CONJUNCTIVE MANAGEMENT OF SURFACE WATER AND GROUNDWATER FOR IMPROVING THE PERFORMANCE OF THE GANDAK PROJECT IN ITS MIDDLE AND LOWER REACHES

by

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INTRODUCTION

In the alluvial plains such as in North Bihar, both the surface water and groundwater sources are highly interacting in a hydrological sense and both the sources are exploitable for irrigation. Due to certain hydrological, technological and socioeconomic factors, both the sources have certain limitations as well as potentials. The surface waters, comprising mostly the riverflows, have dominantly seasonal characteristics and non-uniformity. Unless these flows are regulated by means of storages created in the upstream, they are inadequate to meet the summer and rabi irrigation requirements. Consequently, surface irrigation schemes, based on diversion of run-of-the-river flows through a network of canals, are incapable of supporting cropping intensities higher than 140 percent or so. This is, on the one hand, a gross under-realization of the agricultural potential of the area in view of the congeniality of agroclimate and the fertility of land, and, on the other, leads to counterproductive situations due to poor agricultural drainage and waterlogging in this shallow water table region, particularly in the lower reaches of the command. Both the adverse features of exclusive surface irrigation in North Bihar can be effectively taken care of by conjunctively utilizing the groundwater for irrigation. Adequate availability of groundwater of acceptable quality and at relatively low lifts makes such utilization highly prospective. This additional source of water will take care of both the spatial and temporal inadequacies of the surface water supply, thereby increasing the achievable irrigation intensities to 200-300 percent. Moreover, by providing greater flexibility and better control to the farmers in the supply and application of water, this will lead to satisfying the crop water requirements in a more meticulous and assured way. This will significantly help crop diversification, adopting more remunerative crops and increasing the yield. Also, by depressing the water table and/or piezometric head, it will ameliorate waterlogging and improve drainage, rendering irrigation both hydrologically sustainable and agriculturally productive. Thus, conjunctive use of the two sources for irrigation is not only highly imperative and prospective but also eminently suitable in the extant situation. The strategy, however, has not been adopted in the planning or design of existing irrigation projects in North Bihar.

Gandak Project, one of the two major irrigation projects in North Bihar, the other being the Kosi Project, was implemented in the sixties and early seventies to cater to the irrigation needs in the western region. Diverting waters of the River Gandak by means of a barrage into a network of canals on both its right and left banks, and its eastern canal system, known as Tirhut Main Canal (TMC) beyond 9.05 RD from the offtake at the barrage, is designed to serve a gross area of 677,200 (6.772 lakh) ha lying between the rivers Gandak on the west and Burhi Gandak on the east. The TMC was completed only up to 790 RD by the end of the sixth five-year plan (1980-85) when the project was declared closed, while the distribution system was developed only up to 704 RD. Extension of the TMC up to 909 RD, as originally planned, and further development of the system in order to provide irrigation benefits to the entire area envisaged in the project was stalled primarily due to objection or even resistance by the farmers who were targeted to be the beneficiaries. The objection or resistance grew out of adverse experience of irrigation by those who were served by it in the middle and lower reaches of the Gandak command, below 500 RD of TMC, in terms of unreliable canal supply in the kharif season, inadequate supply for the rabi crops as well as creation and/or exacerbation of waterlogging conditions. As a result of the inadequacy and unreliability of canal water supply in the reach below 500 RD, utilization of groundwater has come up in the area as a complementary, supplementary or alternative measure for irrigation. This utilization is in the form of a few State tubewells, or a considerable number of cooperatively managed tubewells or a relatively large number of private tubewells. However, there has been no attempt at integrating or coordinating this development with the existing or planned Gandak irrigation system resulting in, on the one hand, sub-optimality in terms of agricultural productivity, hydrological sustainability and social equity, and, on the other, complexity in irrigation management of the system.

OBJECTIVES

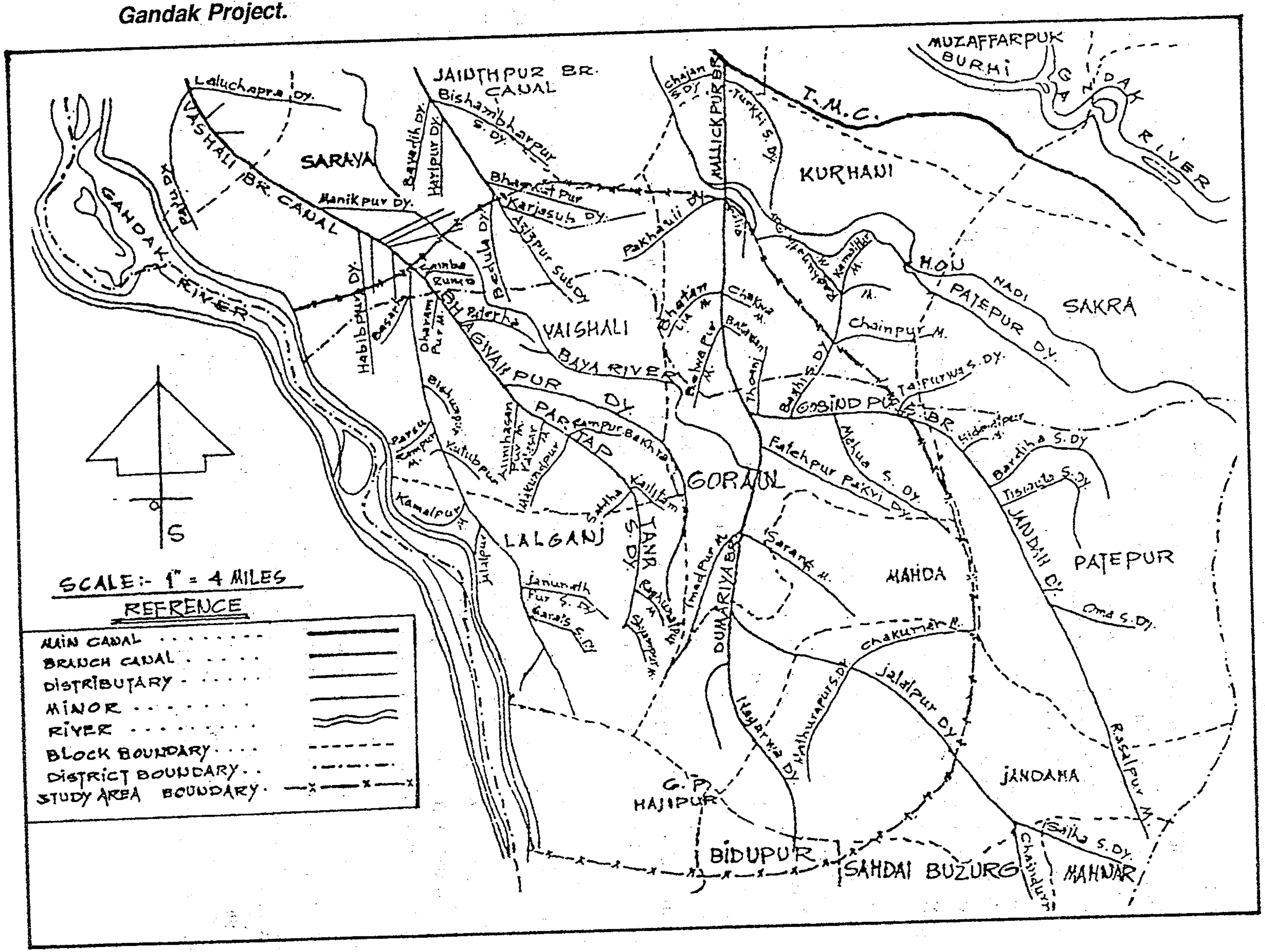
The overall objective of the research is to improve the irrigation performance of the middle and lower reaches of the Gandak irrigation command and other irrigable areas having comparable conditions in terms of agricultural productivity, sustainability of the system and, to a limited extent, social equity. As the strategy for the purpose is recognized to be conjunctive use of surface water and groundwater, the specific objective of the research is to evolve a management framework and to prescribe the necessary policy measures for developing and operating a conjunctive irrigation system which will be agriculturally productive, hydrologically sustainable and socially equitable.

