executive Engineer has a good rapport with local farmers and he usually succeeds in efforts to distribute water equitably.

Data on the hydraulic parameters of canals are readily available with field officials. Operators at all control points are provided with calibration charts which indicate gate openings and discharge for a given head. Assistant Engineers (Mechanical) are responsible for the maintenance of cross-regulators and head regulators but because of lack of funds, regular maintenance work is not done. This results in considerable leakage through grooves and joints and many problems caused by nonfunctioning gates. For example, the screw to lift the gate on one of the two headgates for the Bishunpur Sub-Distributary was missing from 26 August 1992 until the WRD replaced it on 25 October 1993. During this period the gate operator, with the help of some farmers, lifted the gate directly and used bricks to prop it open. The farmers took additional water in payment for the favor.

Since outlets are ungated, water from the parent canal flows uninterrupted into field channels. Where field channels do not exist, water simply floods the land right at the outlet. Most goes to waste.

Inspections

The Executive Engineer, Saraya Division, and all of the Sub-Divisional Officers are required to inspect the irrigation works periodically, particularly during irrigation periods. The Executive Engineer and each Sub-Divisional Officer and Executive Engineer has been provided with a jeep. However, all except two of the vehicles in Paroo, Vaishali, Deoria and Sahebganj sub-divisions have been out of commission for the last three or four years; only the vehicles belonging to the Executive Engineer and Sub-Divisional Officer at Lalganj are in working condition. The WRD does not provide funds for repair. Lack of vehicles and the inadequacy of the fuel ration has adversely affected inspection work. Under these circumstances it has been left to Junior Engineers to solve irrigation problems whenever and wherever possible. It is felt that if proper facilities for inspection were available, irrigation performance would improve.

In July 1993, the Water Resources Department issued guidelines for canal operation during the kharif season to all supervisory staff and executives. Although the guidelines have not been implemented, they address some of the concerns listed above.

3.4.4 Operational Problems in the Vaishali Branch Canal

WRD Engineers in the VBC command area identify the following as the major operational problems:

* Incomplete construction.
* Lack of funds for maintenance.
* Growing indiscipline among field staff.
* Inefficient micro-networks.

Incomplete Construction

Phase 1 of the Gandak Project was declared complete on 31 March 1985. By that time physical development had been undertaken in 27.26 percent of designed command area of the VBC. Construction was stopped on many canals before the necessary structures and features were built to make them fully functional; many distributaries and sub-minors did not have even a single outlet. Even the constructed canal sections, therefore, are difficult and inefficient to operate, to say nothing of the non-constructed canals. In addition, large tracts of lands acquired for construction work remain unutilized. Since then, some additional work has been done to fix the problems as funds have been made available.

Until 1985, Rs 77,100,000 was spent on construction of the VBC system. Since then an additional Rs 4,394,000 has been spent. No allocation has been made for construction since April 1991. Thus the cost of construction per ha of the system is:

$$\frac{Rs\ 81{,}494{,}000}{17{,}250\ ha} = Rs\ 4724\ per\ ha$$

The average cost of construction for the same type of system in Bihar is Rs 7,000 per ha. Physical development in the VBC command has been far below the standard required.

Maintenance Funding

Operation and maintenance allocations are made at the start of the financial year on 1 April each year. Funds are released once a month to operating divisions. Since the Executive Engineer can never be sure how much he will actually receive, maintenance works cannot be preplanned. Casual seasonal laborers are employed to do repairs where required, but this can be done to a limited extent and only to prevent canals from breaching. Allocations are seldom made as per requirements proposed by the Executive Engineer.

The accounts show that since 1985-86, the average maintenance allocation has been Rs 601,222 which amounts to Rs 34.85 per hectare if spread over 17,250 ha. Actual average annual expenditure has been less, only Rs 525,719 per year or Rs 30.48 per hectare. These are very small amounts, far less than the Government of India norms of more than Rs 200 per hectare.

Indiscipline among Field-Level Staff in the Gandak

According to WRD informants, field level officers have become very lax in performance of their duties. They said that, in the early 1970s, when the Gandak System first began providing irrigation water:

* Canal assistants (mates) were provided with spades and baskets which they carried with them at all times, but especially during irrigation periods; they took great pride in keeping service roads and canal banks in good repair.

* Canal assistants also carried water pitchers and would sprinkle water on the service roads to keep the dust down during inspections by sub-division officers.

* Full discharge was allowed in the canal and Junior Engineers would keep regular watch on the canal free board. Whenever water in the canal appeared to be less than it should be, it was noted down. Other relevant information was also noted down.

* Canal assistants, gate operators and Amins were alert to their duties.

* Repair and maintenance estimates were prepared at the end of each season. These estimates after being scrutinized by the Executive Engineer would be sent for approval by the competent authority, who responded without delay. Soon after these formalities were taken care of, work would commence and be completed before the next cropping season.

* There was no lack of funds at that time and farmers had no complaints.

Although this is certainly an idealized picture, it varies so much from current conditions that there is likely to be some truth in it. Nowadays, rarely are the engineers seen on the canal banks. When engineers visit the canal, farmers come to them with their problems but these problems can rarely be solved for lack of funds and other constraints. When the problems are not solved, farmers become abusive and sometimes resort to physical violence. To escape this situation, engineers avoid visiting the canal. Since the engineers are rarely there, most of the lower staff who are supposed to be always available on site also take off.

To further complicate the situation, farmers have become aggressively aware of their rights, and now attempt to secure them through political parties or influential persons. These persons can easily make trouble for the WRD officers.

Inefficient Micro-Networks

The proper development of field channel networks, sometimes called micro-networks, below the outlets is a must if better use is to be made of the canal system. However, the Gandak Command Area Development Authority, which is responsible for the construction of field channels, also suffers from lack of funds. GCADA obtains its funds both from the Central and Bihar Governments on a 50:50 basis. Funds are held up by the state government's inability to match Central Government funding.

Until 1988/89, both unlined and lined field canals were constructed but since unlined channels are often damaged by farmers during kharif and reconstructed during rabi, unlined channels will not be constructed in the future. Lined channels also improve the equity of distribution. The extent of lined channels is based on guidelines issued by the government. In the Vaishali Branch Canal, where irrigation facilities have been developed for 17,250 ha, the recommended length of lined field channels is 473.55 km. To date, only 50 km of field canals have been constructed.

Maintenance of the field channels remains the responsibility of the farmers. For maintenance, GCADA formed Water Users' Associations (WUAs) in 1985/86 in every outlet command likely to receive water from the canals. Once the field channels had been constructed they were transferred to the representatives of the Water Users' Associations who had entered into agreements with GCADA to operate and maintain the field channels in future.

This practice is not proving effective for want of proper monitoring and evaluation. The unlined channels constructed by GCADA were damaged within two years of construction and even lined channels have been affected. Damage to field channels is rampant in areas where water supply is unreliable.

3.11 OPERATIONS IN THE BISHUNPUR SUB-DISTRIBUTARY

The Bishunpur Sub-Distributary (BSD) takes off from RD 78.05 of the Vaishali Branch Canal—almost in the middle reach. The responsible WRD officers claim it to be the best subsystem under the VBC. The BSD was selected as a site to study how a subsystem performs.

The total length of the Bishunpur Sub-Distributary is RD 31.30. It has no effective control structures. No outlets were originally constructed. At present, water flows up to RD 28 only. The design discharge at the head of BSD is 107 cusecs and the design CCA is 13,636 acres.

It was observed that in the absence of outlets, farmers have installed hume-pipes of varying diameters through which they take water. GCADA constructed unlined field channels at outlets with hume pipes. These channels are opened or destroyed during kharif rice cultivation to facilitate the flow of water, but farmers reconstruct these channels during rabi to protect less water tolerant crops.

Table 3.7 shows the particulars of the planned and constructed offtakes from the BSD. As shown in this table, only four of the planned offtakes have been constructed. Only a small part of the planned 13,636 acres can be irrigated from the BSD. Lack of outlets in the distributary and minors has forced farmers to install them on their own.

In addition to non-constructed canals and outlets, there are numerous changes to the design made by farmers. Within the BSD command area, the following were observed:

* There is a left bank outlet at RD 9.0 of the BSD that is not mentioned in the original Investigation Report. From the outlet, there is a 1,000 foot watercourse used to irrigate lands in Rup Narayanpur, a village in the Paroo Block.

* Rustampur Minor was designed for a cultivable command area of 1,225 acres. Since only a part of the Minor has been constructed so far, the present cultivable area is 350 acres. This includes nearly 250 acres of seasonally flooded (chaur) area, which is uncultivated during rabi.

* Rustampur Minor at RD 17.05 was the first canal to draw water from the BSD. Until 1980/81, Rustampur Minor drew no more than 25 cusecs, although designed for 107 cusecs. Farmers forced the authorities to create a barrier below the minor offtake. Two 4-feet diameter hume pipes were placed side by side inside the canal and the remaining bed width plugged. This reduced the canal width from 13.5 feet to 8.5 feet and raised the upstream water level from 9 inches to 12 inches.

* There are 10 outlets along Rustampur Minor, all on the right bank. All of these were installed by the farmers. Below these outlets, GCADA has constructed field channels ranging in length from 150 feet to 1,000 feet; five are lined. In addition to the outlets, farmers have also cut the right bank of the canal at RD 0.1, 3.8, 4.1 and 4.5 to take water.

* No outlets have been constructed on the left bank of Rustampur Minor. As a result, the left bank has been cut by farmers at RD 0.15, 0.5, 0.7, 1.2, 1.8, 2.2, 2.5, 2.8, 3.0, 3.3, 3.8, 4.0, 4.4, 4.6 and 4.9.

* Rustampur Minor has been operating since construction in 1975/76. Lack of maintenance had made the minor unsuitable for irrigation. Noticing the poor condition of the minor and the plight of the farmers, a District Judge from the village of Bhagwatipur tried to mobilize the WRD to get the channel repaired. Failing, he organized the farmers to repair the canal at their own expense. By farmers' efforts, the minor was rehabilitated and now functions satisfactorily.

* An unlisted outlet has been constructed in the BSD left bank at RD 17.3 to irrigate lands in Ratwara village. The village has a cultivable command area of 450 acres and also gets waters from Rustampur Minor. A hume pipe is installed at RD 17.3 with a discharge capacity of one cusec to irrigate a cultivable area of nearly 45 acres.

Table 3.7. Offtakes from Bishunpur Sub-Distributary.

Canal	Location on BSD (RD)	Design discharge (cusecs)	Design CCA (acres)	Constructed length (RD)
WCR 1	0.33	1.60	203.0	0.50
OL 2	0.33	0.54	48.2	nil
Dharphari Minor	1.00	10.06	1,277.5	nil
WCR 4	2.50	3.50	444.5	nil
WCL 5	2.50	2.70	343.0	nil
WCL 6	7.70	2.59	329.0	nil
WCR 7	9.00	2.09	266.0	1.0
WCL 8	16.33	1.41	179.2	nil
Rustampur Minor	17.05	9.64	1,225.0	5.0
Khizirpur Minor	21.30	7.96	1,011.5	nil
WCR 11*	25.00	3.86	490.0	2.0
Samastipur Minor	31.30	14.52	1,884.5	nil
Madhaul Sub-Distributary	31.30	46.89	5,954.2	nil

* Originally this was to be an outlet only, but under public pressure it was converted to Madan Chapra Minor (see below).

Key: WCR = Watercourse (outlet), right bank.
WCL = Watercourse (outlet), left bank.
OL = Outlet, left bank (smaller than a watercourse).

* Outlet WCR 11 has not been constructed at RD 25.0 of the BSD. Instead, Madan Chapra Minor has been constructed in the BSD right bank at RD 25.3 to serve irrigation needs of farmers in the villages of Pandeh and Karamwari. Design features include a discharge of 6.94 cusecs, cultivable command area of 882 acres, and a cultivable kharif area of 617.40 acres.

* Since the Samastipur Minor and the Madhaul Sub-Distributary, both tail end minors, have not been constructed to their designed lengths, a number of outlets have been installed at RD 28 (L), RD 28.2 (L), RD 28.2 (R), RD 28.5 (R), RD 28.7 (L) and RD 29.9. GCADA has constructed field channels below these outlets.

Actual discharge levels against designed discharge of 107.36 cusecs are shown in Table 3.8. Table 3.8 does not necessarily describe water availability in the minors. For example, as described above

Rustampur Minor has difficulty in drawing sufficient water. During 1993 kharif, water was available from 1 July to 14 August (46 days). During 1992/93 rabi, water was available in Rustampur Minor from 14 January to 20 January (7 days) and from 20 February to 27 February (8 days).

Because of the problems in getting water, farmers in Rustampur Minor often construct an earthen bund in the canal bed at RD 17.30, causing water shortages downstream. The earthen bund is allowed to remain for three days before it is removed. This practice has become a bone of contention between farmers above and below RD 17.30 and has resulted in numerous disputes and fights especially during water short periods.

Table 3.8. Discharges in the Bishunpur Sub-Distributary.

Actual discharge: Percentage of design discharge	Kharif 1993		Rabi 1992-93	
	Days	Average discharge (cusecs)	Days	Average discharge (cusecs)
30-50%	1	60	-	-
Below 30%	55	20	49	14

During droughts farmers become severely agitated. During kharif 1992, farmers in Madan Chapra Minor forcibly brought the Junior Engineer to the canal and made him regulate the system to get water to their minor. Farmers realize that this is against the law but said that if canal officers do not do their duty, then force must be used to make them work in the field.

Given this level of water availability it is not surprising that the irrigated area for BSD during kharif 1993 was only 1,654 acres against a target area of 2,321 acres.

3.5 CANAL IRRIGATION IN THE STUDY MINORS

Three minor canals of the Vaishali Branch Canal were selected for detailed study. They are:

* Chakwa Minor, in the head reach of the VBC.
* Madan Chapra Minor, in the middle reach of the VBC.
* Shampur Minor, in the tail of the VBC.

These minors are located respectively in Sahebganj and Paroo Blocks of Muzaffarpur District and Vaishali Block in Vaishali District.

3.5.1 Chakwa Minor

Chakwa Minor is a direct offtake from the left bank of the Vaishali Branch Canal at 30 RD. This minor is designed to irrigate parts of four villages: Nawanagar Milky, Nawanagar Nizamat, Rampur Khurd and Jagdishpur.

Features of Chakwa Minor

A comparison of the present state of Chakwa Minor with the design prepared in the 1970's shows large differences:

* Design discharge at head is 7.17 cusecs. The design head at the minor offtake is 5.09 feet; thus, the minor is designed to run full even if supply in the VBC is low. Discharge now seems to be well below the design figure. Unfortunately, present discharge levels at the head of the minor is not recorded in any of the irrigation registers. Concerned irrigation officials, on enquiry, could not give us estimates of actual discharge.

* Total design length of the minor is 1,300 feet (1.3 RD). Constructed length is only 700 feet.

* Five outlets each irrigating an area between 46 to 375 acres were to be constructed. However, only two were installed. These, due to poor construction and continuous seepage water from VBC bank and have been non-operational for the last eight years. Therefore, farmers have cut the canal banks in nine places to take water.

* The design Gross Command Area (GCA) is 1,300 acres; the design Culturable Command Area (CCA) is 910 acres; design kharif irrigation intensity is 637 acres. The actual irrigated areas are far below the design figure. Our field survey showed that the highest canal irrigated area was 32 acres in kharif 1992, 31 acres in kharif 1991 and only 10 acres in rabi 1991-92.

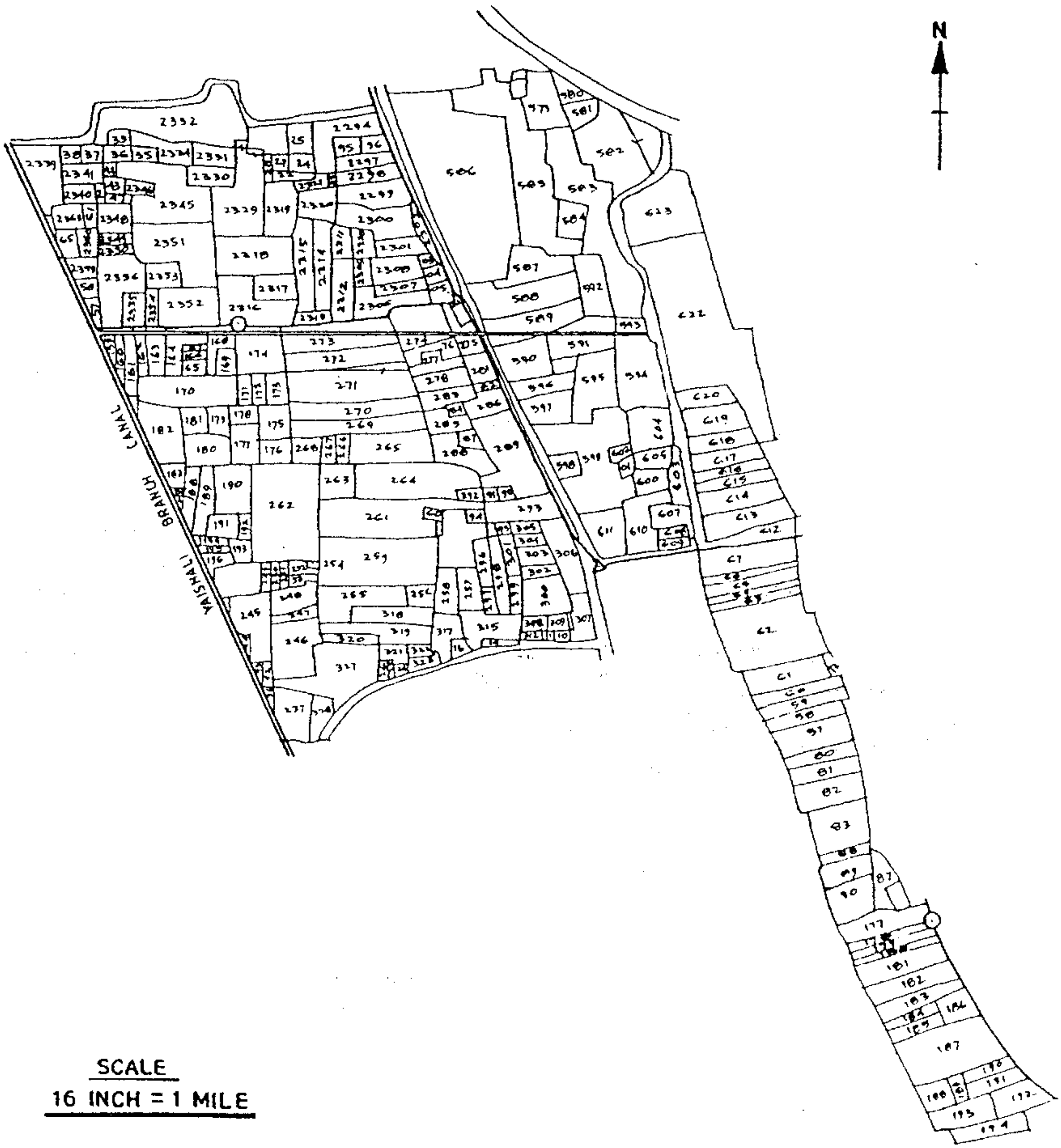
* One canal crossing for a village road was to be constructed. This culvert was constructed by using cement pipe. The pipe broke six years ago and remains unrepaired. Water spills from the culvert onto the road.

* The design computed distribution losses of 12.5 percent. Because of these structural problems, farmers emphatically assert that "40-50 percent of water goes as wastage."

Most of the design features, according to field officers, could not be implemented properly due to a paucity of funds. Also, whatever was implemented has not been maintained properly due to inadequate operation and maintenance grants.

During February and March 1993, as a part of an employment generation program under the Jawahar Rojgar Yojana Scheme, a Government of India funded program, the Sahebganj Block Development Office carried out repair and strengthening work of Chakwa Minor. During the course of the work, local farmers got the work supervisors to install cement pipe outlets in the place of the nine canal cuts. When we made a walk-through survey of this minor, during mid-April 1993, a group of farmers who walked with us and also whom we met in the village said: "Outlets installed after minor

Figure 3.7. The Chakwa Minor.



repairs are really useful for us and now we will not resort to cutting the canal. The present location of the outlets is based on our consensus and we are going to protect them."

When we described our field observations to the local WRD officers, they said: "We are not aware of this, because this work was carried out by the Block Development Office, and they did not ask for our assistance. So we are not responsible for the new outlets installed."

The Study Area

Figure 3.7 shows the Chakwa Minor Command Area. The Amin is responsible for measuring the area irrigated by canal and to list the irrigated fields with their revenue survey numbers for water fee collection at the end of the season. We made a walk-through survey of Chakwa Minor with the Amin to identify the area actually irrigated from the canal. This area covered a total of 216 fields, spread over 67.15 acres shared by the four villages. An area covering 164 fields over 54.2 acres was taken as the Chakwa Minor portion of our Study Area.

As noted above, not even the fields demarcated by the Amin get canal water for irrigation in all crop seasons. Irrigated area differs from one crop season to another. Even within a season, not all cropped area gets all the required irrigations from canal water.

3.5.2 Madan Chapra Minor

Madan Chapra Minor takes off from the right bank at 25.73 RD of Bishunpur Sub-Distributary. This sub-distributary starts at 78.05 RD of Vaishali Branch Canal, thus putting it in the middle reach of the VBC. Madan Chapra Minor irrigates parts of two villages—Pandeh and Karamwari of Paroo block in Muzaffarpur district.

