Gated or Ungated: Water Control in Government-built Irrigation Systems

Comparative Research in Nepal

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To my parents

Preface

This study is a foray into an under-researched aspect of water control in government-built canal irrigation systems in Nepal. It attempts to achieve some understanding of different water control technology, through focusing on three irrigation systems in the *tarai* region of Nepal: the Banganga Irrigation System, the Pithuwa Irrigation System and the Mahakali Irrigation System (Stage I).

The author's interest to conduct this study grew when he was working in the Irrigation Management Project, a long term project (1985-95) introduced to improve the performance of some selected government-built and operated irrigation systems in Nepal. The author believes that understanding how the technical design of an irrigation system affects its management is the key to improving the performance of the system. The present study is an attempt to address both the technical and organizational dimensions of canal irrigation systems.

The author owes his greatest intellectual debt to Professor Lucas Horst, Professor Emeritus of Wageningen Agricultural University (WAU), the Netherlands for his excellent advice, enthusiastic guidance, and continuous encouragement to successfully completing this study. The author is equally grateful to Dr Prachanda Pradhan, who as the second supervisor, offered constant encouragement and help in many ways to complete the study. The valuable suggestions and constructive criticism of these two people during the course of the study were invaluable.

During the fieldwork in Nepal, the author received help of all kinds from many people. To name them all would require more than a page. Most of them he has already thanked in person.

Many farmers of Banganga, Pithuwa and Mahakali helped during the fieldwork. The author will always be grateful to them for their kindness, patience, hospitality and endurance shown during his endless inquiries.

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Finally, he is indebted to his parents and his family for their great patience and encouragement during the period of his absence from home and the sacrifices they have made for the sake of his education.

Wageningen, March 1996.

Statements

1. Farmers are knowledgable and capable actors.
   This thesis

2. Water allocation and distribution in an irrigation system comprise complex interactions between the physical elements of the system and the local environment. The interactions are considerably influenced by the personnel from the irrigation authority and the local farmers, who make both formal and informal decisions at various levels.
   This thesis

3. Many irrigation system design engineers have a bias towards fully gated water control technology for operational flexibility. Flexibility can also be achieved, however, through simple technology.
   This thesis

4. Donor agencies involved in irrigation development in developing countries should consider the capacity of the recipient country to sustain the water control technology that is being introduced.
   This thesis

5. The development of intensive physical infrastructure and organizing water users at the tertiary level of an irrigation system is meaningless if the system does not assure reliable and adequate delivery of water to this level.
   This thesis

6. It is easier to design and construct an irrigation system than to operate and maintain it.

7. Management is based on the premise that things can be done better, which in turn means that one wants better performance. In a socio-political situation where what is legitimate is what one can get away with, can there be any concern about public irrigation system performance? And if there is no desire to manage, what can management techniques do? "*Nagna kshapanake deshe rajakah kim karishyati?*" (In the land of nudists what can a washer-man do?)

   Sundar, A. (1984) quoting from *Panchtantra*.

8. Research is based on longing for understanding and truth. Research practice, however, can lead to painful and unpleasant discoveries.

9. If the construction of a physical structure is poor, the contractor is blamed. For the poor operation and maintenance of an irrigation system, the system manager is accused. But the design engineer is rarely charged with the deficiency in the design.

10. Our knowledge of the interrelationships between water and plant growth far exceeds our knowledge of the interrelations between water and the human element in delivery and utilization.

    Levine, G. (1980)

11. "Everyone is in search of happiness for himself, but absolute happiness is in offering yourself in the service of others."

    Laxmi Prasad Devkota, the great poet of Nepal

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List of Units

^{o}C	celsius
cm	centimetre
cusec	cubic feet per second
h	hour
ha	hectare
km	kilometre
km^2	square kilometre
lps	litres per second
m	metre
MCM	million cubic metre
mm	millimetre
m/s	metres per second
m^3/s	cubic metres per second
ppm	parts per million

List of Abbreviations

AAU	Agricultural Administration Unit
ADB	Asian Development Bank
ADBN	Agricultural Development Bank of Nepal
AIC	Agriculture Input Corporation
AO	Association Organizer
APROSC	Agricultural Project Services Centre
BIS	Banganga Irrigation System
BNP	Basic Needs Programme
CAD	Command Area Development
CADP	Command Area Development Project
CBS	Central Bureau of Statistics
CCA	Cultivable Command Area
CDO	Chief District Officer
CIWEC	Canadian International Water and Energy Consultants
DADO	District Agricultural Development Officer
DDC	District Development Committee
DFAMS	Department of Food and Agricultural Marketing Services
DIHM	Department of Irrigation, Hydrology and Meteorology
DIO	District Irrigation Office
DOA	Department of Agriculture
DOC	Department of Cooperatives
DOHM	Department of Hydrology and Meteorology
DOI	Department of Irrigation
EIRR	Economic Internal Rate of Return
FAO	Food and Agriculture Organization
FD	Farm Ditch
FEWUG	Federation of Water Users' Groups
FIWUD	Farm Irrigation and Water Utilization Division
FOD	Farmer Organization Division
FODC	Farmer Organization Development Coordinator
FPDB	Forest Product Development Board
GDP	Gross Domestic Product
GEOCE	Geo-technical and Civil Engineering Consultants (Pt.) Ltd.
HMGN	His Majesty's Government of Nepal
IBRD	International Bank for Reconstruction and Development
ICID	International Commission on Irrigation and Drainage
ICM	Indian Cooperation Mission
IDA	International Development Agency
IFAD	International Fund for Agricultural Development
IIMI	International Irrigation Management Institute.
ILC	Irrigation Line of Credit
ILRI	International Institute for Land Reclamation and Improvement
IMP	Irrigation Management Project
ISP	Irrigation Support Project

ISPAN	Irrigation Support Project for Asia and the Near East
ISSP	Irrigation Sector Support Project
JT	Junior Technician
JTA	Junior Technical Assistant
LDO	Local Development Officer
LRMP	Land Resource Mapping Project
MFD	Main Farm Ditch
MIDB	Mahakali Irrigation Development Board
MIP	Mahakali Irrigation Project
MLD	Ministry of Local Development
MOA	Ministry of Agriculture
MOF	Ministry of Finance
MOFA	Ministry of Food and Agriculture
MOWR	Ministry of Water Resources
MWPI	Ministry of Water, Power and Irrigation
NGO	Non-government Organization
NFC	Nepal Food Corporation
NIA	National Irrigation Administration, The Philippines
NPC	National Planning Commission
ODI	Overseas Development Institute
OPEC	Organisation of Petroleum Exporting Countries
PIMC	Pithuwa Irrigation Management Committee
PIS	Pithuwa Irrigation System
PWD	Public Works Department
RTB	Research and Training Branch
RWS	Rotational Water Supply
SAO	Supervisory Association Organizer
SAR	Staff Appraisal Report
SMB	System Management Branch
SPCC	Sub-project Coordination Committee
TCN	The Timber Corporation of Nepal
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Programme
UMN	United Mission to Nepal
USA	United States of America
USAID	United States Agency for International Development
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
VDC	Village Development Committee
WB	World Bank
WECS	Water and Energy Commission Secretariat
WUA	Water Users' Association
WUACC	Water Users' Association Coordination Committee
WUG	Water Users' Group
WUO	Water Users' Organisation