It is recognized that these objectives may not be achieved fully and completely in a two-year research. With this recognition, the ongoing research may be considered as the first phase in a continuing process. The objective of this research, therefore, is, on the one hand, to serve as a stepping stone to achieve the overall objective and, on the other, to be complete in itself so that its results can be implemented for improvement of the system under study.

STUDY AREA AND PILOT SUBAREAS

The study area comprises the tail ends of the Vaishali Branch Canal, Jaipur Branch Canal and parts of the Mallickpur Branch Canal, taking off at RD 554, 593 and 704, respectively, on the Tirhut Main Canal of the Eastern Gandak Project. An approximate demarcation of the study area is shown in Figure 1. The study area measures approximately 95,000 ha.

Figure 1. Index map of study area under tail-end command of Tirhut main canal, Gandak Project.



In this study area, four pilot subareas have been chosen in order to study different aspects of the research, keeping in view the above-mentioned objectives. The desired and actual features of these pilot subareas are indicated below.

Pilot Subarea No. 1: Characterizes an area which is in the nominal command of the surface irrigation project but uses groundwater exclusively to meet its irrigation requirements due to non-supply of canal water, or due to being devoid of the access to it. It is located between the tail ends of two distributaries of the Vaishali Branch Canal (VBC). It covers an area of around 317 ha and falls in to two blocks of two districts. Irrigation is provided by a cluster of 36 tubewells with capacities varying from 6.5 HP to 10 HP, and cooperatively managed by the beneficiary farmers who have formed a registered society, named Vaishali Area Small Farmers Association (VASAFA). A map of the command of a typical tubewell in this area is given in Figure 2. Apart from cooperatively managed tubewells, a number of privately owned tubewells have also come up in recent years to serve areas additional to the 317 ha.

Pilot Subarea No. 2: Characterizes an area where groundwater use for irrigation has developed as a result of irregular, unreliable and/or deficient canal water supply. It is located in the command of the Habibpur sub-distributary which takes off from the VBC at 138.2 RD. Only 28.3 RD out of its planned length of 40 RD have been constructed so far. Designed to serve a CCA of 3,100 ha on completion, this sub-distributary presently provides irrigation only up to 12 RD. There are five state tubewells and more than 270 private tubewells in its command, serving mostly high patches of land. An index map of this pilot subarea is given in Figure 3. The actual area of this pilot subarea is determined by the extent of the actual command of the sub-distributary under operation.

Pilot Subarea No. 3: Represents an area where groundwater use has developed in course of time to supplement of complement irrigation through the surface sources. This subarea has been identified to be the command of the Laloo Chapra minor taking off at 100.87 RD of VBC for a length of 26.6 RD. Designed to serve a CCA of 2,604 ha, it carries supplies only up to 6 RD at present, the remaining length being inoperative due to lack of repair and maintenance. There is one state tubewell and 240 private tubewells in its command. An index map of this pilot subarea is given in Figure 4.

Pilot Subarea No. 4: Is characteristic of waterlogged areas in the command, waterlogging occurring either due to topographical depression, or tail-end location, or both. Drainage is the dominant constraint and consideration for irrigation development of such areas. This subarea is around 2,000 ha in Berai-Telghara Chaur along Hajipur-Mahua road and is covered by Dumaria Distributary of Mullickpur Branch Canal. A few state tubewells and a number of private tubewells (around 120) are also located in this area. An index map of this pilot subarea is given in Figure 5.

Figure 2. A typical tubewell command area (map of command area of Tubewell No. B4 in Manora village).

