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CONJUNCTIVE MANAGEMENT IN THE HARDINATH IRRIGATION SYSTEM, NEPAL

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FOREWORD

Socioeconomic development and poverty alleviation in many developing countries depend on water. Governments and Development Agencies recognized this issue and, invested heavily on water resources development projects during the Twentieth Century. Presently, opportunities for further water resources development are limited, either due to the absence of water or due to lack of financial resources. The demand for food is continuously increasing due to a steady rise in population. Irrigated agriculture, which consumes 69% of all freshwater resources, and produces 40% of all food, will require additional 17% water to meet the demand for food. This water is not available from primary sources (rain, snow melt, groundwater). Further, freshwater consumption in irrigated agriculture decreased to meet increasing demand of freshwater for domestic and industrial requirements. Therefore, water from all primary as well as secondary sources (drainage, sewage) will be used conjunctively in agriculture. The conjunctive water use has its implications as evaporation and transpiration of water will concentrate salts and pollutants and threaten environmental sustainability of agricultural lands. Proper institutional and technical strategies must be in place to manage water conjunctively to minimize threat to the environment. This study aims to address this concern.

The broad goals of the study are to, 'Identify *combinations* of institutions and technical strategies to manage surface and groundwater at regional scale, to promote environmental sustainability and to maximize agricultural productivity of water ('crop per drop'), initially in the Rechna Doab in Pakistan and Murrumbidgee Region in Australia'. This report reviews conjunctive water management issues in the Dhanusha District, Nepal.

The study is being carried out by IWMI in collaboration with Pakistan Council of Research Water Resources (PCRWR), and CSIRO Land and Water, Griffith, NSW, Australia. The study is financially sponsored by the Australian Council of International Agriculture Research, Australia.

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1. INTRODUCTION

1.1. OBJECTIVE OF THE STUDY

The present report is a short study of conjunctive use of surface and ground water within the Hardinath Irrigation System, a canal system, in Nepal. This report was prepared as one of four short studies under the Conjunctive Management Project being carried out by the International Water Management Institute in collaboration with CSIRO in Australia, and PCRWR in Pakistan, funded by the Australian Council for International Agricultural Research.

The overall goal of the project is to define technologies, institutions, and management methods for conjunctive management of multiple water sources - particularly surface water and ground water - which prevent environmental problems and promote sustainable irrigated agricultural production.

This study delineates technologies, institutions and management methods in use in the selected sites in Nepal and evaluates their effectiveness in promoting irrigated agricultural production and in preventing detrimental environmental impacts such as waterlogging and salinization, etc.

1.2. METHODOLOGY OF THE STUDY

The present study was carried out through the use of existing documentary evidence and by rapid assessment. The authors visited the scheme to collect documents from various government agencies and to interview farmers and government personnel. Groups of farmers were interviewed in all the major portions of the scheme. Heavy reliance was placed on an earlier study carried out by the Research and Technology Development Branch of the Department of Irrigation of conjunctive management in three irrigation systems, one of which was the Hardinath Irrigation System.

Unfortunately, several types of desired information are totally lacking. For example, there are no records of water flows either in the river that feeds the Hardinath System or in the canals. Similarly, there are no records of well usage. Also, estimates of crop yields are imprecise since government data is not reported on the area studied. For much of this data, we have relied on farmer reports.

1.3. ORGANIZATION OF THE REPORT

The present report is organized as follows:

- Section 2 describes the study site, including the available water resources.
- Section 3 describes the technologies used to exploit these water resources.
- Section 4 describes the institutions that govern the exploitation of these water resources.
- Section 5 describes the methodologies by which water managers - farmers and government officials manage these water resources for irrigation.
- Section 6 evaluates the performance of conjunctive water management in terms of protection of the environment (environmental sustainability) and agricultural production.
- Section 7 identifies the problems and opportunities present in the study site.
- Finally, Section 8 summarizes the results of the study.

2. THE HARDINATH IRRIGATION SYSTEM (HIS)

2.1. IRRIGATED AGRICULTURE IN NEPAL

Irrigation is important to agriculture in Nepal, not because rainfall is low, but because it is poorly distributed in time. Rain is heavily concentrated in the monsoon season between June and September.

Three farming seasons are generally recognized in Nepal:

- Monsoon season from June through October,
- Winter season from November/December through March,
- Early rice season from April into July.

In the sample area, the main (almost exclusive) crop in the monsoon season is rice. The main crop in the winter season is wheat and the main crop in the early rice season is rice.

2.2. LOCATION AND MAJOR FEATURES OF THE HIS

The site chosen for this study is the Hardinath Irrigation System (HIS) near the town of Janakpur in Dhanusha District in the eastern portion of the Nepal Terai. HIS was selected because conjunctive use of surface water and ground water is very important there. The site is large enough to be interesting and small enough to be studied through rapid assessment. Because there had been a previous study there it helped providing needed data (RTDB/IIMI, 1998).

HIS is located in the Terai of Nepal, an extension of the Gangetic Plains into the southern part of Nepal. The area is thus quite flat. Janakpur is only about 100 meters above sea level and the slope down to the Ganges over 100 kilometers south is quite shallow.

HIS diverts water from the Jalad River, one of the tributaries of the Ganges, into two main canals, the Western Main Canal and the Eastern Main Canal. The designed command area is about 2000 hectares. More details of the canal system are given later.

The Hardinath Agriculture Research Farm is located at the middle part of the western main canal. The farm carries out Research and Demonstration of different crops in 30 hectares of its farmland. The farm takes water from the canal as well as from its own deep tubewells.

Upstream of HIS along the Jalad River and its tributaries are 5 smaller farmer managed irrigation systems. In addition, within the command of HIS are over 120 wells used for irrigation and for domestic water use.

The study site consists of the designed command area of HIS.

An Indian Aid Mission to the Government of Nepal carried out construction of the system. The construction started in 1960 and was completed in 1967. There has been no major rehabilitation or change in the system since then. However, HIS is now scheduled to be rehabilitated under the Irrigation Management Transfer Project (IMTP) funded by the Asian Development Bank and USAID.

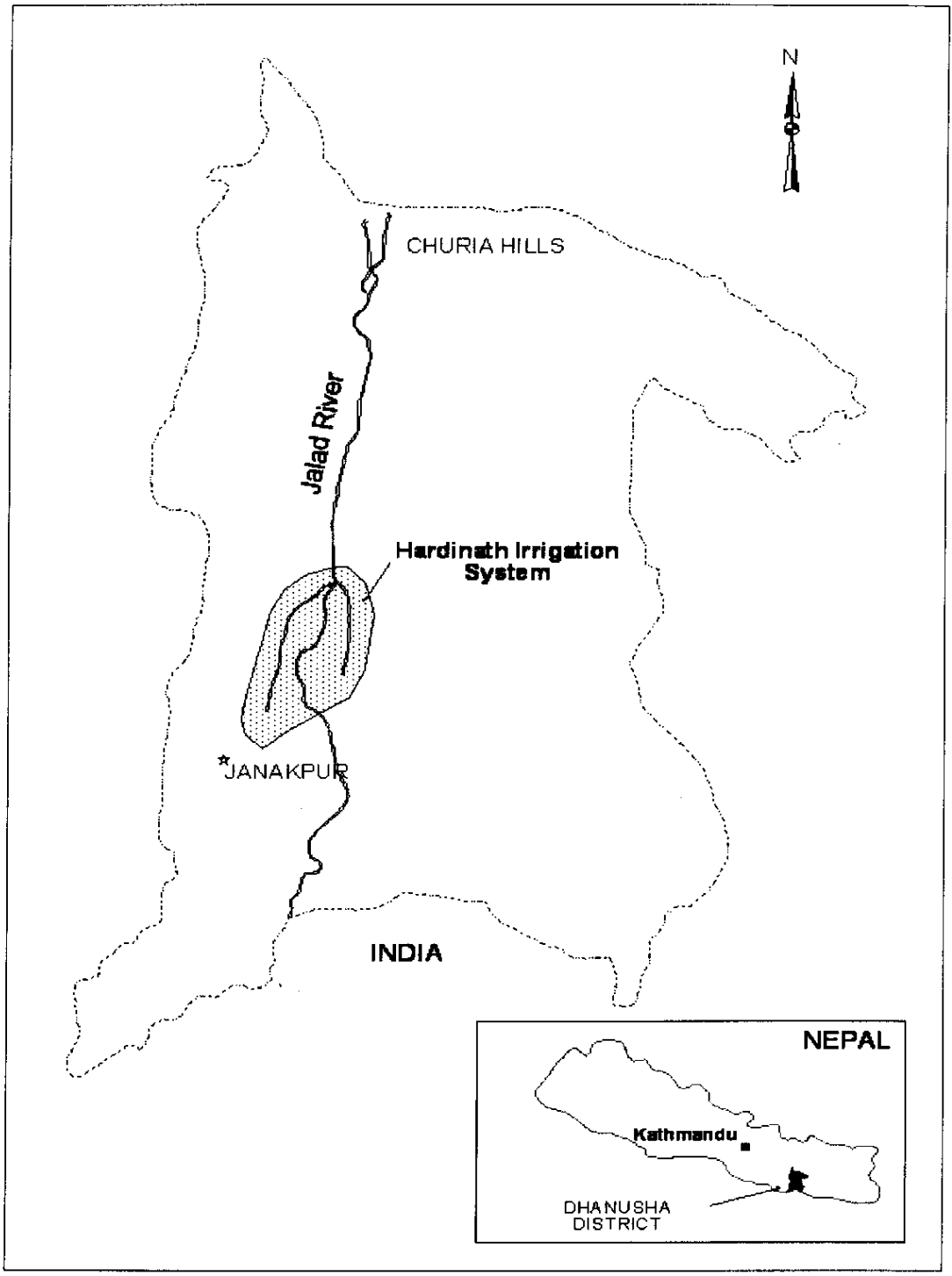

Figure 1. Dhanusha District, Nepal.

2.3. WATER RESOURCES OF HIS

2.3.1. Rainfall

The annual rainfall of the Hardinath Irrigation System area varies from slightly over 1000 mm to about 2400 mm with an annual average of over 1450 mm. Over 80% of this rainfall occur during the monsoon period from June through September. The monthly rainfall data recorded at Hardinath Agricultural Station from 1986 to 1996 is shown in Table 1.

Table 1. Monthly Rainfall at Hardinath Agricultural Station: 1986-96 (mm).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1986	0	15	1	47	82	27	386	371	152	122	0	70	1273
1987	1	40	1	78	12	223	529	913	423	168	0	2	2390
1988	0	58	38	108	52	303	670	609	139	59	0	24	2060
1989	14	12	21	0	132	122	539	193	352	16	0	7	1408
1990	0	23	23	37	211	55	445	160	391	5	0	16	1366
1991	54	1	14	30	25	217	303	235	180	24	0	8	1091
1992	0	3	0	10	260	122	208	170	83	176	2	0	1034
1993	5	2	27	156	89	162	292	575	129	0	0	0	1437
1994	45	37	6	12	90	60	366	284	303	0	0	0	1203
1995	9	20	7	0	21	324	231	551	85	19	28	11	1306
1996	33	3	0	1	14	309	651	254	80	116	0	0	1461
Avg	14.6	19.5	12.6	43.6	89.8	174.9	420.0	392.3	210.7	64.1	2.7	12.5	1457.2

2.3.2. River Flow

The Hardinath Irrigation System draws water from the Jalad River. The Jalad River originates in the Churia Hills and has a catchment area of about 65 square kilometers.

Until very recently, no regular measurements of the river flow were made. Available documents report that the Jalad River has a maximum discharge of 230 cumecs during monsoon floods and a minimum base flow of 0.1 cumec in the spring. Recently the Dhanusha District Irrigation Office (DIO) started to measure the river discharge at the HIS headworks. River flows calculated on the basis of those measurements on various dates are given in Table 2. Table 2 shows that there is a great deal of flow fluctuation in the river source within a short span of time.

Water is abstracted by five Farmer Managed Irrigation Systems (FMISs) upstream of HIS when irrigation is needed. Informal understanding among various water users on the Jalad River has been reached to release at least 60% of the river flow to the HIS (GITEC/GEOCE, undated). However, this has never been practiced. As a result only limited area within HIS can be irrigated.

Table 2. Jalad River Flows at the Headworks of the Hardinath Irrigation System (lps).

1998			1999	
Date	Flow		Date	Flow
17 August	1685		11 January	917
31 August	1760		15 January	596
15 September	1685		29 January	917
21 September	1282		10 February	783
1 October	2595		13 February	324
16 October	1282		4 March	917
18 October	596		12 March	596
4 November	1685		15 March	917
11 November	1124		19 March	596
17 November	917		26 March	426
1 December	1685			
11 December	2693			
20 December	783			
30 December	596			

Source: Dhanusha District Irrigation Office

The winter discharge comes from springs. The nearest spring is located 1.5 km upstream of the canal headworks. During our field survey, farmers reported that recently the river flow at HIS headworks has increased due to the failure of diversion structure of a FMIS and the movement of the nearest spring.

Despite this very recent improvement, the general feeling is that water availability for HIS has decreased. This decrease is attributed by farmers and irrigation officials to deforestation upstream leading to more variability in river flows and to siltation at the river diversion and elsewhere. At the diversion, silt was observed up to the crest level.

Reliability of water supply in the river is a serious constraint and may be aggravated by conflict over water supply with upstream users.