Features of Madan Chapra Minor

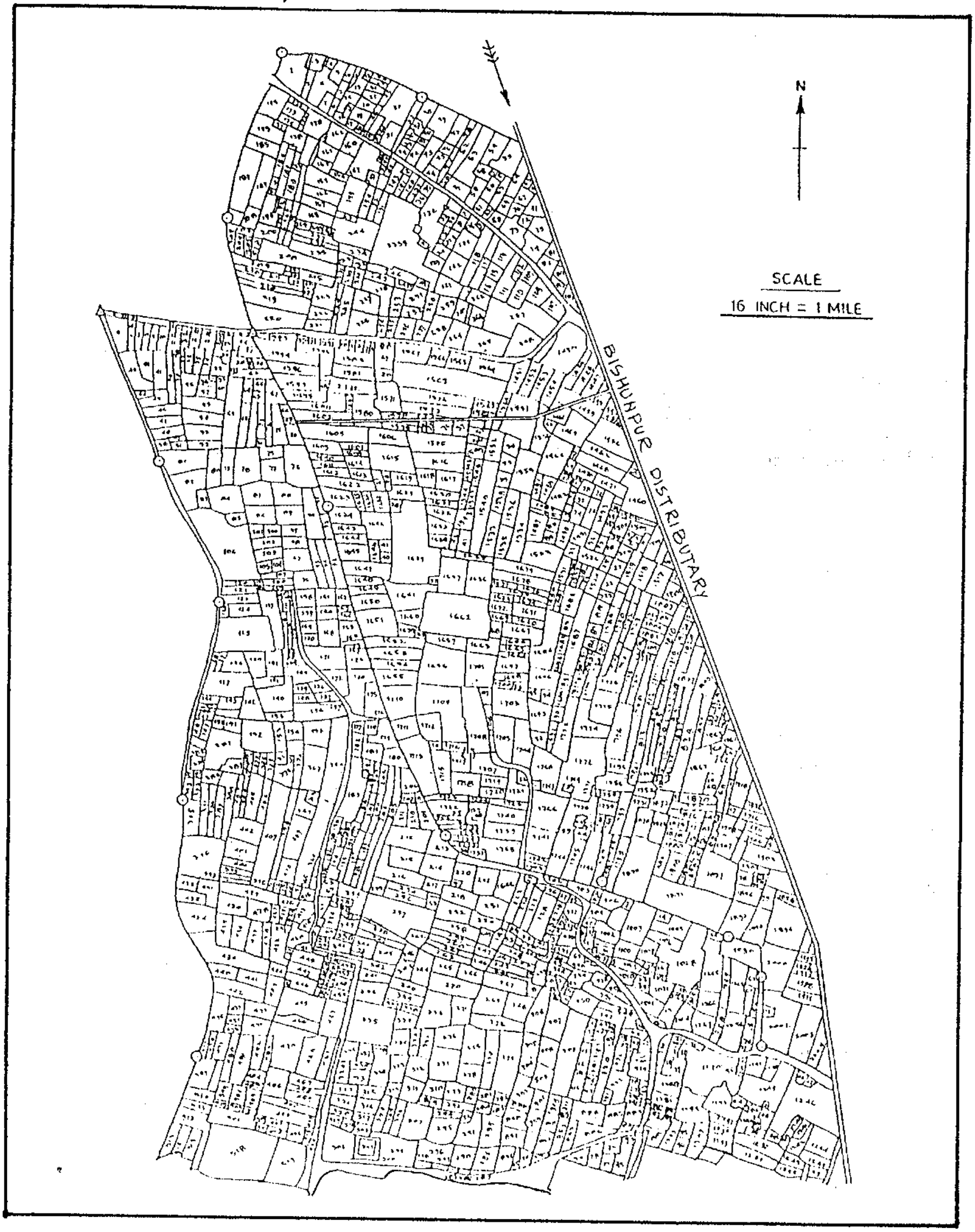
Madan Chapra Minor was not originally included in the plan for the sub-distributary. The plan called for an outlet to be placed on the right bank at RD 25.70. Madan Chapra's design command area was to be commanded from this outlet and from outlets from Rustampur Minor. But according to field officials, "for better irrigation, as per the instructions of the Superintending Engineer, it was proposed to irrigate this area from a direct outlet from the sub-distributary. Since the design discharge of the outlet is 7 cusecs, it has been named a minor canal."

A comparison of the present state of Madan Chapra Minor with the design shows large differences:

* Design discharge at the head of the minor is 6.94 cusecs. It seems that the actual discharge is much less. However, there is no regulator at the head of the minor, and discharge measurement is not made at any point of time during the season, so there is no data.

* The design length of the minor is 2,000 feet (2 RD). The constructed length is 500 feet.

Figure 3.8. The Madan Chapra Minor.



* Three outlets were planned, irrigating respectively 570 acres, 160 acres, and 530 acres. None of these were constructed. In practice, water is taken from the canal through six cuts in the bunds made by the farmers. Over a period of time, due to soil erosion these cuts have increased both in size, reducing the thickness, level and strength of the minor bunds.

* The design GCA is 1,260 acres; the design CCA is 882 acres; the design kharif irrigated area is 617 acres. The actual irrigated area is much less. By field survey, we found that the canal irrigated area was 37 acres during kharif 1992 and 32 acres during rabi 1991/92.

As in Chakwa Minor, these differences are attributed to failure to construct the planned items and to poor maintenance.

The Study Area

Figure 3.8 shows the Madan Chapra Command Area. A survey of the area with the Amin revealed that the present canal irrigated area covers only 504 fields spread over a total area of 78 acres shared by two villages. Of these, 438 fields covering 63.5 acres were taken for detailed study; this area is defined as the Madan Chapra portion of the Study Area.

As noted above, not all of this area is actually irrigated. Fifty-five fields (11 acres) are planted with trees, 19 fields (5 acres) are unused because they are affected by alkalinity (*usar* land), and 9 fields (less than an acre) are used for grass. Other sources of irrigation was also used in the remainder of the area.

3.5.3 Shampur Minor

Shampur Minor takes off from the left bank of the Bhagwanpur Distributary at 31.25 RD. The Bhagwanpur Distributary is the tail continuation the Vaishali Branch Canal; hence Shampur Minor is in the tail reach of the VBC. The minor irrigates parts of four villages: Chintamanpur, Haharo, Chakdaulat and Shampur in Vaishali Block of Vaishali District.

Features of Shampur Minor

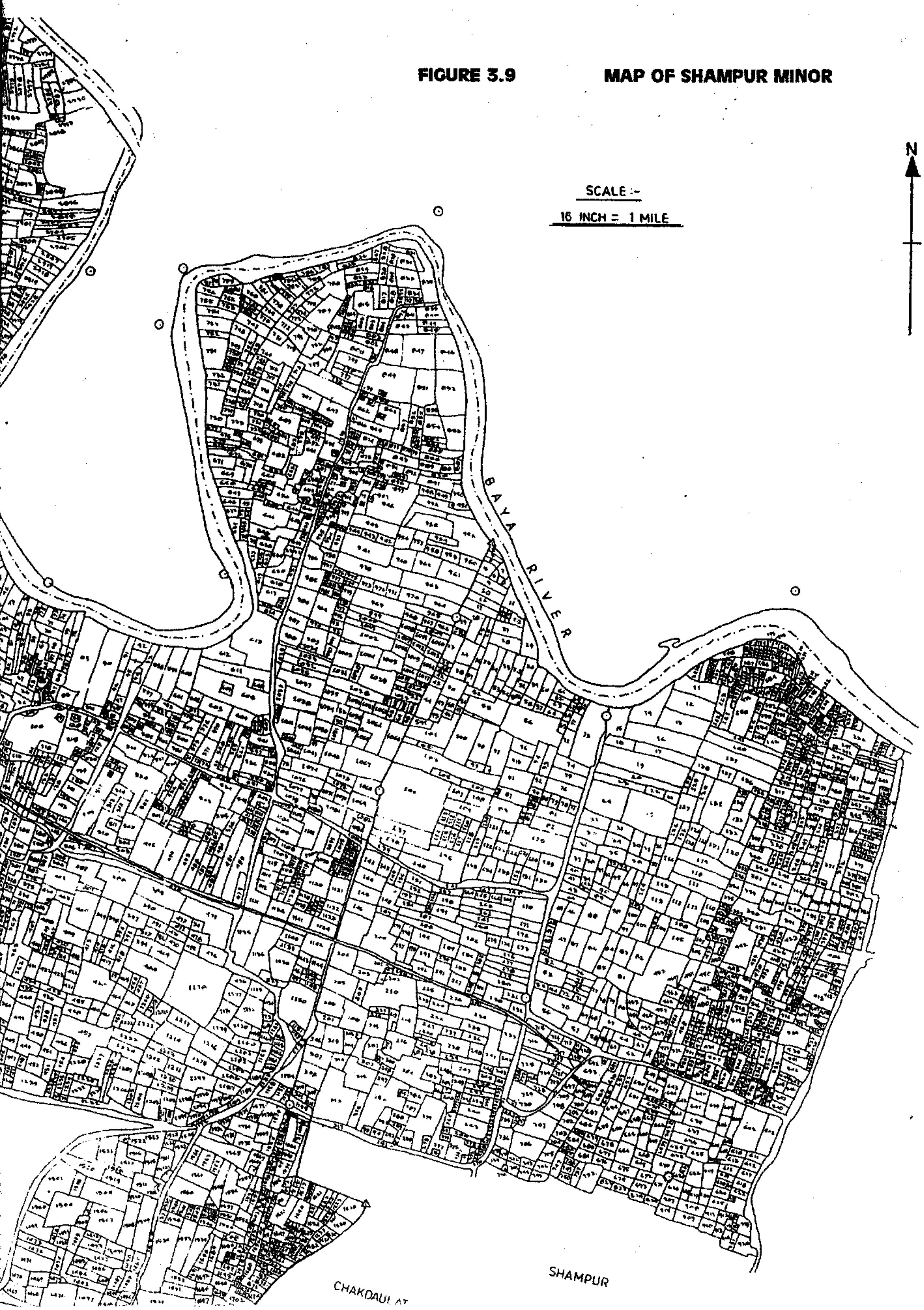
A comparison of the present state of Shampur Minor with the design shows large differences.

* The command area of the minor lies between the Baya River and a chaur area. We found, however, that the location of the minor canal differs significantly from its planned location. The plan map indicates that the minor runs close to the Baya River. Actually, the minor is constructed nearly one thousand feet away from the River.

* Design discharge is 11.07 cusecs. The design provides for a working head of 6" at the head of the minor. As with the other two sample minors, the observed discharge is much less; however, there are no records.


BAYA RIVER
CHINTAMANPUR
HAHARO

FIGURE 3.9 MAP OF SHAMPUR MINOR



* Design length of the minor is 9 RD. Constructed length is 5 RD. However water never reaches the end of even the constructed portion. Below about 3 RD, one can see numerous points where the canal bunds have been used to construct field channels for carrying water from tubewells. At one point near the very tail, a new road crosses the minor without a culvert. The canal has simply been filled in.

* Five outlets were planned, each irrigating between 112 and 808 acres. Only two outlets were installed. Due to faulty construction and improper alignment, they remain unused. In the absence of any functional outlet, farmers take water through 32 cuts in the canal bunds.

* The design GCA is 2,015 acres; the design CCA is 1,410 acres; and the design kharif irrigated area is 987 acres. Our field survey showed that only 15.62 acres were irrigated by canal during kharif 1992. In the absence of adequate length of minor and inadequate water supply in the existing length, only parts of Chintamanpur and Haharo villages get canal irrigation. Chakdaulat and Shampur villages, even after 17 years of minor operation, remain deprived of canal water.

* On either side of the minor in some parts, 30 foot wide strips of land were acquired in 1975 for canal right of way. In the other two canals, only five foot wide strips were acquired. Farmers in Shampur Minor complain that no compensation has ever been paid.

Like the other two minors, most of the design features remained on paper only, as local officials say, "due to inadequate funds."

The Study Area

Shampur Minor command is shown in Figure 3.9. The portion of this area that was demarcated with the help of the Amin and local farmers as irrigated from the canal includes 200 fields and covers 52.2 acres only. This is much less than the full area shown in Figure 3.9.

3.5.4 Canal Irrigated Areas in the Study Area Minors

There are various figures concerning how much area is irrigated from the canals. Table 3.9 summarizes the situation with regard to irrigated area in the sample minors for kharif 1992. In this table, "target area" is the area that the Junior Engineer uses for his calculation of demand; "achieved area" refers to the area the Junior Engineer figures has been irrigated from the canal; "assessed area" is the area reported by the Amin as irrigated from the canal for revenue purposes; "study" refers to the area determined by our surveys of farmers and crops in the field. The figures for the first three columns come from the Executive Engineer's records.

This table clearly shows that there is little relationship between targets and areas irrigated. Moreover, it suggests that neither the reported "achieved areas" nor the "assessed area" are terribly close to the actual area irrigated from the canals, except maybe by accident.

Table 3.9. Target, achieved, assessed, and actual areas irrigated, kharif 1992.

Minor	Target	Achieved	Assessed	Study
Chakwa	80	30	11.00	13.00
Madan Chapra	40	35	20.65	14.98
Shampur	200	30	30.29	6.32

Source: Executive Engineer Office, Saraya, 1992.

3.6 CANAL IRRIGATION IN GANDAK: CONCLUSIONS

This chapter demonstrates that, despite adequate flow in the Gandak River, there are severe problems with the performance of the Eastern Gandak Canal System, particularly in the tail area of the Tirhut Main Canal. The problems include both structural and management problems.

Major structural problems include:

* Missing and incomplete structures due to the cessation of the construction work in March 1985.

* Weak canal banks due to farmer actions, incomplete construction, soil problems, and lack of maintenance.

* Non-functioning structures due to lack of maintenance.

Major management problems include:

* Demand for water determined generally on the basis of experience and canal capacity rather than on either crop needs or farmer demand.

* Slow transmission of demands to the operating officers through long and complicated channels.

* Failure to make deliveries match indents.

* Failure to actually operate the control structures unless forced to by the farmers or by unusual circumstances such as drought.

* Failure of engineers to travel to the field to learn about actual conditions, partly because of lack of transport and partly because of fear of confrontations with angry farmers.

* Poor assessment of irrigated area for revenue and performance evaluation purposes.

* Lack of funds for maintenance.

The result is highly unreliable water deliveries, particularly in the tail of the Tirhut Main Canal. The detailed investigation of the situation in the Vaishali Branch Canal Command revealed that quantities delivered are far less than required, except when water is not wanted. Deliveries are also unreliable, to the point of being virtually unpredictable by farmers. Even though the WRD records show that much less than the target areas are actually irrigated, the figures from the Study Area indicate that even WRD's low estimates of areas irrigated from the canal are greatly inflated.

Without both physical and management improvements, it is clear that the tail area of the Eastern Gandak System cannot provide adequate water for farmers.

The unreliability of canal water deliveries has major consequences for farmers:

* Many farmers must find other sources of water for their crops. Some are forced to depend solely upon rainfall. The use of other sources is discussed in detail in the following chapters.

* Since farmers cannot depend on a regular and timely supply of canal water, planting generally commences with the coming of rains. This usually delays the planting of kharif rice and the cultivation of rabi crops. It also means that choice of crops and varieties is limited. Overall, this reduces productivity.

On the other hand, canal water, when it is available, is cheap. Canal water rates are low and are rarely collected. Also, once the canal is in place it requires relatively little work to get water to the field. For these reasons canal water is attractive to farmers if available.

CHAPTER 4

Sources of Irrigation Water: Tubewells

4.1 GROUNDWATER IN THE STUDY AREA

The Gangetic plains are deep alluvial formations which attain a thickness of approximately 2,500 meters in parts of North Bihar. As in other alluvial formations, most of the area is underlain by aquifers at varying depths. The soil consists of various grades of sand, silt clay and kankar. The aquifers are formed by clean sand beds that constitute between 40 and 80 percent of the soil strata.

Subsurface water in North Bihar flows generally southeasterly towards the River Ganga, a pattern modified by the recharge and discharge patterns of the tributaries of the Ganga. In general, the hydraulic gradient is of the order of 1:5,000. The quality of the groundwater of the aquifer system is good. To a depth of about 100 meters, electrical conductivity ranges between 400 to 950 μmhos/cm indicating low salinity. The water is generally suitable for irrigation.

The aquifers are recharged mainly by the monsoon rains. The Bihar State Groundwater Directorate measures the water table before and after the monsoon every year. As shown in Table 4.1 for Sahebganj, Paroo, and Vaishali blocks, the water table drops as low as 6.10 meters below the ground surface before the monsoon and rises as high as 0.42 meters below the ground following the monsoon. The fluctuations of the water table over the year are generally in the range of one to three meters.

Table 4.1. Water table depths in the study blocks (in meters).

Type of well	Year	Sahebganj Block			Paroo Block			Vaishali Block		
		Pre-monsoon	Post-monsoon	Change	Pre-monsoon	Post-monsoon	Change	Pre-monsoon	Post-monsoon	Change
Surface percolation well	1983	4.40	3.60	0.80	2.29	2.09	0.20	6.10	4.90	1.20
	1984	4.50	2.28	2.22	3.51	1.79	1.72	5.89	3.71	2.18
	1985	4.49	2.06	2.43	3.73	1.57	2.16	3.97	2.09	1.88
	1986	4.30	3.34	1.96	3.36	1.23	2.13	5.59	3.12	2.47
	1987	4.44	2.75	1.89	3.94	2.08	1.86	5.84	3.00	2.84
	1988	4.32	3.48	0.84	3.78	2.37	1.41	5.74	4.14	1.60
	1989	4.17	3.10	1.07	3.70	1.91	1.79	5.82	3.72	2.10
	1990	4.48	2.84	1.64	3.61	2.18	1.43	-	3.35	-
	1991	4.50	3.25	1.25	3.65	2.40	1.35	5.78	3.70	2.08
State tubewell	1983	4.05	3.27	0.78	2.91	1.55	1.37	5.01	4.90	1.25
	1984	5.39	2.83	2.56	4.38	0.97	3.41	4.41	2.53	1.91
	1985	4.14	1.76	2.38	-	0.85	-	-	0.60	-
	1986	3.84	2.07	1.77	4.23	0.42	3.81	3.99	1.93	2.06
	1987	5.61	2.45	3.16	4.77	1.27	3.50	4.50	1.91	2.65
	1988	4.26	4.14	0.12	4.65	2.66	1.99	4.46	2.95	1.51
	1989	4.09	2.89	1.20	4.57	2.02	2.55	4.40	1.86	2.54
	1990	4.02	2.65	1.37	2.39	2.10	0.69	-	1.49	-

Source: State Groundwater Directorate, Minor Irrigation Department, Patna, 1992. Measurements of the groundwater table depth were from figures for the villages of Isachapra, Dharpari and Senbaruna in the Sahebganj, Paroo and Vaishali blocks, respectively.

The relationship between groundwater recharge and usage in Bihar and the Muzaffarpur and Vaishali districts is shown in Table 4.2. This table suggests that only 36 percent and 52 percent, respectively, of the groundwater resources of Muzaffarpur and Vaishali districts have been developed for irrigation. However, these figures should be viewed with caution, most professionals feel that these calculations give only the order of magnitude of the potential groundwater resources.[1]

Table 4.2. Groundwater development in Bihar and the study districts (figures in million cubic meters).

Item	State of Bihar	Muzaffapur District	Vaishali District
1. Total replenishable groundwater	33,773	998	633
2. Utilizable for irrigation	28,706	849	530
3. Actual net draft	6,761	305	260
4. Balance	21,945	544	279
5. Level of development	24 %	36 %	48 %

Source: 'BHU-JAL NEWS,' the Quarterly Journal of the Central Groundwater Board, New Delhi, January-March 1991, Vol.6 No.1.

4.2 WELLS IN THE STUDY AREA

Wells in the study area can be categorized into: (a) dugwells or open wells, which can be further divided in *kacha* or unlined wells and *pucca* or lined wells; (b) shallow tubewells with average depths of 150 feet, mostly owned and operated by farmers; and (c) state owned deep tubewells with average depths of more than a 150 feet. Progress in the development of all three types of wells is shown in Table 4.3.

Farmers have devised many methods to extract groundwater. The extent of extraction and methods have changed over time due to the availability of improved technology and support systems provided by the Government and nongovernment organizations. As shown in Table 4.4, in the study area there has been a shift in methods of extraction. From 1961 to 1981, many kacha wells in Chakwa and Shampur minors were abandoned. Pucca wells have also become obsolete except for those which are used for drinking water. Owners who have installed mechanical tubewells say that the old methods of water extraction required more time and manpower for irrigation than do the newer methods. Also dugwells have slow recharge and often fail to provide adequate water during dry periods.

Three types of tubewell ownership are found in Bihar:

* "Private tubewells"—tubewells owned by individuals.

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[1]The figures in Table 4.2 come from district-level water balances calculated by the State Groundwater Directorate. Wet season recharge of groundwater is computed through a hydrographic analysis of data obtained from an intensive network of observation wells. An appropriate specific yield value for the material within which the water table is moving in the area represented by the observation well is applied. Dry season recharge from surface water irrigation is calculated from estimates of losses to deep percolation from canals and fields based on regional norms. The total mean annual recharge derived from these calculations is reduced by 30 percent, to account for the uncontrollable drainage flow and transpiration by deep rooted vegetation, to obtain "net recoverable recharge."

Table 4.3. Wells in the study districts.

District	Block	Dugwells		Shallow tubewells		State tubewells	
		1987	1991	1987	1991	1987	1991
Muzaffarpur	Paroo	-	-	219	309	5	5
	Saraya	-	-	156	232	18	18
	Sahebganj	18	18	106	164	4	4
Vaishali	Lalganj	128	128	222	275	14	14
	Hazipur	221	221	200	235	10	10
	Vaishali	9	9	148	194	8	8

Note: Blocks are either fully or partly irrigated by the Vaishali Branch Canal.

Table 4.4. Wells and irrigated areas in the study minors (area in acres).

Year	Type of Well	Chakwa		Madan Chapra		Shampur	
		No.	Area	No.	Area	No.	Area
1961	Dugwell	79		53		104	
	Tubewell	11		-		-	
	Tank	1		2		-	
	Total	91	241.61	55	3.19	104	644.09
1971	Dugwell	1				2	
	Tubewell	2				1	
	Others	-				2	
	Total	3	76.50	na	na	5	48.00
1981	Dugwell	2					
	Dugwell/pump	1					
	Tubewell	1					
	Others	2					
	Total	6	24.03	1	5.82	9	115.10

Sources: Respective block development offices, 1991.

* "Group tubewells"—tubewells owned by a group of farmers with generally contiguous landholdings; these include cooperative tubewells which are tubewells owned by formal cooperatives promoted by nongovernment organizations.

* "State tubewells"—tubewells owned and operated by the Government of Bihar.

There are no state tubewells in the study area. Each of the other two types is discussed separately below. In addition, we discuss the use of privately owned pumps to lift water from the Baya River because this is an alternative to private and group tubewells in Shampur Minor. Finally, we discuss the market for groundwater (and river lift water) in the study area.

4.3 PRIVATE TUBEWELLS

A private tubewell is either owned by the owner-cultivator or by the absentee landlord. These tubewells are generally operated and maintained by the owners or their representatives. All tubewells are created by boring a slender shaft into the ground down to a water bearing stratum, generally a sand layer. The bore is lined with pipe. A pumpset (linked pump and motor) is needed to draw water from any tubewell. The bore and the pumpset are the key parts of the tubewell.

4.3.1 Installing Private Tubewells

There are 51 individual owned tubewells in the study area. Chakwa Minor has seven tubewells, Madan Chapra Minor has 20 tubewells, and Shampur Minor has 24 tubewells. The difference in the numbers of tubewells appears to be due to the size of the study area under each minor and not to their locations on the branch canal.

History of Tubewell Installation in the Study Area

All these tubewells have been installed since 1970, 90 percent of them after 1976 as shown in Table 4.5. The largest numbers were installed during the periods of government subsidy schemes between 1976 and 1980 and between 1986 and 1990. Tubewells were installed even though canal operations started between 1975 and 1980 and the highest discharge in the VBC—970 cusecs—was recorded in 1978.

Table 4.5. Installation history of private tubewells in the study area.

Period	Chakwa	Madan Chapra	Shampur	Total
1970-75	1	-	4	5
1976-80	1	8	4	13
1981-85	1	1	4	6
1986-90	3	10	9	22
1991-92	1	1	3	5
Total	7	20	24	51

Reasons for Installing Tubewells

Farmers have varied reasons for installing tubewells. All of the following reasons were given by the tubewell owners in the sample area.

* Non-availability of canal water when needed for crops.

* Upland fields are deprived of canal water.

* Neighboring tubewell owner is unfriendly or does not sell water when required.

* Inefficiency of nearby water seller's tubewell.

* Farmers located between tubewell and buyer's field do not permit conveyance of water through their fields.

* Buyer's field is higher than nearby seller's tubewell.

Significantly, no farmer gave selling water as a reason for investing in a tubewell; all wanted better control over water supply for the farmer's own crops.

Location of Tubewells

As shown in Table 4.6, owners of tubewells gave security of the tubewell as the foremost consideration in selecting a location for the well. To prevent theft, more than 50 percent of tubewells have been installed near homes. Thefts of diesel engine parts and handpumps installed on boring pipes are common in this region. Theft is a general problem in the area: rice harvests and other crops are stolen from fields and state property like electrical wires, telephone cables and poles are easy targets for thieves.

Table 4.6. Reasons for location of tubewells.