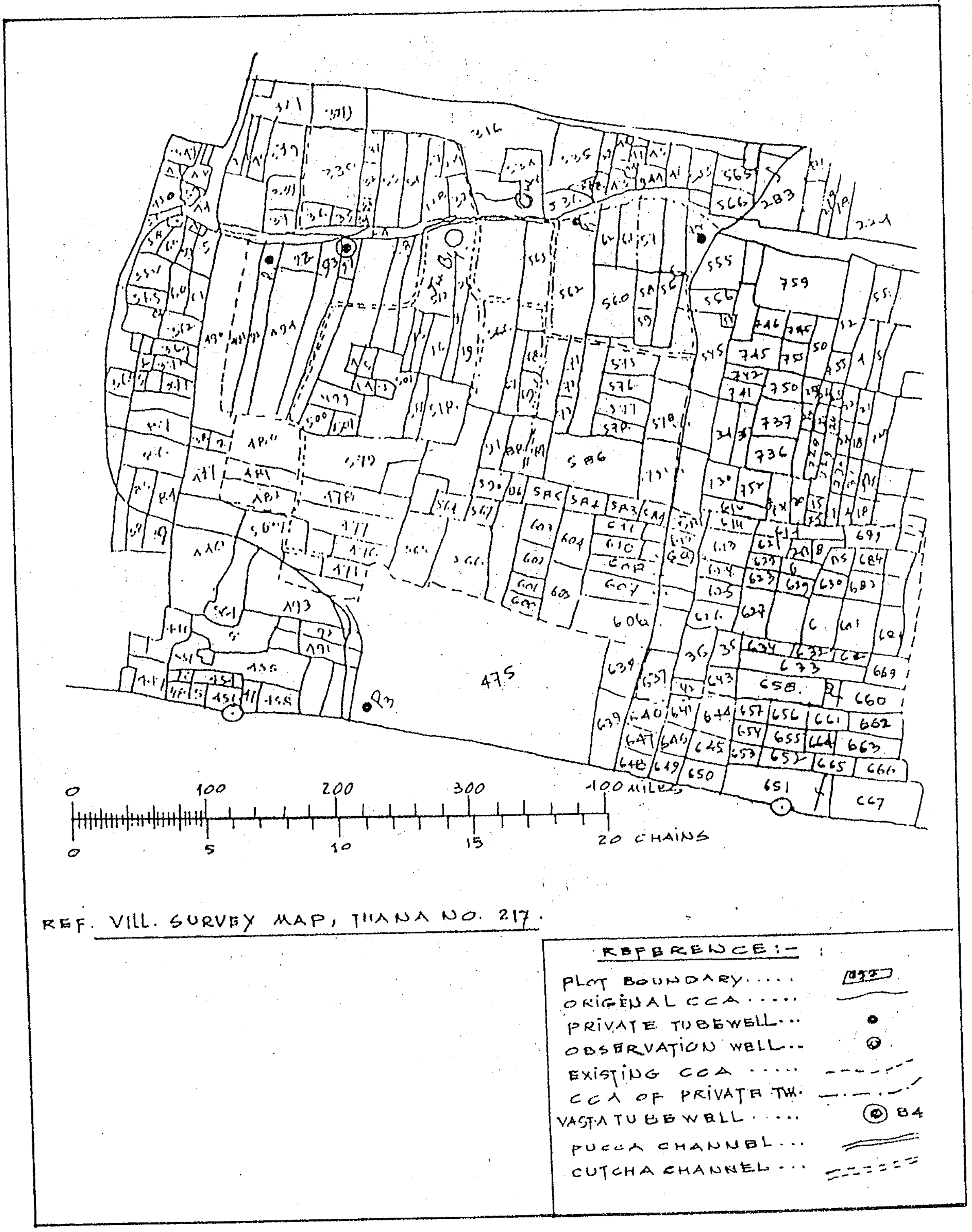


Figure 3. Index map of Habibpur sub-distributary (up to 13.0 RD, EX. Rd 138.20) of VBC.

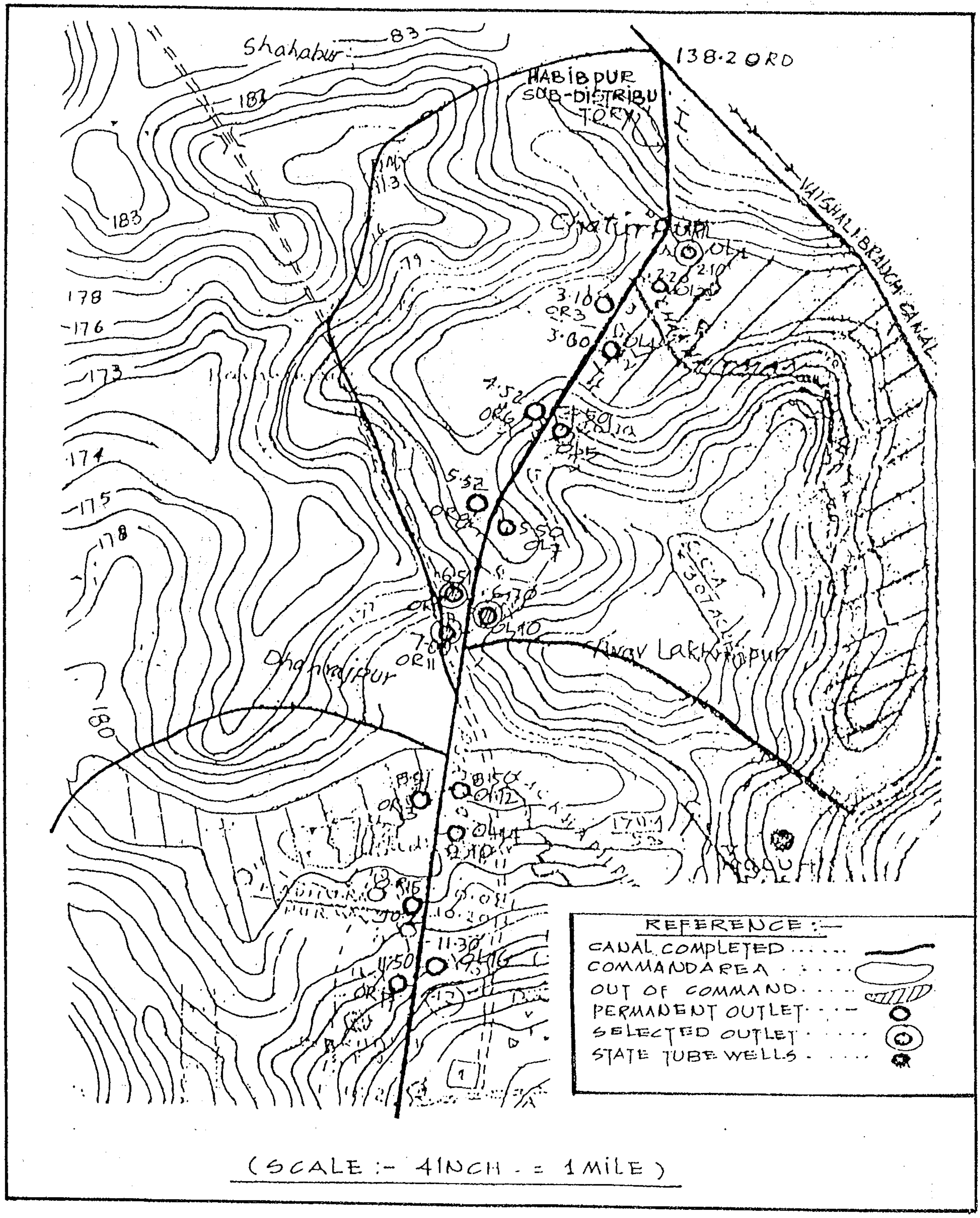


Figure 4. Index map of Laloo Chapra Minor.