Glossary of Nepalese terms used in this thesis

adhakshya	chairman
adhiya	share-cropping in which harvest is shared 50/50 between the landowner and the tenant
Ahir	caste name; relatively low-caste cultivator-grazier
alas	linseed
amin	sub-overseer, subordinate official engaged in land measurement
badahakim	the chief administrative officer of a district
bataiya	share-cropping
bazaar	market place
bhusa	straw
bigha	unit of land area; a bigha is roughly equal to two-thirds of a hectare
birta	land grants made by the state to individuals, usually on a tax-free and inheritable basis
chak	command area, usually 5-7 hectares, served by a group outlet
Chamar	caste name; leather worker, labourer
chaukidar	watchman, patrolman
crore	ten million
dhalpa	ditch tender
dhur	unit of land area; one *dhur* of land is equal to one twentieth of a *kattha*
ghaiya	a variety of paddy which can be grown without irrigation or on *pakho* land
ghanta	unit of time, hour
ghol	quickly inundated low-lying area in the Chitawan Valley
goswara	general
guthi	land alienated by the state or by individuals to finance the carrying out of religious or charitable functions
harwaha	labourer for landlords, formerly of cultivator status
hathiya	period in October, just after the monsoon season
jagir	land assigned to government employees as emoluments; abolished in 1951
jethraiti	a village functionary appointed for the collection of land taxes prior to the introduction of the *jimidari* system in the *tarai* region
jhara	compulsory labour
jimidar	non-official tax collection functionary in the *tarai* region
jimidari	pertaining to *jimidar*
jirayat	taxable land attached to a *jimidari* holding as part of the remuneration of the *jimidar* in the eastern *tarai*
junahari	maize, corn
kattha	unit of land area; one *kattha* of land area is equal to one twentieth of a *bigha*
khalihan	common open yard in the *tarai* village for storing, drying and threshing crop harvest
kharif	growing season of crops harvested in autumn, summer crop in the *tarai* region
khet	irrigated land in the hilly region on which paddy is normally grown
khola	a small stream
kulo	small irrigation canal
kumahal	potter

Kurmi	caste name; relatively low-caste cultivator
lahi	oilseeds
lakh	one hundred thousand
madhesh	*tarai* region
mal	revenue collection office
mauja	village as the primary unit of land tax administration in the *tarai*; a revenue subdivision consisting of a group of villages in some hill districts and Kathmandu valley
mohi	tenant
mool nahar	main canal
muliki ain	legal code of Nepal
nahar	irrigation canal, usually of large capacity
nala	small drainage channel; a small stream
paene	small capacity irrigation canal
pakho	unirrigated land in the hill districts and Kathmandu valley on which only maize, millet, *ghaiya* and other dry season crops are grown
palo	turn
panchayat	a local elected council
pani	water
parganna	a unit of revenue administration consisting of a group of villagers in the eastern *tarai* region; administrative subdivision of a *tehsil*
parma	reciprocity of labour for farming activities as practised in the hill districts
rabi	growing season of crops harvested in spring, winter crops in the *tarai* region
raiti	landholder, common people
ropai	transplantation of crops
ryot	cultivator, peasant
sachiv	secretary
sakha nahar	branch canal
sarsaun	mustard
sinchai	irrigation
sirwar	title of a person managing the land of a *zamindar*
tarai	southern plain belt of Nepal
tehsil	administrative subdivision of a district
tharu	a tribe in the tarai
toli	group of people
tori	rapeseed
ukhu	sugar cane
upadhakshya	vice-chairman
upa-toli	subdivision of the *toli*
warabandi	a system of water distribution, usually practised in the northern states of India, in which an individual farmer is allocated a fixed time and duration to use the canal water
zamindar	landowner
ziladar	subordinate official; head of local branch of canal administration

1 Introduction

Canal irrigation has been traditionally practised in Nepal for many centuries. But the development of modern canal irrigation systems can be said to have commenced only in the 1920s. The increasing investment by the government in the development of modern canal irrigation systems, especially after the 1970s, would appear to have contributed to the country's sustained agricultural production. Despite this effort, however, there is a general contention that most of the government-built modern canal irrigation systems do not function optimally. The reason for this is not clear since there are almost no scientific studies into what actually happens in these systems as regards to their design and water allocation and distribution. This study was undertaken to examine and explore, from the particular point of view of water allocation and distribution, the technical design and the operational features of government-built and operated canal irrigation systems in the Southern plains, the *tarai*, of Nepal. If the limitations of the government-built and operated canal irrigation systems can be identified and the farmers' experience in these systems can be understood, it should be possible to develop appropriate methods for improving water control in public canal irrigation systems.

1.1 Nature of the problem

Population growth and agricultural production

One of the crucial development problems confronted by the Himalayan Kingdom of Nepal is that of providing food to a rapidly increasing population. According to the 1991 census, the population reached 18.5 million at an annual growth rate of 2.10 percent over the decade 1981-91 (Central Bureau of Statistics 1994). At this growth rate, it is likely to reach 37 million by the end of 2025. The average population density of 700 persons per square kilometre of cultivated land is one of the highest in the world (Farrington and Mathema 1991). This figure becomes even more significant, given that in a large part of the country (the Himalayas) human habitation is impossible. Limited irrigable land is another major constraint of Nepal. Only about 14.8 percent of the country's total land area is suitable for irrigated agriculture (CIWEC, Irrigation Master Plan 1990).

Population growth has adversely affected the utilization of the country's limited land resource. The cultivation on marginal land, steep slopes and poor quality soils in the hilly areas, and encroachment of forests in the *tarai* have increased considerably thereby degrading the physical (natural) environment.

From the early 1970s, it became clear that the country faced a crisis of food grain production as the capacity of the predominantly agrarian economy to feed the population was not increasing. Projections made in the mid-1970s suggested that by 1980 Nepal would have an overall deficit in food grains, as total domestic demand outstripped total production (Seddon 1992: 44-45). In 1982, the Asian Development Bank reported that the yield of rice in Nepal had been among the highest in South Asia in 1966, but that about 16 years later it was among the lowest (ADB/HMGN(II) 1982: 35). While crop yields in many South Asian countries have increased, the Green Revolution and adoption of new agricultural technologies have not taken hold in Nepal (Sill and Kirkby 1991; Mahat 1991). The available data suggest that, despite planned development efforts to stimulate the production of food grains, the growth rate in food production has failed to keep pace with the requirements of the rapid growth in population. According to the recent estimate by the National Planning Commission (NPC 1992), the average rate of food grain production over the period 1962-90 grew by 2.1 percent per year, and the productivity of food crops during 1990-92 showed a decline of 1.5 percent (ibid: 3).[1] Clearly, Nepal still faces a relative stagnation in gross food grain production, whatever the reasons may be for the declining productivity.

The problems and crises of Nepal's agriculture and increasing pressure of the population on cultivated land are complex, and are due to several interrelated factors. In the first place, the topography of the country varies from the low plains area, the *tarai* - an extended part of the Indo-Gangetic plains - at an altitude of less than 100 m above mean sea level in the Southern part, through the valleys and slopes of hills and mountains in the middle region, to the great Himalayan range above 8,000 m altitude in the Northern border. This variation gives rise to different climates ranging from the subtropical to the alpine, to diversity in farming, and to varying irrigation potential between the regions. Secondly, despite organized efforts to develop modern irrigation systems the agriculture in the country still largely depends on the rainfall, most of which falls during the monsoon months from June-September. Under rainfed conditions usually one crop, mainly paddy, grows reliably, and farmers are at risk if they use improved varieties of seeds and new agricultural technology, because of the erratic rainfall. Where irrigation is available and the climate allows, two or three food grain crops a year can be grown in the more fertile lands of southern plains.[2]

Given the need to increase food grain production to meet the country's requirements and the least possibility of bringing additional land in the hills under cultivation, it is necessary to intensify cultivation on the agricultural land in the *tarai* where the potential for irrigated agriculture still exists. The Government of Nepal has realized this, and has targeted the development and improved management of irrigation systems in this region as one of the major elements of its current eighth five-year development plan (1992-97), recognizing that the provision of reliable irrigation water supply removes one of the critical constraints to the achievement of increased agricultural productivity (NPC 1992: 263). Better water control leading to increased reliability of irrigation water supply and distribution is seen as having the potential both to increase yield and to allow the intensification of the cropping pattern.