2.3.3. Ground Water

Investigative information available from the Ground water Development Board of Nepal (UNDP, 1992)indicate that most of the Dhanusha District plains, where HIS is located, has excellent shallow zone lithology. Depth to static water level in the Hardinath command area is shallowing everywhere - 2 to 3 meters below ground level - with variation of 1-2 meters throughout the year.

Transmissivity values in the District range from 200 to 8000 m^2/day and shallow tubewell (STW) yields vary between 5 and 15 liters/second. The UNDP/GWDB mapping reveals that the entire HIS command area is classified as a probable area for STW development for irrigation.

A report on the Hydrogeologic Technical Assistance to the Agricultural Development Bank of Nepal calculated the potential number of STWs in the Terai districts for the discharges of 12 lps and 16 lps. According to this report, Dhanusha District has a potential of 2547 STWs. This was based on percolation recharge and perennial recharge. The annual hours of operation of the pumps were 1500 hours and the well density 4.7 wells per sq. km and 7.2 wells per sq. km.

In view of the total potential, the ground water extraction in the area is small. A total of 990 STWs were installed in Dhanusha District as of 1997. Though no statistics on the number of functional STWs were available, the Janakpur ADBN office estimate that not more than 50% of the STWs are functional. Thus, it is not surprising that the farmers reported no case of falling water tables.

3. TECHNOLOGIES FOR EXPLOITING IRRIGATION WATER IN HIS

3.1. THE HIS CANAL SYSTEM

3.1.1. The Canals and Control Structures

The Hardinath Irrigation System (HIS) is gravity fed irrigation system drawing water from the Jalad River (Figure 2). An 80.6 meter long brick masonry weir with two gated scour sluices controlled by spindle type manually operated gates on both sides of the weir diverts water from the river to two intakes, one on each bank of the river. HIS has two main canals: the Eastern Main Canal (EMC) and the Western Main Canal (WMC). Both are ridge canals. The EMC is 5.5 kilometers long with a design discharge of 990 lps at the head and 220 lps at the tail; the bed slope is about 1:3500. The design command area was 1000 hectares. The WMC is 9.9 kilometers long with a design discharge of 990 lps at the head and 538 lps at the tail; the bed slope is about 1:3600. The design command area is 1000 hectares.

The only control structures on the main canals are a series of drop structures ("falls") to control water levels. There are 12 falls in the WMC and 6 falls in the EMC. Branch canals take off from both sides of each main canal just above these falls. The layout plan is shown in Figure 2. Ungated pipe outlets were originally installed for each branch canal all of the same size. As will be discussed later, only some of these are still used.

All development below the heads of the branch canals was left to farmers who have constructed branch canals of varying lengths and capacities. For the most part, only small canals - properly considered tertiary or field canals - were constructed. The tertiary canal lengths are 14.4 km in the EMC and 22.6 km in the WMC. The tertiary canals also lack adequate maintenance and have not been equipped with gated or other proper water control structures. Farmers use stones and mud to control flows when necessary. Much of the water distribution is from field to field.

No flow measuring structures exist anywhere within the system except for the river stage gauge on the headworks. No sediment flushing structures have been provided in the canal network. Finally, no drains are provided in HIS.

3.1.2. Condition of the Canal System

The physical condition of the system is not good. The District Irrigation Office figures that about 50% of the area under the WMC are not getting water because of the reduced canal capacities caused by failure to maintain the canals. Before February 1999, the head reach of the WMC had about 0.9 meters of silt in it. Thus, farmers at the tail of the WMC receive hardly any water. In the EMC, farmers have been cleaning the upper portions of the main canal themselves, thus water flows have been better.

In both main canals, the canal banks have been eroded in several locations, increasing the seepage losses. There is also severe embankment slumping, weed infestation, illegal outlets, damaged and vandalized outlets, and other flow control structures. Many outlets are clogged with sediment.

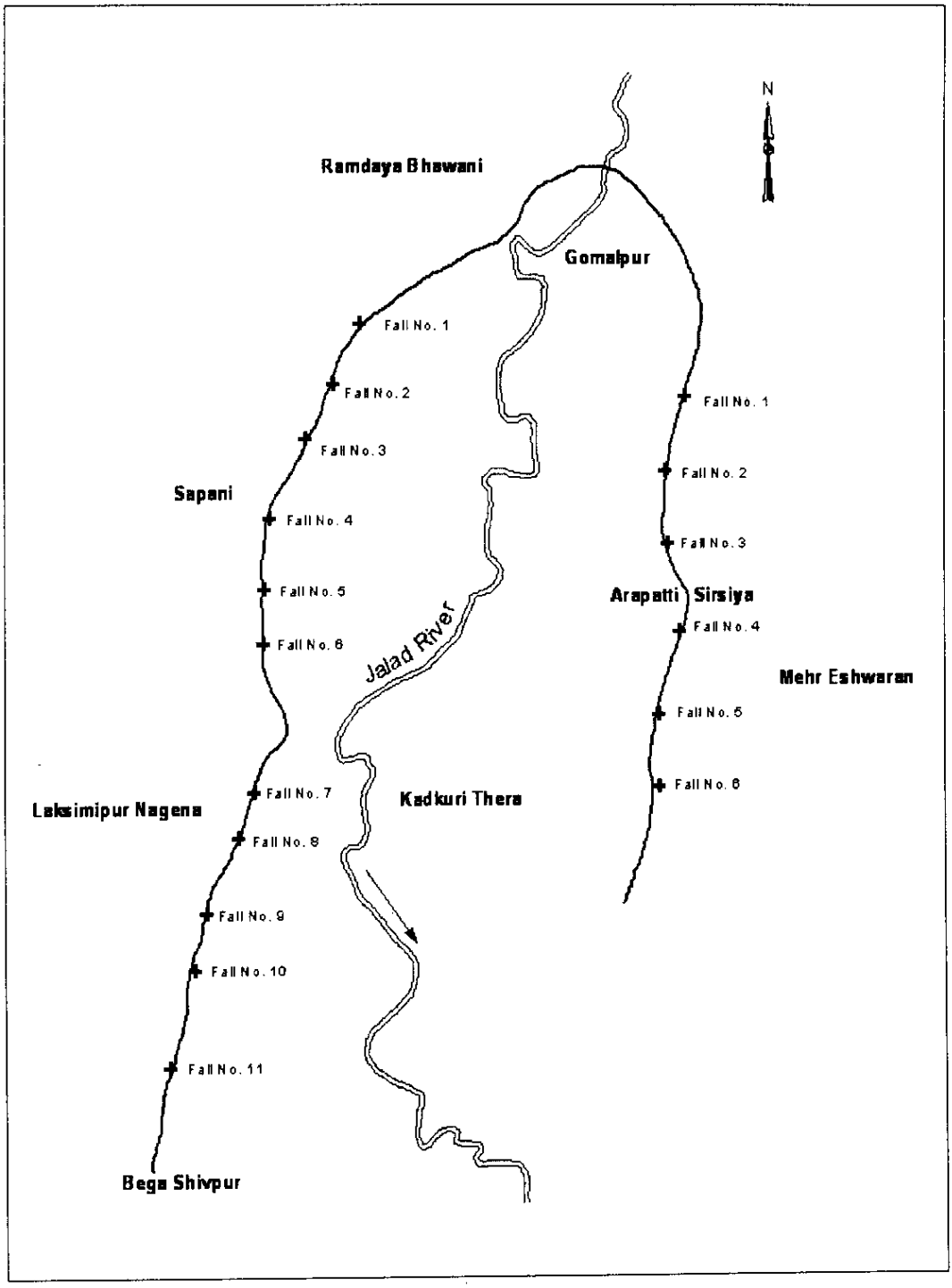

Figure 2. Layout of the Hardinath Irrigation System.

Farmers draw water directly from the main canal either from the outlet or, more often, from cuts in the banks, usually replacing the pipe outlets. The degree of water control is better in the head reach and gets worst towards the tail end of the main canals. The tertiary canals are also maintained inadequately.

Uniformity and steadiness in flow of water in the main canals are not maintained due to the absence of sufficient water control and monitoring mechanism. The flow uniformity is also greatly affected due to diversion of water from several places and ungated pipe outlets.

Beginning in 1999, canal system rehabilitation will be undertaken under the Irrigation Management Transfer Project (IMTP).

3.2. GROUND WATER EXTRACTION

3.2.1. Types of Wells

As indicated earlier, there is tremendous scope for developing ground water resources in HIS command area. This resource, which is being recharged by annual rainfall and perennial river flows through the hills, has to be extracted and used efficiently for the promotion of irrigated agriculture.

To cope with the problems of the canal system, farmers within the HIS command make use of ground water through three types of wells:

- Shallow tubewells (STWs),
- Deep tubewells (DTWs),
- Artesian wells.

Shallow tubewells dominate. However, each is discussed separately below.

3.2.2. Shallow Tubewells

3.2.2.1. Distribution of STWs

HIS provides water to land within 11 villages (Village Development Council areas). As shown in Table 3, nine of these villages have STWs. Laxmipur, Baniniya, Tarapatti and Sapahi villages have the highest number of STWs. Table 3 indicates that there are 115 STWs in these nine villages. All are owned by individuals.

Table 3. Shallow Tubewells in the HIS Command.

No.	Village*	STWs**
1.	Baniniya	25
2.	Tarapatti	21
3.	Gopalpur	6
4.	Laxmipur	28
5.	Sapahi	20
6.	Therakachuri	2
7.	Mithileshwar	9
8.	Baghchaura	2
9.	Bengashivpur	2
Total		115

Source: Janakpur Agriculture Development Project and ADBN Office Janakpur, 1999.
* Village Development Council area.
** These do not include STWs installed without subsidy. The number of such STWs appears to be insignificant.

3.2.2.2. Characteristics of STWs

Most STWs are about 60 feet deep, in a few cases the depths are as little as 35 ft. A four-inch diameter casing pipe of mild steel, a slotted mild steel pipe for screen and well plug are the materials commonly used in a STW. For the screen only the minimum section criteria of matching the grain size of the aquifer has been established. These days there is a tendency to replace mild steel strainers with PVC screen or HDP Pipe Screen.

Diesel pumpsets of 5-8 HP are widely used. Indian manufactured pumpsets are readily available in the market. Japanese made pumpsets are also available in small numbers. Farmers also make use of the engines for other agricultural operations like threshing.

The discharges for four-inch borings fitted with 5-8 HP pumpsets average about 12 lps. The few smaller tubewells use manual pumps, either treadle or rower pumps and have lower discharges.

Pumpsets are always mounted so that they can be moved; generally on small, wooden wheeled carts. There are two reasons for this. First, farmers are afraid of theft of or damage to their pumpsets if left alone. Second, portable pumpsets can be used on more than one boring so that if a single farmer has two or more borings he can use the same pumpset and so that pumpsets can be rented out to others for their own borings or even for pumping from the river.

3.2.2.3. Boring Methods

Investigation of the potential aquifer is the preliminary step in STW installation. Since, most tubewells have been installed with a subsidy, a technician from the relevant agency (the Agricultural Development Bank of Nepal or the Janakpur Agricultural Development Project) usually identifies the aquifer based on the performance of wells in the locality. Electrical sounding

method is also used, but only rarely. Upon the identification of the aquifer the drilling mechanics start boring.

Records reveal that in Dhanusha District the most commonly adopted boring methods are manual rotary (56%), sludge (35%), hammering the casing and screen into the ground (6%), and machine drilling (3%). The Janakpur Agriculture Development Project (JADP) installs machine drilled shallow wells using drilling mud, wire-wound strainers, gravel pack and well development.

Well development seems to be the most neglected part of STW installation in Nepal. The finer grains from the aquifer adjacent to the screen are not properly removed. Generally cow dung used as drilling mud is used as the flushing material for removing the sand particles. Inadequate hours of STW operation are another reason for partial well development. Clogging of well strainer causing well failure is reported to be a common phenomenon.

3.2.2.4. STW Installation and Operating Costs

The present cost for the complete installation and equipping of a 4" STW is NRs 45,000-57,000.

Operating costs for the typical STW include the following:

- Diesel: 1.25 liters/hour @ NRs 16/liter
- Engine oil: 3.5 liters for 80 hours of operation @ NRs 125/liter
- Average annual maintenance costs: NRs 2500-5000

All are operated by the owners themselves. Breakdown maintenance is done by outside skilled labor or local trained farmers.

Assuming pumpage of 500 hours per year and taking maintenance costs to be NRs 3750 per year, the average hourly cost for these three items is:

$$1.25 \times 16 + 3.5 \times 125/80 + 3750/500 = \text{NRs } 33$$

We will take this figure as an approximation of STW operating costs. Note that it does not include any depreciation, nor any cost for the operator. These two items are not usually explicitly figured into the costs by the farmers.

3.2.2.5. Conditions of the STWs

Though no statistics on the number of functional STWs were available, the Janakpur office of the Agricultural Development Bank of Nepal estimates that not more than 50% of the STWs are in operating condition. The reported problems include screen damage, clogging of filters, inappropriate casing material, deficient well development, deficiency in design, earthquake damage in 1988, and others. The number of farmers reporting non-functioning tubewells is increasing.

Fixing wells is expensive so many are scared to do it. For example, to make repairs, the JADP (see below) asks them to deposit NRs 4000 and the cost may be higher.

3.2.3. Deep Tubewells

The Hardinath Agriculture Research Farm located in the command of the western canal of HIS has two DTWs that were installed some 20 years ago. At present, only one DTW is in operation and the Agriculture Farm is using the DTW to irrigate about 30 hectares of its land area.