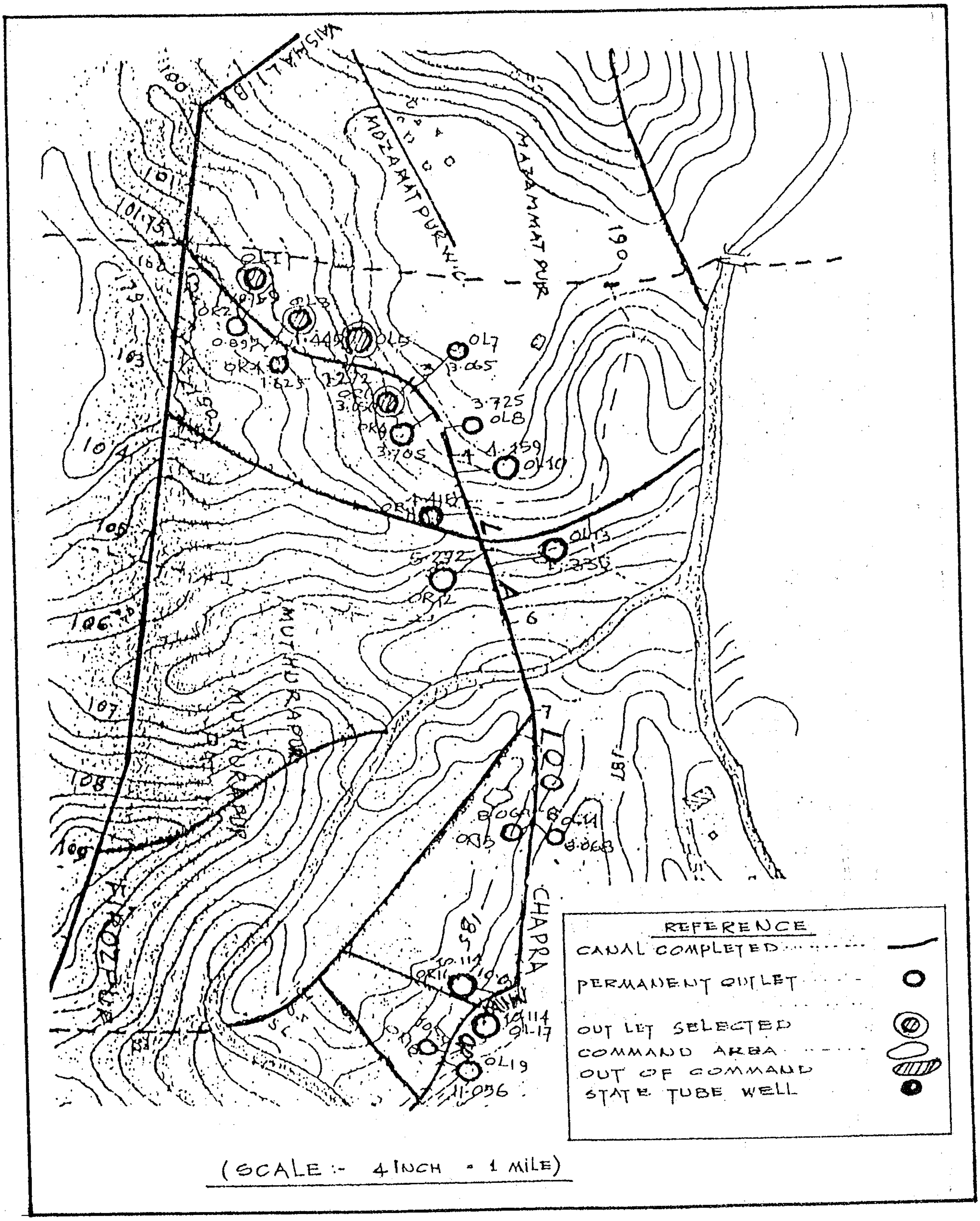
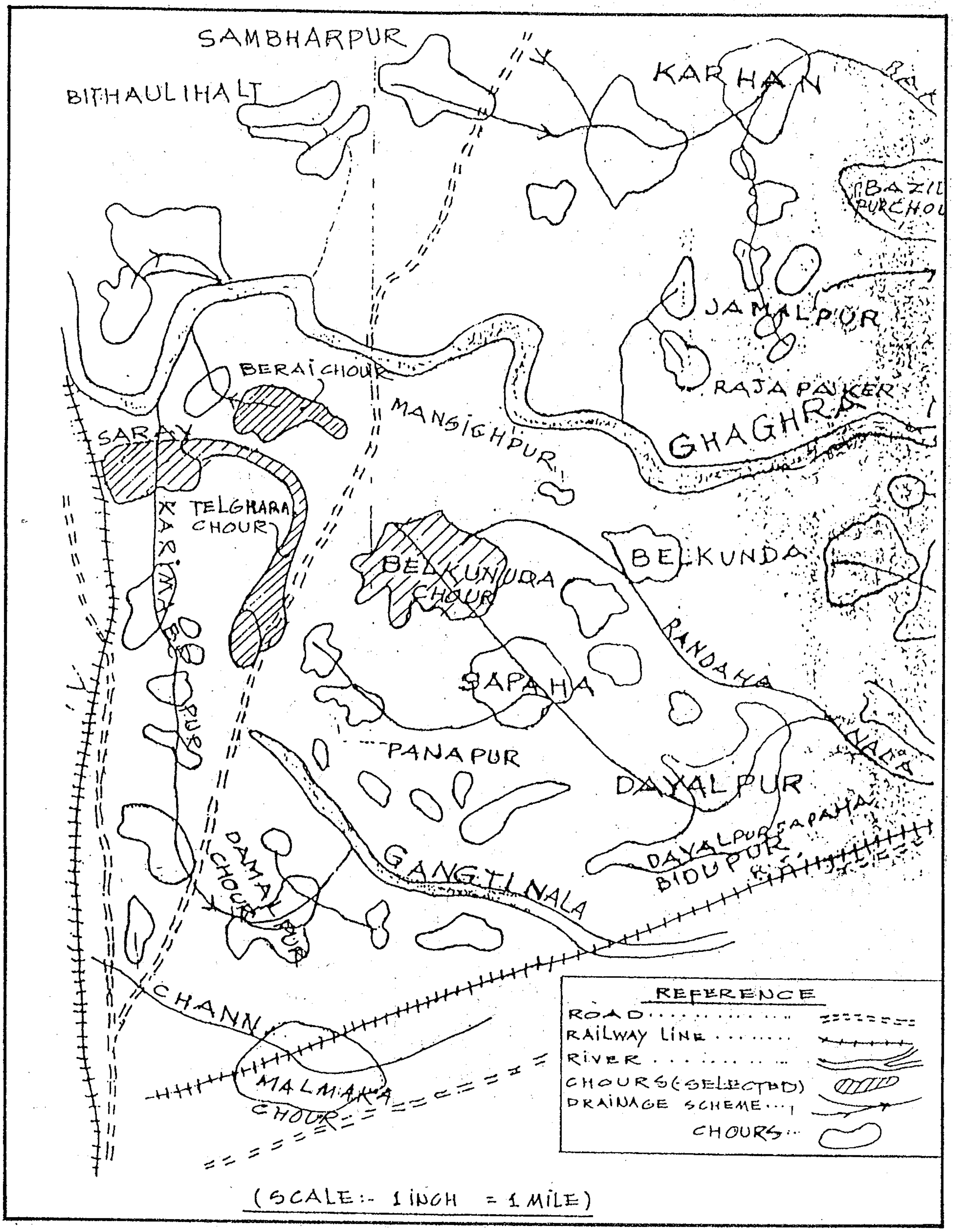