Stated reason	Chakwa	Madan Chapra	Shampur	Total
Security	4	11	11	26
Provide gravity flow to most of the owned fields and potential buyers	2	6	13	21
Provide gravity flow to most potential buyers	1	3	-	4

Aside from security, location is determined by the position with regard to the fields to be irrigated. Elevated land, preferably on the edge of a field surrounded by the owner's own fields, is the preferred tubewell location. This location not only facilitates gravity flow to the fields, but also facilitates sale of water to potential buyers. Figures 4.1, 4.2, and 4.3. provide data on the location of tubewells, depths of tubewells, and depths of groundwater tables in the three minors in the study area.

Figure 4.1. Tubewells in Chakwa Minor.

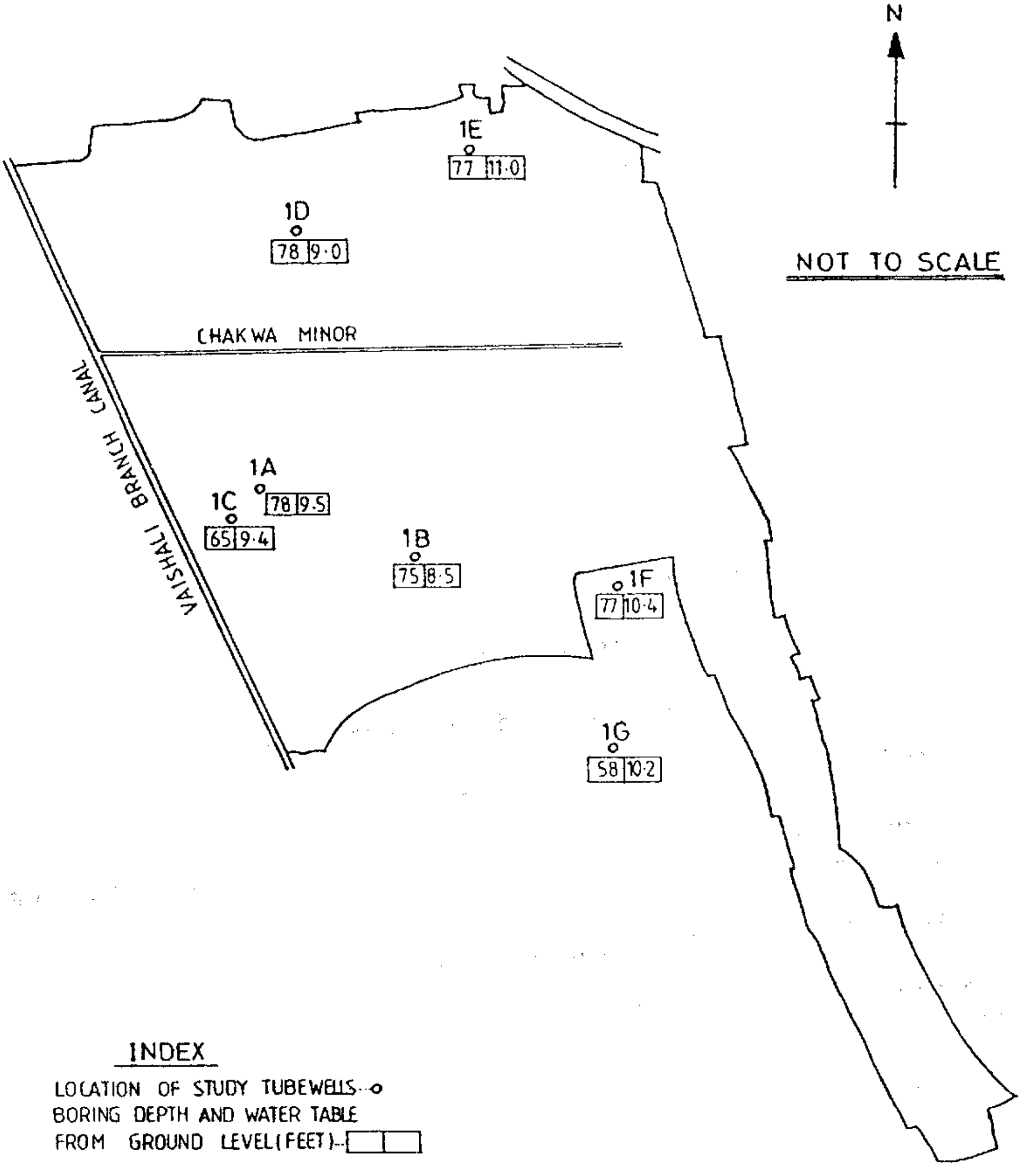


Figure 4.2. Tubewells in Madan Chapra Minor.

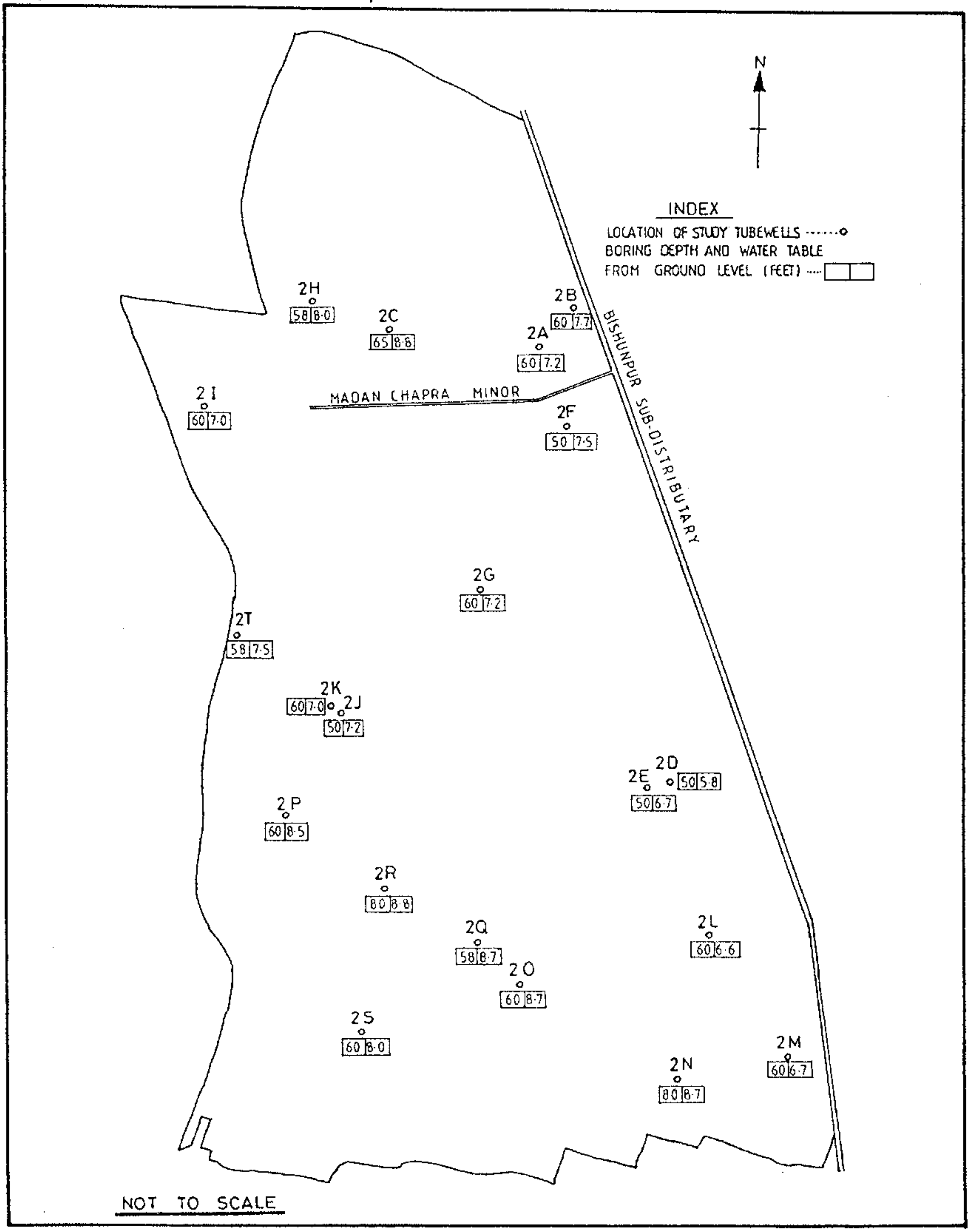
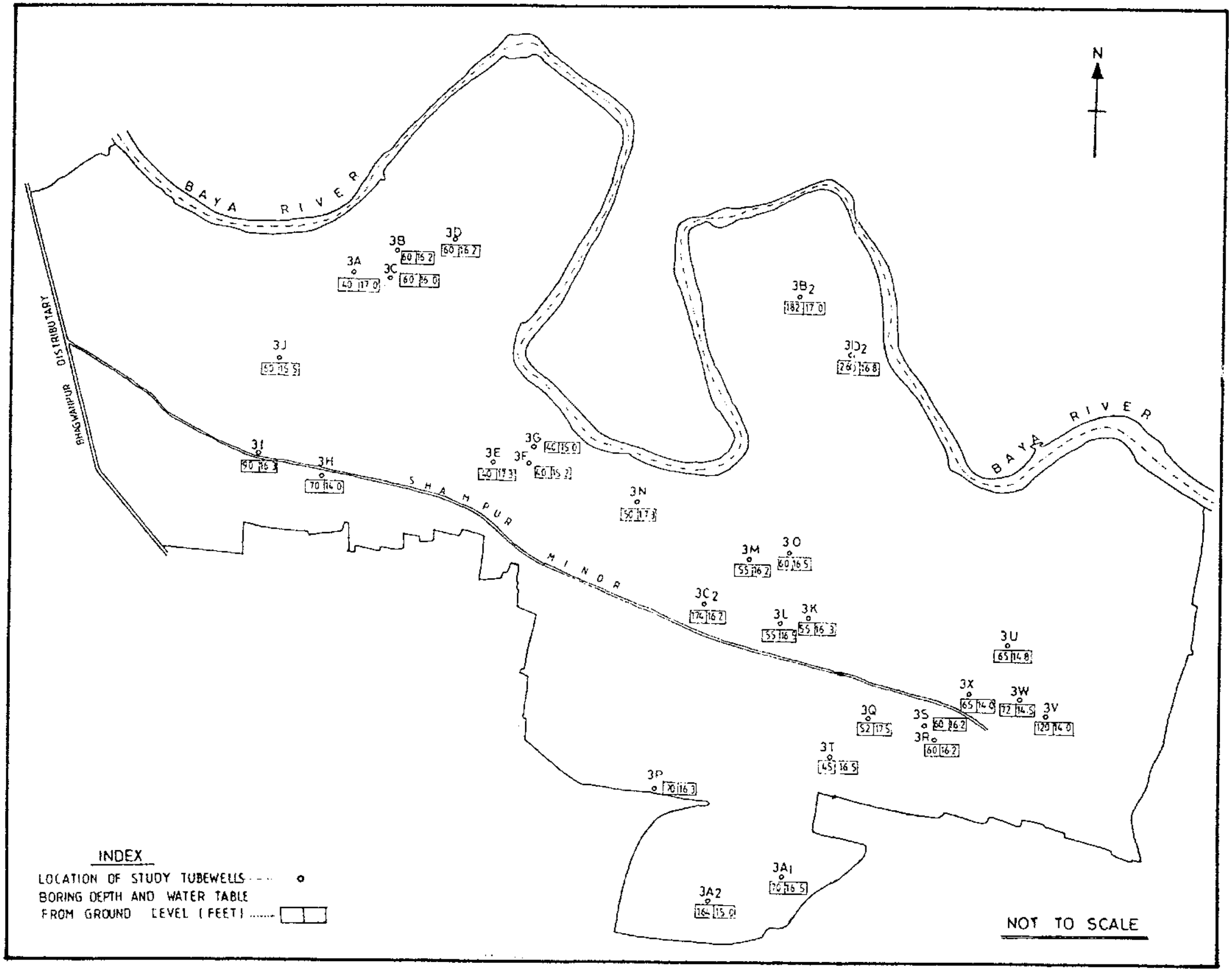


Figure 4.3. Tubewells in Shampur Minor.



Types of Tubewells

Two kinds of tubewells are found in the study area: filter wells and cavity wells.

Pipes for a filter well include sections of blind pipe and sections of perforated or filter pipe, both made from mild steel. The filter pipe is installed in the sandy water bearing strata to allow for inflow of water. In the filter pipe is installed a strainer to keep out sand which would harm the pump and make the water less valuable for irrigation. In Madan Chapra Minor, the average length of filter pipes used is 32 feet and that of blind pipes is 22 feet. These lengths are 22 feet and 30 feet, respectively, in the Shampur Minor. All private filter wells in the study area are sand packed.

Filter wells are fitted with either coir rope strainers or bamboo strainers. The coir rope strainers are a low cost screen for shallow tubewells. The screen is formed by winding a coir rope of three-to-five mm diameter around a circular array of mild steel rods. The frame is strengthened at intervals with iron rings. The surface of the coir acts as a sieve which allows water to pass while filtering out sand. The bamboo strainer is essentially a coir rope strainer whose support frame is made of bamboo strips instead of steel rods. Bamboo strips are laid out lengthwise and fixed to mild-steel rings of 10 to 12 cm diameter placed at 30 cm intervals. Coir rope is then wound around the cylindrical frame. The bamboo strainer was originally developed in Bihar and became popular as a low-cost filter for shallow tubewells throughout the Gangetic plains of Bihar and West Bengal (Michael and Khepar 1989).

A cavity well is made by putting blind pipe down to the top of the water bearing stratum. Then a rod or other instrument is used to stir the area just below the pipe after which the resulting mixture of sand, mud, and water is pumped out. After several repetitions of this procedure, a hemispherical cavity is created just below the end of the pipe, the size of which depends upon how much time and effort has been used in the process of creating the cavity. In theory, all of the fine sand near the cavity has also been removed and the remaining coarser particles serve as a strainer to keep out fine particles from further away.

In the study area, 36 of the 51 wells in the study area are cavity wells even though filter wells are better suited to the aquifers of coarse and fine sand found in the Madan Chapra and the Shampur minors. The average depths of cavity and filter wells are 68 feet and 54 feet, respectively. Details are given in Table 4.7.

Drilling a Tubewell

Borings are undertaken by local drillers called *mistries*. When a farmer hires a mistry, the mistry normally decides the method of installation based on his experience in the village or nearby areas. Also, he usually manages with boring instruments available to him. Normally, he uses a sludger, a hand auger and a wrench. If he does not have these instruments or if he gets more than one job, then he borrows what he needs from other mistries by paying a nominal fee of Rs 3 to Rs 5 per day per instrument. Occasionally, he can borrow instruments from a friend.

The mistry's chosen method of boring and his choice of instruments is strongly influenced by the soil strata of the location selected. These strata are closely observed during the boring process. Most tubewell owners can vividly recall the soil strata discovered during installation and are well able to describe the different kinds of soil and relevant depths.

Table 4.7. Private tubewell characteristics in the study area.

Particulars	Chakwa	Madan Chapra	Shampur
Type of well			
- Cavity	7	11	18
- Filter	-	9	6
Average depth (ft)			
- Cavity well	73	63	63
- Filter well	-	56	52
Average pipe length (ft)			
- Filter pipe	-	32	22
- Blind pipe	-	22	30
Packing for filter wells			
- Sand pack	-	9	6
- Gravel pack	-	-	-
Pipe diameter			
- 4 inch	7	18	24
- 3 inch	-	2	-

Boring is done by means of an earth auger turned by hand. Hand augers are used to penetrate soils that will retain the open hole up to 10 meters depth, including clay, silt and some kinds of sand. Boring is commenced by forcing the blades of the spiral or worm auger into the soil by rotating the augur. When the space between the blades is filled with soil, the auger is lifted out and emptied. This operation is repeated until the hole is bored to the required depth. For deeper wells, a tripod with a pulley block at the top is provided to insert larger auger rods into the hole and lift them out again without difficulty. Once the well hole has been bored, well screens are installed in the water bearing formation.

4.3.2 Pumpsets

In the study area, 40 of the 51 individually owned tubewells are fitted with pumpsets. These have the following features:

* All 40 pumpsets are consist of centrifugal pumps fitted with single-cylinder five-horsepower (hp) diesel engines. Since electrical power is only supplied for between one and two hours a day, no electrical pumpsets have been installed.

* Most pumpsets have been installed on small wooden carts which can be towed away by bullocks to prevent theft. A few have been installed on wooden beams so that they can be manually lifted onto bullock carts.

* The diesel engines have rated speeds of 1,500 rpm. It was not possible to obtain an rpm measuring meter to observe functional speeds.

* The display plates on the diesel engines provide the following information:

  - Engine efficiency is 64 percent.
  - Head range is 16.4 to 26.25 feet.
  - Fuel consumption is 247 grams per hour (translating to a fuel consumption of 1.008 liters per hour).

* Various makes of pumpsets are in use. The most popular is the Bharat; 19 of the 40 pumpsets are Bharat. The remaining 21 pumpsets are of 11 different makes, including Bharatshakti, India and Usha, Kirloskar, Atul Shakti, Harvest, Peter, Wilson, Sathya, Super Bharat and GEF 500. Dealers said that only one out of these 12 makes is manufactured in Bihar.

* The height of the pumpset base is normally determined by the height of a pipe T-section installed at the top of the tubewell pipe. Field measurements indicate that the average installation height of a pumpset is 15 inches in Chakwa Minor, 12 inches in Madan Chapra Minor and 8.5 inches in Shampur Minor. Although this seems to indicate a decline in height from head to tail along the VBC, the reasons for this relationship, if any, between location and height of installation could not be determined.

Making the pumpsets portable is an important feature since it makes it possible to use a pumpset on more than one bore or for purposes unrelated to the tubewell. One tubewell and pumpset owner, not in the sample area, explained that he used his pumpset not only for irrigation but also for fishing in the shallow depression near his village (by pumping water out of shallow separated sections they can strand fish to be picked up by hand).

4.3.3 Tubewell Performance

During the first round of field visits, it was observed that tubewell discharges varied. Therefore, it was decided to test the functional efficiency of the pumpsets.

The 46 functional diesel pumpsets in the study area were surveyed. The slant of the pumpsets was measured to determine whether the pumpset was horizontal or slanted towards the engine or towards the pump. As shown in Table 4.8, 32 of the 46 pumpsets were placed in an improper position.

Table 4.8. Positions of diesel pumpsets.

Minor	Level	Slanted toward engine	Slanted toward pump
Chakwa	2	3	1
Madan Chapra	6	5	8
Shampur	6	7	8
Total	14	15	17

Seventeen of the pumpset owners felt that by tilting the pumpset one to two inches towards the pump it would work better and draw water more quickly. On the other hand, 15 pumpset owners felt that by tilting the pumpset toward the engine, water would reach the outlet more quickly.

Tilting the pumpset seems to seriously affect maintenance costs; this issue is taken up in Section 4.3.6.

It was possible to test the functioning of 26 of the pumpsets.[2] Each of the 26 owners operated the pumpset on request. For each, the following were measured:

* The groundwater table.
* The rate of diesel consumption.
* The discharge of the pump.
* The quantity of sand in the water.

To measure the groundwater table, an ordinary thread with a small stone tied at one end was used. The thread was allowed to drop slowly in the tubewell till it reached water. Diesel consumption was measured by taking measurements in the diesel tank an hour after and an hour before operation of the engine and discharge measurements were made by measuring the time taken to fill a 165 liter drum. To measure the quantity of sand in the water, sand particles were allowed to settle for 10 minutes in a water drum, then collected and measured. Water was first allowed to flow into field channels for 20 to 30 minutes before being collected in the drum.

Though the methods used were crude, they nevertheless yielded interesting results and the owners of tubewells were happy to learn the actual discharge of their tubewells and just how efficient their machines were, particularly since the testing was free of charge. The results are shown in Table 4.9 and are summarized as follows:

Table 4.9. Performance of diesel pumpsets in the study area.

	Chakwa	Madan Chapra	Shampur	Study Area
No. of pumps tested	4	10	12	26
Discharge (liters/s)				
- average	11	10	8	9.2
- range	9-12	7-12	2-10	2-12
Diesel consumption (liters/hr)				
- average	0.95	1.01	1.08	1.03
- range	0.80 -1.10	0.90 -1.13	0.90 -1.60	0.80 -1.60

[2]The testing of the tubewells reported here and later in this chapter was done largely with the help and guidance of Dr. David R. Purkey, a consultant hired to help specifically with this. See Purkey 1992.

* Fuel consumption ranged between 0.800 liters per hour to 1.600 liters per hour. The average fuel cost of pumping water varies between Rs 12.94 per hour in Chakwa Minor and Rs 13.66 per hour in Shampur Minor.

* Water discharge ranged from as low as two liters per second to 12 liters per second.

* In some of the tubewells, there was 70 grams of sand per 100 liters of water. The average quantity of sand per 100 liters of water was 57 grams in Chakwa Minor, 20 grams in Madan Chapra Minor and 42 grams in Shampur Minor.

4.3.4 Non-Functioning Wells

As indicated in Table 4.10, six of the 51 tubewells in the study area—two in Chakwa Minor, one in Madan Chapra Minor, and three in Shampur Minor—are not functioning. The reasons are as given below.

Table 4.10. Status of tubewells.

Minor	Tubewells	Functional wells	Diesel pumpsets	Functional pumpsets
Chakwa	7	5	5	5
Madan Chapra	20	19	16	15
Shampur	24	21	19	18
Total	51	45	40	38

Chakwa Minor

* The owner of field 262 installed a 78 foot cavity tubewell in 1991. Since then he has been unable to either bale out sand from the cavity well or to hire a diesel engine. The owner belongs to the scheduled castes and has 0.90 acre of land.

* The owner of field 190 has a 65 foot cavity well installed in 1971. In addition to increasing repair and operation costs, he was robbed twice and forced to sell his pumpset in 1986. Domestic problems have made it impossible to mobilize sufficient funds to buy another pump. In 1990, he hired a pumpset to irrigate two of his fields. In 1991 and again in 1992 he could not irrigate any of his fields.

Madan Chapra Minor

* The owner of field 220 has a 58 foot bamboo filter well installed in 1978 and used until 1988. In December 1988, the bamboo filter became blocked with sand, preventing discharge of water from the well. The secondhand diesel pumpset which was used in this well is now being used for another well located in a nearby village. Since his two sons have started working in a nearby

town he is not interested in agriculture and therefore is not keen on installing another filter well close to the defunct well.

Shampur Minor

* The owner of field 2253 has a 55 foot cavity well installed in 1972. Due to health and financial problems he has not been able to test the well or to purchase a diesel engine.

* The owner of field 1074 has a 60 foot cavity well installed in 1977. It worked satisfactorily until 1985. Since then water discharge has reduced considerably and the tubewell is not used. The mistry feels that the bottom has caved in and is blocking inflow.

* A 72 foot cavity well in field 79 installed in 1972 is jointly owned by three brothers. It functioned well until the three brothers got into a conflict in 1982 over ownership. Since then the three brothers have separated and the tubewell remains unused.

Also, as shown in Table 4.10, two of the 40 pumpsets are not working.

4.3.5 Tubewell Water Distribution Facilities

Almost all tubewell water is conveyed to the fields through temporary or permanent earthen channels. Many places along the bund of the Shampur Minor have been carved out to be used as unlined field channels to convey tubewell water. Roads have also been cut for the same reason. Those who cut roads and canal bunds do not seem to feel there is anything illegal in what they are doing. According to them, "it is purely a matter of convenience." PVC pipes or mild steel pipes and sometimes underground cement pipes are also used to convey tubewell water. For the most part, the canal system channels are not used since they are so poorly developed. Lining channels for tubewell water, installing underground pipelines, or using PVC pipes laid on the ground are rare although known to be more efficient. The main reason is that pipes or lining are considered costly.