Another DTW has been installed within the command of HIS in Baniniya Village. This well is owned by the Village Development Council and is used to help local farmers irrigate their lands.

Some details of these DTWs are given in Table 4.

Table 4. Deep Tubewells in the HIS Command.

No.	Location	Year of Installation	Depth (m)	Discharge (lps)
1.	Hardinath Agriculture Research Farm	1977	116.6	30
2.	Hardinath Agriculture Research Farm	1980	104.0	35
3.	Baniniya Village	1995	109.5	50

Source: Janakpur Agriculture Development Project, 1997.

3.2.4. Artesian Wells

The Janakpur Agriculture Development Project (JADP) is also promoting the 1.5" artesian wells in suitable areas. It is reported that there are altogether 200 free flowing artesian wells in Dhanusha District. The depth of these wells is in the range of 70 m to 85 m below ground surface. Artesian wells are used for both domestic water and for irrigation. In HIS command, artesian wells are found only in the tail areas. We were not able to estimate the number within HIS command, but it is not high.

The discharge from artesian wells is low - ranging between 3 and 5 lps, only enough for a single farmer. The cost of installation of an artesian well is between NRs 18,000 -27,000. Operating costs are nil.

3.2.5. Ground Water Quality

No farmer reported problems of water quality for irrigation. However, some farmers complained that water from the shallow aquifers is not good for domestic uses - i.e. it stains the teeth and it does not taste good. Water quality is much better from the deep artesian aquifer; where available this is the preferred source for domestic water. There are no artesian aquifers near the headworks hand pump is used to take water from the perched aquifer.

3.2.6. Distribution of Ground Water

Water is generally carried from a well to the fields to be irrigated with earthen field channels. Pipes are not used. In some cases, water is pumped into a canal for conveyance to farmers' fields. Some farmers have installed STWs next to the main canals for this purpose. However, during the monsoon season, when the primary crop is paddy, water is often allowed to flow from field to field rather than constructing field channels.

Farmers generally allow one another to construct a temporary channel through their fields, particularly for winter season crops. These field channels are usually destroyed during the monsoon season.

3.3. Lifting from the River

In several places, particularly towards the tail of HIS, farmers use diesel pumpset to lift water from the river. This use is necessarily limited to areas within a kilometer or less of the river. The pumps used are the same pumpsets used for the STWs. This is not a major source of irrigation hence we will not discuss it further.

4. INSTITUTIONS GOVERNING EXPLOITATION OF IRRIGATION WATER IN HIS

In this paper, we use the term "institution" to refer to state laws and regulations and local customs and to organizations; both can be viewed as rules that serve to guide people in their actions.

4.1. LAWS AND REGULATIONS CONTROLLING SURFACE AND GROUND WATER

Laws, policies, and regulations have been enacted and promulgated by the national government to regulate water rights and water use in Nepal. A brief review of the water sector legislation and policies has been presented in this section.

4.1.1. National Code 1963 (Muluki Ain 2019)

This can be considered the basic law of the country. Among many other items, it establishes a general code of conduct for exercising the right of the public to use water resources to satisfy their needs. It also prohibits the discharge of wastewater and sewage into ground water aquifers. It has underlined definite code of conduct for land cultivation and right of the public to use irrigation water to increase agricultural production.

4.1.2. Water Resources Act, 1992

This act provides that, "the ownership of the water resources available in the Kingdom of Nepal shall be vested in the Kingdom of Nepal." The priority of the use as set in the act is drinking water and domestic use followed by irrigation, fisheries, hydropower generation, industries and mining, navigation, recreation, and other uses. The public can utilize water to meet their needs, but not until they have obtained a license or paid to the individual or an organization, which has a license to use the water resource.

The act provides that water users may form associations for certain uses. These are specifically domestic use, irrigation of personal land (on an individual or collective basis), running a water mill for a cottage industry, for use of a boat, for use of water resources confined to a specific piece of land owned by one person. However, the act notes that those making use of water shall not cause damage to others.

4.1.3. Water Resources Regulations, 1993

The Water Resources Regulations provide guidelines for the effective implementation of the Water Resources Act. It provides detailed information how the license to use water can be obtained and what specific terms and conditions must be considered for its use. Specifically it mandates creation of a District Water Resources Committee for this purpose.

The Regulation states, "who has obtained license for utilization of water resources shall have the right to use the water resource for the purpose as mentioned in the license to the extent of water resources of such a place and area as specified in the license. The license to use water is both sellable and transferable, provided the licensee submits an application to the District Water Resources Committee and obtains permission to do so.

The Regulations also specify that the District Water Resources Committee not only issues licenses but also monitors the utilization of water resources in the district.

4.1.4. Irrigation Policy, 1992 (First Amendment, 1997)

Concerned with chronically poor performance of public sector irrigation schemes and ever increasing operation and maintenance costs, the government has made several policy reforms including the Irrigation Policy of 1992. This policy has been instrumental in supporting user participation in planning, implementation and management of irrigation schemes. Incorporating the implementation experiences over the years, the policy was amended in 1997.

The irrigation policy attempts to define surface and ground water irrigation schemes corresponding to their physical features, users' involvement in system development and management and resource mobilization. It also attempts to draw a concrete policy framework on obligation, accountability, technological and environmental concerns, etc.

The irrigation policy supports investment in irrigation infrastructure through capital subsidies which for ground water development range from 30% (previously 40%) for an individual private shallow tubewell to 75% for a community STW.

4.1.5. Comment on the Laws and Regulations

Although the Water Resources Act assigns "ownership" of both surface water and ground water to the Kingdom, and requires licensing for the use of water, few licenses have been issued, particularly for ground water. The Water Resources Act specifically exempts irrigation by landowners or associations of landowners from the licensing requirement. Thus the present use of water for irrigation is largely unregulated by the Act.

Note that there is no attempt to restrict ground water use; rather the government has been promoting its use as specified in the Agricultural Perspective Plan (APP, 1995).

This has hardly been implemented so far. To regulate the use of the ground water resources, the government has recently decided to set up a team who will review the issue and formulate a legislative framework for the presentation in the country's parliament.

4.2. Water Rights

Since it is not regulated by the key laws, irrigation from surface water is largely regulated by customs and court decisions that make up a set of water rights (Khadka, 1996). Only in government irrigation systems is the irrigator legally required to pay a fee for water. Water rights have been recognized in custom and often in law, especially in thousands of the Farmer Managed Irrigation Systems (FMISs) in the country. A person's traditional water share should not be stopped because of provisions of the Water Resources Act or Regulations. Some of these issues may adversely affect the government interventions. In such a case the government is liable to pay compensation for acquiring the right of using water resources.

Customarily the ownership of land governs irrigation from ground water. The owner of the land has the right to use his land for any specific purpose, including irrigated agriculture. In doing so, the owner may also use the ground water available in his land. While using the land, one should not disturb the public and the utilization of land should be within the regulations set forth by the government. Under the prevailing practice the owner having a certificate of entitlement of land is required to pay the land tax at the rate fixed by the government.

These basic principles apply in HIS as well as in the rest of Nepal. There is a large amount of variation within FMISs on specifics of assignment of water rights to individual farmers. We will not take up this issue in detail in this paper for two reasons. These are: The WUAs that should create and enforce these water rights are only nascent organizations (see below) and the basic water distribution customs within small areas are simple rotations among farmers with highest on the channel having the first right to take water.

4.3. DEPARTMENT OF IRRIGATION (DOI)

The Department of Irrigation under the Ministry of Water Resources is responsible for irrigation development and management throughout Nepal. A Director General heads the DOI. The basic structure of the DOI is shown in Figure 3.

4.3.1. DOI Organization for Surface Water Irrigation

There are DOI Regional Directorates located in each of the five development regions and District Irrigation Offices (DIOs) in all seventy-five districts of the country. The DIOs were established in 1988.

Responsibilities for surface and ground water irrigation are clearly demarcated at both central and district levels. The Regional Directorates and DIOs are solely responsible for surface irrigation development including river control works. The DIOs have the primary operating responsibility for government irrigation schemes. Also, the DIO is to act as a key body in the District Water Resources Committee formulated under the Water Resources Act, 1992. It is to provide guidance on issuance of water user licenses.

Within the DIO, each staff member has roles and responsibilities defined by DOI at the center. The organizational structure of DOI is presented in Figure 4. The Dhanusha DIO has 34 staff members, including the Chief, four Engineers, a Geologist, 10 Overseers, technical assistants, administration and accounting staff, an Association Organizer, two mechanical gate operators, and a surveyor.

The Dhanusha DIO, with some support from the center, is responsible for implementation of the Irrigation Management Transfer Project (IMTP) in HIS. This project, funded by the Asian Development Bank and USAID, is aimed at transferring all management responsibilities for HIS and 10 other government irrigation systems from the DOI to water user associations made up of the irrigators within the systems. IMTP work in HIS includes efforts to organize the farmers, to work with them to plan and carry out physical rehabilitation of the system, and to provide advice and other assistance to the WUAs to make the transfer of responsibilities successful. IMTP work began in HIS in 1998. To date, the Water User Associations (WUAs) have been organized (see below) and efforts to plan the rehabilitation have begun. It is expected that physical works will begin in 1999.

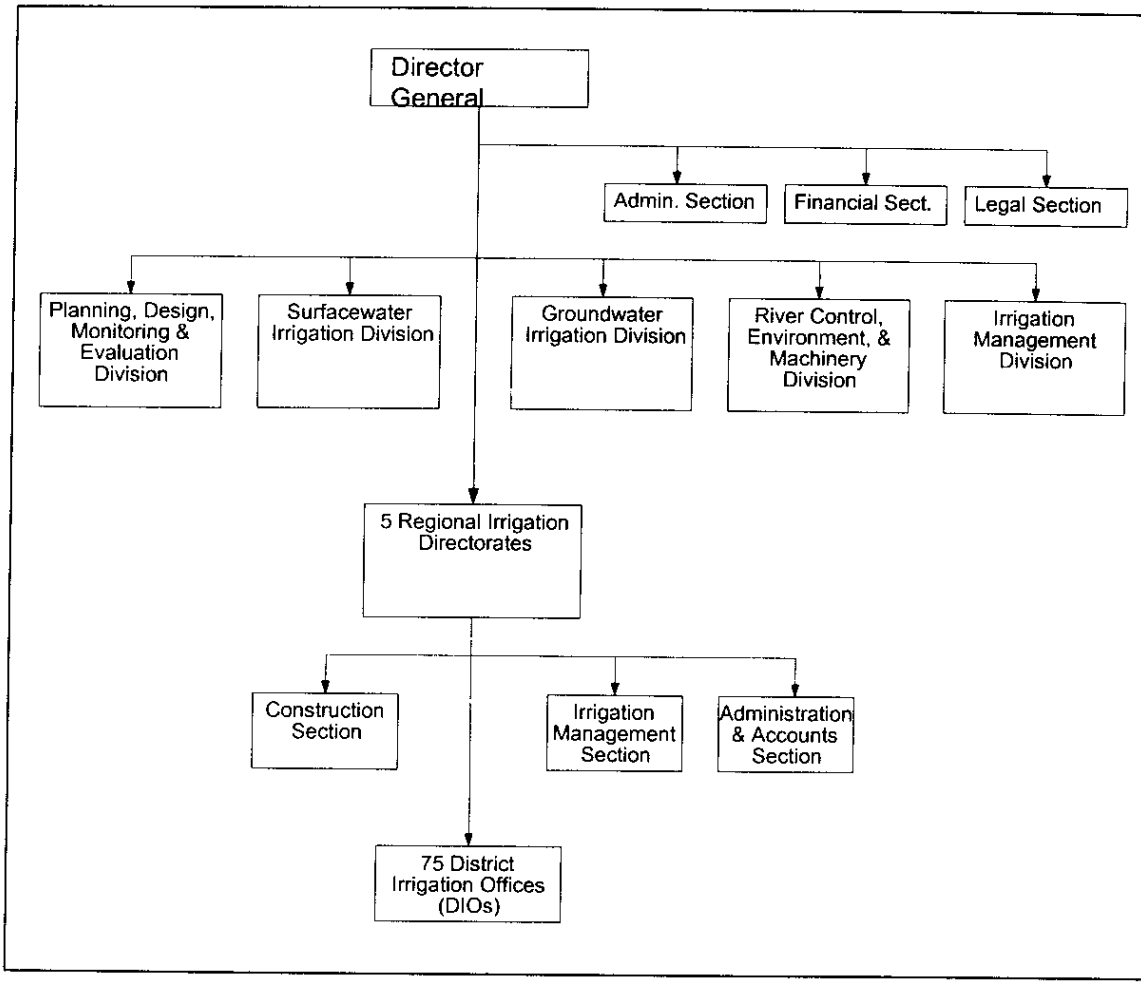

Figure 3. Organization of the Department of Irrigation.