Figure 5. Index map of Telghara Chour selected under Pilot Subarea No. 4.



DATA COLLECTION

Types and Nature of Data

The following types of data are being collected during the research:

a) *Hydrological and geohydrological:* This relates to patterns of river flow, rainfall, water tables, groundwater quality, groundwater recharge, aquifer characteristics, etc.

b) *Canal operation and irrigation:* Information on schedules of canal operation from the headworks to the outlet in various crop seasons, extents of irrigation done for different crops, and related matters are collected with reference to the study area, in general, and to the concerned pilot subarea, in particular.

c) *Existing tubewells and their features:* Location of tubewells, ownership and operation, capacities and sizes, depths, energy sources and other relevant information on existing tubewells in the study area, in general, and in the concerned pilot subareas, in particular, are collected.

d) *Performance of tubewells and groundwater use for irrigation:* Information on hours of operation of tubewells, discharges, constraints in operation, extents of irrigation done in various crop seasons, etc., are collected mainly from primary sources with respect to the concerned pilot subareas.

e) *Socioeconomic information of farmers:* Socioeconomic profile of the farmers in the study area with respect to income level, farm holdings, whether tubewell-owning, literacy level, etc. is to be ascertained primarily by means of suitably formulated questionnaires for sample areas.

f) *Farm productivity, cropping patterns and cropping intensities:* Information on these aspects of agriculture is collected with respect to areas which are in the canal command, or are irrigated by tubewells, or are conjunctively irrigated, or are practically unirrigated.

g) *Remotely sensed data:* Image and satellite maps of the study area are being obtained in order to get information on waterlogged areas, cropping patterns, etc.

h) *Economic data:* Data related to economics of irrigation, from surface water and groundwater sources, as well as to economics of agriculture are being obtained. Cost of surface irrigation must take into account both the direct cost to farmers in terms of pricing of canal water supplies as well as the hidden cost to the society in terms of cost of installation and operation, and maintenance of the infrastructure of the surface irrigation system. Similarly, the cost of groundwater irrigation must include the cost of installation of the infrastructure of groundwater irrigation as well as the cost of operation and maintenance of this infrastructure. The economics of agriculture involves getting information on costs of various inputs and the prices of agricultural products.

The program of collection of these data has been designed according to the nature of information to be ascertained, which is classified as follows:

1. *Basic Systemic Information:* This comprises data which reveal or specify the nature and properties of various systems involved in the study, such as: (a) physical system given by the relevant topographic and geologic features, (b) hydrologic system given by the rainfall, river flows and patterns of water table fluctuation, (c) agricultural system indicated by the agrologic properties of the soil and agroclimate, and (d) irrigation system given by the relevant features of the Eastern Gandak Irrigation Project. This data is being collected from secondary sources, mainly from the concerned government departments and agencies.

2. *Time-Series Information:* Time-series data is being collected in order to ascertain the irrigation-related development and trends over the years. For this purpose, a 15-year period, 1976-90, is adopted. This data is being collected from secondary sources and would indicate surface irrigation development, groundwater irrigation development and agricultural development in the study area as well as trends of waterlogging over time.

3. *On-Line Information:* This includes information required to assess the current status and performance of the system, particularly with respect to canal supplies, tubewell operations, irrigation done and resulting agricultural performance and outputs indicated by cropping patterns, cropping intensities and yields. This will also include monitoring of the water table.

4. *Socioeconomic- and Management-Related Information:* Information on socioeconomic conditions of the families in the command area is being collected by means of household surveys based on suitably formulated questionnaires. Also, information on management processes actually in effect leading to management decisions at various levels is also being collected through personal interactions and inquisitive observations by field-level observers.

METHODOLOGY OF DATA COLLECTION

The methodology adopted for data collection depends on the nature information, its significance in analysis and interpretation and the time available. Much of the data about systemic and time-series information is being collected from secondary sources. Hence, identification of appropriate sources and the availability of adequate data with them are real problems to contend with in this exercise.