In addition, highly fragmented landholdings[3] make it difficult for a tubewell owner to locate his well so that he can reach all of his fields without crossing someone else's land. If a channel must cross someone else's land, the landowner generally demands water at discounted rates as compensation. Also, for those well owners who sell their water, there is no assurance that today's buyer will continue to buy in the future. In these situations, most farmers prefer temporary channels rather than making a major investment lying on someone else's land.

Thirty of the 46 owners of functioning tubewells in the study area convey water to their fields through unlined field channels only; the remaining 16—including 1 in Chakwa Minor, 3 in Madan Chapra Minor, and 12 in Shampur Minor—convey water partly with PVC pipes and partly through unlined field channels. Only five tubewell owners—all in the Shampur Minor—have their own PVC pipes averaging 100 feet in

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[3]Land fragmentation is a widespread phenomenon sometimes seemingly carried to extremes. For example, one sample farmer owns 0.90 acre divided into four fields located in two different places. Another sample farmer owns 6 acres divided into 29 fields in eight different locations. This fragmentation decreases farming efficiency and increases costs.

length. Others rent pipes from nearby towns at Rs 10 per 100 feet per day. Damage to pipes is charged at replacement cost. Distances to fields are often much greater than 100 feet so many rent more pipe than this to supplement the field channels.

4.3.6 Finances of Installation and Equipping Private Tubewells

The cost of installation of a tubewell includes the costs of (a) pipe and strainer; (b) the labor of boring the well; and (c) a pumpset. Installing and equipping tubewells in the study area have been greatly influenced by the sources of finance available, including subsidies, loans, and private resources.

Subsidy Schemes for Groundwater Development

Beginning in 1980, the Government of India, as a part of a poverty alleviation program, has subsidized various types of asset creation, to use them as a means for income generation. Among other things, subsidies have been granted for tubewells and pumpsets. The subsidy schemes are administered by the Block Development Office. Each year a new target for subsidies has been fixed based on the resources made available by the government. Hence the number of tubewells and pumpsets subsidized under these schemes has varied every year. As shown in Table 4.11, eligibility for subsidies under all these programs has been based on caste or size of landholding.

Table 4.11. Subsidies for tubewells.

Item	Eligibility	Subsidy
Tubewell	- Scheduled caste/tribe (irrespective of land/holding)	100 %
	- Marginal farmers (0 to 2.5 acres)	90 %
	- Small farmers (2.5 to 5.00 acres)	70 %
Diesel pumpsets	- Scheduled caste/tribe (irrespective of land/holding)	100 %
	- Marginal farmers (0 to 2.5 acres)	33 %
	- Small farmers (2.5 to 5.00 acres)	25 %

Sources: Land Mortgage Bank, Madarna, 1992; and Block Development Office, Vaishali, 1992.

In addition to the main program, other subsidies have been granted. Diesel pumpsets were distributed by commercial banks to marginal farmers during 1976, 1984-86 and 1988-89 and to small farmers during 1981-82 and 1988-89. Beginning in 1988-90, a subsidy of Rs 3,000 per well has been provided to small and marginal farmers through the Framework Action Plan for Foodgrain Production, a special program of the Government of India (Planning Commission 1988) aimed at increasing food grain production in 169 districts in 14 states. The program covers one of the study districts (Muzaffarpur). Funds from an Integrated Rural Development Programme were used for giving subsidies for pumpsets to small and marginal farmers below the poverty line.

Under the main subsidy scheme, the Block Development Office informs farmers of the availability of the scheme through its official notice board; the information spreads through word of mouth. Those who would like to get a subsidy send written applications through their Village Council leader. The Block Development Office selects the persons to be granted the subsidies to the number of units sanctioned by the government. The farmers complained that "recommendations by suitable persons are important in this process." Each subsidy for a tubewell includes the items shown in Table 4.12. The amount of pipe and drilling costs covered has varied over the years.

Table 4.12 Items covered by subsidy for a 4-inch diameter tubewell (1992).

Item	Quantity	Cost (Rs)
- Mild steel pipe	100 ft	4,900.00
- Nipple	1	21.85
- R-valve	1	382.32
- T-set	1	81.92
- Handpump	1	205.00
- Drilling charges	100 ft	1,120.00
- Other charges	-	500.00
Total Value		7,211.09

Source: Block Development Office, Paroo Block, October 1992.

During the initial years of the scheme, farmers got the full quota of pipe length irrespective of proposed depth of well. Some farmers got up to 140 feet of pipe out of which they could sell as much as 50 percent. From 1985, allotted pipe length was reduced to 80 feet, irrespective of the length applied for. Normally, farmers apply for more than the allotment in the hope of getting at least 80 feet. According to the scheme, a Supervisor from the Block Development Office is supposed to visit the site and certify the length of pipe actually installed. However, the Supervisor usually does not visit the installation site or he visits after installation is completed. In either case, he certifies the length which the farmer quotes.

In practice, 20 of the 51 tubewell owners in the study area received surplus pipe. The surplus pipe was generally sold outside of the village after a few months or even after two years. In Madan Chapra, filter pipe, as well as blind pipe, are used for some tubewells. But filter pipes are not provided under the subsidy scheme. Thus they can sell the blind pipe that has been replaced with the filter pipe. A list of subsidized pipe allocated, installed, and sold is presented in Table 4.13.

Pumpsets are also subsidized, but, as described below, most farmers prefer to purchase secondhand pumpsets. As noted above, scheduled caste farmers get a 100 percent subsidy for pumpsets. For all other farmers, secondhand pumpsets are cheaper than the subsidized pumpsets. Under the rules of the subsidy scheme, only new pumpsets can be purchased. Table 4.14 shows pumpset subsidies received by well owners in the study area.

Bank loans have also been available to some for the purchase of new pumpsets.

Table 4.13. Details of subsidized tubewell pipes installed and sold (length in feet).

Case	Allotted length	Installed length	Sold length
Chakwa			
- Case 1	140	70	70
- Case 2	90	60	30
- Case 3	80	20	60
Madan Chapra			
- Case 1	117	57	60
- Case 2	100	60	40
- Case 3	80	60	20
- Case 4	80	50	30
- Case 5	80	50	30
- Case 6	80	50	30
- Case 7	80	30	50
- Case 8	80	20	60
- Case 9	80	60	20
- Case 10	80	60	20
- Case 11	80	50	30
- Case 12	80	60	20
- Case 13	80	50	30
- Case 14	80	60	20
- Case 15	80	50	30
- Case 16	80	60	20
- Case 17	80	30	50

Note: Farmers in Shampur Minor did not receive tubewell subsidies.

Table 4.14. Subsidies for diesel pumpsets.

Minor	No. of farmers and year	Pumpset price	Subsidy amount	Subsidy (%)
Chakwa	2 (1987)	8,000	2,640	33
Madan Chapra	2 (1984)	6,000	1,800	30
	1 (1985)	6,000	1,800	30
	1 (1986)	6,000	1,800	30

Note: All farmers qualified for subsidies as "marginal farmers." No farmers qualified from Shampur Study Area.

Costs of Tubewell Installation

Table 4.15 shows the costs of the key elements of a tubewell.

The average cost of tubewell pipes in the Chakwa Minor is higher than in the other two minors because cheaper filter wells have not been installed here. Local drillers are not familiar with filter tubewells; also, secondhand filter pipes are not readily available. Cavity tubewells are generally deeper than filter tubewells thus requiring more pipe.

In Madan Chapra and Shampur minors, farmers obtain filter pipes by purchasing them at lower than the market price from scheduled caste farmers. These latter farmers obtain the pipe for free from a government tubewell installation subsidy program for scheduled caste farmers.

Diesel pumpsets are eight-to-nine times more expensive than tubewell pipes. If a farmer owns a tubewell he can always hire a pumpset. For these reasons, while 51 farmers own tubewells, only 40 of them own pumpsets: 5 farmers in Chakwa Minor, 16 in Madan Chapra Minor, and 19 in Shampur Minor (see Table 4.10). Others rent pumpsets from nearby pump owners or from outside the village.

To keep costs down, most tubewell owners have purchased secondhand pumpsets with their own funds. The use of subsidies or bank loans requires purchase of new pumpsets. Of the 40 pumpset owners, 30 bought their pumpsets secondhand either from those who got them under the 100 percent subsidy schemes (mostly scheduled caste farmers) or from those residing outside the block. Reported distances range from 19 to 52 km. Purchase from a distance is done to avoid problems with the Block Development Office which administers not only the subsidy schemes, but also all other development activities in the block.

Table 4.15. Cost of tubewell installation (in Rupees).

Item	Chakwa	Madan Chapra	Shampur	Study Area
Boring pipes				
- average	2,504	1,685	1,524	1,904
- range	2,060-3,060	1,032-1,684	1,269-1,739	1,032-3,040
Diesel pumpset				
- average	4,183	4,913	3,937	4,344
- range	2,500-6,300	4,000-5,522	2,800-4,511	2,500-6,300
Labor				
- average	510	362	452	441
- range	400-760	358-367	432-489	358-760
Total cost				
- average	6,891	6,647	6,017	6,518
- range	5,140-8,742	5,411-7,745	4,715-6,803	4,715-8,742

Buyers of secondhand pumpsets generally prefer those which are four-to-five years old. Such pumpsets are sold for between Rs 3,496 and to Rs 3,937 each, while new ones cost between Rs 5,063 and Rs 5,504. As indicated in Table 4.16, the average difference in price between new and used pumpsets averages Rs 2,904; this is greater than the Rs 1,800 or so available as a subsidy to many of the farmers. It is worth noting that ten pumpset owners who got theirs under a subsidy scheme or with a bank loan have retained rather than sold their pumpsets.

Table 4.16. Procurement of secondhand diesel pumpsets.

	Chakwa	Madan Chapra	Shampur	Study Area
No. of purchasers of used pumpsets	4	11	15	30
Distance of purchases of used pumpsets (km)	47	52	19	35
Average purchase price of a used pumpset (Rs)	3,586	3,496	3,937	3,728
Average price of a new pumpset (Rs)	5,420	5,504	5,063	5,273
Difference in price between used and new (Rs)	2,291	3,499	3,242	2,904
Average age of used pumpsets when purchased (months)	63	54	52	54
Sources of funds:				
- Own money	1	7	12	20
- Own+borrowed from neighbors/relations	3	4	3	10

To purchase secondhand diesel engines, tubewell owners normally use their own money and if they do not have enough they obtain interest-free loans from neighbors or relatives.

Table 4.17 shows increases in tubewell costs since 1970. The costs of pipes and installation labor steadily increased over the period. The cost of diesel pumpsets, however, shows an odd decline after 1980. Prior to 1980 there were not many secondhand pumpsets available, hence most farmers had to buy new pumpsets. The average pumpset cost dropped when secondhand pumpsets became available.

Table 4.17. Changes in average installation costs (in Rupees).

	1970-75	1976-80	1981-85	1986-90	1991-92
Item:					
Pipes	771	1,185	1,248	1784	2521
Labor	272	285	443	447	590
Diesel pumpset	3,875	5,175	4,240	4200	4425
Total:					
Pipes+labor	1,205	1,171	2,160	2730	4400
Boring+pumpset	4,919	6,645	5,931	6431	7536
No. of owners:					
Boring only	2	3	1	4	1
Boring+pumpset	4	10	5	17	4

4.3.7 Tubewell Operation and Maintenance Costs

Tubewell operation and maintenance costs include four items: energy (diesel) and oil, maintenance (including parts), costs for an operator, and depreciation. Costs of conveying water to the field are not considered here, because costs are generally small except where pipe is used. Costs of conveyance also varies greatly depending upon the location of the fields to be irrigated with respect to the well.

The costs of running a diesel pumpset in the study area in 1992 are, except for operator costs and depreciation, summarized in Table 4.18. This table shows that the average operation and maintenance cost, not counting operator costs, ranges from Rs 13.22 per hour in Chakwa Minor to Rs 14.10 per hour in Shampur Minor. Using these figures together with the average discharges given in Table 4.9, the average cost of 10,000 liters of water ranges from Rs 3.34 in Chakwa Minor to Rs 4.90 in Shampur Minor.

Table 4.18 Operation and maintenance costs of private tubewells.

	Chakwa	Madan Chapra	Shampur	Study Area
Usage (hours/year):				
- average	243	267	222	244
- range	159-336	175-262	187-296	159-336
Annual cost (Rs):				
a. Diesel				
- average	1,590	2,047	1,920	1,938
- range	1,037-2,197	2,007-2,117	1,564-2,002	1,037-2,197
b. Oil				
- average	536	703	517	603
- range	333-895	653-787	444-696	333-895
c. Maintenance				
- average	1,088	841	694	807
- range	482-1,330	743-1,106	521-783	482-1,330
Total O&M cost:				
- average	3,214	3,591	3,131	3,348
- range	1,851-3,931	3,401-3,915	2,685-3,409	1,851-3,931
Average pumping cost (Rs/hr):	13.22	13.45	14.10	13.72
Average water cost (Rs/10,000 liters):	3.34	3.74	4.90	4.13

Source: Reports from the owners of the 26 tested pumpsets.

Energy

In the study area, energy for private tubewells is supplied exclusively by diesel since the electricity is not reliable and is available for an average of two hours a day only. Diesel engines, like all internal combustion engines, also consume fair amounts of lubricating oil.

The diesel and oil costs shown in Table 4.18 are far higher than in most other states in India. In other states, electrical pumpsets are generally used. In most states in India, including Bihar, electricity tariffs for pumpsets are set by the size of the motor rather than by usage. In Bihar, the electricity tariff for a pumpset is Rs 22.50/hp/month. At this rate a five horsepower motor would cost Rs 1,350 per year to run. A comparison of electricity versus diesel and oil costs for a five horsepower pumpset in Madan Chapra Minor would be as follows:

Total hours run per year = 267 hrs
Total annual diesel cost = Rs 2,750
Power cost for a diesel pumpset = Rs 10.30/hour
Total annual electricity tariff = Rs 1,350
Power cost for an electrical pumpset = Rs 5.06/hour

Given this disparity, it is not surprising that in the study area the average number of machine hours per year is three-to-five times less than in other states such as West Bengal, Andhra Pradesh and Tamilnadu (Raju 1993). Even machines that pump from open wells in hard rock areas in these states are run twice as much as private tubewells in the study area.

Maintenance

Because most diesel pumpsets have been purchased secondhand, they are expensive to maintain. Improper maintenance such as failure to clean and service the pumpset regularly, operating it in a slant position, using adulterated diesel, and improper repair, results in parts being frequently replaced. Farmers complain that original spare parts are not always available and the available spare parts are usually of poor quality.

Maintenance costs are affected by the positioning of the pumpset. As shown in Table 4.19, slanted pumpsets require more repairs. Farmers appear not to know that operation of their pumpsets in a slanted position raises maintenance costs significantly.

Table 4.19. Pumpset slant and maintenance cost.

Minor	Slant toward engine			Slant toward pump			Horizontal	
	No.	Slant (in)	Average maintenance cost (Rs)	No.	Slant (in)	Average maintenance cost (Rs)	No.	Average maintenance cost (Rs)
Chakwa	3	2-3	1,148	1	3	1,550	1	482
Madan Chapra	5	1-5	763	8	2-3	1,123	6	531
Shampur	7	1-3	721	8	2-4	943	6	386
Study Area	15	1-5	821	17	2-4	1,063	13	460

Operators and Depreciation

Though no operator was found to be employed to run diesel engines, owners claimed that they figure Rs 2 per hour for the operator and another Rs 2 per hour for boring. Water was not costed confirming that costs are calculated for water extraction only for the water itself. There is no set figure for depreciation of the pumpset since there is no accepted lifespan.

4.4 GROUP TUBEWELLS

Group tubewells, jointly owned and operated by several farmers, are being promoted as a more effective way for poor farmers to exploit groundwater. Group tubewells have been promoted by non-government organizations (NGOs) and, occasionally by government organizations. In some cases, farmers have created group tubewells on their own, particularly those who have learned of such things through observation of group tubewells promoted by an NGO. Tubewell groups may or may not have legal status. A study of group wells (Nagabrahmam and Raju 1987) in five different Indian states showed that the viability of the group depends upon its size and homogeneity.

In the Gandak Command, two kinds of group tubewells are found: VASFA tubewells and local group tubewells. VASFA tubewells are group tubewells installed and managed by the Vaishali Area Small Farmers Association (VASFA). Local group tubewells are those created by local farmers on their own initiative.

During 1972-78, 4 VASFA group tubewells were installed in the study area in Haharo Village under Shampur Minor. Haharo Village also has one local group tubewell. Neither kind of group tubewell is found elsewhere in the study area.

4.4.1 VASFA Tubewells

Vaishali Area Small Farmers Association (VASFA)[4]

VASFA is a farmer's cooperative association headquartered in the town of Vaishali and serving members in the area surrounding Vaishali.

VASFA was founded in 1972 with help from an NGO then called Peoples' Action for Development India (PADI). PADI is now known as Council for Application of People's Action in Rural Technology (CAPART). Initially, VASFA received a grant of Rs 400,000 from the Government of Norway. Of this, half has been used as a revolving fund for development works carried out by VASFA, particularly for construction of tubewells. The other half of the grant has been kept in the loaning bank (Central Bank of India) as a security against loans.

The following are the main objectives of VASFA:

1. To provide agricultural training and impart knowledge of modern agriculture to farmers, particularly small farmers.

2. To organize different kinds of activities for the betterment of economic and social conditions of small farmers.

3. To attract farmers to industries based on agricultural produce.

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[4]Most of the information about VASFA is based on its annual reports, and discussion with VASFA officers. Additional information is derived from CWRS and WALMI (1993). For more information, see Pant 1991.

4. To arrange loans for community tubewells, agricultural machinery, warehouses, and pesticide sprayers.

5. To act as a link between CAPART, the Vaishali Sangh, the Agricultural Finance Corporation and other organizations and institutions which are working for the development of agriculture.

6. To organize special regional working groups of farmers.

7. To obtain funds from persons, associations, trusts, and national and international institutions for the development of VASFA.

VASFA is managed by an executive committee consisting of a President and 3 Vice-Presidents, each representing one of the three zones where VASFA works. These officers are elected by all members for terms of one year and three years, respectively. A Treasurer representing CAPART and a General Secretary are nominated jointly by CAPART and VASFA for terms of 6 years each.

Government support for VASFA is coordinated through a joint committee of government officials and farmers. The Commissioner of the Tirhut Division serves as President of the committee. The President of VASFA serves as Vice-President while the General Secretary of VASFA acts as the Secretary of the committee. The members of this Committee are Deputy Commissioners of Vaishali and Muzaffarpur districts, senior officials of the government, and three progressive farmers of the area. These farmers may or may not be the members of VASFA.

Establishment of VASFA Tubewells

Although VASFA uses several means to improve the lives of its members through improving their agricultural production, establishment of group tubewells is basic to their strategy.

VASFA has actively promoted the establishment of group tubewells. The procedure involved first is the selection of a village having many small and marginal farmers by the General Secretary of VASFA with the help of block officials. A VASFA organizer then identifies one or more sets of farmers having small and contiguous holdings within an area of 20 to 40 acres of land. He then would work to persuade them of the benefits of a jointly owned tubewell. Once the group is convinced and agrees to follow VASFA's rules, VASFA would provide help with bank financing and technical assistance to install and equip the tubewell. However, the tubewell is owned and operated by the group rather than VASFA. Members have to repay the bank loan; the cost is divided among the group members in proportion to their landholdings within the command of the tubewell. These tubewell groups are called *Krishak Dal* and are the basic constituent groups of VASFA. There are currently 37 VASFA tubewell groups.

Once a tubewell group is established, VASFA also provides other assistance, including the use of power threshers, sprayers, and other agricultural equipment. Other needed materials and marketing facilities are also provided to group members. Also, those farmers who cannot meet their household requirements even after a good crop on account of the small size of their holdings are provided assistance to establish other income producing activities in animal husbandry, fisheries, poultry, household industry, etc.

Tubewell group sizes vary from 15 to 45 farmers. Initially it was decided that the size of the group should not exceed 20 members, but local factors and demands led to abandonment of this rule. Generally farmers having land over 5 acres are not included. Every attempt is made to see that the holdings of group members are contiguous so that they can be efficiently commanded by the tubewell. Group members are also made aware of the responsibilities of entering into an agreement for obtaining a bank loan for the installation of tubewells and for other purposes.

The process of installing and equipping a VASFA tubewell is as follows:

* Members pay Rs 5 each as an admission fee and Rs 3 as an annual membership fee to VASFA.

* For the tubewell site, one member has to donate 0.02 acres of land to VASFA.

* Each member has to submit a copy of the record of his landownership and has to sign an agreement to follow the rules of VASFA.

* The tubewell group elects a group leader.

* Once the group is established, an application for a loan is submitted to the bank. The bank provides the funds from VASFA's revolving fund.

* The funds are used for the drilling of well and installing of pipes, construction of tubewell cabin, installation of pumpset, energization, and construction of field channels.

* At this stage the members enter into a direct agreement with the bank according to which the borrowed amount is treated as a loan to individual farmers.

According to the constitution of VASFA, the repayment of the loan is to commence after three years of its sanction. Each farmer is required to repay his loan with interest over five years in bi-annual installments. Earlier it was planned that each member farmer would be required to earmark 10 percent of his irrigated area towards repayment of the loan. The crops grown on this land would be harvested and sold under the supervision of VASFA staff; the earnings would be remitted to the bank and credited against the loan. However, this was not possible due to lack of VASFA staff. Repayment has been left entirely to the members.

Management of VASFA Tubewells

Each group leader is responsible for the management of the tubewell with the help of VASFA officials. Tubewell management includes allocation of pumping time, well operation, timely maintenance and repair to the tubewell and field channels, maintenance of irrigation records, and maintenance of financial accounts.

For allocation, time is generally allotted to the members as per the proportion of their land in the tubewell command. Sometimes it is allocated by mutual agreement. Non-members can purchase pumping time. However, the priorities are: (1) members' land in the command, (2) non-members' land in the command, and (3) land outside the command.

Tubewell operation is generally carried out by the group leader or by one of his family members. The operator is required to maintain records of pumping time taken by each individual user. Usually operators maintain the records on a piece of paper or in a note book rather than in proper record books. This practice results in various problems in maintenance and preservation of the records.

Maintenance of the tubewell is arranged by the group leader. Expenses incurred on maintenance and repair are shared by members as per their share in the tubewell command. For the maintenance of field channels, two systems are followed. In one, members clean and maintain the field channels up to their plots only. In the other, members work as a group to maintain the channels.

Conflicts are rare. When they occur, the prevalent and most effective mode of conflict resolution is a group meeting. VASFA officials sometimes attend these meetings. Cases were found where recalcitrant members were threatened with termination of their membership, but no terminations have been reported.

Pumping charges are fixed by the group leader with the consent of his group members. Water charges of electrical and diesel operated tubewells are different and charges to non-members are much higher than charges to members. All four VASFA tubewells in the study area have diesel pumps. The 1992 pumping charges were fixed at Rs 14 per hour for members and Rs 20 per hour for non-members. Members pay their pumping charges at the time of sale of the crop but non-members are generally required to pay immediately after taking water. This system is not rigid; sometimes non-members pay on a monthly basis. The group leader collects the pumping charges and pays the electricity bills or purchases diesel.