Irrigation development

Up to the middle of 1992, a total area of about 599,000 hectares, which is about 30 percent of the country's total irrigable area, had been provided with irrigation facilities under the government funding (NPC 1992).[3] This is only about 22 percent of the total land area under cultivation in the country. Of the total hectares with irrigation facilities, about 84 percent is covered by (gravity flow) canal irrigation systems.

A more serious problem than the small proportion of the area provided with irrigation facilities is the performance of government-built and operated canal irrigation systems, especially the large irrigation systems. Despite huge investments of scarce domestic resources and external borrowing for the development and improvement of public irrigation systems, most of these systems have not been operating to their full potential or capacity. The performance study of five major (large) government-built and operated irrigation projects - three large operational irrigation systems and two deep tube well systems, all financed by external donor agencies - by the Water and Energy Commission Secretariat (WECS) and the World Bank (IBRD) in 1982 reported that there was no significant difference in either cropping intensity or yield between command areas receiving irrigation and adjacent areas not receiving irrigation from the project. Further, in spite of spending considerable sums on the repair, maintenance, and operation of these systems every year, the supply of water was not timely, reliable or adequate. According to the study, the principal reasons for this state of affairs of government-operated irrigation systems were: ill conceived project, poor design, incomplete development, unsound construction, inadequate maintenance, poor water scheduling and lack of confidence on the part of farmers as regards the reliability of water delivery, the political difficulties of enforcing water scheduling, and problems in collecting water rates. The study concluded that a combination of interrelated infra-structural, management and institutional problems were (currently) severely constraining the performance of the projects, and that the projects suffered from (engineering) design deficiencies and unsatisfactory management after the completion of the projects (WECS/IBRD 1982). Specifically, the study pointed out problems related to water (control) management.

The study on institutional and management aspects of large scale public irrigation projects by WECS in 1984, pointing out many institutional weaknesses, reported that the failure to pay adequate attention to water management and to involve farmers (formally) in it had been a major weakness in most large scale irrigation projects. Among other institutional improvements at (system) project and supra-project level, the study recommended the formal involvement of water users right from the outset of the project to the operation, maintenance, and the assessment and collection of water charges for sustained benefit from such public irrigation systems (ibid, Executive summary: 15-16).[4]

Between 1984-93 in the light of these performance studies, many government-operated canal irrigation systems in Nepal were redesigned and reconstructed or rehabilitated in an attempt to achieve their potential, and many are still under improvement. Over this period, the extension or intensification of physical infrastructure at tertiary level, on-farm development, and the emphasis on the overall improved management of the system (called irrigation system management) have increasingly gained recognition in the country. The increase in the operational and maintenance burden brought about by the intensification of physical infrastructure plus the problems in the collection of water fees have led the government (and also the donor agencies) to seriously pursue farmer involvement in the (system) management. It is believed that the farmer involvement will, among others, also result in both equity in water distribution and increased efficiency in water use. Accordingly, existing institutional and organizational arrangements for the development and management of irrigation systems have been reformed e.g the enactment of the new 1992 Irrigation Policy, and the promulgation of the 1992 Water Resources Act which gives legal mandate for the formation of water users' organization within irrigation command areas. This has resulted in the gradual emergence of formal water users' organization in many public irrigation systems in the country.

Virtually all irrigation systems (re)designed and (re)constructed by the government from the early 1970s onwards have had, and many projects under construction still have, the assistance of international donor agencies. Whereas the donor agencies have directly or indirectly influenced the irrigation development policies and implementation approaches, an inevitable and visible consequence of their involvement has been the transfer and/or superimposition of different technologies intended for improved water control, depending upon the origin of the international consultants appointed for such donor-funded projects.

It has been increasingly recognized that the success of an irrigation system clearly depends upon more than merely providing a physical infrastructure to bring water to the cultivated fields. A whole range of operational and qualitative features - the scheduling, timing and predictability of supplies, the volume of water supply available, mode of water distribution, defined role of the operating agency and farmers in water management, and the direct as well as indirect costs entailed in its use - have a vital bearing upon the overall productivity of the system, the resulting crop patterns, and the distribution of benefits between localities, communities, and individuals.

1.2 Focus of the research: water control in government canal irrigation systems

Water allocation and distribution, water control, is the core process of an irrigation system. It is the process by which the available water is divided and distributed to the smaller command units or irrigation blocks within the system, which in turn is distributed further down to the individual water user who must control it to place it in the crop root zones in particular fields. In this process, as Chambers (1980) notes, 'who gets what (how much), when and where', is the central and universal issue. Around this issue, human actions and interactions take place resulting in the (re)design, (re)construction, and (re)shaping of the physical and organizational arrangements. The process of water control in canal irrigation systems is the subject of this study.

This study begins with the thesis that water control in irrigation systems is a function of both the technical/engineering and social control. The technical/engineering control here refers to the technology[5] and the design of the physical infrastructure of irrigation systems, and the social control refers to organizational and institutional arrangements for the allocation and distribution of water, maintaining the physical infrastructure and the water users. Together, the physical infrastructure and organizational arrangements determine how much water goes where. An analysis of both aspects in the context of the local farming system should lead to the more general issue and complexities of water control in irrigation systems.

Two facts guided the research focus on government-built and operated canal irrigation systems: (i) varied technical design and operational features of canal systems due to the involvement of different donor agencies, and (ii) challenges and complexities in the management of government irrigation systems. The general objective of this research was to examine water control in government-operated irrigation systems in the *tarai* in the context of the local farming systems. The emphasis of this study is on the understanding of the technology and design of the physical system, the process of water supply and distribution followed by system managers, and the ways in which water users influence this process.

This study also attempts to examine water control in government canal irrigation systems from the perspective of both farmers and irrigation engineers. Because, as Levine (1980: 58) pointed out, 'what is optimum from an irrigation system point of view is not necessarily optimum from the farmers' point of view; these optima must be reasonably close for efficient use of the resources available to both irrigation system and farmers; a change in the resources available to either results in a change in the water-use level. Change in the water-use level may in its turn require changes in organization and administration, i.e., in the control capability of the irrigation system.'

The specific objectives of this thesis are to:

(i) describe and analyse the range of technologies, technical design, and organizational arrangements,
(ii) map the process and outcome of the external interventions on both the technical and organizational arrangements,
(iii) map the water control process, and
(iv) demonstrate empirically the relations between technical and organizational arrangements for water control

in government-built canal irrigation systems by providing case studies of canal irrigation systems in Nepal. The research question thus includes the extent and influence of farmers in the water control process, and accounts for how this process is influenced by both technical and organizational patterns of the canal system. The changes in the technology and institutional arrangements for the operation of government canal systems over time will also be examined.