Tables and formats have, however, been formulated for each type of data to be collected from secondary sources in order to help the data collectors to seek and compile the required information.

On-line data on canal supplies, tubewell operations being done and consequent irrigation, and agricultural activities being performed in the pilot subareas in a given cropping season is being collected. For canal supplies, four outlets each have been selected in operational length of 13 RD of the Habibpur sub-distributary in Pilot Subarea 2 and in 6 RD of Laloo Chapra minor in Pilot Subarea 3. Similarly, for the Pilot Subarea 1, eight tubewells have been selected for on-line data observations. Starting from the statistical requirements of sampling, the choice of outlets and tubewells included in on-line data collection was finally influenced by the operational realities and the availability of skilled manpower.

Canal supplies from the selected outlets were measured by means of Parshall flumes installed for the purpose while supplies from the tubewells were computed from readings on the V-notches installed in receiving tanks. Durations of canal supplies were ascertained from the canal operation records while those of tubewell operations were ascertained from the records of tubewell operators who were specially requested and trained for the purpose.

A few observation wells, varying in number from 2 to 4, have been identified in each pilot subarea for monitoring of the water-table fluctuations. Also, four gauging stations are being used for recording the water levels of the waterlogged areas in Pilot Subarea 4 in order to ascertain their drainage features.

For the socioeconomic survey and the analysis, villages have been selected in relation to the outlets/tubewells selected for on-line data collection. Stratified random sampling has been used for selection of sample households. Stratifications are based primarily on the size of land holding, number of landless laborers, and size of the households in a particular village. Secondarily, caste is considered for sampling. Sample households are interviewed by the field observers on the basis of a questionnaire. Besides these interviews, group interviews and discussions with key informants, such as Mukhia and V.L.W., are also held for eliciting additional information and for cross-checking.

DATA PROCESSING AND ANALYSIS

Various types of data are collected in specially formulated tables (10 tables for on-line information and 22 tables for systemic and time-series information). After screening the collected data for inaccuracies or inconsistencies, it is entered into computers in suitable formats, using software like dBase and SSPS. This data can then be examined and analyzed for various needs. Based on analysis done so far, the following observations can be made.

Functioning of Tubewells: Functioning of tubewells in the study area is found to distinctly depend on their ownership and management. Most of the community-owned and community-managed tubewells, being the sole source of irrigation in the area they serve, were found to be operative during the period under study, i.e., June to December 1991. A few tubewells, however, were non-operative either due to unresolved conflicts among the beneficiaries or unattended problems of maintenance. Private tubewells, particularly in areas where they coexist with an alternate source of irrigation (canal supplies, in this case), seemed to operate mostly in response to a pronounced stress in availability of water or for a distinct advantage in irrigation from a source under the full control of the beneficiary. In kharif season, farmers take recourse to tubewells for irrigation only during the initial stages of seed-bed preparation and nursery, when the requirements are limited and the canal is not running. As rice, the dominant kharif crop, is water intensive, they almost exclusively depend on canal water in the remaining period, as canal water rates are not only highly subsidized but are also based on area irrigated and not on volume of water used or number of waterings done. Tubewells are used more during the rabi and for cash crops.

During the period under study, water from private tubewells was reportedly not used for kharif crops due to good rains and due to canal supplies being adequate for their residual needs. These tubewells may possibly have been used during nursery periods in rice cultivation. However, several private tubewells were found to be operative in December 1991, particularly for irrigating more remunerative crops such as vegetables and oil seeds. None of the State tubewells in the study area were reported to be operative due to electrical, maintenance or manpower problems.

Canal Supplies: The reaches of the sub-distributary or the minor under study were found to carry much less discharge than what they were designed for and what was necessary for the proper functioning of the various outlets. The observed deficiency in discharge may be due to one or more of the following factors: limited availability of supplies, lack of demand, design defects, maintenance problems and operational constraints. While exact causative factors for such deficiency are yet to be established, these were the major factors, apart from the lack of maintenance of canal reaches and structures, for the much reduced efficiency of operational of canals. For example, both Habibpur and Laloo Chapra minors received less than 50 percent of their respective minimum design discharges during the kharif irrigation.

Performance of Irrigation: The performance of irrigation in terms of agricultural outputs vis-a-vis inputs may be seen from Tables 1, 2 and 3 for VASFA area, Habibpur command and Laloo Chapra command, respectively.

Table 1. Farm productivity of VASFA area under tubewell irrigation for kharif 1991.

Community tubewells	No. of plots studied	Total Plot area under irrigation (ha)	Irrigation Discharge (Cumecs)	Duration (Hours)	Inputs: Fertilizer (kg/ha)	Inputs: Labor (man-day/ha)	Outputs: Grain (q/ha)	Outputs: Fodder (q/ha)
V2	3	0.691	0.023	13	70	78	28.20	13.90
V6	8	1.189	0.024	11	55	77	21.95	11.02
V11	3	0.335	0.019	42	84	128	22.40	12.40
V12	3	1.630	0.010	17	58	89	20.90	10.12
B4	17	1.709	0.011	17	74	80	27.00	14.00
B7	11	0.140	0.012	-	65	89	20.48	10.50
B11	6	0.450	0.005	17	56	78	22.20	12.11

Table 2. Farm productivity of Habibpur command for kharif 1991.

Outlet No.	No. of plots studied	Total plot area under irrigation (ha)	No. of times of irrigation	Depth (mm)	Inputs Fertilizer (kg/ha)	Inputs Labor (man-day)	Outputs Grain (q/ha)	Outputs Fodder (q/ha)
OL1	4	0.30	3	100	140	220	19.00	22.00
OL1	4	2.56	3	100	130+600	173	21.00	25.60
OR9	8	1.33	2	100	124+508	205	18.23	23.50
OL10	13	1.16	2	100	110+10	158	18.62	23.50

Table 3. Farm productivity of Laloo Chapra command for kharif 1991.

Outlet No.	No. of plots studied	Total plot area under irrigation (ha)	No. of times of irrigation	Depth (mm)	Inputs Fertilizer (kg/ha)	Inputs Labor (man-day)	Outputs Grain (q/ha)	Outputs Fodder (q/ha)
OL1	10	0.344	5	112	157+610	218	16.13	19.20
OL3	6	0.708	2	112	54+212	216	11.79	14.20
OL5	7	0.668	3	112	85+150	177	18.00	21.03
OR6	17	1.488	3	100	85+500	216	17.44	20.57

Note: Fertilizer comprises Urea + Cow dung.