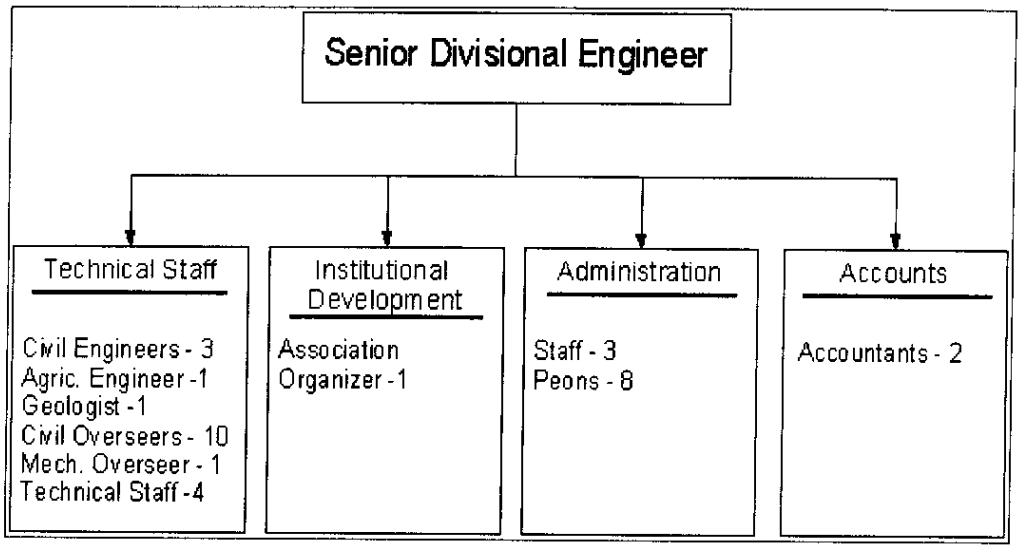

Figure 4. Dhanusha District Irrigation Office.

4.3.2. DOI Organization for Ground Water Irrigation

The Ground Water Irrigation Division of DOI is responsible for ground water irrigation. This division is undertaking the Ground Water Resources Development Project (GWRDP) in the Terai. For the GWRDP, a network of Ground Water Field Offices (GFOs), covering 2-3 Terai districts each is responsible for ground water development. The GFOs report directly to the central Ground water Irrigation Division. The GWRDP is responsible for implementation of ground water investigation activities including the several donor assisted shallow aquifer investigation programs/projects and any other ground water investigation projects. The GFOs are also responsible for implementation of small-scale ground water irrigation projects.

For Dhanusha District, the GFO is located in Jaleshwor, the head quarter of the adjoining district of Mahottari. In 1997-98, government launched the implementation of the 20 year Agriculture Perspective Plan (APP, 1995) under which irrigation has been considered as a priority input. The APP makes development of ground water through STWs the centerpiece of its Terai irrigation strategy. The emphasis on STWs is driven by the fact that they are in the private sector and therefore highly responsive to the incentives.

Under the APP the government has started a new seven-year community ground water project, funded by the Asian Development Bank with technical assistance from the Canadian International Development Association. The project covers 12 Terai districts, including Dhanusha District, in the eastern and central development regions. Under this arrangement a new project coordination unit has been established in Mujhelia near Janakpur, the headquarters of Dhanusha District.

4.4. THE GROUND WATER DEVELOPMENT BOARD

The Ground Water Development Board (GWDB) is a body within the Ministry of Water Resources. The Water Resources Secretary chairs the GWDB. The DOI Director General and the Deputy Director General for the Ground Water Division are among the members of GWDB. Generally the GWRDP Coordinator works as the Member Secretary of GWDB. This body is responsible for, among other activities, planning and overseeing development of ground water for irrigation in the Terai as proposed by the APP.

4.5. WATER USER ASSOCIATIONS (WUAS)

Formation of water user associations (WUAs) wherein water users are organized in multi-level organizations depending upon size and structural complexity of system is wide spread in both government managed and farmer managed irrigation systems throughout Nepal. In government managed systems this concept has been more pronounced since the promulgation of the 1992 Irrigation Policy. In line with this policy, the District Development Committee organized a WUA in 1995 for the whole HIS. However, this WUA took no part in managing HIS and has been replaced.

Under the IMTP, the DIO Association Organizer worked with farmers to establish two WUAs, one for the Eastern Main Canal and one for the Western Main Canal. Within each WUA, there are branch canal committees representing the farmers under each outlet. These organizations were registered on 23 April 1998 in the office of the Dhanusha District Water Resources Development Committee. A separate Coordination Committee comprising representatives of both WUAs has been formed to manage the division of water at HIS diversion structure.

The WUAs are the representatives of all the farmers (2,617 households) with 1,617 hectares of land covering altogether 11 villages (VDCs) of the command area. The members of the WUAs land falls under the command of HIS. Each outlet has a representative in the General Assembly which elects the 4 officers (Chairman, Vice Chairman, Secretary, and Treasurer) of the Main Committee. Each outlet has a Branch Committee comprising 7 or 9 members including Chairman, Vice Chairman, and Secretary who also acts as Treasurer. The organizational structure of the WUAs in HIS is shown in Figure 5.

HIS was selected for management transfer under the ongoing Irrigation Management Transfer Project (IMTP). Under this project, the system is to be rehabilitated. The WUAs have an important role to identify the improvements needed in the irrigation infrastructure. Together with DOI staff, they are to prepare an action plan for system improvement and sign a memorandum of agreement defining the roles and responsibility of the government and WUAs. Actual works are not expected to start for some time because they have to identify the work to be done by contractors and that to be done by WUAs themselves. The WUAs have to put up 26% of the cost of rehabilitation, which could be in the form of labor. There is a Sub-project Management Committee chaired by DIO Chief and includes farmer representatives to oversee the rehabilitation work.

Until the rehabilitation works are completed, the WUAs are to carry out O&M functions jointly with the DIO. After completion of rehabilitation, management of the whole system will be turned over to the WUAs. The present government policy is to turn over all systems up to 2000 hectares, including HIS.

The WUAs have constitutions. These were prepared from a sample set given to them by the DIO by a drafting committee comprising of farmers with education and familiarity with such things. The committee's draft was discussed in the General Assembly and ratified with some changes. Under the constitutions, the functions of the WUAs include:

- Distribution of water to farmers.
- Management of water resources.
- Distribution of water by rotation when there is shortage.
- Encouragement of scientific farming.
- Encouragement of coordination between farmers and agricultural technicians.

The WUAs are also obligated to collect fees.

Discussions with farmers revealed that not all farmers are, as yet, aware of the WUAs, or, if they are aware, understand the functions. Also, it appears that the WUA Branch Committees in HIS are not aware of their roles and responsibilities. The WUA officials would like the Branch Canal Committees to develop field channels, collect irrigation fees, monitor water distribution and help maintain the irrigation system.

4.6. Agriculture Development Bank of Nepal (ADBN)

The Agriculture Development Bank of Nepal (ADBN) is the major institution involved in STW development in the country. ADBN has played a pioneering role in the promotion and development of STWs in Nepal since 1970.

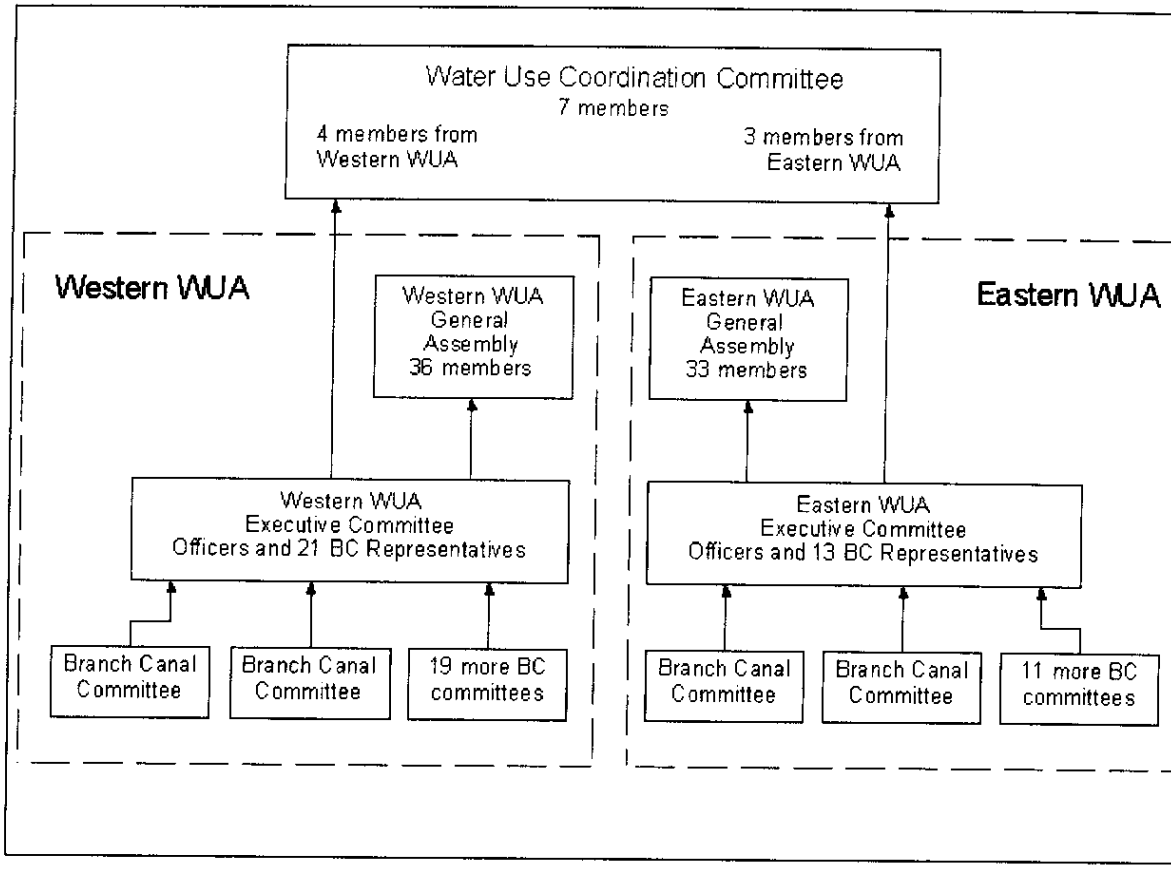

Figure 5. Hardinath Irrigation System Water User Associations.

ADBN helps develop shallow tubewells, and other means of using ground water for irrigation (e.g. hand pump and rower pump types) through the provision of loans, subsidies and technical assistance. STW loans are disbursed to individuals as well as groups of three to four people. The government subsidizes up to 75% on loans taken on a group basis and 30% (in 1998 40% and before that 50%) on individual basis. The ADBN has a subsidy quota amount for each Terai district each fiscal year. Bank officials in Dhanusha District claimed that if there is unsatisfied demand for new irrigation equipment, they manage to get additional resources from the central office. This has been possible because the ADBN gives high priority to STW promotion.

As of July 1998, ADBN has supported the installation of over 45,000 STWs expected to irrigate 154,460 hectares in the whole country. In addition to the standard STW technology, ADBN has supported the installation of dug wells, artesian wells, and surface lift systems as well as rower/treadle pumps, turbine pumps, hydraulic rams, and solar pumps. Under micro irrigation, the Bank has assisted in sprinkler and drip irrigation systems. Under the ongoing APP, ADBN is expected to support the installation of 8,800 STWs irrigating about 22,000 hectares annually.

The ADBN has made recent changes in it policy and procedures because of a fall off in demand for the loans (discussed later). The present policy on giving loans to individuals for STWs is as follows:

1. A farmer with a landholding of 0.33 hectare is eligible to get loan and the subsidy. Previously the area could not be less than 1.0 hectare.

2. The farmer can be paid directly with the cash or issued a coupon from ADBN for buying or collecting STW equipment from a dealer authorized by the Bank.

3. ADBN organizes training in well boring for mechanics. For implementation of the APP, ADBN and DOI are supposed to work in a coordinated manner. The newly established office of DOI at Mujhelia is to work only on the aspect of organizing training for such mechanics.

4. The Bank is to prepare a publicity campaign to create mass awareness of the APP program for development of ground water.

The ADBN procedure for sanctioning a loan for a STW is:

1. The farmer or group of farmers fill in a Demand Form and submit it to the nearby ADBN field office. Copy of the land ownership certificate for which the irrigation facility is proposed has to be attached. Usually the land has to be used as a collateral in getting the loan.

2. ADBN field staff is required to make an inspection of the proposed site and recommend that the site is suitable.

3. Boring is done by the trained local mechanics.

4. Upon successful installation of a STW, ADBN staff is required to make an inspection visit and prepare the well certification record. A STW with a discharge of over 6 lps is considered to be successful.

5. A subsidy of 30% of the loan amount for individually owned STW & 75% for group STW is given. The loan may cover not only the boring but also the purchase of the pumpset. When ADBN issues well certification, the subsidy is deducted from the loan amount. For STWs and for lift and sprinkler irrigation, a three-month grace period is provided before loan repayments start.

6. Every six months, an installment on the loan amount has to be paid. The total loan amount should be paid to ADBN in a period not exceeding five years from the date of the loan agreement.

7. An annual interest rate of 16.5% has been fixed; the previous interest rate was 17.5%.

ADBN's contribution to installation of STWs in the HIS command has so far been rather limited because of the JADP program (see next section).

4.7. JANAKPUR AGRICULTURE DEVELOPMENT PROJECT (JADP)

The Janakpur Agriculture Development Project is engaged in ground water irrigation by developing both STWs and DTWs in a portion of Dhanusha District. This project, which has now been terminated, was implemented jointly by the governments of Nepal and Japan for about 20 years. Some of the activities have however been continued, including ground water irrigation development, under the regular program of the Nepal government.

Beginning in 1977, JADP has been installing shallow, deep and artesian wells in Dhanusha District. A list made available by the project office gives the salient features of 154 tubewells of which over 20% are artesian wells. The artesian aquifers are generally below 200 ft. The discharge from a tubewell was found to vary from 4 lps to 60 lps with the depth of boring from 115 to 225 ft. JADP has categorized about 25% of its wells as unsuccessful due to low yield or no discharge at all. Many of the JADP wells are in the HIS command area.