1.3 The theoretical considerations and analytical approach

The physical elements of canal irrigation systems and different hydraulic levels

To understand a canal irrigation system, the usual starting point is the physical system - the physical domain itself. A canal irrigation system of some scale primarily consists of a set of physical artifacts such as dams, barrages, weirs, reservoirs, pumps, network of canals (and drains), water regulating structures and the like, which are made and used by people to deliver and distribute water obtained from natural sources - rivers, lakes, streams, springs, aquifers - for crop production.[6] In a 'conventional' gravity flow irrigation system, the physical arrangement of the canal network and structures produces different hydraulic levels, and each hydraulic level is connected to the other below by a control or regulating structure generating a hierarchical pattern.[7] The hydraulic levels proceeding downward from the diversion point are generally termed primary, secondary (includes distributary and minor canals), and tertiary (similar terms are used for drainage systems). The subdivisions into different hydraulic levels reflect the (organized) complexity of the system.[8] As noted by Uphoff (1986), physical structures form a link between water and water users. Both physical structures and hydraulic levels are the places for actions, interactions, and intervention.

Socio-technical nature of irrigation systems

In recent years, it has been established that irrigation systems are not merely physical artifacts independent of human or social actions, but that they are socio-technical entities. The fact that the use of irrigation technology involves people, produces social change, influences social relationships among the people involved, and affects socio-economic growth of individuals and communities demonstrates the social dimension of an irrigation system. Below the socio-technical characteristics of canal irrigation systems are briefly discussed.

In the first place, the creation of canal irrigation systems, especially the large canal irrigation systems, requires a considerable amount of resource investments in terms of capital (money), materials and labour. An individual farmer in developing countries is often not in a position to make investments in developing such irrigation schemes because of his/her low productive power e.g. small landholding, weak tenurial status, social norms and so forth. So those individuals, group of people or institutions that are involved in the investments will own and control access to the physical infrastructure and water. Consequently, formal and/or informal relationships will be (re)established between people or a group of people/institutions by ways of contracting (leasing land, share cropping), water sharing, water trade, and labour. The tenurial arrangement of land, land rights and land value will also change (Huppert 1987).

Thus, irrigation systems give rise to differential access and renewed entitlements to physical infrastructures, water and land.

Secondly, managing such irrigation systems requires an organized group of people with authorization and responsibility to carry out specified functions. Coordination of management activities requires organization and strategic decisions. Division of tasks, responsibilities and discharge of management functions may follow a hierarchical pattern. In most large public irrigation systems, government functionaries who are mostly non-farmers or non-cultivators are delegated with the authority to manage the systems. By virtue of their authoritative position and power, these functionaries develop a particular relationship with water users and/or their representatives.

Thirdly, in canal irrigation systems, the supply and distribution of water entails a social process, and has many clearly marked social implications. The socio-technical nature of an irrigation system is most clearly visible in this process. The technical (physical) and organizational activities involved - operating and maintaining canals, scheduling water turns, communication, decision making, resolving conflicts etc - necessarily give rise to new social relationships among the people using the canal water. Differential rights to water and physical infrastructure emerge. For examples: head-end and tail-end farmers, water distribution in proportion to land-holding size, use of a specified common outlet etc.

Water control at different levels

Water control begins from the point of diversion or storage and ends in the root zone or where the excess water after the application to cropped fields is drained. As is shown by Uphoff (1986: 29-42) in the three-dimensional irrigation management matrix, water control can be sequentially divided into four activities: acquisition, allocation, distribution and drainage. Some activities may have less importance in a given setting. For example, in hill irrigation in Nepal, drainage is of minor importance due to the soil conditions and topography, and can usually be ignored.

In an irrigation system, as Freeman and Lowdermilk (1985) have noted, the meanings and requirements of water control change as one moves from one level to another. To elaborate the meanings of water control, they considered the physical infrastructure of a canal irrigation system to be consisting of three levels: (i) main system (primary level), (ii) middle level (local command level), and (iii) farm level.

At the primary level, where the canals are relatively large, unlined and often subjected to erosion and sedimentation, water control means keeping the flow of large volumes of water within certain key parameters, such as minimum and maximum flows, and full supply level (FSL), so that the main system functions smoothly. At this level, the requirements of varied tertiary units in terms of soils, crop patterns, and crop growth stages, are aggregated and dealt with based on average irrigation water requirements and behaviours. Managers of the main system, especially of large irrigation systems, think of water control in terms of operational stability. In this respect, as Reidinger (1980: 268) noted in his study of an Indian canal irrigation system, the (main) system is managed rigidly.

At the farm level, water control means the application of small amounts of water in crop root zones. At this level, water control primarily should enable farmers to adapt rapidly to the changing conditions of soil moisture and the crops which may vary widely within and among fields. Since farmers gain according to the productivity of water on their farms, they cannot afford to focus on average behaviour of the main system but must distribute the water according to the varying conditions of fields and crops (multi-cropping and varying growth stages). Therefore, farmers want operational flexibility.[9]

At the middle level, where the main system and farm systems interlink and form an interface zone, water control basically means dividing the water of the main system into volumes appropriate for farm application. This level is also the middle (management) domain where the farm system overlaps with the water supply system (Keller 1990: 52). At this level, water control should therefore be such that the differing objectives of main system management and local farms are meshed productively and harmoniously. Control at this level means having the organizational capacity - rules and tools - to distribute water from the main system to cultivated fields in such a way that the farmer can control it for productive use. In this respect, the middle level is also the place where most interactions and negotiations - both formal and informal - between water users and water authority personnel take place. Indeed, managing or controlling water at the middle level in a government-built canal irrigation systems is a matter of considerable challenge both technologically and organizationally. It brings together two (main) groups of people - government or agency people who are the designers and managers, and farmers - who are managing enterprises that have very different objectives. In this study, the emphasis will be on water control activities at this level, although the main system management will be discussed and the water use activities at farm level will be described.

Technology, organization, and control

The management or control of irrigation systems is primarily a derivative of design or technology. The three modes of water supply and distribution - continuous, rotation, and on-demand (sometimes combination of these) - practised in canal irrigation systems have significant implications for the extent or intensity of human actions and interactions. Continuous supply of water usually requires physical structures with very low level of sophistication, and involves least social actions and interactions between operating agency people and water users, and also between the water users. The rotational supply and distribution imposes few encounters between the members of the (system) operating agency and the water users compared with the canal systems operating on on-demand mode. The on-demand mode of supply and distribution entails higher level technological sophistication. The technology of manually operated and adjustable gates - which is commonly used in canal irrigation systems in Nepal - requires high organizational input in terms of the number of operating personnel and their skill and efficiency for the effective control over the distribution of water. The members of agencies responsible for operation have to coordinate the individual demands for water and transform them into a practical water distribution schedule. Since water control (division) structures are potentially key places for actions and intervention, the risk of their misuse and abuse increases under weak control. Clearly, the greater the number of physical control points, the greater the management tasks.[10]

Where and when water is limiting and a scarce commodity, control becomes highly important. Scarcity of water increases the value of water, and creates tension among the users. Individually and/or collectively, water users tend to compete for scarce water. Farmers at the head end of a canal system will try to use more water at the cost of those at the tail end. The attention then turns to the process of acquisition and allocation which determines the access of users to water. For effective control of water in terms of time, quantity and location in such a situation, a disciplined and tightly controlled organization is required as a necessary complement. This is not to say that effective control is required in situations of water scarcity only. Even in situations of abundant water, if the control over water diminishes, farmers tend to use increasing quantities of water whenever available, in anticipation of possible water shortages; this leads to problems of over-irrigation, waterlogging or salinity.

That the organization for water control in an irrigation system depends upon the technical pattern of the system has been observed by many researchers who studied the social relationships and organizational aspects of irrigation systems. Below some examples on the relations between technology, organization, and control are reviewed and discussed.