The figures of farm productivity arrived at from the analysis of data and which are presented in these tables reveal certain outstanding facts regarding agricultural performance of tubewell and canal irrigations. In tubewell irrigation, the productivity in grain output in terms of quintals per hectare (q/h) is about 1.5 times that in canal irrigation, while the inputs in terms of fertilizer applied and manpower employed per hectare are 2-times and 3-times, respectively, higher in the latter than in the former. Also, in canal-irrigated area, fodder output per hectare is about 1.5-times more than that in the tubewell-irrigated area. These findings will be verified by more data to be obtained and by further analysis of collected information.

Socioeconomic Status: From the analysis of socioeconomic information collected so far, certain general observations about the study area as a whole as well as certain specific observations regarding the socioeconomic status of a pilot subarea may be made. In the study area, the population is predominantly agricultural. However, different pilot subareas display some significant variations in this regard. In the Pilot Subarea 1, more than 90 percent of the people are agriculture-dependent, whereas in Pilot Subareas 2 and 3, it is about 80 percent. This can be explained by higher and more reliable productivity of agriculture in the tubewell-irrigated area than in the areas having canals as the primary source of irrigation. However, the proportion of the agriculture-dependent population is least (about 50 percent) in the drainage-congested and waterlogged Pilot Subarea 4. In this pilot subarea, the percentage of people in government jobs is about 22 percent compared to almost nil in the other three pilot subareas. Due to agriculturally counterproductive ecological conditions prevailing in this area, people have to seek and take recourse to alternative occupations for their livelihoods. Another revealing feature concerning the economics of agriculture vis-a-vis other occupations is that while the annual income of people earning more than Rs 1,000.00 is about 30 percent in Pilot Subarea 4, it is almost nil in Pilot Subarea 1, about 20 percent in Pilot Subarea 2 and about 3 percent in Pilot Subarea 3. Collating this with the agricultural productivity and occupational dependency of people in different Pilot Subareas, it is apparent that the income generating capacity of agriculture as an occupation is poor. This finding may be corroborated directly by carrying out a farm budget analysis.

While, in general, the land holding pattern shows a preponderance of small and marginal farmers in the study area, different pilot subareas have revealing variations in this regard. While only up to 15 percent of the farmers own less than 1 acre of land in other pilot subareas, it is more than 40 percent in Pilot Subarea 4. This shows that in the absence of any motivation towards the process of land consolidation, due to unmitigated poor productivity of land in Pilot Subarea 4, land has remained fragmented and continues to fragment further due to divisions in the family. This inference is to be confirmed by more comprehensive analysis of socioeconomic survey data as well as by direct questioning of farmers.

Other features of the socioeconomics of the study area are more or less uniform. Agricultural laborers constitute about 8 percent of the total labor force. As for the cast composition, the proportion of scheduled castes varies from 2 percent in the Pilot Subarea 4 to 15 percent in the Pilot Subarea 2. The study area has no scheduled tribal population.

INTERIM FINDINGS

While the results of comprehensive analysis are yet to come, some interim findings about the status of the irrigation system of the study area may be indicated on the basis of the investigations made so far. These findings may be stated, first, separately for each pilot subarea, and then in an overall manner.

Pilot Subarea No. 1. Provision of irrigation through cooperatively owned and managed tubewells was a venture both in cooperative action as well as in rejection of what was perceived as an imposition of an inappropriate and counter productive irrigation system, started in 1971 in the Vaishali region of the command of an exclusively surface irrigation project under the dynamic leadership of a social organizer, Mr. Dewan. This venture grew in scope and coverage for a decade, starting from 10 tubewells in 1971 to 36 in 1982. Since 1982, however, there has been no further growth or expansion of this movement of cooperative and community irrigation. Apart from some external factors such as deterioration of the availability and reliability of the electrical supply, inherent conflicts of interests between large and small farmers in the same command and other problems of management and maintenance began to surface, and they were disincentives for growth of the membership of the cooperative society from its more or less stagnant level of about 781 farmers.

The experience of two decades of irrigation exclusively through groundwater in an area of more than 300 ha, which would have been otherwise served by the surface irrigation project, is worth noting. The cropping pattern practiced in this area is more diversified and remunerative than in canal irrigated areas. Cultivation of vegetables and tobacco, apart from the usual kharif crops of rice and maize, has been observed in this area. The yield per hectare is also believed to be better in this area. Running at an average of 4 hours per day, the tubewells have served to maintain the water table within 0.5 m of rise or fall over the years, thus ensuring sustainability of irrigated agriculture. Given the choice, the farmers of this area are still averse to canals being brought to the area.

Pilot Subarea No. 2. Defects and deficiencies in the design and operation of the distribution system are obvious in this pilot subarea. Originally planned for a length of 40 RD with a CCA of 3,100 ha, the distributary was constructed up to 28 RD to serve a CCA of 1,270 ha. For the last several years, however, this distributary has been rendered inoperative due to siltation, weed growth and other problems of repair and maintenance. In the kharif season of 1991, about 50 percent of the total number of 10 outlets in the operational length of 13 RD were non-functional due to one reason or another. Also, the first 2.1 RD of this distributary passes through a depressed area resulting in heavy seepage loss and waterlogging. In order to ensure the supply to all the outlets in the downstream reach of this distributary, the canal must run over bankful capacity in this initial reach, posing danger of breaches of the banks. Lining of the canal in this reach of 2.1 RD length would greatly improve the irrigation performance of this distributary.

Inadequacy of supply was another factor towards deficient functioning of the system. Out of the requirement of 10.7 cumecs even for the presently operational 13 RD of this distributary, it received only an average of 0.33 cumecs for about 45 days for which the distributary ran in the four months (July to October) of the kharif season.

There is hardly any clamor for extending the supply beyond 13 RD or even for enhancing the supply in the presently operational reach of the distributary. This apathy or indifference of the potential beneficiaries is due to the adverse effects attendant with such extension or enhancement. Canal irrigation is viewed at best as a mixed blessing by the farmers in this reach.