The JADP procedure for assisting the farmers in tubewell installation and purchase of pumpsets is similar to the ADBN procedure. Following a farmer request, JADP staff locates potential boring sites in the farmer's plot. Unlike ADBN, JADP is not a lending agency and therefore asks farmers to deposit an estimated amount in the project office. For STW development farmers previously had to deposit NRs 1800 to NRs 2000 in cash before the well was installed. Part of the deposit was then reimbursed so the wells cost NRs 1200-1400 each. The required deposit has now been increased to NRs 4300 in cash and the farmer has to buy the pipe, because the program is now run under government funding without outside assistance. Pumpsets are not included in the program. For the installation of DTW previously a group of farmers had to deposit NRs 46,000 which now has been increased to NRs 136,000.

Since the HIS is in the proximity of JADP, most of the STWs in the area have been installed by this program. ADBN's contribution has so far been rather limited in the area. The tubewells developed by JADP are machine drilled and are reported to be in better operating conditions as compared to ADBN wells. In HIS area it was estimated that about 15% of the wells are non-functional.

4.8. DISTRICT ADMINISTRATION OFFICE (DAO)

The District Administration Office (DAO) can play significant role in making effective conjunctive use of surface and ground water. The Chief of DAO is the chairperson of the District Water Resources Development Committee and thus can play a key role in the use of water resources in the district. Regarding ground water, DAO could identify which blocks should be given high priority for intensive tubewell development and help develop a mechanism to work with the district level water agencies to ensure that other inputs like the village roads and electricity are provided for the promotion of conjunctive management of water resources.

As of now the Dhanusha DAO has not been very effective in this area.

4.9. DISTRICT AND VILLAGE DEVELOPMENT COMMITTEES

The District Development Committee (DDC) and the Village Development Committees (VDCs) are bodies comprised of representatives elected through the political parties. Under the government's decentralization policy, the DDC is responsible for preparing the district development plan. The DDC is also responsible for coordination of the activities of various line agencies, non-government

organizations (NGOs) and local bodies, including the VDCs) in planning, implementation and monitoring of the district development programs. Government line agencies are to act as technical units providing necessary technical expertise and human, material and financial resources in launching development programs.

Similarly, each VDC is responsible for preparing a development plan for its village area. VDC areas often include more than one actual settlement. VDCs are also supposed to coordinate the activities of various line agencies, NGOs and local bodies at the village level.

The Dhanusha DDC has no program pertaining to irrigation development.

VDCs are allocated government resources for their development activities. In the HIS area, some VDCs are planning to support STW boring by supplying cash to needy farmers to supplement the loan/subsidy provided by ADBN or JADP. They have collected request letters from some farmers. But they have yet to develop a mechanism of implementation. Also, the Kachauri-Thera VDC has deposited the money to install 3 village owned DTWs in the village area.

4.10. THE WATER MARKET

From the information obtained from ADBN and JADP, it was found that there are about 115 STWs (Table 1), 3 DTWs (Table 2), and several artesian wells in the HIS command area. Given that there are also constraints on the availability of canal water, there has been development of a market in ground water in the command area. Two ways of water marketing exist: sale of water (actually pumping service), and rental of pumpsets. The latter are used by the renter for his own boring, if he does not own his own pumpset, or for lifting water from the river. Water is carried from the STW or lift pumpset to the buyer's field through temporary or permanent earthen field channels.

A key point in this market is that water is not valued as such. A buyer pays for pumping service. This is clear because well owners justify the price charged on the basis of operating costs, not on the basis of the value of water. Also, the cost of water lifted from the river, or for renting a pumpset, is the same as the cost of ground water.

STW owners use their STWs to irrigate their own crops, none has installed an STW primarily to sell water. However, most well owners also sell water to their relatives or to the fellow farmers in the neighborhood. Each STW owner usually has a number of regular buyers. Often an STW is pumped far more for others than for the owner's own use.

The reported price for pumping ground water is in the range of NRs 50 to 60 per hour. However, not all buyers pay this price; some buyers are close relatives: such persons provide the diesel only. They may also give the owner a small present, such as a little mustard oil. STW owners usually ask for prior or immediate payment from those who pay cash.

Farmers reported no problem in making temporary field channels in their neighbors' fields to take their own fields. Sometimes they irrigate the upper fields and gradually shift to the far end fields. They were even found to cultivate the fields in a staggered way that would facilitate the rotational irrigation of their crops. It was reported that, in some cases, farmers buying water regularly from the same STW owner cooperate in constructing and maintaining a field channel that allows them to take the water from the well to the fields of all of them. However, they do not buy water

collectively. Rather each farmer makes a separate deal with the STW owner. Water may be conveyed up to two kilometers from the STW.

One key feature of this market is that well owners always demand payment, from those who must pay cash, immediately. Payment is not delayed. If a buyer has a close relationship with the well owner, he may be able to provide diesel, in which case he is still paying immediately.

4.11. CUSTOMS AND CULTURE

All of the earlier discussions except the discussion of the water market deal with government agencies or government recognized water rights and water user associations. The local people, however, have a set of institutional resources that can be used for water resources management if they find it useful to do so. The local people are identified by their language as Maithili people and the area is sometimes called Mithila. Unfortunately, there are no ethnographies of the Maithili that can be used to identify these institutional resources and the short study period was not sufficient time to inventory such resources.

However, the Maithili people are much like other North Indian people found in the Indo-Gangetic Plains. Indeed, the primary concentration of Maithili people is in Bihar in India. This suggests that the key social organizational principles that widespread in the area are likely to be relevant to the Maithili people. These organizational principles include, among others: village, caste (jati), kinship, and faction (Leaf, 1998). Indeed, one Nepali anthropologist (Bista 1996: 119-129) describes the Maithili, along with several other Terai groups, under the heading of "Brahman, Rajput, and Occupational Castes" rather than as a group in their own right.

The general acceptance of the validity of these concepts makes it possible for farmers to organize themselves as a village group, if they want to. On the other hand, or to create subgroups within a village on the basis of factions (generally aligned with political parties), on the basis of caste, or as a group of close relatives (e.g. "brothers").

There are other cultural principles, such as Hindu principles that suggest one should help another, that make it possible for some individuals to cooperate, even without a relevant organizational concept, but without guarantees of continuation of such cooperation over time. The hierarchical concept implied in caste, affects the ability to cooperate, since cooperation between persons of different castes is not supposed to be equal, but must reflect the superior-subordinate relation. Thus, for example, it is quite likely that a seller of water will accept a lower payment from a caste mate, particularly a close relative, than he will accept from a lower caste buyer of water.

The great majority of the farmers within the HIS area belong to the Yadav caste, a lower caste. This affects their willingness and ability to create larger cooperative groupings since higher caste persons can often interfere with the groups created by lower caste persons.

Nepal has a multi-party system of democracy. There are numerous political parties. As mentioned, local factions are generally associated with political parties (although membership is generally based on local issues and interests rather than national ones). There are instances where because of the political reasons, people disagree on mutually beneficial development works, making collective action more difficult.

The basic mode of supravillage cooperation is through coordination by government - a basic South Asian pattern and one that not only is traditional but is often pushed by government officials since it is to their personal advantage (Leaf, 1998). Thus, locally managed supravillage groupings, however, require appeals to other concepts such as the idea of "association" or other western cultural imports. These generally function only when supported by the government, as are the present WUAs in the HIS.

It follows from this discussion that farmers often can, without too much difficulty, organize themselves in subgroups within a village, or sometimes at village level. However, at supravillage level, and sometimes even within villages, government intervention or, at least, approval is needed to ensure cooperation.

4.12. PRIVATE BUSINESS AND SERVICE ORGANIZATIONS

There are also various private organizations that play a subsidiary role in water resources development and management. For example, recently, private drilling agencies have been emerging in the area. There are also the mechanics who maintain pumpsets. Of course, as discussed below, farmer decisions about irrigation are based in part on the costs and benefits of irrigation. The benefits are dependent in part on the existence of the organizations that provide marketing infrastructure for crops, etc. These are not further discussed here.

5. MANAGEMENT METHODS IN THE HIS

By management methods, we refer to the techniques used by managers to:

- to make decisions about distribution and use of water for irrigation,
- to implement those decisions,
- to monitor the implementation and results of those decisions.

These techniques are necessarily constrained by the water resources, technologies, and institutions available. In addition, however, they are also constrained by the resources available to managers to use the techniques.

Therefore, in this section, we identify the managers, define the scope of their management responsibilities, identify the limiting resource constraints, and then explain the management methods used.

5.1. CROP WATER APPLICATION

The main cropping sequences prevalent in HIS command area are:

- Monsoon Paddy - Wheat
- Monsoon Paddy - Oilseeds/Pulses/Tobacco/Vegetables
- Monsoon Paddy - Potato
- Monsoon Paddy - Fallow
- Early Paddy - Monsoon Paddy - Wheat
- Sugarcane

It is obvious that the most important crop grown in HIS command area is monsoon season paddy. Almost the whole area is cultivated in paddy during the monsoon season. The other major crops are wheat, potatoes, oilseeds and pulses; all planted during the winter season. About 60% of the area is planted with wheat in the winter season, most of the remaining area is covered with a variety of crops. Early paddy is grown only in limited areas because of lack of water. Most of the remaining area is fallow during the early monsoon season. Maize which is a major crop grown in many parts of the country is hardly planted in the HIS command area. Most of the area is double cropped but there is little triple cropping. Sugarcane is an annual cash crop and is grown only on a limited scale.

Upland areas where irrigation water is not easily available have fruit orchards with vegetables and pulses. The orchard usually includes fruits trees such as mango, lychee, blackberry and guava.

For most crops, the method of water application is basin flooding. Within a single farmer's area, he will have several bunded basins. Most farmers have no channels to these basins; generally water flows from one to another within the area. In many cases, one farmer will get his water from another farmers' fields.

5.1.1. Preferred Water Application for Monsoon Paddy

Farmers plant both local and high yielding paddy varieties and also make use of chemical fertilizer. Farmers reported that with assured irrigation they grow improved varieties and apply chemical fertilizers. In rainfed areas they go for local varieties. The 1998 monsoon paddy was heavily

infested by the insects and farmers made an unsuccessful attempt to control it by using high doses of insecticides.

For paddy, farmers to prepare a nursery for seedlings by plow and level a plot. Generally farmers use about 500 square meters for each hectare of field to be planted. The plot is seeded by broadcasting. While making the nursery, the farmers take care that the seedbed remains wet, well manured and fertilized. One month old seedlings are considered ideal by farmers for transplanting. The seedbed is generally prepared in June at the beginning of the rains so that transplanting occurs in July following the preparation of the regular fields by plowing and leveling.

During land preparation, the land is soaked and puddled to decrease percolation, increase water holding capacity, and check weed growth. If cracks develop in the heavy clay soils, much water is lost by deep percolation. The researchers in the Hardinath Agriculture Farm reported that water used by farmers to complete land preparation is much more than required because the activity is stretched over long period. This is largely due to the labor shortage in the area. Since local wage rates are low (NRs 40-50 a day) many people go to Punjab in India. Also, there is little or no mechanization. Since paddy is the most important crop and planted in the entire area, farmers find it hard to have timely planting and saving the scarce water resource.

Farmers believe that, during crop growth, submergence (up to 10 cm) of the soil is favorable for paddy until grainfilling is complete. They believe that evapotranspiration should be maintained at the potential evapotranspiration rate to achieve high yields. Following grainfilling, the field can be dried.

The results of experiment for gross water requirements of paddy in the Hardinath Agricultural Farm at different growth stages range from 10 to over 16 mm/day. Depending on the crop variety and the growth period the consumptive use varies. For a 100 day variety the seasonal consumptive use ranges from 1000 mm to 1600 mm.

Although submergence of paddy is preferred for almost the whole crop growth period, farmers believe that the most critical period is the grainfilling stage. If water is short, farmers will make strong efforts to get sufficient water during grainfilling.

5.1.2. Preferred Water Application for Winter Wheat

Winter wheat is cultivated where water supplies are more favorable, i.e. in those plots close to the canals, borings, or moist areas. Wheat is directly seeded into the fields in December, following land preparation. Improved varieties and fertilizers are used.

Farmers usually prefer two waterings for wheat; the first should be 22 days after seeding and the second 22 days later. Results from an experiment in the Hardinath farm indicate that the total seasonal consumptive use of wheat ranges from 240 to 266 mm. The consumptive use during the peak period - from flowering to grainfilling - stage is 3.4 to 3.9 mm/day.

Farmers believe that the first watering is critical for wheat; the second is much less important.

5.1.3. Preferred Water Application for Early Monsoon Paddy

Early paddy is planted in small areas as it is grown in the dry months of April and May season and harvested in July, preferably prior to the onset of heavy monsoon rains. For early rice, paddy seedbeds are prepared in late March or early April.

The preferred water application for early monsoon paddy is exactly as for monsoon paddy. However, there are severe limitations to the area where it can be planted. Early monsoon paddy is found in the HIS only in three areas:

- At the head reach of HIS where there is some canal water to supplement ground water,
- On the Hardinath Research Farm where the canal water is augmented by ground water from its own deep tubewells.
- At the tail ends of the canal systems where there are artesian wells.

In most of the middle and tail of the system, neither canal nor surface water is available during the early monsoon season and rainfall is scanty. In the tail, as there is no surface water available, farmers have not installed STWs and the entire area is purely rainfed, except for the few farmers with artesian wells.