In the comparison of rice-based irrigation systems in the Philippines, Malaysia and Taiwan, Levine (1980) observed that effective control was achieved as a result of the combination of technology and a set of social actions, and that operational efficiency increased with increasing control.[11]

Applying an ecological perspective to the irrigation context, Coward (1980: 22) argued, 'If one operates with the assumptions that irrigation institutions and organizations are in part a response to the physical and natural habitats in which they occur, one is alerted to the notion that planned modifications in the relative water supply (supply versus demand) available in a system or rearrangements of the canal layout and/or outlet locations can have important implications for the organization of social relations.[12] In effect, most so-called technical decisions are simultaneously technical and organizational decisions: as soon as a particular technical arrangement has been selected, organizational arrangements are partially prefabricated'.[13] Further, on the studies of communal and public irrigation systems in Asia, he noted that social arrangements derived their continuity from the pattern of the physical structures for conveying and distributing water and the pattern of land holding (Coward 1985). Similarly, Bottrall (1981), Barker (1985), and Chambers (1987) have argued that the problems of irrigation management (control) are basically linked to the organization and design of the (irrigation) systems.[14]

In the analysis of farmer participation in irrigation management, Uphoff (1986: 59-61) pointed out, 'The structure of an irrigation (physical) system consists of levels of operation which are established by physical points of control, such as points of offtake and regulating gates, between the water source and farmers' fields. Levels in irrigation systems are most clearly defined in terms of physical structures which form a link between water and water users. Parallel to the levels of operation, levels of organization are created socially when individuals or group of people - water user(s) or water authority personnel - at a certain level of operation engage in the organizational activities like decision making, resource mobilization, communication, and conflict management'. He further notes, 'The socio-technical nature of an irrigation system is manifested in the interaction of physical and social sets of activity. At all levels in the system, these two sets of activity combined control over water and water users.

Horst (1983) argued, '... increase in the number and sophistication of control structures in an irrigation system increased the risk of their abuse ...', and raised a question, 'how far it is realistic to stick to a technology of adjustable structures requiring huge numbers of staff, when one can clearly see that these numbers cannot be reached for many years to come'. With respect to farmer participation, technical design of an irrigation system is one of the strategic determinants of farmers' willingness to participate in the management of irrigation water, and chances of their participation decrease with the level of sophistication of the technology (Horst 1990). Farmers would prefer to have rather simple water control structures that are easy to operate and maintain.[15]

Engineers, however, tend to use sophisticated control structures in canal irrigation systems without giving much attention to or trying to understand their implications for the organization required for the control over the supply and distribution of water. As a result, the technology is unused or misused and becomes inoperative, and/or if possible modified to suit the local realities.

How can the complexity of water control in canal irrigation systems be understood? Which analytical approach could or should be followed? The natural science of irrigation or civil engineering disciplines does not seem to have developed an approach to explain the complexities yet. In the following paragraphs, some analytical approaches which are increasingly used by the researchers in examining the relations between technology, people and social processes are presented.

Different approaches to the study of irrigation systems

The literature on irrigation and irrigation systems shows two groups of disciplines and professionals engaged in the research. One group clearly belongs to technical/engineering disciplines - hydraulics, soil science, crop science, hydrology, meteorology, soil mechanics, construction engineering, surveying and the like - which study physical processes of water flow in open channels, soil-water-plant relationships and so forth, treating irrigation and irrigation systems as purely technical subjects. The other group belonging to social science disciplines - rural sociology, public administration, management science, economics, political science, social anthropology - look at irrigation systems from a social science perspective. Most studies by social scientists on irrigation systems focused mainly on irrigation organization and were carried out in the late 1970s and 1980s. Indeed, normal professionalism makes the professionals and researchers of each group examine irrigation systems from their own interest, values, and methods (Chambers 1988). But, as Chambers (1988) says, 'normal professionalism, well performed, is competent with simple and static problems, but at a disadvantage with systems which are complex and transient. ... canal irrigation systems are difficult for it to handle effectively' (ibid: 71).

The recent body of literature (Mackenzie et al. 1985; Swantz 1989; Bijker 1990) tends to suggest the use of the socio-constructivist approach (the social construction of technology) to understand the relations between peoples, technology, and physical and social process involved in the use of technology. Another approach used recently by researchers to study irrigation development projects is the actor-oriented and interface approach (Siriwardena 1989; Zaag 1992). Below these two approaches are reviewed briefly.

Social constructivist approach

The social constructivist approach is based on the premise that the material objects (technology, physical artifacts like machine, tools etc) are socially constructed, and are the outcome of processes of social shaping. Technologies are made by people, and the objectives and interest of people influence their ultimate shape. In the process of development, people continuously construct, reconstruct and transform the material object (technology) in conjunction with social boundary conditions.

In context of irrigation, the people involved in shaping the technology are politicians, economists, government officials, engineers, and farmers, all of whom have varying interests, objectives and knowledge. In the process of creating (designing and constructing) the irrigation system, these people talk, negotiate and struggle with each other about the ultimate result. In this process of social interaction, they mutually determine the final shape of the technology. The process of social shaping occurs not only during the creation of an irrigation system, but it continues even after the system is completed and put into use. When irrigation systems are in operation, farmers and engineers are constantly trying to either adapt the existing technology or reshape it to match the change in irrigation situations. That is, in reality, irrigation systems and their human participants are both dynamic and integrated.

Design and construction are thus formed in *arenas* wherein different people interact as social *actors* to decide upon the nature of the technology. The arena and the social interaction are functions of time and space and may take different forms: loan negotiations between the government and donors, a design meeting between foreign consultants and government engineers, a formal meeting in the irrigation office, a meeting in the house of a farmer leader, an informal gathering in the field for water distribution during irrigation seasons. Usually the processes of design and construction are presented in the form of a project cycle or stepwise organised process. This is the normative representation of this process. By contrast, the notions of *actors* and *arena* help explore what people and groups of people actually do and how this occurs. It can be applied equally to both situations where external agents like government officials and engineers introduce new technology, and where farmers themselves shape and reshape their land and water use infrastructures.

Actor-oriented and interface approach
People are not merely actors, they are *knowledgable and capable actors* having interests, strategies, resources, and power (Giddens 1989). The actor-oriented and interface approach primarily emphasizes the importance of: (i) analysing the dynamic and emergent character of interactions taking place between different group of actors such as, in the context of irrigation, engineers, farmers, local political leaders and landlords; (ii) explaining how the objectives, perceptions, interests and relationships of various groups are reshaped as a result of their interactions; (iii) and exploring how these interactions are affected by and, in turn themselves influence, the situation itself. Methodologically, this approach focuses more on the understanding of social phenomena through everyday situation and interactional processes, and is a necessary complement to the social constructivist approach.

While both the approaches described have a clear advantage over technical ways of explaining what goes on socially around the technology, their very (methodological) focus on the understanding of social phenomena probably inhibits a balanced examination or analysis of complexities of water control - which includes physical process as well - in irrigation systems.

Integrated approach
Nowadays, it is conventional wisdom that irrigation systems should be examined in their entirety with a 'whole system' approach (Keller 1990). Ideally, professionals of different disciplines working in an interactive and interdisciplinary mode could provide better and complete analysis of an irrigation system. But, very seldom are the necessary human and capital resources available to allow such a comprehensive research design, and for canal systems, as Chambers notes, 'Even with all professional eyes open, a canal irrigation system is less easy to define, observe, or dissect ...' (Chambers 1988: 40).