Income and expenditure accounts are maintained by the group leader; he is required to produce these records at group meetings. Profits from tubewell operations, if any, are distributed among the members. Similarly, members must pay their shares of the deficits.

Spread of the VASFA Group Tubewell Model

VASFA was founded in 1982, the first organization of this type in the area. CAPART works as a semi-government agency under the Ministry of Rural Development of the Government of India and the Central Bank of India.

Over a period of time group tubewells have attracted more farmers in this region. As shown in Table 4.20, CAPART has assisted six different organizations, all modelled on VASFA, to install 263 group tubewells. Not all of these group tubewells still function

Table 4.20. VASFA and similar tubewells in the Gandak Area.

Year	District	Association	Tubewells
1972-78	Vaishali	VASFA	60
1989-80	West Champaran	SHASFA	82
1981-83	Muzaffarpur	VASFA GASFA MASFARKA GASFARKA BASFARAKA	36 29 14 15 27
Total			263

Source: Consultancy-cum-Guidance Centre of CAPART, Vaishali, February 1993.

The Director of CAPART's Consultancy-cum-Guidance Centre in Vaishali has said that the "demand for group tubewells is increasing, and up to February 1993, we have sent 40 more proposals to CAPART for approval." Under the present scheme, CAPART provides a grant of 80 percent for each group tubewell and members have to contribute the remaining 20 percent. This large subsidy may be a major reason for the popularity of these tubewells.

4.4.2 The Local Group Tubewell

One out of the four VASFA group tubewells located in Haharo Village, was dominated by upper caste Rajputs. The group also had five Scheduled Caste members. In interviews these five farmers said that the Rajputs did not allow them to take part in group decisions and discriminated against them in water distribution. As a result, in 1973, all five Scheduled Caste members walked out of the VASFA group and formed their own group in 1973. Since they have contiguous landholdings, they decided to organize their own group tubewell. They purchased their tubewell and diesel pumpset with the help of a bank loan taken on joint responsibility and fully repaid the loan within 3 years.

Management

A senior member of the group looks after overall operation and maintenance. Expenditure incurred on repairs and maintenance is equally shared by all five members. Water is usually pumped on a first-come first-served basis. However, during a crisis they establish a pumping schedule by consensus. During the last 20 years, members say they have not had problems in water distribution.

Each member has to arrange diesel on his own for the required duration of pump operation. If any diesel is left in the tank at the end of pumping, the member can take it back. More often he sells it to the next user at the market rate.

4.4.3 Installation of Group Tubewells

Both types of groups (VASFA and local) have selected elevated points for tubewell location to facilitate gravity flow to the fields. Drilling methods were the same hand methods used for private tubewells except that VASFA provided a hydraulic drill for part of the drilling of the VASFA wells. The local group and two VASFA group tubewells have installed 4 inch diameter wells while the other two VASFA groups have installed 6 inch diameter wells. The local group has installed a cavity well. All four VASFA groups have installed filter wells. Unlike private filter tubewells, three of the VASFA groups have provided more expensive but superior gravel packing of the pipe to facilitate sustained discharge levels. All five groups installed 5 horsepower pumpsets. Gravel packing prevents clogging with sand. Table 4.21 gives details of the five group tubewells in the study area.

Table 4.21. Group tubewell installation details.

Well	Year installed	Type	Depth (ft)	Filter pipe (ft)	Pack	Pumpset tilt* (in)
Local	1973	Cavity	70	-	Sand	2.0
VASFA 1	1971	Filter	164	62	Sand	2.5
VASFA 2	1973	Filter	174	55	Gravel	3.0
VASFA 3	1973	Filter	182	61	Gravel	2.5
VASFA 4	1973	Filter	260	61	Gravel	2.0

* All pumpsets are slanted toward the pump.

As shown in Table 4.22, the installation cost of the VASFA tubewells was more than double the installation cost of the local group tubewell because of the greater depth—164 to 260 feet as compared to 70 feet—and use of gravel packing. The local group tubewell is basically the same as a private tubewell. The average depth of a private tubewell (see Table 4.7) is about 62 feet and the other features are the same as those of the local group tubewell.

Table 4.22. Installation costs of group tubewells (in Rupees).

Well	Pumpset	Pipe	Labor	Total
Local	5,500	840	210	6,550
VASFA 1	5,800	3,280	5,395	14,475
VASFA 2	6,000	2,610	4,295	12,905
VASFA 3	6,000	3,640	7,817	17,457
VASFA 4	6,000	3,640	6,114	15,754

4.4.4 Group Tubewell Distribution Facilities

Like private tubewell owners, tubewell groups have not invested extensively in their distribution networks, even though they have an assured group of users. Two VASFA tubewell groups and the local group have unlined field channels only. Two VASFA tubewell groups have lined channels on one direction for 30 and 40 feet, respectively. No pipes are used. Members of the VASFA tubewell groups say that constructing lined field channels is a function of the VASFA organization.

In one VASFA tubewell (VASFA 4), we measured travel time from the discharge point to a nearby user's field. The distance was 278 feet; the time taken to reach the field when water is first pumped into the dry field channel was 21 minutes. This meant that the user was paying an hour's pumping charges for the first hour but getting only 39 minutes of water. The user commented that "others have fields at far more distance and it takes more than an hour to reach their fields."

4.4.5 Operation and Maintenance of Group Tubewells

Table 4.23 describes the performance of four of the five group tubewells. The performance of the VASFA tubewells is roughly comparable to the performance of the private tubewells as shown in Table 4.9. The discharge rate of the local group tubewell, however, is far below the performance of any but the worst of the private tubewells. As shown, the gravel packing also helps to keep out sand.

The VASFA tubewells are older than most of the private tubewells and are used much more (see below). That the performance of the wells is comparable to that of the newer private wells reflects superior maintenance practices. Maintenance work, even engine repair, is provided at cost by trained mechanics at the VASFA workshop in Vaishali. This service ensures good quality parts and repair. On request, VASFA pump mechanics also visit the site for checking and minor repairs.

When tested, the local group tubewell had a terribly low discharge. There seems to have been a major problem with the well itself.

Table 4.23. Group tubewell performance.

Well	Sand (g/100 l)	Discharge (l/s)	Fuel use (l/hr)
Local	40	3.25	1.00
VASFA 2	0	10	1.25
VASFA 3	16	13	1.25
VASFA 4	0	10	1.25
VASFA average		11	1.25

Note: VASFA 2 was not tested because the pumpset was under repair during our field survey.

Group tubewells provide groundwater access to more farmers—both members and non-members—than do private tubewells. This should increase the usage of the tubewells. Group tubewell usage and reported costs are shown Table 4.24. VASFA tubewells are used for considerably more time (an average of 626 hours per year) than is the local group tubewell (185 hours per year). The local group tubewell usage actually is less than the average usage of private tubewells (244 hours per year) as shown in Table 4.18.

Increased usage lowers the portion of total operation and maintenance expenditures on oil and maintenance. Increased usage, however, does not lower pumping costs very much since the largest part of the cost is fuel. Fuel costs make up 52 percent of total operation and maintenance costs for the local group tubewell, an average of 68 percent for the VASFA tubewells, and an average of 58 percent for private tubewells.

As reported in tables 4.18 and 4.24, pumping costs for VASFA tubewells average 12.90 Rs/hr; pumping costs for the local group tubewell average 13.58 Rs/hr; and pumping costs for private tubewells average 13.77 Rs/hr. Because of the poor discharge rate of the local group tubewell, water costs for local group members are almost four times higher than the water costs for VASFA members.

Table 4.24. Annual operation and maintenance costs of group tubewells.

Well	Usage (hrs/yr)	Diesel (Rs)	Oil (Rs)	Maintenance (Rs)	Total cost (Rs)	Pumping cost (Rs/hr)	Water cost (Rs/10,000 l)
Local	185	1,298	444	770	2,512	13.58	11.60
VASFA 1	520	4,548	1,243	1,230	7,021	13.50	3.75
VASFA 2	801	7,005	1,821	1,410	10,236	12.78	-
VASFA 3	730	6,388	1,661	953	9,002	12.33	2.63
VASFA 4	453	3,964	821	1,270	6,055	13.37	3.71
VASFA average	626	5,476	1,387	1,216	8,079	12.90	3.25

Note: All these figures refer to 1991-92. No water cost is given for VASFA 2 because the discharge rate was not determined.

4.5 TUBEWELLS IN EASTERN GANDAK COMMAND: CONCLUSIONS

The discussion in this chapter shows that tubewells are a viable alternative to canal water for irrigation.

* First, because the Gangetic plains are alluvial, good quality groundwater is available almost everywhere in the area at relatively shallow depths.

* Tubewells, either privately owned or owned as a group, are available to a large number of farmers. Since the early 1970s large numbers of tubewells have been installed and the materials, technical knowledge and skilled labor are widely available.

* To the average farmer, installation of a tubewell is an important investment, but one within the reach of wealthier farmers. However, there have been and continue to be many subsidy programs that put acquisition of a tubewell within reach of most of the farmers. Those who cannot get subsidies generally reduce costs by purchasing secondhand pumpsets.

* Farmers generally invest in a tubewell to irrigate their own lands. Thus those with smaller holdings generally do not invest in tubewells, unless through a group tubewell.

* All tubewells in the area are fitted with diesel pumpsets. Electricity is available for no more than 2 hours per day. Thus operation of tubewells is relatively expensive. Although the Bihar electricity tariff provide a subsidy, the farmers cannot take advantage of it. For this reason, tubewells are used less than would be expected.

* There is immense scope for improvement in care and maintenance of pumpsets. Poor operating positions and maintenance increase costs. Farmers also complain that good quality parts are not available.

* The tubewells installed by VASFA are deeper and technically better than private tubewells. VASFA, with outside help, has been able to provide strong technical support.

Overall, groundwater pumped from tubewells is a good way to get reliable irrigation water and one which is widely available to those who are willing to invest in a tubewell. However, the operating costs are sufficiently high so that farmers are reluctant to pump as much as they could.

CHAPTER 5

Sources of Irrigation: Lifting from the River

5.1 INTRODUCTION

THE AREA OF Shampur Minor Command, part of the study area, is bounded on its north and east by river Baya (see Figure 3.9). The river flows through three of the four villages of the Shampur Minor area. Although the major part of Baya's flow is now diverted to the Gandak Tirhut Main Canal, sufficient flow remains so that water can be lifted from the river for irrigation.

Until 1967, farmers lifted river water manually. They used two kinds of manual lifts: a counter poised bucket lift, and a two-man counter poise bucket lift which lifted water by having an operator walk on the beam to shift weight. Farmers recall 14-16 bucket lifts having existed in this area of which only two remain.

When the villages were electrified in 1967, a farmer in Chintamanpur village installed an electric pumpset to lift water from the river. He operated this pumpset until 1974 when, motivated by the dwindling hours of power supply, he replaced his electric pumpset with a diesel pumpset. Others followed.

Within the study area, which includes only portions of the three villages in the Shampur Minor Command bordering the Baya River, five farmers own diesel pumpsets for lifting water from the river.

In addition to the individually owned lift devices, there are three state owned and operated river lift schemes. All were installed in the 1970s. Of these, three are not functioning for lack of repairs or because of disputes over who should operate them. Only the state lift scheme in Haharo village is functioning. All of these have electric pumpsets and distribute water through buried pipes. All are officially located outside the command of Shampur Minor since the policy of the state is to install state lift or tubewell irrigation systems only where no canal irrigation system exists.

While a few farmers make use of water from the one functioning scheme, overall, these schemes are not of much importance to the local farmers, largely because the one functioning scheme can supply water for no more than the approximately two hours a day that electricity is available. Also the buried pipelines limit flexibility in distribution. Since these schemes are outside the command of Shampur Minor, they are also outside of the study area. Therefore they are not further discussed here.

The remainder of this chapter focusses on private river lift mechanisms.

5.2 RIVER LIFT PUMP ACQUISITION

All of the private lift pumps use diesel engines. All are mounted on wooden carts for mobility.

A private river lift pump includes the following components:

* Diesel pumpset.

* Suction pipe to lift water from the river.

* Distribution pipe to carry water to the fields or to a field channel.

* Wooden cart for transporting the pump.

Pumps are not permanently installed at one site. Instead they are kept at home when not in use and brought to the river bank for use, hence the necessity for the cart. The pumpsets are the same 5 horsepower pumpsets used for tubewells.

On an average, pumps lift water 17 feet from the river to the top of the river bank. However, because of the river bank slope and the height of the wooden cart on which the pump is mounted, owners have to use 25 feet of suction pipe. Pump owners also have 100 to 200 feet length of PVC pipe for water distribution.

Table 5.1 shows the costs of these components (except for the carts) for the five pumps in the sample area. As shown in this table, one pump was acquired in 1974, three in 1990 and one in 1992. The acquisition cost in 1990 was three and a half times the 1974 cost; the difference was mostly caused by inflation. The diesel pumpset installed in 1992 was less expensive than those purchased in 1990 because it was a second hand purchase. All of the other pumpsets were purchased brand new.

Installation of two river lift pumps in 1990 was facilitated by a nearby sugar mill factory in Gaurol town. The factory provided a loan of Rs 9,000 at 6.5 percent interest per annum; the then current bank interest rate was 12 percent. In return, the pump owners agreed that each would devote one-acre to sugarcane to be sold to the factory.

Table 5.1. Cost of individual lift pump components (in Rupees).

Pump	Year	Pumpset	Suction pipe	Delivery pipe	Total cost
Pump 1	1990	9,000	625	600	10,225
Pump 2	1990	9,000	625	550	10,175
Pump 3	1990	9,000	625	600	10,225
Pump 4	1992	7,300	750	625	8,675
Pump 5	1974	2,500	250	200	2,950

Note: Pumps 1, 2 and 3 are in Chintamanpur village, pumps 4 and 5 in Haharo and Shampur villages, respectively.

Private river lifting is not confined to farmers owning diesel pumpsets. Rented pumpsets are also used both for irrigating a renter's own lands and for selling pumping services.

5.3 PUMP LOCATION AND DISTRIBUTION FACILITIES

All along the river bank, there is a space 5-to-7 feet wide, in some places just 3-to-4 feet wide, between edges of the cultivated fields and beginning of the slope down to the river. This space is generally used as a pedestrian path and bullock cart road. Since there are no river bank protection measures, soil erosion and small gullies can be seen in many places.

Every individual owner has a fixed site on the river bank close to his own plots where he locates his pump for irrigation. Generally, pump owners carefully select a point in the public space away from the gullies. If the public space is not sufficient, the pump owner may have to get permission from a cultivator to station his pump inside a nearby field. As compensation the pump owner provides one or two hours of free irrigation in a crop season to the land owner. If the pump owner sells water to others, he may have to relocate the pump depending upon the location of the buyers' plots.

All pump owners use a combination of PVC pipe and unlined field channels to convey water to the fields. Because the river bank is lower than most of the fields, the pump needs to push the water through pipes to the point where it can flow by gravity through field channels. Thus all pump owners have 100-200 feet of PVC pipe. If necessary, pump owners or water buyers can also rent pipe Rs 10 per 100 feet per day. Pipes for rent are available in nearby towns. Sometimes users rent from other pump owners of the same village. Two of the five sample pump owners regularly rent pipe; each usually rents 100 feet for use in distribution.

In addition, other farmers are generally willing to let a pipe pass through their fields temporarily. This makes it possible to change the location of the pump and the fields irrigated. However, even 200 feet is generally not enough to reach all of the user's fields, hence field channels are also needed.

5.4 PUMP OPERATION AND MAINTENANCE

We evaluated the performance of three of the five private river lift pumps. The results are shown in Table 5.2.

The discharge figures shown in Table 5.2 are significantly higher than the measured discharge figures for private tubewells. The river lift pumps had an average discharge of 11.2 liters per second, whereas the private tubewells had an average discharge of 9.2 liters per second. This difference may be partly due to the newness of the pumpsets but is also due to the fact that the tubewell pumpsets which have to cope with well recharge (how fast the water can be sucked from the soil). There is no wait for recharge when lifting from the river. Moreover, structural problems in tubewell pipes, tubewell cavities, and sand in the water affect pumpset performance and lower the discharge.

The average lift pump discharge figure is not significantly greater than the average discharge of 11 liters per second for VASFA tubewells. The VASFA tubewells, however, are deeper and better constructed than are the private tubewells; also VASFA pumpsets are better maintained than are private pumpsets.

Table 5.2. Performance of private river lift irrigation pumps.

Pump	Discharge (l/s)	Diesel Use (l/hr)
Pump 3	10.5	1.10
Pump 4	12.0	0.90
Pump 5	11.0	1.25
Average	11.2	1.08

Table 5.3 shows the routine operation and maintenance costs based on owners' reports. Operation and maintenance costs are mainly dependent upon fuel costs, hence increasing the hours does not greatly affect the per-hour costs.

Pumping costs average Rs 10.89 per hour. This is significantly lower than pumping costs for both private tubewells and group tubewells (Table 4.18 and Table 4.24). The likely reason is that three of the five pumpsets are new and one of the others has been well cared for.

For the three pumps whose discharge was measured, these figures give an average water cost of Rs 2.70 per 10,000 liters. The combination of lower pumping costs and higher discharge makes this water significantly cheaper than tubewell water.

Table 5.3. Operation and maintenance costs of private river lift pumps (in Rupees).

Pump	Usage (hrs/yr)	Diesel	Oil	Maintenance	Total cost	Pumping cost (Rs/hr)	Water cost (Rs/10,000 l)
Pump 1	177	1,239	402	717	2,358	13.32	-
Pump 2	165	1,155	369	655	2,179	13.21	-
Pump 3	816	6,289	1,636	1,000	8,925	10.94	2.89
Pump 4	830	4,872	1,856	210	6,938	8.36	1.94
Pump 5	623	5,456	1,394	1,161	8,011	9.65	2.44
Average	522	3,802	1,131	749	5,682	10.89	2.70

Note: All costs refer to 1991-92 (3 crop seasons). Pumps 3, 4 and 5 are, respectively, 18 months, 12 months and 15 years old.

5.5 RIVER LIFT PUMPS IN GANDAK COMMAND: CONCLUSIONS

This chapter shows that where river water is available, private lift pumps are a good alternative to tubewells. They have similar characteristics except that they are more flexible, have higher discharges, and are cheaper to operate. However, their use is limited mainly by the need to operate from a river.

CHAPTER 6

Sources of Irrigation Water: The Water Market

6.1 WATER ENTERING THE WATER MARKET

WATER SALES HAVE taken place in the study area for a very long time. Water lifted from open wells or the rivers used to be provided in return for a portion of the crop. Today, however, open wells have been replaced by tubewells; and manual river lifting mechanisms have been replaced by diesel pumps.

Farmers in Shampur area explained the replacement of the manual river lift mechanisms with diesel pumpsets as follows:

(a) In an 8 to 10 hour day, a manual lift can irrigate 0.20 to 0.30 acres of rabi crops. On the other hand, a diesel pumpset, can irrigate the same area in just one hour.

(b) A manual lift requires a full-time laborer. The cost will be Rs 25 for his labor plus meals, totalling Rs 35 per day. Also, a family person is needed to manage the water distribution. The cost of irrigating the same area with a diesel pumpset will be much less. If the farmer purchases the water from others, it will be only Rs 20, and will be less if he owns his own pumpset. Using the diesel pumpset, a farmer can save Rs 15 and he is spared the problems of dealing with a laborer.

The same conditions apply to a comparison of lifting water from an open well, either manually or with bullocks, and pumping water from a tubewell. That is, water pumped with diesel engines has replaced traditional lifting because not only do diesel pumps require less manpower for operation, they also have higher discharges, and are easier and cheaper to operate.

In addition, canal water is being provided to a portion of the area. However, canal water is not sold; it does not enter the water market. Canal water is provided by the state to authorized lands. It is illegal to sell canal water. More importantly, canal water is too unpredictable to be sold. For the same reasons, the small amount of water available in the Shampur area from state river lift schemes also does not enter the water market.

In the local water market, water itself is neither priced nor sold; pumping services are sold. Thus buyers pay for pumping of both groundwater from tubewells—both private and group—and pumping of river water by privately owned pumps are sold. There is no essential difference between these sources in the eyes of buyers and sellers. However, the market for the river lift pumping is, naturally, limited to areas near rivers.

Since the great majority of sellers in the sample area are tubewell owners, most of the following discussion focusses specifically on them. However, all of the basic principles refer also to river lift pump owners.

6.2 SELLERS AND BUYERS

For all well and pump owners the primary motive for installing a tubewell or acquiring a pump is to obtain a sure supply of irrigation water for their own crops. However, all owners consider possible sales to others when considering investing in a tubewell; all owners consider themselves potential suppliers of irrigation water to others. Owners expect earnings from pumping to meet at least part of their operation and maintenance costs; they hope to irrigate their own lands free of cost.

Well owners always consider potential buyers when locating their tubewells. Locations near the edge of fields are preferred. Also, they consider which people might be potential buyers, including relatives and caste mates.

Any farmer who does not own his own functioning tubewell is a potential buyer of water. Even those with access to canal water may need to buy water at times because canal supplies are erratic. Most buyers have small or marginal landholdings. Many buyers are relatives of the seller; others are sharecroppers who do not want to invest in a well. Demand from buyers varies over space and time depending upon the crop(s) planted, the weather conditions, access to other water sources, particularly canal water, and the cost of buying water relative to the value of the crop.

Table 6.1 shows the numbers of sellers and buyers in the study area. One interesting point is that of the 37 water sellers, 5 do not have functioning pumpsets. These well owners rent pumpsets to irrigate their own fields and sell water at the same time.

Table 6.1 also shows that sellers irrigate, on the average, 1.98 acres each. Buyers irrigate, on the average, 0.48 acres. Sellers generally have larger landholdings than buyers. Tubewell owners invest in tubewells primarily to serve their own fields; only those with larger holdings find it worthwhile.

Table 6.1. Private tubewell pumping service sellers and buyers.

	Chakwa	Madan Chapra	Shampur	Study Area
No. of sellers	5	15	17	37
No. of buyers	25	79	82	186
Area (acres) irrigated				
- sellers	5.84	32.56	34.76	73.16
- buyers	14.65	47.47	37.40	89.52
Average area (acres)				
- sellers	1.17	2.17	2.04	1.98
- buyers	0.59	0.60	0.46	0.48

Table 6.2 gives some information on buyers and sellers for all four types of sources in the study area. This table shows that the tubewell group members have, on the average, considerably smaller holdings than do the private tubewell owners. The shared investment costs of group tubewells make it reasonable for these farmers to invest in a tubewell.

Table 6.2. Sourcewise buyers and sellers.

	Private	Local group	VASFA group	River lift
No. of users - sellers/members - buyers	 37 186	 5 -	 60 36	 5 75
No. of users - pump owners/members - buyers	 1 5	 5 -	 15 9	 1 15
Area (acres) irrigated - per seller/member - per buyer	 1.98 0.48	 0.40 -	 0.69 0.50	

Generally, a buyer buys pumping services from one seller only. Buying from one seller allows the development of longer term relationships and also minimizes costs and difficulties of changing water conveyance facilities—most unlined field channels—whenever the buyer buys from a different seller. To minimize conveyance costs and conveyance losses, most, but not all, buyers buy from the nearest seller.

6.3 THE PUMPING PRICE

Sellers in the study area, including managers of group tubewells and owners of river lift pumps, have formed informal cartels to set prices. The pumping price is fixed at a uniform rate over the local area through informal meetings and discussions. Although pumping prices have varied among the three minors in the past, in 1992 the pumping price was Rs 20 per hour for all three minors.