Generally, only those with artesian wells go for early rice. As is shown below, water pumped from an STW is considered too expensive if there is no additional source of water.

5.1.4. Water Application for Other Crops

A major portion, perhaps 40%, of the HIS area is planted with other crops during the winter season. These other winter crops include potatoes, pulses, tobacco, peas, mustard, onion and vegetables. For most of these crops, furrows are made in the bunded fields; irrigation is by flooding the furrows.

Potato is the only cash crop that has a potentially large market in the area. Potato is the usually irrigated only once in a season by flooding. Vegetables are grown on a small scale for home consumption and need more frequent waterings. Vegetables are hand-watered. The other crops mentioned are not usually irrigated as they are grown on the residual soil moisture.

5.2. Distribution of Surface Water in the HIS

For the distribution of water from the Jalad River via the HIS canal system, there are three sets of managers to be considered. These include the District Irrigation Office (DIO), the water user associations (WUAs), and the farmers collectively.

5.2.1. Canal Management by the District Irrigation Office (DIO)

In Nepal, government irrigation system development has taken two forms. In the first, the government built the main system only and the rest was left to farmers to develop. In the second, the government has done much more, sometimes down to on-farm development works. The Hardinath Irrigation System was developed under the first form.

When Hardinath Irrigation System was built, no participation was sought from farmers during construction of the headworks and main canals. After commissioning, the responsibility for

operations and maintenance (O&M) of the headworks and main canals was taken over by the then Canal Department through Hardinath Sub-Division office. An irrigation service fee was levied on the irrigators to pay for irrigation services and the collected fees were sent to the national treasury. Until 1998, O&M for the HIS main system officially remained the sole responsibility of the Department of Irrigation, successor to the Canal Department. This responsibility was assigned to the District Irrigation Office. Since 1998, canal operations, including operations of the headworks have been the joint responsibility of the DIO and the WUAs.

The resources provided to the DIO by the government for O&M have not been adequate. The annual budget for O&M in HIS has generally been much less than required to meet O&M needs. Over the past 10 years, the total annual O&M DIO expenditure for the HIS has varied between NRs 80 to NRs 240 per hectare. The actual requirement is in the order of NRs 600 per hectare in present NRs. Due to lack of adequate budget, desilting of main canal was not done for the last three years. No major rehabilitation has ever been done. Also, the real amounts provided for management of the HIS have decreased over time. In the past, for example, the budget was sufficient to hire temporary workers to act as gate operators or, more often, to undertake routine maintenance. No such funds have been available for the past few years. Pay for the DIO staff is also low and the staff members are not well motivated.

The HIS head regulator is operated by the DIO; three operators are assigned to the head regulator. According to both farmers and DIO staff, prior to 1998 the DIO would operate the headworks and main system as follows:

- From mid-July to mid-September, when river flows are high, the headgates for both main canals were left open and the canals ran continuously. This is the major portion of the monsoon paddy season.

- For the rest of the year, irrigation water was supplied to each main canal on a rotation. Rotations were made by alternately opening the main canal headgates for four days each.

Reportedly, in the past, no operations were carried out by DIO staff on or below the main canals. However, they would inspect areas to see how well farmers were distributing water.

As pointed out earlier, the poor physical condition of the canal and the lack of control structures are major constraints to canal operations. As mentioned, the poor physical condition was caused in part by lack of maintenance funds.

5.2.2. Canal Management by the Water User Associations (WUAs)

As mentioned, until 1998 there were no regular organizations of the farmers for irrigation system management within the HIS. With the formation of WUAs under the Irrigation Management Transfer Project, the WUAs have began to play a direct role in system O&M. Beginning with winter season 1998-99, canal O&M is handled jointly by the WUAs and the DIO. When physical rehabilitation is completed by the IMTP, it is planned that the WUAs will take full O&M responsibility.

The present division of responsibilities between the DIO and the WUAs is that the headgates for the main canals are operated by a DIO staff member, theoretically as advised by the Canal Coordinating Committee created by the two WUAs. All other operations are carried out by the WUAs with

occasional DIO advice. The WUAs invite DIO officers to their meetings, although the DIO staff told us that they rarely attend.

5.2.2.1. Headworks Operations

The Coordination Committee of the WUAs meets when there is scarcity of water at the source. For winter 1998, they decided initially that they would allow water into both canals during the critical irrigation period for wheat (around the 22nd day). Later, however, it was decided, to allow maintenance work in the Western Main Canal, that water would be given to the Western Main Canal only for the first wheat irrigation but the Eastern Main Canal headgate would be left open to divert water from the Western Main Canal. Thus water was directed alternately into the main canals for three weeks beginning in the last week of January. Then the Western Main Canal was closed and the Eastern Main Canal left open.

Some committee members noted that the DIO staff member who is supposed to operate the headgates as per the Coordination Committee's orders, does not always do so.

5.2.2.2. Operations below the Headworks

The Chairmen of both WUAs said that their O&M goals are that every member should get water for his fields, and that every member should contribute for maintenance based on the area he irrigates. He also stated that water distribution should be as equitable as possible without partiality.

The WUAs decided that water would be delivered continuously when the canal flows at full supply level (i.e. water supplies are plentiful as in monsoon season), but that when there were shortages, they would implement schedule deliveries. It was decided that the schedule would depend upon the area to be irrigated.

For winter 1998, the WMC WUA implemented a schedule by closing upper outlets on the main canal when irrigation under those outlets was finished. The WUA has employed a man to monitor water distribution. He checks the areas to be irrigated and closes outlets when done. The general rule is 4 bighas (1.5 bigha makes a hectare) require water for 2 days. They have 24 outlets; during the three weeks the canal was open, some outlets ran as much as 8 days. During the first portion of the period, the outlets at Falls 1, 2, and 3 took all the water, then the lower outlets got water when the upper ones were closed. Following the three week open period the canal was closed for cleaning. Although the original plan was that they would be able to complete the work and reopen the canal in time to give a second irrigation to the wheat crop, when we were there, it was apparent that they would not complete the cleaning work on time. Also the river flow was low and they thus were not planning to give a second irrigation.

The EMC WUA also planned rotational deliveries for the winter 1998-99 season. In addition, they planned to stagger crop operations so that they can get water to all in the winter. for this first season of operations, they defined two sections of the main canal: 1) the outlets at Falls 1-3, and 2) the outlets at Falls 4-6. Like the WMC, they have hired a person to implement this rotation during the whole season.

In the longer WMC, the farmers told us that this season is the first winter season that water has reached the tail of the main canal; a fact that they attribute to the scheduled and controlled deliveries. Also, there were no complaints made to WUAs or the DIO by the farmers over WUA management in winter 1998-99.

During the monsoon season, the WMC WUA officers expect that the entire present command area (1700 bighas or 1133 hectares) will be irrigated, almost all under paddy. The actual potential area is bigger and they hope to bring more area under irrigation in the future. The EMC WUA officers also expect to irrigate the whole of the command of EMC during monsoon season. Also, like the WMC WUA, they expect to be able to expand the area irrigated.

Below the main canal, it is the responsibility of each branch committee to distribute water to all those who have registered as members of the WUA and who want water. To become a member, a farmer must pay a one time membership fee of NRs 10 to ensure his water right. The WUA officials stated that they would not offer membership to a farmer if they could not get water to him. It is the BC committee who decides on members. Thus the schedule depends on these agreements and the availability of water.

In fact, in winter 1998-99, water distribution below the outlets was carried out more or less by individual farmers according to long established precedence rules.

During the year, the WUA Main Committees hold monthly meetings where they discuss water deliveries during the preceding month and make necessary adjustments. Planning is supposed to be done by season. The WUAs are charging members irrigation fees of NRs 120 per hectare for both wheat and paddy. The branch canal committees are collecting fees which they will pass on to the Main Committees for deposit in the bank.

5.2.2.3. Maintenance and Rehabilitation

As mentioned earlier, until 1998, maintenance of the headworks and main canals was the responsibility of the DIO; maintenance below the main canals was the responsibility of the farmers collectively. In fact, however, little maintenance was done by the DIO, and, reportedly, maintenance below the main canals was sporadic and not very effective.

As described below, in the upper portions of the EMC area, farmers have a history of cooperation in maintenance. No such history exists in the WMC area. However, following the formation of the WMC WUA, the WUA decided to undertake the desilting of the WMC. As mentioned earlier, there was almost a meter of silt in the head reach of the WMC. This work began in January 1999.

Under the IMTP, rehabilitation of the system will be done. Most of the interaction with DIO personnel is on the subject of rehabilitation. To date, the WUAs and the DIO have jointly identified the improvements required and are developing action plans and agreements that will specify the work to be done by the WUAs and the contractors. No works have yet been undertaken. Under the IMTP, the WUAs must agree to cover 26% of the costs of the physical works, usually in the form of labor.

It is expected that rehabilitation works will be begun during the 1999 early monsoon season. Thus there is expected to be no canal irrigation during this season.

5.2.3. Collective Management of O&M by Farmers

Prior to the formation of the WUAs in 1998, farmers collectively took responsibility for certain activities. As noted earlier, farmers have customary distribution practices below the outlets so that water is distributed without a great deal of conflict. However, little maintenance was done. One major exception was that, in the Eastern Main Canal, an annual meeting of the local leaders (not

necessarily VDC officials) would be held to plan maintenance of the upper portions of the main canal. The work would be carried out through labor contributions. One interesting feature reported was that the leaders asked for lone day of labor per household from landless in addition to larger labor contributions from farmers. Their argument was that better irrigation helped the landless by creating more opportunities for labor to work on the farm.

5.3. Distribution and Use of Ground Water in the HIS

Ground water management is almost exclusively carried out by individual farmers, either through the use of their own wells, or by buying ground water (pumping services) from others.

A farmer with a functioning STW or artesian well has absolute control over when he takes his water; his primary physical limitation is the discharge of his well. A farmer dependent on someone else's well is dependent on the arrangements he is able to make with the well owner. In either case, the source is more dependable and more controllable than is river flow.

The major problem is the cost of obtaining ground water. Most importantly, as we will show, the cost of irrigation from an STW is high enough that farmers have to consider carefully the returns against the costs whenever they operate their pumps or whenever they buy water for irrigation. Because of the high cost, ground water is generally used for irrigation only when rainfall or canal water are insufficient. Rainfall is free, of course, and canal water is much less expensive than STW water.

In this section, we discuss management of wells for the irrigation of the primary crops: monsoon paddy and winter wheat. Then we take up the questions of selling water and well installation, before concluding with some general observations on management of ground water in HIS.

5.3.1. Use of Ground Water for Monsoon Paddy

There are two concerns, 1) providing irrigation water for the paddy seedbeds, and 2) providing water for the crop once it is in the field. Seedbeds are normally planted in June and the paddy is transplanted to the main field in July. The rice is harvested in October or November.

During July and August, the periods of heaviest and most reliable rainfall, there is little need for irrigation of paddy. During this period, too, the canals have the most abundant flow and many farmers can use canal water to supplement the rainfall. Thus, except for extended dry spells, farmers hardly make use of the STWs for irrigating monsoon paddy. Most problems arise early in the season, while preparing the seedbeds, and later in the season during the critical grainfilling stage in September-October.

Farmers reported great variation in crop yields depending on water availability and the use of other production inputs. Reported yields under rainfed conditions are about half of those reported for irrigated conditions. This difference occurs not only because of the less reliable source of water, but also because, under rainfed conditions, farmers plant local rather than improved paddy varieties and use far lower amounts of fertilizers.

Farmers said that they make use of ground water to get increased production and in general they have to give one ground water irrigation each season. Some farmers having elevated areas where canal water cannot reach depend upon STWs or lifting from the canal. Such farmers generally

irrigate their paddy crop at least three times including during the critical grainfilling stage. As shown below, they cannot afford to keep water flowing continuously in the fields as is considered ideal. Even farmers with access to canal water report that most have to irrigate with ground water at least once a season.

For example, one informant had 6.7 hectares of land in five locations. Some of this land is too high to get water from the canal. He owns two borings and one pumpset. He is using improved rice varieties now with chemical fertilizer; without the borings he would use traditional paddy varieties. He irrigates his seedbed three times from the borings if necessary, but waits for rain for transplanting. In one of the higher plots, he irrigates solely with purchased ground water because it is not located near his borings; in this plot, he plants only monsoon paddy, it is left fallow the rest of the year. In the others he uses canal water if possible or if not pumps from his borings. One of his borings is located immediately adjacent to the WMC so that he can use the canal to take water to his land.

Given the variability of the onset of the monsoon, it often happens that the rains do not arrive before it is necessary to prepare and plant the seedbeds in order to ensure the correct timing for the winter crop. Thus, for paddy seedbeds, farmers often must depend on STW water. For paddy seedbeds, up to 3 shallow irrigations may be provided if the rains are deficient. Normally, each irrigation requires 8-10 hours of STW pumping per hectare. At the average operational cost of about NRs 33 per hour, this amounts to at least NRs 264 per hectare per irrigation. At the lower quoted sale price of NRs 50 per hour, this amounts to at least NRs 400 per hectare per irrigation. However, because each hectare of seedbed serves about 20 hectares of field, a farmer with a relatively small holding will need to pay only fractions of these costs; thus groundwater will be used for paddy seedbeds when considered necessary.

The situation is quite different for irrigation of the crop, because the cost of ground water irrigation can become a major component of the cost of paddy production. Production costs for irrigated paddy production include: human and bullock labor, chemical fertilizers, organic manure, plant protection (pesticides), seeds and irrigation costs. For normal management decisions, the farmers do not consider household labor inputs, use of own draft power, use of farmyard manure, or returns to land or other capital investment as part of the costs. All of these should be considered to properly evaluate the profits from irrigated agriculture.