In the present study involving both technical and organizational dimension of canal irrigation systems, however, a conceptual framework based on the integrated approach is adopted. Figure 1.1 shows the schematic presentation of the conceptual framework. For analytical purposes, the concepts of practice, social interaction, and intervention have been adopted from Bourdieu (1977) and Giddens (1987, 1992).

The concept of practice here refers to the visible actions and undertakings of people which can be studied through observation (Bourdieu 1977: 95-97). It enables us to understand how a certain type of water control technology provokes particular activities of water allocation and distribution in an irrigation system.

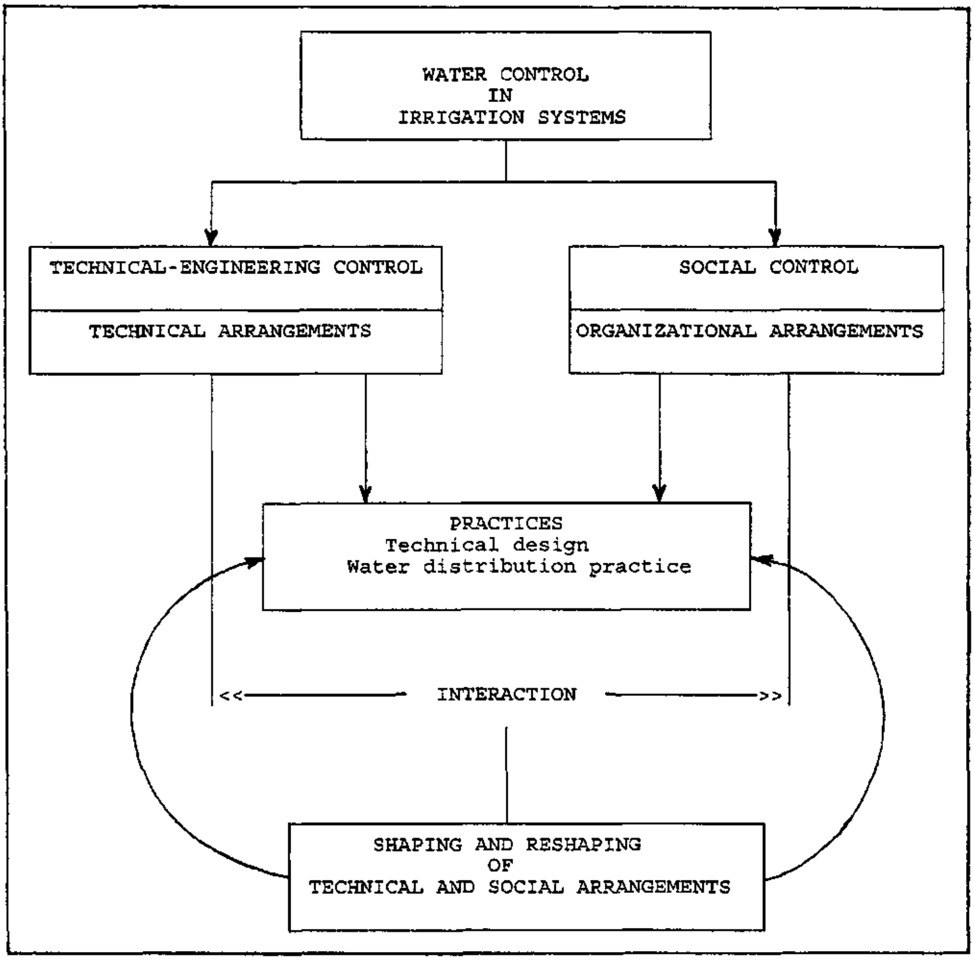


Figure 1.1 Conceptual framework for the study of water control in an irrigation system

The concept of social interaction means the processes resulting when people come together and exchange material goods and share experiences. The interaction of different social groups, such as small and large farmers, head and tail-end farmers, design engineers and operating engineers, planners, politicians and agricultural labours etc, make an irrigation system function. Observation of social interaction might reveal the dynamics of a pattern of practices followed in controlling water in the irrigation system. As Zaag (1992a) has rightly noted, social interaction is a particular case of practice.

In irrigation development, intervention essentially occurs and is aimed at changing the existing technical and social order. The concept of intervention here refers to the process which introduces new criteria in technical and organizational arrangement that are intended to eventually change the existing pattern of practices in an irrigation system.

1.4 The research methodology

This research was conducted on government-built and operated canal irrigation systems in the *tarai* region of central and western Nepal. It is based on the case study method and involved combining quantitative and qualitative tools and techniques for the collection of data and their interpretation.[16] A complex process like water control in canal irrigation systems would not have been fully understood with the quantitative data and their evaluation alone. Qualitative information was used to support quantitative observations.

Selection of sites

For the better understanding of the complex water control in government canal irrigation systems, three sites (irrigation systems) in the *tarai* were selected for intensive data collection. In the beginning, it was decided to conduct in-depth study on only two government-built and operated canal systems. It was expected that large government canal irrigation systems would require more complex technical and organization forms which would have high applicability to the further development of public irrigation systems in the country. As the field research progressed in the two sites, one more canal irrigation system was chosen. This third irrigation system had a particular technical pattern which had never before been used in government canal irrigation systems in Nepal and whose effectiveness had provoked much discussion among government engineers and donor agencies. It also incorporated the organized involvement of water users in the planning and construction of tertiary level physical facilities. The field study on this site which is in the far west of the country could be conducted only for a short period of two months (December 1992 - January 1993) because of the time limit and the seasonal accessibility.

The three main criteria used for the selection of study sites were as follows:

(i) Water supply conditions: Research has shown that water supply conditions affect management practices. The general expectation would be an intensive management where the supply was less abundant, and less management where water is abundant.

(ii) Technical difference: It was expected that this would allow the observation of a range of management practices - management being the derivative of the design. This criterion is related to the water supply conditions too. It can be expected that different water supply conditions would determine different technologies to use the available water.

(iii) Relative age: This criterion was to account for the change or evolution of technical pattern and management practices over time and to relate the phases in technical (and managerial practices) development to changes in irrigation or agricultural objectives (e.g. introduction of crop diversification).

Though most parts of the *tarai* are accessible, accessibility to the sites was an important criterion not only for the point of view of research management, but also for the expected supervision and monitoring from Wageningen. The possibility to travel and to transport research equipment from one site to another were important considerations.

A final criterion was the availability of design information on the irrigation systems, and time-series records of water supplies. It was desirable to select sites for which initial maps, drawings, and other relevant documents of the canal system were available.

There were two main reasons for focusing research on the canal irrigation systems in the *tarai* region. Firstly, this region has the maximum number of and largest hectare coverage by government-built and operated large to medium scale canal irrigation systems, and secondly it has largest remaining potential in the country for the further development of irrigation systems using river water resources.

Figure 1.2 shows the location of each of the three sites that were chosen for intensive data collection. The Banganga Irrigation System at Taulihawa in western *tarai* has limited water supply. It is one of the three old government irrigation systems in Nepal, and was improved under the Command Area Development Project in 1982-90. From 1990 to 1992, the International Irrigation Management Institute in Nepal (IIMI-N) was engaged in organizing farmers of this area to help improve the system performance. The second site, the Pithuwa Irrigation System in inner *tarai* of Chitawan district, was designed and constructed by the government. It was improved by the organized effort of Pithuwa farmers who formed an organization to manage the system themselves. It was expected that the study of this irrigation system would reveal conditions for farmer organization and management of government irrigation systems. The Mahakali Irrigation System (Stage I) was identified as having abundant water supply, but the irrigation system had been redesigned and remodelled to be operated on rotational water supply.