As shown in Chapters 4 and 5 (see also Table 6.3 below), pumping costs in 1992, excluding capital and operator's labor costs varied between 10 and 14 Rupees per hour. The difference between pumping price and pumping cost is viewed as a return to investment and to the labor of operation. In fact, well owners explicitly state that Rs 2 per hour of the difference between price and cost covers the cost of the operator, although no owner hires operators.

Informal meetings among tubewell owners to discuss the pumping price are held as needed, generally when there is an increase in diesel, oil or spare parts prices. Meetings are usually held in a mutually convenient place, sometimes under a tree. No records or minutes are kept. Since there is no compulsion to attend, not all tubewell owners come to these meetings. Communication among owners is by word of mouth.

Table 6.3 shows the increases in diesel, oil, and pumping prices over the last 19 years. This table shows clearly that owners have increased pumping prices in response to diesel price increases. However, the relationship between diesel price and pumping price is not rigid. It is clear that diesel prices have increased faster than pumping prices over this period. The comparatively higher pumping prices for groundwater in Shampur Minor were attributed by the well owners to the higher diesel price (Rs 0.50 to Rs 1) charged by the local retailer.

Table 6.3 also indicates a sharp rise in oil prices, particularly after 1985. Oil prices increased by Rs 10 between 1984 and 1985, and by another Rs 8 in 1991. In 1992, the prices increased thrice to Rs 51 by year end. Tubewell owners say these jumps in oil prices was a major cause for the 1992 increase of 2 Rupees in pumping prices.

In March 1993, diesel was being sold at Rs 7.50 by local retailers in the villages even though diesel was being sold at Rs 6.52 at the pump station. This was sufficient reason for well owners to increase the pumping price to Rs 22.50 or Rs 23. This increase was decided by the cartel and was introduced during the hot weather season of 1993.

Table 6.3. Changes in diesel, oil, and pumping prices.

Year	Diesel price (Rs/l)	Oil price (Rs/l)	Water price (Rs/hr)		
			Chakwa	Madan Chapra	Shampur
1975	1.68	8	10	-	-
1980	2.42	10-12	12	8	11
1982	3.41	15-16	13	10	12
1983	3.72	16	13	10	15
1984	3.71	17	13	10	15
1985	4.33	27	15	12	16
1989	5.36	28	18	15	18
1991	5.38	35	18	15	18
1992	6.52	41-42-51	20	20	20

Notes: Diesel and oil rates were provided by diesel pump stations. Water rates are based on recall by farmers in the respective minors.

The idea of reducing prices to increase sales volume was discussed individually with a few tubewell owners. Each expressed inability to do so:

"How can I alone do this, even though I personally see a positive point in this suggestion?"

"I am not sure others will agree to this proposition. Maybe in the next meeting (of tubewell owners) we have to discuss this. But, the elders may not agree"

"If you [the owner] alone decrease the water selling prices to attract more buyers, then what will happen?"

"First of all I can't do this. Because, this will create enmity with other tubewell owners. In turn, I may not get diesel or engine or pipes or any spare parts in an emergency. Being the tubewell owner, I have to maintain smooth relationships with other owners, of course, for mutual benefit. Just for the few hundred Rupees that I may earn by decreasing pumping prices, I don't want to develop a bad relationship with other owners."

Most tubewell owners are pursuing a high-margin low-volume strategy. They do not see sale of services as the main reason for having invested in their tubewells; to them, the primary benefit of the tubewell is irrigation of one's own fields.

The attitude of some of the river lift pump owners is in marked contrast to this. When discussing maintenance, one of the river lift pump owners said:

> "I have invested money on this (pump) on my own initiative. So I take care of it as if it were a milking cow. Regular cleaning and proper handling are essential. My pump gives a good discharge (11 l/sec) and I sell water whenever buyers want—early morning or late evening being cool hours. I do not dictate my terms for sale timings. So, buyers definitely opt for my pump and I earn good money by selling water."

This owner, at least, is interested in selling pumping services as a way to earn an income.

6.4 LEVEL OF SERVICE

Table 6.4 compares key indicators of pumping performance for the different types of sources. This table shows clearly that the different sources have different levels of discharge performance; river lift pumps are clearly the best, followed closely by the VASFA tubewells. The local group tubewell is the worst. Since the buyer is supposed to pay the same rate for all of these sources, he clearly gets better value for his money from river lift pumps and VASFA tubewells than he gets from either private tubewells or the local group tubewell.

Comparison of pumping costs reveals that river lift pumps are, from the point of view of a seller, a somewhat better investment than tubewells. River lift pump owners, on the average, earn Rs 2 per hour more than do tubewell owners from their sales. However, this is in part due to the newness of the river lift pumpsets, since their lower maintenance costs keep down the pumping costs. By purchasing new pumpsets, three of the five river lift pump owners have incurred greater investment than have the great majority of the tubewell owners.

Table 6.4. Sourcewise comparison of average pumping performance.

Source	Discharge (l/sec)	Pumping cost (Rs/hr)	To pump 10,000 liters	
			Minutes	Rupees
Private tubewell	9.2	13.72	18	4.13
VASFA group	11	12.90	15	3.25
Local group	3.25	13.58	51	11.60
River lift	11.2	10.89	15	2.70

Table 6.5. Comparison of pumping service sales.

	Private	Local group	VASFA group	River lift
Average usage (hrs/year) per seller pump	162	185	610	522
No. of users - pump sellers/members - buyers	 1 5	 5 -	 15 9	 1 15
Average usage (hrs/year) - per seller/member - per buyer	 90 14	 37 -	 30 19	
Average area (acres) irrigated - per seller/member - per buyer	 1.98 0.48	 0.40 -	 0.69 0.50	
Pump usage percentage - sellers/members - buyers	 56 44	 100 -	 72 28	

The performance differences shown in Table 6.4 largely explain the differences in usage shown in Table 6.5. Both river lift pumps and VASFA tubewells average far more hours of usage per year than do the other two categories. Buyers prefer them to other sources. River lift pumps serve an average of 15 buyers apiece, VASFA tubewells serve an average of 9 buyers apiece, but private tubewells serve an average of only 4.9 buyers apiece. As might be expected only members of the local group used their tubewell.

Table 6.5 also shows that owners, including members of group tubewells, use the pumps for a larger number of hours than do buyers. More than three-fourths of VASFA tubewell pumping hours are used for members while only 55 percent of private tubewell time is used by owners. This actually understates the owners' use for their own fields because it covers only the 37 tubewell owners who sell pumping services; nine others use their tubewells only for their own fields.

In addition to pumping the water, water has to be conveyed from the seller's pump to the buyer's fields. In the study area, the buyer is responsible for water conveyance. Water conveyance is generally done through unlined field channels or PVC pipes. If the seller has a PVC pipe, he usually lends it to the buyer. PVC pipes can also be rented from nearby towns at Rs 10 per 100 feet per day. However, it is cheaper to construct earthen field channels.

The idea of investing in water conveyance facilities to attract or keep buyers was discussed with tubewell owners. Owners made it clear that they prefer not to invest in conveyance facilities, partly because of the difficulties in getting rights of way across others' fields that were mentioned in Chapter 4. Thus none of the owners in the sample area have constructed lined field channels or underground pipelines and only five tubewell owners and five river lift pump owners have purchased PVC pipes. Owners agreed that investing in water conveyance infrastructure would possibly attract more buyers. However, they pointed out that this would only create more work for them. Not only would they have to supply more water at the times demanded, they would also be put to the task of collecting money from more farmers, a task they claimed was not an easy one at the best of times.

6.5 TRANSACTING SALES

There are two standard ways of handling the sale of pumping services, by paying in cash at the time of the sale or by providing diesel and paying the balance in cash at a later time. In either case, the buyer is supposed to pay the full rate charged by the seller.

Collection of fees is considered a problem by sellers; sellers have difficulties in collecting fees. In many cases they are not able to collect the full fees. A seller's ability to collect fees depends greatly on the social and economic relationships between himself and the buyer. Important factors include:

* Kinship: Every farmer wants to maintain good relations with at least some family members, both those in the same household and those elsewhere; all persons are partly dependent upon family members.

* Caste: Caste remains a very important determinant of social behavior in this area. Members of the same caste view each other as distant kinsmen. Generally lower caste members are supposed to show respect for upper caste members; an attitude sometimes enforced by direct action against lower caste members.

* Economic Power: Poorer persons are often partly dependent upon help from or the goodwill of wealthier persons.

* Personal Qualities: Some sellers move aggressively to collect fees; aggressiveness seems to be rewarded with some degree of success.

There is a partial correlation between caste and wealth; most of the wealthier people are members of the upper castes while most members of the lower castes are among the poorer people. Most sharecroppers are lower caste members.

Difficulties in collecting fees arise with regard to both when payments are made and how much is paid. We will deal with how and when payments are made first.

Payment Schedules

Table 6.6 shows how the 182 out of the 186 buyers from the 37 sellers of private tubewell services paid their 1991-92 debts. This table shows that 41 percent have not yet paid their fees in full even after the end of a year.

As shown in Table 6.6, how and when payment is made are strongly affected by the caste and kinship relationship between buyer and seller:

* No family member paid cash at the time of service; and after a year a full 70 percent of family members had not completed payments.

* Only one-third of same caste buyers paid their fees at the time of service. 82 percent of those who provided diesel had not fully paid at the end of a year.

* In contrast, 87 percent of lower caste buyers paid immediately in full. Even among those who provided diesel, 60 percent had paid up fully; 50 percent had paid by the end of the crop season.

* Higher caste buyers also tended to provide diesel rather than pay immediately in cash. None of those who provided diesel had paid at the end of a year.

Table 6.6. Payment schedules for tubewell pumping services.

Payment mode	Buyer's relation to seller				Total
	Family	Same caste	Lower caste	Higher caste	
Full cash payment at time of service	-	9	65	4	78
Diesel provided at time of service	66	17	10	11	104
Cash payments					
a. immediately	-	-	-	-	-
b. after 15 days	6	-	2	-	8
c. after 1 month	4	5	1	-	10
d. end of season	29	5	4	7	44
e. after 1 year	2	1	-	-	3
f. b+c	1	1	-	-	2
g. b+d	3	1	1	1	6
h. b+e	2	1	1	-	4
i. c+d	8	2	1	-	11
j. c+e	2	1	-	-	3
k. d+e	7	1	1	-	9
Balance unpaid	46	14	4	11	75

Table 6.7 shows payment schedules for buyers from other sources. Caste and kinship play a lesser role for the tubewell groups; also it is not possible to identify the family and caste of the "owner" of tubewell groups. Also, both members and buyers from tubewell groups pay more or less on time. The local group does not sell to outsiders. Two members of one of the VASFA groups have only provided diesel.

Amounts Actually Paid

All except two of the sellers in the study area stated that their selling rate was Rs 20 per hour (1992). One of the two exceptions charged Rs 16 per hour and the other Rs 18 per hour; they had three and nine buyers, respectively. In reality, sellers generally are not able to collect dues at this rate. Actual amounts collected by sellers vary with the social and economic relationships between buyers and sellers.

Table 6.7. Sourcewise comparison of payment schedules.

	Local group	VASFA group		River lift
		Member	Non-member	
No. of buyers	7	60	36	75
Full cash payment at time of service	-	-	-	
Diesel provided at time of service	7	60	36	
Final cash payment - after 15 days - after one month - end of season - after one year	 10 7 - -	 2 46 7 3	 12 23 3 -	
Balance unpaid	-	2	-	

Table 6.8 shows the actual amounts collected during the field period in the sample area. This table very clearly shows that significant numbers of buyers pay less than the full rate. A full 46 percent of buyers from private tubewell owners and 33 percent of buyers from river lift pump owners pay less than the full rate.

The mechanism by which buyers pay less than the full rate is to provide the diesel and then pay only part of the remaining costs. Sellers always collect something. In fact, as Table 6.8 shows the minimum collection of Rs 12 per hour is close to the average operating costs.

The following are important points about Table 6.8:

* The majority of family members, both the immediate family and those in other households, pay less than the full rate. In the case of private tubewells, only 14 percent of family members pay the full rate.

* A full 61 percent of same caste members pay less than the full rate to private tubewell owners, although 100 percent pay the full rate to river lift pump owners.

* Although they may have to be aggressive to do so, sellers are able to collect the full rate from the great majority of lower caste buyers—94 percent for both private tubewells and river lift pumps. The lower caste buyers generally have small or marginal landholdings and most of them are tenants. To reduce the cost of cultivation, which they have to bear on their own, they try to minimize expenditures on water by purchasing pumping services worth Rs 60 to 200 only. The tenants say, "this is within our paying capacity, hence we do not default in payment."

Table 6.8. Effective pumping rates collected by sellers.

Actual rate (Rs/hr)	Buyer's relation to seller				Total	Percentage
	Family	Same caste	Lower caste	Higher caste		
Private tubewell						
12-14	1	-	-	1	2	1
14-16	4	4	-	3	11	6
16-18	22	9	-	3	34	19
18-19	7	13	2	4	26	14
19-20	3	4	2	2	11	5
20	6	19	63	10	98	54
Total	43	49	67	23	182	100
River lift						
16-18	7	-	-	3	10	13
18-19	7	-	1	1	9	12
19-20	5	-	1	-	6	8
20	11	7	31	1	50	67
Total	30	7	33	5	75	100

Note: VASFA tubewells are not included because the full amount is almost always collected. Being a group of different castes, "concessions in payment do not arise" as said by its members. The local group does not sell to outsiders.

* The majority of higher caste buyers—56 percent in the case of private tubewells and 80 percent in the case of river lift pumps—pay less than the full rate. If a lower caste farmer is the seller and has a good sized landholding and the buyer is a higher caste farmer with a small landholding, the seller may be able to collect the full pumping fee. One such case existed in Madan Chapra Minor.

Even the two well owners who sold pumping services at less than the market rate had trouble collecting. One seller, a farmer in Shampur Minor, sold at Rs 16 per hour to three buyers. However, one of them, a higher caste man, managed to pay only Rs 15.30 per hour over the season. The other seller, also in Shampur Minor, sold at Rs 18 per hour and had nine buyers. Six of these belonged to the seller's caste and paid Rs 15-16 per hour. However, the other three buyers belonged to a lower caste and paid the full rate.

6.6 WATER MARKETS IN GANDAK COMMAND: CONCLUSIONS

Water from tubewells and private river lift pumps enters the water market. However, it is the pumping services that are sold. Canal water does not enter the market.

Although they install tubewells to irrigate their own fields, all tubewell owners, including members of tubewell groups, consider selling pumping services to pay part of the cost of the tubewell acquisition and operation. Tubewells are sited to allow sales. River lift pump owners explicitly view sales of pumping services as an important reason for acquisition of their pumpsets. Buyers tend to be farmers with smaller holdings located close to the tubewell; they often have some kind of ongoing relationship with the seller. However, virtually all farmers can purchase pumping services if they wish to.

Standard prices are set by local tubewell owners by common agreement. Prices are explicitly linked by sellers to costs of operation. However, the actual price paid varies according to the relationship between buyer and seller. Kinship, caste, wealth, and personal qualities all affect the actual price paid.

Overall, it cannot be said that the market is well developed. Most private tubewell owners use their tubewells far more for their own fields than to provide water for buyers. Where available, buyers will buy more from the VASFA group tubewells and from river lift pumps. In both cases, these services are better buys since the buyer gets better discharge for the same per hour cost. Buyers, however, view pumped water as expensive and try to minimize purchases of pumping services.

CHAPTER 7

Irrigation in the Study Area: Farmers' Choices

7.1 SOURCES OF WATER FOR CROPS

WATER IS A key factor in crop production, one that every farmer wishes to control to assure good returns for his efforts. In the Eastern Gandak area, there are various sources of water available, including:

* Rainfall
* Canal
* Tubewell
    - private tubewell
    - group tubewell
    - state tubewell
* Dugwell
* River lift
    - private river lift
    - state river lift

There are also alternative lifting devices available for use with wells including diesel pumpsets, treadle pumps, and hand pumps.

Rainfall, canal, tubewells, and dugwells are available to most farmers in the Gandak Command. All of these, except for state tubewells and state river lift, are available to at least for some farmers in the study area. Farmers choose among these sources depending upon a variety of factors including crop needs, availability when needed, suitability for the crop, and cost. Most farmers depend on more than one of these sources.

The preceding chapters have described the key characteristics of the major methods used. This chapter explores the choices made by farmers in the study area to throw light on the interaction of factors that determine the relative dependence on these sources.

7.2 CROPS IN THE STUDY AREA

The cropping patterns in the three sample minors are very similar. The major crops and intercropped cultivars are:

Crops

1. Rice	7. Tobacco
2. Wheat	8. Onion
3. Maize	9. Pea
4. Arhar	10. Khesari
5. Mustard	11. Sweet potato
6. Toria	12. Chili

Intercropping

13. Maize+Arhar	16. Wheat+Yellow mustard
14. Tobacco+Garlic	17. Potato+Maize (winter)
15. Wheat+Gram	18. Potato+Garlic

The main cropping sequences are shown in Table 7.1. In addition, some fields are planted with perennial crops including fruit trees, timber trees, and grass.

Yields of rice and wheat, the most important crops, are low in the area. Table 7.2 shows the rice yields in the study area for kharif 1992. Factors keeping yields low, include the following:

(a) Farmers use 15 varieties of rice, 6 varieties of wheat and 5 varieties of maize. Many are local varieties; others are third and fourth generation seeds. Poorer farmers, including sharecroppers, generally use local varieties to reduce the cost. Non-availability of good quality seeds in the local markets is, as some farmers pointed out, a major reason for low yields.

Table 7.1. Major cropping sequences in the study area.

Kharif	Rabi	Summer
Rice	Wheat	Fallow
Rice	Wheat	Maize
Rice	Wheat	Green gram
Rice	Maize	Fallow
Rice	Toria	Fallow
Rice	Sweet potato	Fallow
Chili	Chili	Maize
Tobacco	Tobacco	Maize
Vegetables	Vegetables	Vegetables

Table 7.2. Rice yields in the study area during kharif 1992 (kg/ha).

Minor	Average yield	Yield range
Chakwa	1,605	741-2,470
Madan Chapra	1,774	461-3,087
Shampur	1,512	308-2,717

b) Fertilizer use is relatively low. Both chemical fertilizers and manure are used. Madan Chapra farmers use between 25-80 kg/ha of chemical fertilizers for rice; Shampur farmers use 23-92 kg/ha; Chakwa farmers use 18-67 kg/ha. Manure used varies form 3 to 16 bullock cart loads per hectare.

c) The Agriculture University located in the Gandak Command argues that poor water management is a major reason for low rice yields (RAU 1987).

d) Farmers cite other reasons for low yields, including highly fragmented holdings (see discussion of Madan Chapra Minor in Section 7.4.2), low plant populations, and drainage problems in some areas (see discussion of Chakwa Minor in Section 3.4.3).

e) In Chakwa Minor, there is an ongoing land consolidation process, one of several such programs in the state. Farmers are uncertain about getting back their own fields after the consolidation process is completed and are thus unwilling to invest in items that will increase the value of the land they are using. Thus fertilizer use is low in the area.

f) Tenants, mostly sharecroppers, make up a large part of the farmers. In November 1991, the State of Bihar issued a regulation giving ownership rights to the tillers, i.e., to tenants, after some time. Since then, land owners refuse to give land to long term tenants. Owners now change the tenants very frequently, in some cases every season. Tenants therefore are not willing to invest in improving the land, so they use little fertilizer.

There appears to be a growing interest in perennials, particularly fruit and timber trees, in the study area. Some farmers, including small and medium landholders said, "Fruit orchards and timber trees are like life insurance. We are sure of getting money when they are grown. Even half-grown trees can be sold whenever we are in need of money. This is not true of food crops. And food crops need continuous care, which needs more labor. Family members alone can manage trees and we need not bother about inputs after its initial growth." This attitude has clearly been influenced by increased labor wages, difficulties in getting good agricultural laborers, uncertainty and inadequacy of canal water, and tenancy problems.

7.3 CROP IRRIGATION REQUIREMENTS

Irrigation of Rice and Wheat

Rice and wheat are the dominant crops in the area. For that reason, irrigation for these two crops dominate considerations of irrigation sources. Table 7.3 shows the recommended irrigations for rice and wheat.

Table 7.3. Irrigation requirements of rice and wheat in Gandak Command.

Crop	Recommended no. of waterings	Recommended time of watering	Days after sowing	Total required (cm)
Rice	20-25	1-3 days after standing water disappears	-	120-150
Wheat	4	Crown root initiation Boot Milk Dough	21 65 90 110	24

Source: Soil-Water Management Centre, Rajendra Agricultural University, Pusa, Samastipur, 1987.

Farmers in the area plan on irrigating both rice and wheat four times during the respective seasons. For rice, although 20-25 irrigations are recommended, the problem is that water may not be available. Because rice is grown only during the rainy season, rains can be depended upon for some portion of the water requirement. The farmers say, "Generally these soils are alluvial. The Gandak River flows close by. This influences the groundwater table in our area. The high groundwater table and two to three weeks rainfall keeps moisture in the soil."

Following this reasoning, farmers figure that they have to provide four waterings to ensure a rice crop. The timings are: (a) transplanting; (b) flowering; (c) grain filling; and (d) before maturity.

Farmers in the study area, use the check basin method of irrigation. In this method the field is divided into smaller units so that each unit has a nearly level surface. Bunds and ridges are constructed around the area forming a basin within which the irrigation water is controlled. The supply channel is aligned on the upper side of the area and there is usually one lateral channel for every two rows of check basins. The basins are filled to the desired depth and the water is retained till it infiltrates into the soil.

Farmers defend this method for rice by saying, "This helps to build up sufficient water content, which helps for wheat growing after rice." The local Agriculture University agrees and suggests a basin size of 40 square meters for highest water use efficiency (RAU 1987). In practice, basin sizes vary far from this suggested size. During discussions farmers told us that they have not yet been convinced.

Irrigation of Other Crops

Every crop has its own proper water requirement and irrigation pattern. Although farmers are aware of the differences among crops, when considering irrigation patterns over a season, they fall into describing four irrigations of all crops other than perennial tree crops and grass. That is, the four irrigation patterns for rice and wheat serve the farmers as a conceptual model for crop irrigation.

The major exceptions are the perennial crops: fruit trees, timber trees, and grass. Grass is kept in a very few fields for forage and generally is not irrigated. Trees, however, are more valuable and sometimes are irrigated. However, many trees can tap the high water table directly making irrigation unnecessary even during the dry summer season.

7.4 IRRIGATION IN THE STUDY AREA

7.4.1 Sources of Irrigation

To understand how farmers use the different sources of irrigation water, we traced the sources of irrigation for the individual fields in the study area by questioning farmers. We asked farmers about four crop seasons: kharif 1991, rabi 1991-92, summer 1992, and kharif 1992.

We found that farmers use the following terms for sources of irrigation:

* Rain: where for a particular irrigation, a field has been entirely watered by timely rainfall.

* Canal: where a field has been irrigated entirely by canal water for a particular irrigation.

* Tubewell: where a field has been irrigated entirely by tubewell water for a particular irrigation. For this discussion no distinction is made between irrigation from the farmer's own tubewell or from someone else's tubewell.

* Dugwell: where a field has been irrigated entirely by water from a dugwell for a particular irrigation.

* Canal and rain: where for a particular irrigation, a field has been partly watered by timely rainfall and partly irrigated by canal water.

* Canal and tubewell/dugwell: where for a particular irrigation, a field has been partly irrigated by canal water, and partly with water from a tubewell or dugwell.