Table 5 shows revenues and cost of production for one hectare of monsoon paddy, not including the cost of irrigation. This indicates that the gross profits would be about NRs 20,000 per hectare. We believe that this overstates the profits since yields are often lower than the 3 tons per hectare reported by our informants. A reduction of half a ton would lower profits by NRs 5,000.

Uptill now, government irrigation fees have been very low and often uncollected, hence farmers have generally considered canal water, like rainfall, and a free commodity. This may change if the WUAs are able to enforce their price of NRs 120 per hectare for a season's irrigation from the canals.

Table 5. Representative Per Hectare Costs and Revenues of Production for Irrigated Paddy.

Item	Unit	Quantity	Price (NRs)	Value (NRs)
Revenue				
Value of production	metric ton	3.0	10,000	30,000
Costs				
Seeds	kg	45	20	900
Chemical fertilizer	kg	150	17	2550
Insecticides	sum	-	-	750
Human labor	person-day	75	50	3750
Bullock/tractor rental	sum	-	-	900
Gross Profit				21,150

Note: These figures are averages of several interviews with farmers, at some of which there were more than one farmer who discussed the questions and reached a representative answer. These figures are not based on a formal survey of farmers' reported costs and production. This table refers to 1998 monsoon season.

Ground water costs are significantly more. Farmers say that it takes 10 hours of pumping to irrigate a hectare of paddy. Therefore, if a farmer has to buy ground water at NRs 50 per hour, he has to pay NRs 500 per hectare per irrigation. If there was inadequate rainfall, farmers say they would have to irrigate paddy at least three times to get a crop. This makes the cost of irrigation about NRs 1500 per season. Even if he owns his own STW and figures costs at the operating cost figure of NRs 33 per hour, he would have to pay NRs 330 per hour for ground water irrigation.

Given the present profitability of paddy (Table 5), investment in ground water appears to be worthwhile. Although farmers do not evaluate their own and their family's labor as part of the cost of production, farmers do take family labor and capital into account when evaluating additional investments. If we add 100 person days of family labor per hectare as an input (a low estimate) to Table 5, we reduce profits by NRs 5000; expense of another NRs 1500 for irrigation then begins to become more significant and farmer-reluctance to spend on STW irrigation becomes more explicable.

The biggest problem reported by farmers is lack of cash when needed to buy ground water. Well owners are unwilling to delay payments until after the season; privileged persons (close relatives for example), including well owners, have to, at least, provide the diesel needed for the pump operation. Non-privileged persons have to come up with the cash either before pumping or immediately after it.

5.3.2. Use of Ground Water for Winter Wheat

Unlike paddy, wheat is directly seeded, usually near the end of December. Farmers believe that winter wheat should be watered twice, once 22 days after seeding, generally in mid-late January, and then 22 days later, generally in mid February. Standing water is not desired. The first watering is considered critical and most farmers will not plant wheat unless they have some assurance of water. The second watering is not considered critical and many farmers will not give a second watering when costs of irrigation are high. As explained earlier, in 1998-99 winter season, the

WMC WUA more or less decided to completely forgo providing canal water for the second irrigation in order to allow them to finish cleaning the head reach of the main canal.

Table 6 shows the costs and profits for a hectare of winter wheat without accounting for irrigation, household labor, own draft power, and farm yard manure. This shows that the profit from a hectare of wheat would by a little under NRs 10,000, without considering the cost of irrigation.

Table 6. Representative Per Hectare Costs and Revenues of Production for Irrigated Wheat.

Item	Unit	Quantity	Price (NRs)	Value (NRs)
Revenue				
Value of production	metric ton	2.4	7,000	16,800
Costs				
Seeds	kg	120	7	840
Chemical fertilizer	kg	120	17	2,040
Insecticides	sum	-	-	150
Human labor	person-day	60	50	3,000
Bullock/tractor rental	sum	17	-	850
Gross Profit				9,920

Note: These figures are averages of several interviews with farmers, at some of which there were more than one farmer who discussed the questions and reached a representative answer. These figures are not based on a formal survey of farmers' reported costs and production. This table refers to 1998-99 winter season.

Water is provided as follows:

- Although November through March are the driest months of the year, there is a chance that rain will fall (Table 1). If there is adequate rain at the proper times, farmers give no irrigation.
- In some parts of the HIS canal water is normally available for the first watering. It is less reliable for the second irrigation because of decreased river flow. As mentioned earlier, farmers have, in the past, viewed canal water as a free good. That may change if the WUAs enforce fee collection.
- One farmer estimated that it takes eight hours to irrigate a hectare of wheat. Then a person who has to buy ground water will pay NRs 400-500 per hectare per irrigation. A farmer with his own tubewell will pay about NRs 264 per hectare per irrigation in operating costs.

As with paddy, if we consider returns to family labor and capital, profits are even more vulnerable than profits from paddy. Generally, if farmers have to use ground water, they give only the first irrigation to reduce costs and to avoid the problems of not having the needed cash.

5.3.3. Installing a Tubewell

The crop economics shown above would indicate that installation of a tubewell would be highly desired even though farmers often try to use alternative sources to avoid the high operational costs of their tubewells. In fact, there is a clear demand for installation of wells, including STWs, DTWs,

and artesian wells. Artesian wells are restricted to a relatively small portion of the HIS tail area and will not be further considered.

As reported earlier, the present cost of installing an STW is about NRs 50,000. If this can be amortized over 20 years, the annual cost is NRs 2500. A farmer with access to canal water spends perhaps NRs 2000 per hectare per year to buy ground water from a well owner. Even a well owner has to spend up to NRs 1000 per hectare per year in operating costs. Thus, it seems uneconomical to invest in an STW for a one hectare farm.

The value of an STW depends a great deal upon a farmer's landholdings. The process of land fragmentation has ever been resulting in a decrease in average landholding size of a farm family. The average landholding is less than a hectare, and that too is spread in several parcels at various locations. For a farm smaller than a hectare, it is clearly not worthwhile to invest in an STW for own use, whereas for a farmer with much larger landholdings, it may be more worthwhile, even to the extent of installing 2 or more borings. Several farmers have more than one boring, although most have only one pumpset which can be moved among the borings.

There are two factors that have a major effect on the value of the purchase of an STW:

- One factor is the possibility of getting a subsidy for the STW. A few years ago, the subsidy rate was 50% for wells purchased with a loan from the JADP or the ADBN. With such a subsidy, the purchase of an STW is a good deal because even though the cash outlays are the same, having an STW gives the farmer control over his water supply.

- The second factor is the possibility of selling water to others. Sales of even 100 hours of pumping a year at the consensus rate would bring in NRs 5000 or more. The average rate is somewhat lower, but if sales bring in NRs 2000 per year, the STW almost pays for itself.

For farmer's own use on a one hectare farm, a tubewell purchased at a 50% discount is a borderline investment, because operating costs are so high when compared with the capital cost. Thus it is not surprising that the ADBN reported a significant drop in demand for STWs over the past three years as the subsidy has been decreased from 50% to 30% or less. It is also not surprising that at least one Village Development Committee is considering use of government development grants to supplement the ADBN and JADP subsidies.

The high operating cost, when compared with the investment cost also explains why few farmers are willing to purchase an STW unless they also have access, at least sporadically, to cheaper canal water. In most of the middle and tail of the system, canal water is not generally available. Thus STWs are found up to the sixth fall in the under the WMC (aside from the northern areas where groundwater is not available. STWs are found in most the command of the shorter EMC. The tail of the WMC and the extreme tail of the EMC are purely rainfed, except for the few farmers with artesian wells.

There is a potentially good return to the investment in an STW if sales of 200 hours or more a year can be realized. For example, we learned of one STW that sells water for 10-20 hours per day when ground water is in demand. However, there were no reported cases where an STW was installed only to serve the ground water market; in all cases, the well owner also uses the well for his own lands. We suspect the reason lies in the unreliability of the market, given that most farmers attempt to minimize their use of ground water because of the relatively high costs.

Why then are there not more STWs installed in the area? First, as pointed out, the ground water market is not considered reliable and, without sales of water, an STW is not necessarily a good investment, particularly at a subsidy rate of only 30%. Second, as explained to us by farmers, there are other difficulties involved. These include the difficulty in putting together enough cash at a single time to put up the deposit required by the JADP program. For the ADBN program, the primary problems reported by farmers are the red tape and extra payments involved in getting a loan.

The present subsidy programs offer a 75% discount for purchase of a tubewell (STW or DTW) by a group of farmers. We asked why farmers did not get together to purchase an STW. Farmers told us that they were not capable of organizing themselves for this purpose. While we doubt that this is the complete truth, there are real difficulties involved. As one farmer pointed out, they would have to choose a spot and because the farmer on whose land the STW is located would have an advantage, choosing the spot is difficult. As pointed out above, the local social capital does not include any common concept of a small group of field neighbors jointly owning a capital item such as an STW, although a version of an FMIS would serve the purpose.

A DTW is simply too expensive for a small group of farmers to consider. However, one village in the HIS command has installed a DTW for irrigation by village members. It is conceivable that villages could install and operate a network of STWs to serve the villagers. However, at present, village level governments do not have all the powers necessary to create and operate public utilities such as this would be.

5.3.4. Well Usage

We have pointed out that cost considerations limit both the installation and use of wells for irrigation even though there are rich groundwater resources underlying almost the whole of the HIS area. The annual average use of STWs in the area is reported to be in the range of 400 to 550 hours against a potential use of 1500 hours. This clearly indicates underutilization of the STWs. This is, however, considerably higher than the average use. For the Terai as a whole, one study (Koirala 1998) reported an annual average of 162 hours per STW. Another study (IIMI 1991) reported an annual average of 168 hours per STW.

The underutilization may occur because the presence of canal water in at least part of the area some of the time reduces the total per hectare cost of purchase water or operating an STW to a more reasonable figure than it would be in areas without canal systems. That is, farmers appear to be unwilling to depend fully on STWs because of the high cost; most use of STWs for irrigation is conjunctive use.

This attitude is explicable if we remember that the average irrigated landholding is less than a hectare. As shown earlier, a farmer with one hectare of land can expect to make a return to his labor and capital of about NRs 30,000 from a crop of monsoon rice followed by a crop of winter wheat. This is about NRs 2500 a month to cover family expenses, a low value. This should be compared with possible earnings from going to Punjab to work as an agricultural laborer. In Haryana and Punjab there is a demand for labor and wages up to Indian rupees 100 per day are reported. This would be about NRs 150 per day. Even if a migrant works only 20 days a month, he earns more from such labor than from farming in the HIS. Farming in the HIS is simply not profitable; farmers told us that, on an average, they barely make their expenses as is; thus they are not prepared to invest more.

6. PERFORMANCE OF THE HIS

This section attempts to evaluate the performance of the systems for exploiting water for irrigation within the command of the HIS. We are severely hampered by the lack of flow records, either for the river or for anywhere within the canals.

We consider three items:

- water distribution to see where the water goes,
- agricultural production to learn what the product of that water is,
- environmental effects to see whether the present use is environmentally sustainable or whether the affected natural environment can be improved.

Each is dealt with separately below.

6.1. WATER DISTRIBUTION

If we consider just the canal system, water distribution within the HIS area is extremely poor. The HIS was designed to serve an area of 2,000 hectares, but currently it is providing monsoon season irrigation for only 1,200 hectares and winter season irrigation for about 300 hectares.

Recent figures from a survey carried out by the District Irrigation Office (DIO) for the Irrigation Management Transfer Project (IMTP) have found that, as developed by the farmers, the actual command area is 1,617 hectares: 845 hectares under the EMC and 772 hectares under the WMC. There are 1200 farm families to be served by the EMC and 1429 to be served by the WMC. This the area where farmers feel they have a claim to canal water.

Failure to serve the designed command, even in monsoon season, is due to three reasons:

- Part of the problem is lack of water and variability of flows in the river. Both main canals were designed to have capacities of 990 lps. But the recorded discharge in the EMC on 15 January 1999 was 168 lps and the discharge in the WMC on 16 January 1999 was only 105 lps. These flows are only 16.8% and 10.5% of the design discharge. Aggravating the situation are the five FMISs upstream from the HIS, each of which commands about 200 hectares. During times of water shortage, farmers of these systems divert most of the surface flow with brush dams.

- Failure to serve the designed command area is also due to the poor conditions of the canal system caused by lack of maintenance as described earlier. Poor condition of the canals and structures leads to high losses and lack of ability to control the flows. In addition, because the design and construction of the water distribution system was simply left to unorganized farmers, there are numerous places where the canals were not constructed to serve the planned area.

- Finally, lack of personnel and operations planning have left operation of the canal system to unorganized farmers. The result has been, as expected, that farmers near the head of the system take the water they feel they need without regard for farmers further downstream.

However, farmers make use of the abundant ground water resources available in the area to supplement the canal water. Some downstream farmers make use of the irrigation return flows by

pumping the river water. Thus, in parts of the HIS area, particularly in the head reaches of the two main canals, despite the deficiencies of the canal system, farmers have access to adequate water supplies. However, a big chunk of the command area is purely rainfed as it receives no irrigation water. Also, even farmers in the head areas of the main canals reported that they have to make occasional use of ground water from STWs to supplement the canal water.