Research management

After spending some months in Kathmandu taking care of logistic support, obtaining maps, preparing research equipment, and collecting relevant project documents, the researcher started the study in October 1991. The collection of field data continued until May 1993. In order to understand the local environmental setting within which the canal system operated, and day to day activities of farmers and farming activities, the researcher lived at Banganga (Taulihawa) for about twenty months, from October 1991 - May 1993. The other two systems were visited in turn every month, with each visit lasting at least a week. Living at the research site, moving along and around the canals at odd hours, and interacting with

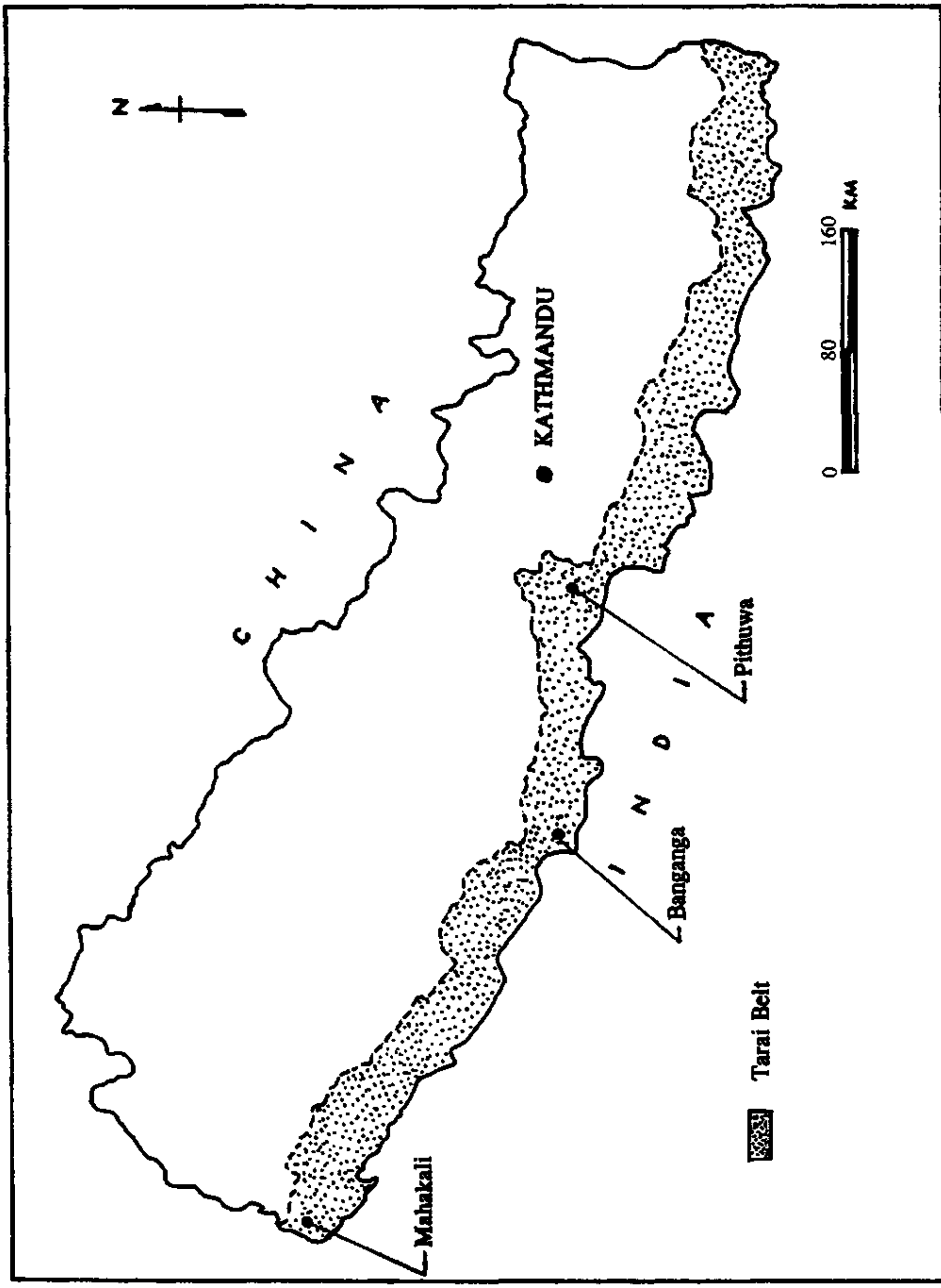


Figure 1.2 Location of the three irrigation systems studied

villagers, farmers, farmer leaders in their fields, villages, and market places greatly enhanced the understanding of not only the water-related and non-water related constraints but also gave firsthand knowledge of historical development, actual practices of water distribution, and how and why things were done the way they were done. Moreover, it also allowed the researcher to gain the farmers' confidence.

To carry out the study on three systems, two assistants were hired and stationed at the two sites. Each had a Bachelor's degree in agricultural science. They were deliberately chosen for their agricultural training so as to help get the researcher with an engineering background a better understanding of agricultural practices. In addition, local persons were hired and trained to perform canal flow measurements.

The data

As stated earlier, the primary focus was on the observation of water allocation and distribution at the middle level of the canal system, while observing the water supply at the main system merely to find out the total supply in the system. However, some irrigation blocks or units at the tertiary level were selected, to look at how farmers managed the available water at the field level. These blocks were selected on the basis of water availability, feasibility of measuring the incoming flow, representation of the head and tail of the system or part of the system, representation of different groups of farmers, and manageability of the research. The process of water control at the middle level of each system serving these selected irrigation blocks was continuously observed for the period from October 1991 to May 1993, except in the Mahakali Irrigation System. This allowed the researcher to observe consecutively the irrigation activities during wet and dry seasons.

In the field, both qualitative and quantitative tools and methods were used to collect the data. The main qualitative tools and techniques applied were participant observation, structured and/or unstructured interview. The first few months were spent in open or unstructured interviews and in participant observation to obtain general understanding of the farming systems and the irrigation-related activities. The researcher participated and interacted with the local farmers during the observation of farmers' formal and informal meetings, whether in the irrigation office, in the village or in the farmers' fields. Living in the study sites enabled the researcher to engage in informal and open conversations through which many opinions and unrecorded facts about the irrigation development and operating procedures were explained. The interviews and observations were carefully noted in field diaries. To the researcher, daily writing and maintaining field diaries was a unique experience in that it was unbelievable that so much information could be collected through unstructured conversation. The language, of course, was not a problem for him.

Another important tool used to collect historical information and evidences was the study of archives and records available at the irrigation offices. The study of archives and records led to further interviews with a number of key senior engineers of the Irrigation Department to clarify or verify some of the information recorded in the archives.

All farmers who owned and/or cultivated the fields in the selected branch and irrigation blocks were interviewed. In the large irrigation systems, many farmers within the command of a secondary level canal had fields in more than one irrigation block served by the canal. Thus, some farmers at the tail end were simultaneously head-end farmers because of the location of their field. The interviews with them had to be conducted carefully. Moreover, repeated interviews and conversations took place, especially with key farmer informants, or crucial actors, for clarification and verification of the information and opinions. In addition, relevant socio-economic and household information was collected using pre-tested questionnaire. The questionnaire were used at the end of the research period after the researcher had gained enough of the informants' confidence through frequent interaction and open interviews. Hence, the answers to questions were more reliable than would have been the case if the questionnaire had been used in the beginning of the research.