Less important sources include:

* Hand Pump: where a field has been irrigated entirely from a hand pump installed on a tubewell. Hand pumps are used for drinking water, are used occasionally for small fields planted with non-food crops when the need for water is particularly acute.

* Treadle pump: where a field has been irrigated entirely from a treadle pump installed on a tubewell. These pumps were developed as a low cost alternative to diesel or electric pumps. However, they require a great deal of labor and can be used to irrigate only small areas.

* Flooded fields: where a field, due to its low level, has filled with rain water which remains over an extended period. Elsewhere in the Gandak area, ponds develop seasonally in natural depression areas known as chaurs. But in the study area, flooded fields are located along the Vaishali Branch Canal in Chakwa Minor area. These flooded fields are mainly located in borrow areas from which soil was taken for the VBC bunds. Seepage water from the canal, together with rain water floods these fields to depths of 4-8 feet. Water can remain as much as 10 months, drying up only during May and June. In these fields, special varieties of rice are planted by broadcasting, no fertilizers are used, and boats are needed for harvesting.

In addition to fields irrigated by these methods, fields with unirrigated crops and fallow fields were also identified.

7.4.2 Irrigation in Kharif

Rice is by far the most important crop during kharif, in part because of the heavy rainfall in most years. Since rice is the main food crop, farmers try to ensure good yields. Farmers in the study area overwhelmingly cultivate a long age rice variety, known locally as Aghani rice. They generally sow the seedbeds in June and harvest in November, unless delayed by lack of water at the beginning of the season.

During kharif season, rice cultivators mainly use four sources of water: rain, canal, tubewell, and the combination of rain and canal. Tables 7.3, 7.4, 7.5, 7.6, 7.7, and 7.8 show how the individual fields were irrigated in the three sample minors during kharif 1991 and kharif 1992. In these tables, "unirrigated" refers to cultivated fields that contain perennial or other crops that generally do not require human intervention for water. Both of these seasons were considered low rainfall years, kharif 1992 was considered a drought season by many.

Chakwa Minor

As shown in Table 7.4, in Chakwa Minor the first irrigation depended largely upon rainfall. This first irrigation is for establishing the crop in the field and is very important. Canal irrigation at the beginning of the season is quite unreliable because farmers farther up the Gandak System use the canal water to establish their crops. Hence farmers depend upon rainfall—generally delaying sowing until the rains come—or tubewells.

For the second irrigation in kharif 1991, the pattern was similar to that of the first irrigation. For the third irrigation, however, tubewell use dropped greatly as canal use rose. Canal use rose to a peak for the fourth irrigation. This change occurred because canal water became available late in the season when farmers further up the Gandak System harvested their crops. Overall, farmers in Chakwa Minor plant and harvest 2 to 3 weeks later than farmers further up the system so that they get some canal water.

Table 7.4. Sources of irrigation for kharif 1991, Chakwa Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	83	88	102	41	24.7	24.4	36.0	15.0
Canal	3	16	47	109	0.8	3.3	10.7	31.3
Tubewell	56	48	7	1	21.4	20.7	3.0	0.9
Canal+Rain	14	4	-	7	2.3	0.8	-	3.2
Other	-	-	-	-	-	-	-	-
Unirrigated	8	8	8	6	5.0	5.0	4.5	3.8
Fallow	-	-	-	-	-	-	-	-
Total	164	164	164	164	54.2	54.2	54.2	54.2

Table 7.5 shows the pattern of irrigation sources during kharif 1992 in Chakwa Minor. The overall usage pattern is very similar to that for kharif 1991.

Table 7.5. Sources of irrigation for kharif 1992, Chakwa Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	80	72	85	39	20.8	19.2	31.1	15.8
Canal	20	21	34	103	7.3	8.1	11.2	32.1
Tubewell	48	46	10	1	18.6	17.5	3.1	0.1
Canal+Rain	5	11	26	15	0.9	1.8	4.8	2.9
Other	-	-	-	-	-	-	-	-
Unirrigated	11	14	9	6	6.6	7.6	4.0	3.3
Fallow	-	-	-	-	-	-	-	-
Total	164	164	164	164	54.2	54.2	54.2	54.2

Madan Chapra Minor

Table 7.6 shows the kharif 1991 pattern for Madan Chapra Minor. One feature immediately visible is that fields are smaller in Madan Chapra Minor than in Chakwa Minor or in Shampur Minor. Also, tubewell water was used only for the first irrigation, rather than for both the first and second irrigations as in Chakwa Minor.

Table 7.6. Sources of irrigation for kharif 1991, Madan Chapra Minor.

Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	321	50	50	-	43.1	11.0	11.1	-
Canal	51	14	1	350	8.9	1.6	0.1	46.9
Tubewell	41	-	-	-	8.7	-	-	-
Canal+Rain	2	350	363	7	0.3	48.2	49.7	1.5
Other*	2	2	-	-	0.6	0.6	-	-
Unirrigated	21	22	24	81	1.9	2.1	2.6	15.1
Fallow	-	-	-	-	-	-	-	-
Total	438	438	438	438	63.5	63.5	63.5	63.5

* This includes two treadle pumps.

Compared to Chakwa Minor, there was greater use of canal water in Madan Chapra Minor after the first irrigation. During the second and subsequent irrigations, Madan Chapra canal water users got together and tried to assure water delivery to the minor. Farmers said, "Whenever there is a problem in canal water flow, some of us, usually youths, get together and argue with upper reach villagers. We also fight sometimes, and bring water to our village. In fact, we have to monitor the water both during day and night for two days at least."

As shown in Table 7.7, the pattern in Madan Chapra during kharif 1992 was somewhat different. The main problem was that the drought meant that upstream users prevented water from reaching the Vaishali Branch Canal during much of the season so that the farmers' work to get water to their canal could not help. Hence, (a) although canal water was available early in the season, the drought meant it was not available during the middle of the season; (b) there was greater use of tubewell water throughout the season; (c) the second irrigation was largely skipped because neither canal nor rainwater were available; and (d) rain was considered sufficient for the third irrigation. Only for the fourth irrigation was canal water sufficient. In the middle of the season, Madan Chapra farmers were so desperate for canal water that they dragged the WRD Junior Engineer to the field to get him to operate the canal to bring water to them. Unfortunately it did not solve the problem.

Shampur Minor

In Shampur Minor, as shown in Table 7.8, the pattern of use during kharif 1991 was similar to the pattern in the other two minors during the same season, except: (a) Shampur Minor farmers depended much less upon canal water than did Madan Chapra farmers; and (b) a very large number of fields in Shampur Minor are planted with unirrigated crops. Shampur farmers consider both rainfall and canal water very unreliable; tubewell water is considered costly particularly for water loving rice. Hence there has been a massive shift to crops that do not depend upon irrigation. Overall, the area planted with rice is relatively small.

Table 7.7. Sources of irrigation for kharif 1992, Madan Chapra Minor.

Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	201	5	348	2	23.6	1.8	50.5	0.4
Canal	126	2	26	290	18.7	0.7	3.7	37.0
Tubewell	75	9	7	1	16.8	2.0	1.5	0.2
Canal+Rain	-	-	10	-	-	-	1.7	-
Other*	4	-	1	1	1.1	-	0.1	0.4
Unirrigated	32	422	46	144	3.3	59.0	6.0	25.5
Fallow	-	-	-	-	-	-	-	-
Total	438	438	438	438	63.5	63.5	63.5	63.5

* This includes rain and tubewell (3 fields), canal and tubewell (2 fields), and treadle pump (1 field).

Table 7.8. Sources of irrigation for kharif 1991, Shampur Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	69	31	48	3	15.4	7.1	10.4	0.4
Canal	16	9	11	38	3.3	2.3	2.7	8.7
Tubewell	1	2	-	-	0.2	0.3	-	-
Canal+Rain	3	20	14	5	0.6	4.4	2.8	1.0
Other*	-	-	1	1	-	-	0.1	0.2
Unirrigated	111	138	126	153	32.7	38.1	36.2	41.9
Fallow	-	-	-	-	-	-	-	-
Total	200	200	200	200	52.2	52.2	52.2	52.2

* This includes one case of canal plus dugwell and one case of canal plus tubewell.

As shown in Table 7.9, in Shampur Minor in kharif 1992, (a) as in kharif 1991, most of the fields were planted with crops other than rice; (b) lack of rainfall and canal water meant that, as in Madan Chapra, the second irrigation was skipped; (c) some farmers had to skip the third irrigation also while others got sufficient rainfall and (d) canal water became available only for the fourth irrigation.

Table 7.9. Sources of irrigation for kharif 1992, Shampur Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	78	9	65	2	17.7	1.8	14.4	0.3
Canal	2	2	4	69	0.3	0.3	0.7	15.6
Tubewell	10	-	-	-	2.2	-	-	-
Canal+Rain	2	-	-	-	0.5	-	-	-
Other	-	-	-	-	-	-	-	-
Unirrigated	108	189	131	129	31.5	50.1	37.1	36.3
Fallow	-	-	-	-	-	-	-	-
Total	200	200	200	200	52.2	52.2	52.2	52.2

Overall Findings

Overall, the following observations can be made about kharif irrigation in the sample areas:

(a) During kharif season more farmers depend upon rainfall than upon any other source of water, even though rice is the dominant crop.

(b) Because canal water is scarce or unavailable during the early part of the season when upstream farmers are establishing their crops, farmers in the study area often delay sowing and transplanting while waiting for heavy rains. This means that their schedule is 2-3 weeks later than that of upstream farmers.

(c) The second most important source of water during kharif is canal water, particularly during the fourth irrigation. Canal water is important for the fourth irrigation because rainfall has dropped during that period. More importantly, canal water is available late in the season because upstream users no longer need it, having begun drying and harvesting their rice crop.

During kharif 1992, late season canal water caused problems in the study area. We observed surplus water in the fields and overflowing in the canals even when most of the farmers were ready to harvest their rice. Irrigation officials defended the water as water supplied for early rabi crops.

(d) Dependence upon groundwater is low during kharif. Some farmers use tubewells for the first irrigation to establish their crops. Only the Chakwa Minor farmers were willing to use tubewells later in the season and that only for the second irrigation. During kharif 1992, despite the shortage of rainfall and canal water, few farmers used tubewell water during the latter part of the season.

Use of Groundwater during Kharif

Low use of groundwater during kharif is caused by the high cost of pumping. An acre of rice generally takes about nine hours of pumping from a tubewell for one irrigation. If pumping services are purchased, an irrigation costs about Rs 180. Each irrigation thus significantly raises the cost of production. Since a local rice variety is used together with low fertilizer use, yields are generally low. Farmers are thus very cautious about increasing the water cost. Some farmers, mostly in Chakwa Minor, are willing to pay the cost of two irrigations from tubewell water, while most others are willing to pay the cost of, at most, one irrigation from tubewells.

Farmers say: "Usually we get at least the first irrigation from rain ... In fact, our sowing operations are largely dependant upon rainfall and it may be delayed. Since the first irrigation is very important for the growth we will provide it either by rain or tubewell water. The second irrigation is required during flowering, the third irrigation during grain filling, and the fourth irrigation before maturity. Depending upon the availability of cheaper sources of water, we provide these irrigations." Farmers will also use water for tubewells for establishing rice seedbeds.

For tenants and small holders who have to buy pumping services, the cost of tubewell irrigation is quite high. Sharecroppers, in particular, because they have to give up half of the crop, watch the costs of production very carefully. During kharif 1992, some sharecroppers abandoned their rice crops, saying that the cost of more than one or two irrigations from tubewells made the total cost of production greater than the potential earnings from the crop.

Even tubewell owners provide all four irrigations by tubewell water to very few fields—just enough to provide rice for home consumption—even if rainfall and canal water fail. In all three minors, only one field during kharif 1991 and two during kharif 1992 were irrigated all four times from tubewells.

7.4.3 Irrigation in Rabi

The main crop in the rabi season is wheat. In the study area, wheat is sown after the rice harvest in November and December. Most fields remain moist even up to the middle of December. Ideally wheat is sown by the end of November. During the season, it gets four irrigations at the times recommended by the Agricultural University (see Section 7.3).

Some wheat is sown as late as mid-December, largely because of delays in rice cultivation. The irrigation schedule of late-sown wheat differs from the earlier-sown crop due to the low temperature at initial stages of crop growth, a reduced growth period and effective rainfall at critical stages. For late-sown wheat, farmers plan for two irrigations—one at crown root initiation and the other just before flowering.

For wheat cultivation, farmers mainly use three sources of water: rainfall, canal water, and tubewell water.

Chakwa Minor

The pattern of water source use in Chakwa Minor during rabi 1991/92 is shown in Table 7.10. This table shows that (a) a number of fields were left fallow (about 18%); (b) an equal number were flooded during the rainy season—these were planted with a special rice variety; (c) a similar number of fields (around 28%) depended upon rainfall and tubewells for the first two irrigations; (d) farmers did not use canal

Table 7.10. Sources of irrigation for rabi 1991/92, Chakwa Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	45	51	60	61	12.7	15.4	18.7	25.4
Canal	3	5	14	39	0.8	1.4	3.6	10.8
Tubewell	50	41	24	1	21.4	17.2	12.4	0.9
Canal+Rain	-	-	-	-	-	-	-	-
Other*	29	29	29	29	5.3	5.3	5.3	5.3
Unirrigated	8	9	8	5	3.3	4.2	3.5	1.1
Fallow	29	29	29	29	10.7	10.7	10.7	10.7
Total	164	164	164	164	54.2	54.2	54.2	54.2

* All of these fields are flooded fields.

water to any significant extent until the last two irrigations; and (e) during the last irrigation, farmers used canal water in place of tubewell water.

A trend of decreasing use of tubewells can be seen throughout the season. During the fourth irrigation, canal water was available at the right time, hence it was preferred to the more costly tubewell water.

Madan Chapra

Table 7.11 shows the pattern of use of sources in Madan Chapra during rabi 1991/92. This pattern is very different from that in Chakwa Minor. In Madan Chapra: (a) there were no fallow or flooded fields; (b) for the first three irrigations, a large and increasing number of fields (46%-58%) could be irrigated from canal water; (c) tubewell use dropped from 27 percent during the first irrigation to 4 percent of the fields by the fourth irrigation as farmers replaced costly tubewell water with canal water; and (d) few farmers actually gave a fourth irrigation.

The lack of a fourth irrigation may appear surprising. Farmers in Madan Chapra, however, believe that wheat can be grown with just three irrigations. Also, much of the area was planted with late-sown wheat which use fewer irrigations. Late sowing of wheat was common because, during kharif 1991 many farmers waited for rain to sow their rice.

In the Shampur Minor area, during the rabi season, the percentage of area unirrigated increased to 15 percent towards end of the season. This was 3 percent in the 2nd irrigation and 15 percent during the 3rd irrigation.

Table 7.11. Sources of irrigation for rabi 1991/92, Madan Chapra Minor.

Source	No. of Fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	1	1	-	-	0.4	0.1	-	-
Canal	200	249	252	9	23.9	31.6	32.5	1.4
Tubewell	119	64	33	18	21.9	14.7	7.6	3.9
Canal+Rain	-	-	-	-	-	-	-	-
Other*	2	1	1	2	0.5	0.1	0.2	0.3
Unirrigated	116	123	152	409	16.8	17.0	23.2	57.9
Fallow	-	-	-	-	-	-	-	-
Total	438	438	438	438	63.5	63.5	63.5	63.5

* This includes 2 treadle pumps (first irrigation only), and four cases of canal plus tubewell.

Shampur Minor

Table 7.12 shows the sources used for irrigation in Shampur Minor in rabi 1991/92. This table shows that (a) as during kharif, the major part of the area was sown with crops which need little irrigation, mostly fruit or timber trees; (b) canal water use was very small throughout the season; (c) tubewell use decreased over the season; (d) unirrigated fields increased over the season as some short duration crops (vegetables) were harvested; and (e) there were no fallow fields.

Overall Findings

Overall, this data indicates the following:

(a) As expected, rainfall alone is less important than during kharif. However, it provides the needed water for a fair number of fields, at least for two of the minors.

(b) Canal water was important only for one of the minors. It was the only one with reasonably abundant water supplies during rabi. This suggests that even farmers in the other two minors would make greater use of canal water, instead of depending on rain, if it were available.

(c) Groundwater is more important in rabi than in kharif. However, tubewell use decreases over the season.

Table 7.12. Sources of irrigation for rabi 1991/92, Shampur Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	19	28	1	-	3.8	5.5	0.2	-
Canal	6	1	-	5	1.1	0.2	-	0.9
Tubewell	13	5	3	-	3.3	1.3	0.6	-
Canal+Rain	-	1	-	-	-	0.3	-	-
Other*	8	4	4	4	1.5	0.9	0.9	0.9
Unirrigated	154	161	192	191	42.5	44.0	50.5	50.4
Fallow	-	-	-	-	-	-	-	-
Total	200	200	200	200	52.2	52.2	52.2	52.2

* This includes 4 plots irrigated from dugwells throughout the season and two plots irrigated from canal plus tubewell at the first irrigation.

Farmers consider the first irrigation very important. However, canal water supplies are low because farmers upstream in the system want the water for the same purpose. Hence many farmers in the sample area use tubewell water. Over the season, farmers turn to cheaper sources of water (rainfall and canal water) or do without it in order to keep their production costs low.

7.4.4 Irrigation in Summer

Summer season, also called the hot season, runs from March to June. During summer, much of the area is left fallow and there is no dominant summer crop. Some farmers plant small areas of high-value crops such as vegetables or very hardy crops such as some oilseeds; maize is also planted.

Almost no rain falls except at the very end of the season. All crops, except the perennials which tap the groundwater directly, depend upon irrigation during summer. The canals are generally closed for maintenance and because flow in the Gandak River is low during summer. Groundwater is the only source of irrigation.

Chakwa Minor

Table 7.13 shows the sources of irrigation in Chakwa Minor during summer 1992. This table shows that (a) as expected, most (75%) of the fields are left fallow; (b) 22 fields had perennial crops in them that were watered by rains at the end of the season; (c) 14 fields continued to be flooded; and (d) only five fields had irrigated crops in them. Of the five irrigated fields, four were irrigated using tubewells and one using a hand pump. In both cases, four irrigations were given. These were high-value crops that could justify the use of costly tubewells.

Table 7.13. Sources of irrigation for summer 1992, Chakwa Minor.

Source	No. of fields				Area (acres)			
	1	2	3	4	1	2	3	4
Rain	-	-	8	14	-	-	1.7	7.4
Canal	-	-	-	-	-	-	-	-
Tubewell	4	4	4	4	1.3	1.3	1.3	1.3
Canal+Rain	-	-	-	-	-	-	-	-
Other*	15	15	15	15	2.5	2.5	2.5	2.5
Unirrigated	22	22	14	8	9.9	9.9	8.2	2.5
Fallow	123	123	123	123	40.5	40.5	40.5	40.5
Total	164	164	164	164	54.2	54.2	54.2	54.2

* This includes one hand pump irrigating 0.4 acre. The remainder are flooded fields.

Madan Chapra Minor

There was no irrigation and no summer cropping in Madan Chapra Minor.

Shampur Minor

In Shampur Minor, only two fields were planted with seasonal crops. One, covering 0.1 acre, was irrigated from a tubewell and the other, covering 0.1 acre, was irrigated with a hand pump. Both contained high-value crops and both received all four irrigations.

Overall Findings

It is surprising that, given access to groundwater through the tubewells, there are so few fields planted during summer. Only Chakwa Minor had any significant number planted. Of course, the large number of fields in perennial crops in Shampur Minor keep those fields in production throughout the year.

The major limitation seems to be one of labor. An effort at reasonable production during the summer requires the use of tubewells throughout. This raises production costs. Only high-value crops can justify the cost. However, high-value crops have high labor requirements. Although there is no overall labor shortage, farmers report problems with managing hired labor and prefer not to depend upon it.

In 1993, the Water Resources Department proposed that canal irrigation for summer crops be provided from 1994. At the time, farmers expressed vehement opposition since they had begun to cultivate pulse crops in late rabi with retained soil moisture.

7.4.5 Pumping Hours in Different Seasons

The importance of tubewells and river lifts varies with the seasons. Table 7.14 shows how total pumping hours for tubewells and river lift pumps in the study area varied across the four seasons. It should be especially noted that this table totals the number of pumps, and hence comparisons should not be made up and down the columns.

Table 7.14 clearly shows that, except in Chakwa Minor and in Madan Chapra Minor during kharif 1992, groundwater and water lifted from the river are much more important during rabi than during kharif. During rabi, the pumps are run around twice as long as during kharif.

Table 7.14. Total pumping hours in different seasons.

Minor	Kharif 1991	Rabi 1991/92	Summer 1992	Kharif 1992
Chakwa	519	532	436	1,051
Madan Chapra	558	1,922	810	2,480
Shampur private tubewell	1,064	2,516	13	1,367
Shampur VASFA tubewell	781	1,722	93	837
Shampur Local Group tubewell	48	137	-	95
Shampur River lift pump	868	1,350	49	715

Note: These numbers are the totals for all pumps.

Chakwa Minor is an exception. The farmers in Chakwa Minor use their pumps for the first two irrigations in both seasons, whereas the others generally use their pumps only for the first irrigation during kharif. The pumping hours were greater in kharif 1992 than in kharif 1991 because of the perceived drought.

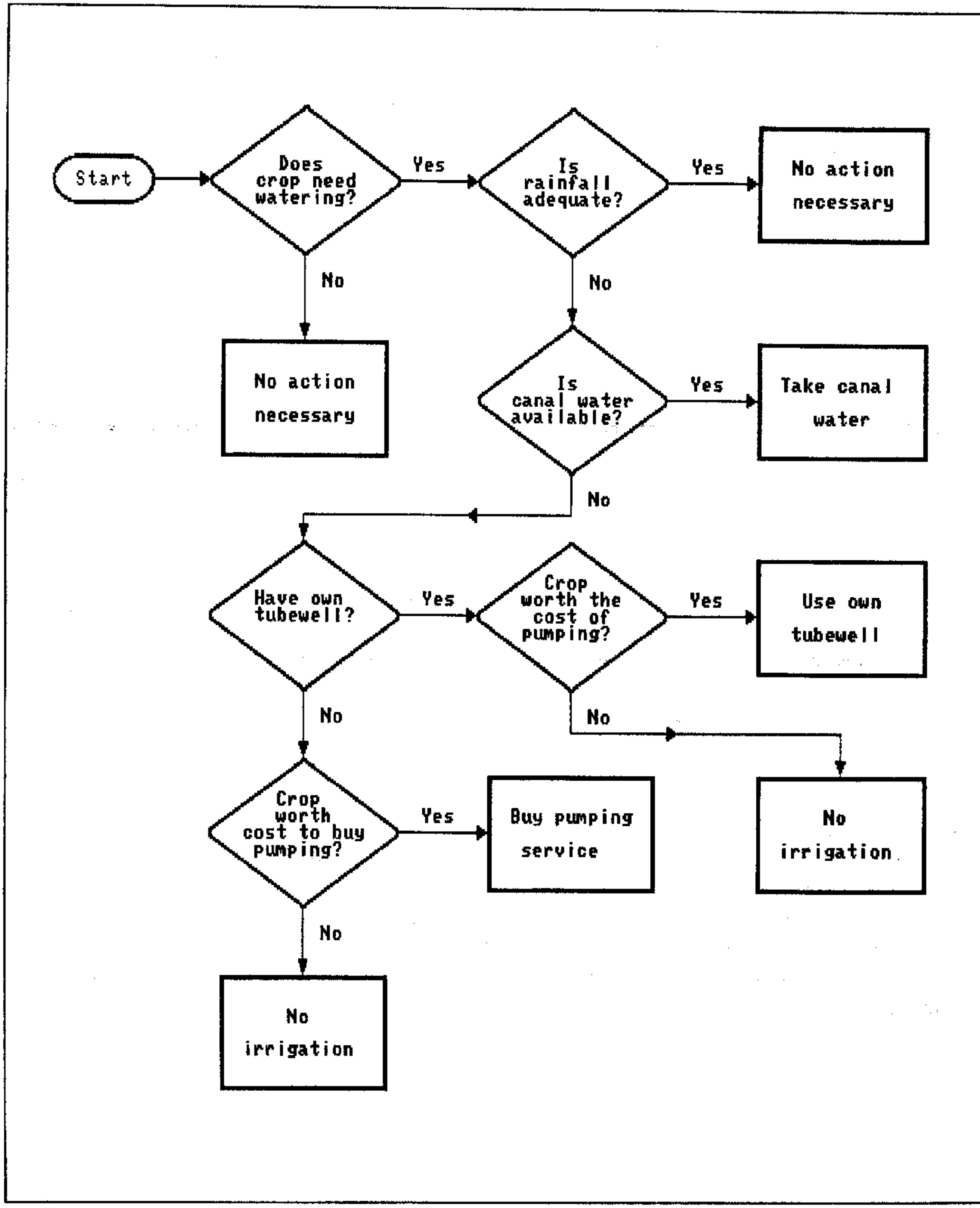
The other exception is the fact that during kharif 1992, Madan Chapra pumps were run more hours than during rabi 1991/92. As shown earlier, except for the first kharif irrigation, Madan Chapra farmers depend upon canal water. Canal water did not come in kharif 1992, so they replaced a large part of it with tubewell water.