Right from the beginning, groundwater use for irrigation was considered as a complement for the inevitable deficiencies of the surface irrigation in the command of this distributary. Five State tubewells were installed in its command to cater to the irrigation requirements of higher patches or otherwise inaccessible areas in the command. Subsequently, a number of private tubewells came up in the command as a consequence of non-functioning or malfunctioning of the system and unreliable or deficient supplies from the canal. The State tubewells did not run in the recent kharif season for lack of repair and maintenance. Adequate information on the operation of the private tubewells in this season has not been available.

Pilot Subarea No. 3. A dominant factor in the functioning of the Laloo Chapra minor is the progressive deterioration in its irrigation performance due to lack of repair and maintenance. constructed for a length of 26.8 RD to serve a CCA of about 2,600 ha, it used to provide irrigation up to 20 RD. In the recent kharif season, however, it was found to carry water only up to 6 RD, the remaining length being inoperational due to silting, weed growth, other factors of maintenance and a deficiency of supply. Compared to a discharge of 0.3 cumecs required to supply to all the outlets of the presently operative 6-RD length of the minor, an average discharge of 0.15 cumecs was available for about 45 days during which time the minor ran, in the kharif period. Due to piping, burrows made by rats and unauthorized cutting by the villagers, there were frequent breaches and consequent interruptions in supply.

In the command of this minor, groundwater use for irrigation has been developed to supplement the canal irrigation. The only State tubewell installed in its command did not operate in the recent kharif season. No information was available about the functioning of the large number of private tubewells in the command. A few tubewells which were monitored did not operate due to lack of demand for irrigation.

Pilot Subarea No. 4. This pilot subarea lies in a topographical depression and waterlogging as well as lack of adequate drainage constitute the dominant problem afflicting its agriculture. The sources of ingress of water into this area are accumulations of rain and surface runoff, flood flows from the river, flows from upstream chaurs and escape from canals. The contribution of subsurface flow from upstream irrigated areas is yet to be established. The two chaurs being investigated, Telghara and Berai, have been observed to have a maximum depth of inundation of the order of 0.5 m in September. In the 2,000 ha of land included in this pilot subarea in and around these chaurs, submergence in the kharif season ranges from 30 to 50 percent.

Solution of problems inhibiting agriculture in this area may involve (a) checking or reducing ingress of surface water into this area, (b) providing and accelerating drainage of the accumulated water, (c) using the chaur as an efficient retention basin, (d) reducing subsurface drainage into the chaurs, (e) increasing verticle drainage and sub-surface drainage out of the chaurs, (f) promoting aquaculture and agricultural practices in keeping with the submergence characteristics of the chaurs, and (g) provision of tubewell irrigation, particularly, for rabi cultivation. Different measures may be considered for each of these categories of solutions. The effect of conjunctive use of surface water and groundwater for irrigation in the upper reach command area should be evaluated in this context.

AN OVERALL VIEW OF THE FINDINGS

The functioning of the eastern Gandak Project below 500 RD is beset with various types of problems, as outlined above, and consequently, its performance is far below what was envisaged at the project-planning stage. Conceivably, there are several factors producing this performance level. It may be partly due to problems in main system operation and management and partly due to developments in the upstream utilizations which were not planned or taken into account. Another factor may be the lack of proper maintenance and repair of the downstream system in the study area. Lack of communication, both physical as well as institutional, between the system users and the system operators/administrators as well as other management deficiencies may also explain part of the low performance level. Certain deficiencies in the design of the structural components of the canal system have also been found to present problems in full-scale operation of the canal. For example, certain cross drainage works in the system begin to show signs of distress if the canal discharge exceeds a certain value which is lower than the design discharge. Also, operation of the canals at full discharges is inhibited by risk of breaches, as the escape channels, which act as safety devices, are encroached. Improvements in regard to all these factors may bring about some improvement in the performance of the system below 500 RD. However, the three basic premises for the unsatisfactory performance of the middle and lower reaches of the system, i.e., unreliable supplies during the kharif, inadequate supplies during the rabi and creation or exacerbation of waterlogging would largely remain valid even with this improvement. Provision of irrigation water requirements for the kharif crops during the unpredictable periods of rainfall failure or deficiency during the critical stages of plant growth is severely constrained in the lower reaches by the hydraulics of open-channel flow, where water diverted at the head regulator into the canal has to travel more than 150 km satisfying upstream needs on its way through numerous diversions and abstractions, in order to meet the emerging requirements in these reaches. Different degrees of uncertainty in canal supplies is unavoidable in such a situation even though there may be "water available" in an aggregate sense. As far as irrigation in the rabi season is concerned, deficiency of supply in the lower reaches is inevitable due to the hydrology of unregulated river flows and increasing rabi requirements in the upper reaches.

For these problems, increasing use of groundwater in conjunction with the existing surface irrigation system may prove an effective corrective and ameliorative measure. In fact, it may bring an ailing and socially unacceptable irrigation system to health, vigor and high social acceptability. The techno-economic and management measures to be adopted to promote conjunctive use to optimally improve the performance of the system need to be evolved, and the ongoing research project is aimed at this need.

OUTLOOK

The analysis, as well as inferences and findings based on it, are only tentative at this stage, as they are based on limited data, and other data is still in the process of being collected. Regarding the features of irrigation and agricultural performance, data relate to only one crop, i.e., the kharif crop. Data relating to the other important crop season, i.e., rabi, is still being collected. Similarly, information about summer and perennial crops is not yet available. Also, data being collected now will hopefully be more reliable, systematic and comprehensive, as the benefit of the experience in data collection in the initial period of research is being made use of.

It is apparent, however, that the deficiencies and deformities afflicting the Gandak irrigation system in the middle and lower reaches of the main eastern canal are being identified and diagnosed through the ongoing research exercise. Also, the current research effort is throwing light on the identification and role of corrective and ameliorative measures, particularly, conjunctive use of surface water and groundwater for irrigation. The emerging developments bring forth somewhat more complex management problems to be resolved in order to make conjunctive irrigation agriculturally more productive, hydrologically more sustainable and socioeconomically more equitable. Policy prescriptions for resolving these management problems will hopefully be available as a final output of the current research programme.

BACKGROUND DOCUMENTS

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