Both the DIO and the farmers feel that, under both main canals, there is potential to expand the HIS command area. We have no figures that would allow any such prediction. However, physical improvements to the canal system and management improvements can certainly stretch the presently available river water further. It may be, however, that significant expansion would be possible only by making additional use of ground water.

6.2. AGRICULTURAL PRODUCTION

Yields reported by farmers under full irrigation for the two major crops were given earlier: 3.0 tons per hectare of high yield rice and 2.4 tons per hectare for wheat. Irrigation is extremely valuable since farmers estimate that rainfed yields are about half of these figures.

However, these are not high yield figures. The causes of these low yields include both poor water supply and low fertilizer use. We did not investigate the causes for low fertilizer use but we note that a) all chemical fertilizers are imported, mostly from India, and b) Nepal is working on a policy to deal with fertilizer imports. Availability may be a factor, as well as reluctance to invest without assured water.

As noted earlier, the consumptive requirement of wheat in the area is about 250 mm. If we sum the average rainfall over December through January, we find it comes to about 60 mm (Table 1). If all irrigation is provided from STWs, and we ignore transmission losses, we can calculate the total ground water provided as follows. Reported time to irrigate 1 hectare of wheat is 8 hours and the average STW has a discharge of 12 lps. The total amount of water supplied in 8 hours from an STW is thus:

$$8 \text{ hr} \times 3600 \text{ sec/hr} \times 12 \text{ lps} \div 1000 \text{ lt/m}^3 = 345.6 \text{ m}^3$$

If this is applied to one hectare (10,000 m^2), the total applied is 34.6 mm.

Therefore if one irrigation from an STW is given, rainfall is normal, and no canal water is used, the total supplied is only about 35 mm from ground water plus 60 mm from rainfall or less than 100 mm; less than half the consumptive requirement. Even if a second irrigation from an STW is given, the total amount is only about 130 mm or about half of the requirement.

This implies dependence on the unreliable canal water on the one hand, and underirrigation on the other.

The situation is better for monsoon paddy. Let us take the consumptive requirement as 1000 mm (lower end of the reported scale) for a 100 day rice variety and assume that it is transplanted in early July to take maximum advantage of the rains. The average rainfall for July, August, and September is 1023 mm (Table 1). Rainfall alone is just enough, although any decrease in rainfall or lack of rainfall at critical times will adversely affect the crop. Thus, the canals and the STWs are better viewed as insurance for the rice crop than as essential.

6.3. Environmental Management

At present, there is no significant environmental problems associated with water use being reported. Aside from the reports of poor quality water for drinking in upper aquifers, the only issues are:

- The Jalad River floods at times. The river shows a tendency to outflank the headwork during floods if no corrective action is taken. Downstream of the headworks, the river is encroaching on the WMC head reach. The District Irrigation Office estimates that rehabilitation and extension of flood protection works up and downstream of the headworks is needed to protect about 175 hectares under outlets 1 and 2 of the WMC.

- In a few small areas, lack of drainage is a problem. No drainage networks have been developed. The command area is sloping from north to south. Many natural drains exist in the command area. Excess water from the area flows to these natural drains, some farmers drain excess water to neighboring fields and eventually to the natural drains. Overall the area is well drained except for waterlogging in some local depressions and some plots have excess water problems due to drainage congestion by the rural road networks. No estimates of the area affected exist but the total area is small, perhaps about 20 hectares in the tail end of the Western Command.

- Farmers and residents of parts of the area, particularly in the head reaches of the system, report that the ground water in the shallow aquifers tastes bad and stains their teeth. They have no concerns about use of the water for irrigation. Nor do they attribute health problems other than stained teeth to the water quality. Since there is no industry above the HIS, this appears to be a natural problem. No investigation has been made.

Overall then, there are no serious environmental problems associated with water use in the HIS area.

7. PROBLEMS AND OPPORTUNITIES IN CONJUNCTIVE MANAGEMENT IN THE HIS

The HIS canal system clearly does not provide the planned service to farmers. Yield levels are low and not all the area is irrigated. In parts of the HIS command, farmers have, with government support, installed STWs and other wells to supplement the rainfall and canal water with ground water. As discussed earlier, this does not fully solve the problems of water shortage during the winter and early monsoon crop seasons. Fortunately, at this time, environmental problems associated with water use are minimal.

In this section, we summarize the problems and then identify the opportunities to improve the situation for the farmers in the HIS command.

7.1. PROBLEMS

HIS is not providing the irrigation service to the desired extent because of various problems related to availability of water at the river source (Jalad river), physical conditions of the system, institutional, O&M and agricultural.

The problems of HIS include the following:

7.1.1. Problems of the Cropping System

- Crop yields are low even under fully irrigated conditions. This is associated with low use of fertilizers as well as with poor water supply. There is also limited diversification because of lack of markets.

7.1.2. Problems of the Canal System

- The canal system depends upon diversion from the Jalad River whose flow varies greatly. Problems include abstraction of water by upstream farmer managed irrigation systems, as well as flow variations due to rapid runoff following heavy rains. Overall there may be a trend of decreasing flow in the river since construction of the HIS.

- There are design problems. There are few control structures. Outlets are ungated and the same size irrespective of the area to be irrigated. Design and construction of the distribution system below the outlets was left to the unorganized farmers. Hence branch canals are not well designed and secondary and field channels have not, in general, been built.

- The physical condition of the HIS is bad. While the head works are in reasonable condition, the main and branch canals have deteriorated due to the inadequate system maintenance and failure to control encroachments on the banks and cuts in the banks. The regulating structures (falls and outlets) are also not in good condition due to poor maintenance. The capacity of both the east and west canals have been reduced significantly because of the deposition of sediment and widespread bank cuttings.

- Until recently, operations by system managers have been confined solely to operations at the head gates - at most a rotation of deliveries between the EMC and WMC. All other operations were left to the farmers who developed norms for operation that gave more or less absolute priority to upstream farmers. Consequently, water distribution is not equitable. Farmers in the

head reaches get more water than do downstream farmers. Farmers at the tail do not receive canal water.

- Government allocations for O&M have been insufficient. Also, collection of irrigation service fees from the water users has been poor and O&M allocations have been unrelated to collections.

- Under the Irrigation Management Transfer Project, two WUAs have been created to take over management of the HIS canal system. These WUAs have some weaknesses. The major weakness is the fact that the Branch Canal committees are not yet taking their responsibilities fully.

7.1.3. Problems of Ground Water Exploitation

- Use of the large reservoir of ground water in the HIS area is limited for a number of reasons. Most importantly, the benefits of operating STWs (the primary type of well) for irrigation cover the operational costs only if STW pumping is used as a supplement to a cheaper source of irrigation water.

- The incremental profits from the purchase of an STW are low. Installation of an STW makes economic sense only for farmers with larger landholdings and a potential to sell water to others. However, even for such farmers, the purchase of a tubewell is economic only if it is subsidized.

- ADBN and JADP, the prime agencies promoting ground water irrigation in the area, have been reducing the cost subsidy over the recent years. Moreover, these agencies, though working in the same area have no mechanism of mutual consultation and cooperation for planning intervention programs.

- Subsidies for group tubewell installation remain high (presently 75%), but farmers find it difficult to organize themselves to take advantage of this subsidy when costs of operation make the benefits of an STW only marginal. Farmers also report that costs of getting loans and subsidies, particularly from ADBN, are somewhat higher than the official costs.

- Farmers report many problems of poor design and installation, incorrect pumpset installation, poor quality equipment, and fuel quality. As a result, about 50% of the STWs installed with support from the ADBN are reported non-functional.

- There is a market in ground water pumping services. It is constrained because well owners often demand immediate payment but small farmers often lack cash to pay immediately. Also, most of the STWs lack developed water distribution systems. Only those farmers having lands close to boring sites can use an STW.

- The JADP did not include pumpsets in their STW development packages. As a result many small farmers with borings do not own pumpsets. These farmers have to rent pumpsets at the same rates as for buying water.

- The Department of Irrigation has had a policy of not assisting in tubewell development in the command areas of its surface irrigation schemes, thus hindering development of conjunctive management. The DOI assigns surface water and ground water activities to separate Divisions that work independently of each other.

- Presently there is no regulation of ground water exploitation, although reported problems due to this lack are few. The Ministry of Water Resources have decided to draft ground water legislation, but no action has as yet been taken.

7.2. Opportunities

Problems are often associated with inherent opportunities for solutions. These include:

- Improving agricultural production in the HIS area requires not only improving the water supply but, perhaps more importantly, improving the profitability of farming by a) finding ways to make the cultivation of rice and wheat more profitable, and b) by developing markets for other more profitable crops. If farming were more profitable, improvements in water supply could (and would in our opinion) largely be made at farmers' instigation. This report, however, is not aimed at making recommendations in this area.

- Rehabilitation of the canal system and improvement of management can improve the distribution of canal water greatly. The IMTP is already working on this.

- At present conjunctive management of ground and canal water occurs only at the level of the individual farmer. The recent establishment of the WUAs offers an opportunity to improve water distribution throughout the whole HIS through conjunctive management at the main canal level. Under present conditions, ground water is economic to use only as a supplement to canal water. If the canal water were supplemented directly by the WUA - by pumping into the canals - the two sources could be used more efficiently. The existence of STWs located immediately next to the main and branch canals would make this simpler to do if the planning can be done effectively. Also, if needed, under the present subsidy schemes, the WUA could purchase new wells at a 75% discount. The leaders of the WMC WUA mentioned that they were already thinking along these lines. However, the IMTP, under which the DIO supports the WUAs, makes no provision to help promote conjunctive management at the WUA level and the DIO is not prepared to provide this assistance.

- The high level of subsidy for group wells also suggests that farmers might be willing to form groups to purchase wells. However, as the farmers themselves explained, they will need help from an outside catalyst agent to resolve basic problems in organization.

- Increasing the subsidy for well installation might lead to installation of more wells. This in turn, might lead to reductions in the price of purchased water. Given the economics explained above, however, it appears that the subsidy level would have to be quite high. Also, given the operating costs caused by high diesel and oil prices, it is not clear that reducing the market for the average STW would help.

- There is consideration being given to lowering STW operating costs. Specifically, under present tariffs set by the government, electric pumpsets are much cheaper to operate than are diesel pumpsets, although unlike diesel pumpsets, electric pumpsets are not portable. However, rural electrification has not proceeded very far. The WMC WUA leaders told us that they would like to have electrically driven STWs directly operated by the WUA to pump water into the canals. They are hoping to take advantage of the current rural electrification program of the government in their area.

8. CONCLUSION

Farmers in the Hardinath Irrigation System have access to unreliable river water and a large reservoir of easily accessible ground water. Conjunctive use is practiced in the Hardinath Irrigation System. The locus of conjunctive management is the individual farmer. Despite hindrances, conjunctive use leads to higher agricultural output than would happen otherwise, but not much higher.

The biggest hindrance to more use of ground water is the economics of ground water usage for irrigation. The profitability of the present cropping system is low and cannot justify to the farmers the investments they must make in installation and operation of wells except under some specific conditions.

Under present policies, there does not seem to be much scope for improvement in irrigation water supply through conjunctive management, except if the newly formed WUAs take on responsibilities for conjunctive management at main canal level. Other possibilities would arise if greater subsidies were to be given for well installation and operation or if through other means the profitability of farming in the area were to be increased significantly.

The present available technologies for conjunctive management appear to be adequate, except:

- The design defects in the HIS canal system should be rectified.
- Tubewell installation needs to be done more carefully so that fewer shallow tubewells become defunct within a few years of installation.
- Changing the power source for pumpsets from diesel engines to electric motors would make them economically more attractive.

The institutions are not adequate:

- Numerous government institutions are involved. However, there is no coordination, even among those, such as the ADBN and JADP, that serve the same function.
- Although ground water exploitation is not at present causing any problems, there is no regulation. Regulation may become important in the future.
- The biggest problem is lack of adequate local level institutions to take on effective conjunctive management responsibilities. The new WUAs may be able to serve this function in the future if developed in the correct direction.

Management methods and resources for management need improvement:

- Maintenance is a major problem for both the canal system and the STWs. Resources provided and trained manpower are inadequate.
- Canal water distribution needs considerably more attention, including development of proper water distribution rules, mobilization of the manpower needed to carry out water distribution according to the rules and to enforce the rules, and development of methods for overseeing water distribution.
- Conjunctive management at a level higher than that of an individual farm requires devising appropriate methods; the technologies exist but the management methods will be totally new.

Nepal's Agricultural Perspective Plan (APP, 1995) makes installation of STWs the center piece of its Terai irrigation strategy. The idea is that well-controlled year round ground water supply will accelerate agricultural growth rates to a level that will allow agriculture to play a leading role in creating rural prosperity. Also STW development is less expensive that installation of DTWs and surface systems. The APP identifies four important constraints to STW development in the Terai: lack of rural road network, poor servicing facilities and extension work for diesel pumpsets, inadequate credit system and investment subsidy and not fully developed farming system, and poor information dissemination mechanism.

The APP's emphasis on STW development suggests that the Government of Nepal will provide large subsidies for installation of STWs. The mechanism is to be the Ground Water Resource Development Project to be carried out by the Department of Irrigation. Under this project, the government hopes to establish 200 community STWs annually in the Dhanusha District. This work has not yet begun.

Our study, however, indicates that the biggest constraints to the development of ground water for irrigation lie in the economics of ground water exploitation. Indeed, they suggest that most farmers can afford to use ground water only to supplement rainfall or surface water. The best way to get around this problem would be to work on other ways - such as development of markets, crop price supports, etc. - that would make irrigated agriculture more profitable.

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