7.5 FARMERS' DECISION PROCESSES: CONCLUSION

The various decision principles expressed in the preceding section can be summarized as follows:

(a) Of the three major sources of water for crops, farmers rank tubewell as the most reliable. Neither canal nor rainfall is reliable. Rainfall is clearly more reliable during kharif than during rabi. However, because rice is the major crop in kharif, water demands are also much higher. Overall, relying on rainfall during kharif is only a little less risky than during rabi.

Figure 7.1. Model of farmers' irrigation decisions.



(b) Of the three major sources of water for crops, farmers rank rainfall as the cheapest, canal as the next cheapest, and tubewell as the most expensive. Rainfall has virtually no cost. Canal water has a potential cash cost if the irrigation is assessed and if the government forces payment. More importantly, getting canal water can require cooperative effort—like the Madan Chapra villagers protecting the flow—and requires some investment in the form of canal construction and controlling of the flow. The costs of tubewell water include mainly the cost of running the pumpset, but also include building the distribution system and actually controlling the water flow.

(c) The cost of pumping from a tubewell is very high compared with the potential profit from a crop, given the low yields. Farmers weigh every hour that their pumpsets run. A tubewell owner may use his tubewell to irrigate his crop more times than will a farmer who has to buy pumping services because, for the buyer, the price is much higher.

Figure 7.1 models farmers' decisions based on these principles. A surprising feature of this model is the preference for rainfall as the main source of water for crops. The high cost of pumping groundwater clearly explains why farmers prefer other options. However, it might be expected that farmers would prefer canal water to rainfall. However, in the study area, canal water is no more predictable than is rainfall. Also, during kharif, rainfall can be heavy enough so that having both canal water and rainfall, if both come in full measure, can damage crops. As it is, in the Chakwa Minor area, the combination of seepage from the Vaishali Branch Canal and rainfall floods a sizable area and lowers productivity.

CHAPTER 8

Improving the Institutional Environment for Managing Irrigation

8.1 FARMERS' REACTION TO THE INSTITUTIONAL ENVIRONMENT

The low productivity levels discussed in Chapter 7 are clearly caused in part by a low level of investment in crop production, as well as by unreliable water supplies. It is a reasonable supposition that unreliable water supplies are one, but clearly not the only, reasons that farmers are not willing to invest heavily in crop production. Other factors include current market prices, land fragmentation, difficulties in getting good quality farm labor, among others. It is clear, however, that improving crop production in the area requires improvements in irrigation services.

We suggest that farmer irrigation behavior and key aspects of farm production are determined largely by the farmers' evaluations of the comparative availability, reliability and cost of the sources. These evaluations for the three common sources of water can be summarized as follows:

* Rainfall is the cheapest source and is available to everyone when it rains. While rainfall is relatively reliable during kharif, water demands are also high because the main crop is rice. During rabi, rainfall is less reliable but water demands are less. Overall, dependence upon rainfall carries a slightly greater risk during rabi than during kharif. There is no rainfall during summer.

* Canal water is somewhat costlier than rainfall, less because of the cash cost than because of the effort needed to bring it to the fields. However, canal water is highly unreliable and is totally unavailable to many farmers.

* Groundwater from tubewells is reliable and available to most farmers. However, the cost of providing tubewell water is considered very high. The cost of extensive irrigation from tubewells can bring the total cost of production to more than the market value of the crop, particularly for rice and wheat, the main crops.

These evaluations are determined by key aspects of the environment of these farmers. This suggests that improving irrigation services requires changing some of these key aspects.

Some of these aspects are natural, including the following:

* Rainfall is highly concentrated during the kharif season, and varies significantly from year to year.

* Water availability in the Gandak River varies greatly with rainfall.

* There are rich groundwater sources and a high water table over the whole area.

Social organization among the farmers clearly affects irrigation choices—kinship and caste affect prices of pumping services among other things. However, farmer social organization is clearly less important in farmer management of crop water sources than are the costs and reliability of the sources.

Of greater importance are the environmental aspects created by government and non-government institutions, including the following:

* Despite adequate water in the Gandak River for most of the year, construction and management problems keep the Eastern Gandak Canal System from delivering the planned quantities of water and make deliveries highly unreliable.

* Pipes, drilling services, and pumpsets for the installation of tubewells to tap the groundwater are easily available to farmers in the local markets. Government subsidies are also available for poorer farmers.

* Even poor farmers and farmers with very small landholdings can own a tubewell through membership in a group tubewell. There are institutions to provide technical and financial support for the tubewell groups. Others can get access to groundwater by purchasing pumping services from tubewell owners.

* The high prices of diesel, oil, and maintenance in the market keep pumping costs high. Electricity is not a viable alternative in the area because the power authority cannot supply it in sufficient quantity.

Improving irrigation services requires changing these features of the environment.

8.2 IMPROVING THE PERFORMANCE OF THE EASTERN GANDAK CANAL SYSTEM

Improving the performance of the Eastern Gandak Canal System requires both extensive work on the physical system itself as well as improvements to the management systems.

Physical Improvements to the System

Needed improvements to the physical system include the following:

* Repairs must be made to many parts of the system from the head of the main channel down to the very tail of the system. Weakened canal banks need to be strengthened and broken and inoperative control structures need to be repaired.

* Distribution systems in the tail reach of the Tirhut Main Canal beyond RD 554 have not been developed fully, causing various operating problems. Following a careful study of the situation, the distribution canals, control structures, and outlets needed to resolve the operational problems should be completed. Completion of the whole distribution network to RD 704 might be the solution if funds are not a constraint.

* Distribution networks—watercourses and field channels—below functioning outlets should also be completed to encourage farmers to use canal water efficiently.

* In this area, depressions collect water and remain flooded for up to 10 months a year. This problem is aggravated in some places by incomplete or poorly constructed canals. Also, some depressions have been created in borrow areas used for the canal construction. Productivity of such areas requires effective drainage.

All of these repairs require funds. In the current financial situation in Bihar, it is not likely that the State Government can provide the needed funds. Therefore, other alternatives need to be investigated, including trying to mobilize farmers. As noted in Chapter 3, there are local examples of effective mobilization of farmers to repair and improve the canals and structures.

Management Improvements

Even without the massive investments needed to improve the physical system, many aspects of canal management can be improved. These include the following:

* The Gandak Command stretches over a vast area. Communications within this vast system are too slow to allow for reasonable adjustment to operations. Therefore, a fast telecommunications system is needed.

* Most irrigation officers lack data to show the true situation with regard to water deliveries and water use. Although water is supposed to be monitored at every turnout, this does not occur. Records exist only for major control points. More importantly, as pointed out in Chapter 3, the estimates of irrigated areas are far from accurate. There is a real need to develop proper data collection, transmission and analysis systems so that system managers know what is really happening.

* Water demand is currently based on past experience and the carrying capacity of the canals, whereas it should be based on actual crop needs. The data system mentioned above could provide the proper data. The process by which water demand is aggregated also needs to be made more efficient by cutting out some of the steps and using a fast communication system.

* The WRD should have a system by which Superintending Engineers can check whether Executive Engineers take only the amounts they request so that system operators further down the system get their share. This will force the staff near the head of the system to be very careful in their demands. Overall, the WRD needs to develop within its ranks an orientation toward making the irrigation system perform well and provide a good service to the farmers.

* Well-defined operational procedures should be developed, together with farmers and operating staff, and documented in an operations manual. This will enable supervisors and farmers to check on the performance of gate operators and other field staff.

* Field officers do not visit irrigation sites for fear of being insulted and harassed by farmers who usually complain about the physical condition of the system. Requests to make the system dependable in the short term cannot be carried out under the prevailing rules and regulations. Field officers cannot take decisions even for small repairs and this leaves them helpless in front of the farmers.

* All government departments currently operate in virtual isolation from each other. One of the main functions of the Gandak Command Area Development Authority (GCADA) is to integrate and coordinate the activities of the various departments, including the Water Resources and Agriculture Departments. There is a real need to define both mechanisms and expectations from coordinated effort so that it can be monitored. One possibility would be to give GCADA powers to control and coordinate the activities of the key Departments working in the command.

* Farmers are clearly concerned about the performance of the canal system; this is clearly shown by the Madan Chapra farmers' organized efforts to ensure that water reaches their minor canal. Given the difficulties of effectively managing a huge system like the Gandak System, farmers' concern should be tapped by the government by organizing farmers to take an active part in system management at all levels. Currently, when farmers feel that they must take action with regard to canal irrigation, they use their village organization which is often inappropriate. Also, because their organizations are not recognized as having a legitimate interest in canal system management, they are ignored or face opposition from the government officers.

* Operation and maintenance activities are badly underfunded. More funds need to be provided. Given the financial plight of the State of Bihar (public employees often go unpaid for months at a time), the necessary funds probably cannot come from the state coffers. The evidence is that farmers would be willing to help if their help will actually improve the adequacy and reliability of the canal water supply and if they are convinced that the funds are being spent to make the canal system work well. There is a need to link funding with system performance. Also, the water rates collection system must be modified in line with the new financing system.

* Summer irrigation is not provided and most lands remain fallow during this period. The value of summer irrigation should be discussed with farmers and efforts made to promote it to increase cropping intensity.

As is evident, a great deal of effort and expense is needed to make the Eastern Gandak Canal System function well.

The major causes of the problems of the Gandak System according to the WRD officers themselves are: inadequate funds, lengthy and complicated decision-making procedures, insufficient decentralization of decision making, and farmers' negligence and irresponsibility. It is clear that these are problems. In addition, however, there seems to be others, including: a lack of effort on the part of the officers, overstaffing, and little accountability of officers to the users and their colleagues.

Of greatest importance perhaps is the lack of good data on what is really happening in the system. Without these data, there can be no accountability and attempts to improve performance cannot succeed.

8.3 IMPROVING THE EFFECTIVE USE OF GROUNDWATER IN THE GANDAK COMMAND

Widespread use of groundwater for irrigation in this area is quite possible given the amount of groundwater that exists. An effective groundwater extraction mechanism is known: the tubewell. Other extraction mechanisms need not seriously be considered; farmers have already rejected them for good reasons.

As documented earlier, the main reason for the lack of use of groundwater is that the cost of providing groundwater for irrigation is high compared with crop values. The issue is how to reduce the effective cost of tubewells. The comparison of the attractiveness of private tubewells, VASFA tubewells, and river lift pumps, shows that farmers are keenly aware of the differences in the costs of water produced by different pumpsets. The implication is that even small reductions in effective costs would increase the usage of tubewells and river lift pumps.

Tubewell Installation

Availability of tubewells is not a major problem. Almost any spot can serve as a site. The local market can provide all the materials and services needed to install a tubewell. While the cost is not a small consideration for local farmers, the cost is within the means of most of the farmers with larger holdings. In addition, government subsidies exist that make it possible for most poorer farmers to purchase a tubewell if they feel it is a good investment.

The efficiency of the subsidies could be improved by better supervision of the drilling process and by supplying the actual amount and type of pipe needed for that particular tubewell. Given the amount of pipe not used by the person receiving the subsidy, it is possible that the same number of subsidized tubewells could be installed at 60 to 80 percent of the current cost. This would make it possible to offer subsidies to more farmers.

The findings of this study seem to indicate that the performance of the pumpset is the main factor is determining overall tubewell performance, it would be possible to improve the wells themselves. The VASFA wells clearly show that the deeper filter wells with gravel packing are more efficient over the long run and give better discharges. Although such wells are more expensive, it may be that they are more cost-efficient and should be encouraged through the subsidy programs.

Price of Energy

The single biggest component of operational cost is diesel fuel. Since diesel fuel has many other uses, proposing some form of additional subsidy for tubewell use is not practical. Using electricity would be an attractive alternative to farmers, particularly given Bihar's preferential tariff. However, the massive state investments required to generate more electricity will not be made in the short run. In these circumstances, there does not seem to be much that can be done to reduce the prices of energy or other components.

Pumpset Efficiency

As explained in Chapter 4, a remarkable number of operators are ignorant of the best way to use and care for their pumpsets. Many farmers believe that operating the pumpset in a slanted position increases discharge. While the evidence for this increase in discharge is non-existent, there is clear evidence that operating in a slant position increases maintenance costs. One step therefore would be to carry out a program to educate pumpset owners and mechanics in the better care and operation of their pumpsets.

According to the farmers, getting good quality parts for pumpsets is a major problem. State or NGO intervention in the form of setting up an alternative organization to supply quality parts might help upgrade the level of the parts in the market.

One of the reasons that maintenance is so important is that so many pumpsets are purchased second hand to save money. Perhaps a more widespread subsidy for the purchase of new pumpsets would help upgrade the quality.

Conveyance Losses: Conveyance losses of tubewell water are often high, particularly when conveyed from the pump to the field in a temporary earthen channel. A program to get farmers to make use of more effective means would also help. Promoting the use of PVC pipe and training farmers in constructing more efficient earthen channels would also help. The use of lined channels would also help but might be viewed as both expensive and too inflexible.

Water Market

The local water market serves primarily to make groundwater available to those whose holdings are too small to warrant the installation of their own tubewell. Currently, most tubewell owners do not view the sale of pumping services as the main purpose of their tubewells, hence they do not consciously compete among themselves for buyers. They even go to the extent of trying to act like a cartel by setting a fixed price. In fact, as was shown, buyers have some influence over the price and the average effective price is somewhat below the standard local price.

Lowering the price of pumping services would happen if the efficiency of the tubewells were raised significantly. Otherwise, even with the entry of additional sellers, it is hard to see how the market will reduce effective prices.

Group Tubewells

The effective price of tubewell water for VASFA members is somewhat less than for private tubewell owners, largely because of the efficiency of the VASFA tubewells. The main advantage is that VASFA, as a larger organization, has insisted on technically better borings and has set up a source of high quality maintenance services. The second advantage is that, because the investment is spread over a number of group members, those who have only small holdings find the investment worthwhile.

Encouragement of group tubewells may be a useful way to increase groundwater use. However, it must be recognized that VASFA, and many of the groups that have modelled themselves on VASFA, have had considerable technical help and support, including funds, from NGOs or the government.

8.4 GOVERNMENT MANAGEMENT OF MULTIPLE SOURCES OF IRRIGATION WATER

As shown in the earlier chapters, farmers are making conjunctive use of surface and groundwater for irrigation. There is real concern that these two resources should be managed conjunctively on a macro level so that the most efficient use can be made of the total water resources. In Bihar, however, there are no serious attempts to manage these resources conjunctively.

The most immediate reason is an organizational one:

* Canal irrigation in Bihar is managed by the state's Water Resources Department (WRD). Each of the major irrigation schemes in the state, including the Gandak Irrigation System, has its own organization under the WRD. A detailed description of the Gandak Organization is given in Chapter 3.

* Groundwater exploitation is also monitored and, to a small degree, managed by a wing of the WRD called the Minor Irrigation Department. The Minor Irrigation Department is currently responsible for supporting small-scale surface systems, installing and operating state tubewells and state lift irrigation schemes, and with monitoring the use of groundwater for irrigation.

* Until 1981, the Minor Irrigation Department was directly responsible for promoting the private development of groundwater. At various times the Department provided rigs for drilling private wells, technical assistance to farmers, and administered subsidy programs. By 1981, direct assistance had ended and in 1981 the Minor Irrigation Department turned over the handling of subsidies to the Block Development Offices. The Department is no longer directly involved in managing or supporting the private extraction and use of groundwater for irrigation.

In the Gandak Command and in the other major irrigation systems, there is no coordination between the canal officers and the Minor Irrigation officers. Staff receive orders from their respective heads and provide information to their heads. Decisions are taken independently, even though their functions are closely and mutually dependent on the same resource base. An Executive Engineer, who has worked in both the Departments, reported, "They [the field officers] are supposed to work according to guidelines from above and are answerable only to vertical hierarchies."

The Minor Irrigation Department staff are organized on the basis of administrative boundaries (blocks and districts). Canal irrigation staff are organized according to hydraulic boundaries. Within many branch canal commands, there are large areas that, like the Vaishali Branch Canal command, are under both surface water and groundwater irrigation.

The Executive Engineer mentioned above also said, "When the canal irrigation systems were designed and operated, it was thought that the whole area under the command could be fully irrigated by canal water. Hence, it was thought that only the Irrigation Department would need to be in charge of the area." In planning for the large irrigation systems, no consideration was given by the government to the use of groundwater, either for providing full irrigation to unirrigated areas in the command area or for supplementary irrigations during periods of surface water shortage.

Moreover, canal water distribution is planned and executed without reference to the extent of groundwater irrigation; targets for canal water delivery ignore the areas irrigated from tubewells. Furthermore, the groundwater irrigated area is not reported in the figures of minors and branch canals.

On the other side, the Minor Irrigation Department, which is responsible for reporting areas irrigated from groundwater, takes no cognizance of canal irrigation. Therefore, the same area is reported separately as being irrigated from tubewells and from canals.

Since the canal officers are unaware of the extent of use of groundwater, they cannot make use of this data in planning their canal deliveries. Since the Minor Irrigation officers are unaware of the use of canal water in tubewell irrigated areas, they can provide no guidance to the canal officers.

This problem means that there is no capacity to manage total water resources equitably, sustainably and efficiently. Distributing the same amount of surface irrigation water to areas differing in availability of groundwater may be neither equitable nor efficient. Within the Eastern Gandak Command, the high water table means that large areas are susceptible to waterlogging and damage from salinity and alkalinity. Neither threat can be controlled without more coordinated effort at management of all water resources.

The lack of conjunctive management at the group level in an environment of extensive conjunctive use at the individual level is somewhat like having two cooks preparing parts of the same meal, from the same limited food supply source, but without any communication about how much of the food stock the other is using nor what type of food, nor how much of it, the other is preparing (Raju and Vermillion 1993).

8.5 CONCLUSION: ANSWERS TO THE KEY QUESTIONS

In the first chapter, we identified some key questions for this study:

* What are the different sources of irrigation water and the extent of their use within a canal command area?

* In a canal command area laced with rich groundwater resources, how do farmers evaluate and manage multiple sources of irrigation water?

* What are the institutions developed by farmers to manage groundwater resources and under what circumstances are the different institutions most advantageous?

* What features of the canal management systems determine its performance relative to groundwater extraction?

* What features of the government programs determine farmers' attitudes toward use of canal water and groundwater development?

The study has answered the following questions:

(a) *Different Sources of Irrigation Water.* In the command of the Vaishali Branch Canal at the tail of the Eastern Gandak System, the major sources as identified by farmers include the canals, tubewells with diesel pumpsets, and rainfall. Sources of lesser importance include river lift pumps, dugwells, manual pumps on tubewells, and seasonally flooded fields. The question of extent of use is complicated because multiple sources are likely to be used for the same field during any one season. In fact, rainfall dominates. Canal water comes second and tubewells third.

(b) *Farmer Evaluation and Management of Multiple Sources.* We pointed out that farmers have a very clear set of preferences in the use of water sources based on availability, reliability, and cost of water from the different sources. Rainfall is the preferred source, followed by canal water, followed by tubewell water. Tubewells, despite their general availability and high reliability, are considered very expensive, so their use is minimized.

(c) *Farmer Institutions to Manage Groundwater.* There are three institutions that are used by farmers to manage groundwater use for irrigation:

* Most groundwater exploitation is through private, individually owned, tubewells.

* Farmers now have tubewell groups to provide irrigation services to their members. Of course, the tubewell groups were not developed spontaneously by the farmers. Rather there were inputs from an NGO, and from government agencies. Since then, some farmers have created other tubewells on the model of the Vaishali Small Farmers Association groups.

* Farmers have developed a market in pumping services to distribute groundwater to those who do not own tubewells. This market is highly influenced by various aspects of the local social organization, particularly caste and kinship relations.

However, the farmers have no mechanisms for communal control over the use of groundwater. At the moment there seems to be no need. Given the reluctance to use the tubewells because of the cost, there is clearly no overexploitation of the extensive groundwater resources available in the area.

Although we did not explore in full the conditions under which individual tubewell ownership or group ownership is more advantageous, we pointed out that group tubewells are useful for farmers whose holdings are too small to make investment in their own private tubewell worthwhile. Of course, this presumes, as was pointed out in Chapter 6, that the primary motivation for installing a tubewell is for use on the well owner's own fields rather than for sales to others.

d) *Canal Management Systems.* Water delivered in the tail of the Eastern Gandak System is inadequate in quality and unreliable. The causes of this situation include severe physical problems with the canals and control structures. They also include some major management weaknesses which are detailed above as well as in Chapter 3. A major problem is the lack of accurate data on canal flows and areas irrigated. The managers operate the system without knowing what is really happening.

e) *Government Programs.* As shown earlier in this chapter, various factors in the actions of the government agencies strongly affect the evaluations of sources of water for crops. These factors include the deficiencies in canal system management and lack of funding for fixing the canal system, failure to integrate management of surface water and groundwater, the subsidy programs which make widespread ownership of tubewells possible, the assistance provided to farmers' associations created by an NGO, and lack of electricity or other cheap sources of power.

The study has shown that farmers make use of rainfall, canal water, and groundwater in conjunction with each other. However, the fact that they prefer rainfall as a crop water source, followed by canal water, followed by groundwater is determined by the government agencies and programs and by the crop market and the fuel market conditions. These factors explain the underdevelopment of groundwater use in the canal command despite the obvious advantages of such use from an outside perspective. The government can change the farmers' pattern of use of the sources by changing the way it manages the canal system and by helping the farmers' make improvements in efficiency of tubewells. Reducing the cost of power would be the fastest way to get farmers to switch to groundwater; however, doing so is very difficult in the near future. For organizational reasons, there is no capability within the government of taking a holistic view of the management of total water resources so that the development of surface and groundwater in conjunction with each other can take place. Without that capability, it is unlikely that the government can make significant improvements in the environment in which farmers make their irrigation choices.

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