Flow measurements were taken regularly at the head of the secondary level canal and at the selected key points in the main canal using current meters. A 'pygmy' current meter was used for flow measurements at the secondary level canals, and cut-throat flumes were installed at the head of the tertiary canals to measure the flows entering the tertiary block. The flows into the tertiary canals were measured twice daily during the irrigation period, whereas the flow in the supply canal was measured once a day or twice a week, depending on the condition of the supply in the main canal.

The cropped area in the tertiary blocks for both the wet and dry seasons was measured using a 30 metre measuring tape. The total area of the blocks obtained by the field measurement was not significantly different from the figures recorded at the irrigation office. The direction of water flow within the blocks were also mapped, to ascertain the farmers' method of irrigating their fields. For the recording of the cropped area, crops grown, and water flow path, the researcher and his staff had to prepare land parcel maps for each of the irrigation blocks.

Quantitative data on physical factors such as rainfall, temperature and evaporation were obtained from the nearest meteorological station, and used carefully, making allowances for local effects. In the context of this study, the time and information available, it was not appropriate to invest effort in an attempt to obtain very accurate figures for rainfall, estimated evapotranspiration or crop water requirements. Similarly, the data on the soil characteristics of the command areas were obtained from the most recent soil analysis report. Additional information to further understanding of water control came from the findings of two MSc students who did their field work on water distribution in one of the three irrigation systems studied. The interaction and discussion with them during their stay in the field gave valuable input to further exploration.

Problems and limitations of irrigation research in Nepal

For a better understanding of the dynamics of water control in canal irrigation systems, it is required to have time-series data on a number of related variables: flows at the water source, canal flows, rainfall distribution, irrigated area, crop pattern, crop yields, land distribution and so forth. One would expect that such data would be well recorded and maintained in case of government-operated canal systems, though the access to them could be difficult. In Nepal, the availability of such data is poor. In many cases, technical documents including design documents (maps and reports) have been mislaid or are missing, and with limited time and resources for data collection, the researcher is usually constrained to use the data collected within a year or two and what can be obtained from interviews. This was the case with the present study.

However, the researcher had an advantage over other researchers in being an engineer with the Irrigation Department. This allowed him to gain access to the research sites and official documents readily. On the other hand, being a researcher originating from the Irrigation Department was also a disadvantage. Despite efforts made to remain (to act as) an independent researcher, it was not easy to remain aloof from the problems of the researched groups (farmers, field staff and officials of the irrigation office and others), and objects (irrigation systems and structures). The researcher was often faced with the requests from and expectations of both farmers and irrigation staff (colleagues in the department): farmers requesting more water, complaining about the head-end farmers, junior field staff requesting for either transfer or recommendation for promotion. Amidst these requests and frustrations of the people, the researcher had to learn how to conduct a balanced study.

1.5 Preview of the thesis

This thesis has the following structure. Chapter 2 outlines briefly the physiography, land and water resources, and farming systems of Nepal, focusing on the *tarai* region. This is followed by a historical outline and discussion of the development of government canal irrigation systems and the current policy. Common technical features of the *tarai* canal systems and their general performance are also presented.

Chapters 3 through 5 present a detailed description of each of the case studies. In each case study, the focus is on the technology, technical design, and organizational arrangement for water supply and distribution. In Chapter 3, the Banganga Irrigation System is described and examined in detail. This chapter presents the consequences and implications of the gated water control technology which was designed for operational flexibility.

Chapter 4 describes the Pithuwa Irrigation System which comprises a simple water control technology of proportional distribution through ungated pipe outlets. The focus of this chapter is on the organizational mechanism or arrangement of the farmers to manage the system initially built by the government.

Chapter 5 presents the case study of the Mahakali Irrigation System. The focus of this chapter is on the "structured" design concept based on which the physical infrastructure of the irrigation system was remodelled. How farmers look at this design is examined.

Chapter 6 presents the synthesis and comparative analysis of all the three case studies. A summary of the findings and the implications for further intervention to government built systems are presented in the concluding Chapter 7.

Notes

1. One of the reasons for failure to meet the food grain production is the excessive size of the command areas of many irrigation systems. The command areas are out of proportion to the availability of irrigation water.

2. The poor performance of Nepalese agriculture has often been attributed to bad or poor (weather) monsoon, and to the failure to extend irrigation sufficiently in the *tarai*.

3. This figure is the sum of the cultivable command areas of the irrigation systems considered completed, and does not necessarily indicate the availability of irrigation water to all of this area.

4. In public sector irrigation development, the observations by both Chambers (1980), '... the conventional way of planning and designing follows a top-down approach in that government agencies make all major decisions with very little predesign or preconstruction involvement of local people ...', and Coward (1985b), '... most rehabilitation efforts ... often pursuing an officious approach that allows the state to ignore the investment history of the locale. Often this approach results in a new technological apparatus being placed into a muddled property context ...' have special relevance in the context of Nepal.

5. Technology here is used in its broad sense. It includes all artifacts for controlling irrigation water, the mode of operation and methods of water delivery, and related knowledge and skills.

6. The irrigation systems throughout this thesis refer to canal irrigation systems unless specifically mentioned.

7. According to Levine (1977) most large and medium-scale canal irrigation systems in South Asian countries are "comprehensive", while Wensley and Walter (1985) and Horst (1983) referred them as "conventional". In conventional systems, the command area is supplied with water through a complex network of canals that branch at different levels, and each lower level canal is connected to the higher level canal by a flow regulating structure.

8. See Simon, Herbert A. (1988:195), *The Sciences of the Artificial*, MIT Press, for the complex system. A complex system, according to him, is made up of a large number of parts that interact in a non-simple way. In such a system, the whole is more than the sum of parts, not in an ultimate metaphysical sense but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole. He also refers to Weaver, W. (1948) who, in Science and Complexity, *American Scientist* 36: 536, has distinguished two kinds of complexity - disorganized and organized.

9. Operational flexibility is defined as the capability of the system to comply with changing demands and supplies (adopted from Horst 1983). Irrigation systems are subjected to inter and intra-seasonal variations in the supply and demand of water due to variations in the supply at the water source, crop patterns and crop growth stages.

   Flexibility, in broad sense, is the ability to respond to changing needs, and obviously a desirable trait in an irrigation system. The physical and organizational infrastructures of an irrigation system appropriate for one stage in a country's development will probably not be appropriate for another, since the development environment is continuously evolving e.g. increased agricultural production for self-sufficiency, export and industrial support, to crop diversification. The need for systems to be adaptable increases over time. However, over this time period, the capability of a system to adapt usually declines.

10. The location of structures and their number are governed primarily by the natural conditions of the command area such as topography, size of the command area to be served, size of landholdings, soil conditions of the potential locations for structures, and farmers' skills in managing water.

11. Operational efficiency here refers to the measure in which the irrigation supply could meet the actual field water requirements (Horst 1987).

12. The characteristic element of ecological perspective as noted by Coward Jr. is its emphasis on "the role of the physical-environmental factors in shaping, limiting or determining various forms of group-shared behaviour and regularities which lie behind them" (with reference to Berry, John W., 1976: Human Ecology and Cognitive Style).

    Coward differentiates institution from organization as a concept associated with ideal behaviour and expectations which can be used as a generic concept for the variety of rules that help to pattern social behaviour: norms, folkways, customs, convention, fashion. For example, the custom of performing a ritual ceremony at the headwork of a community irrigation system as in Indonesia's *Subak*.

13. See also Browning, Theodore E. (1974), "Irrigation and Moisture-Sensitive Periods: A Zapotec Case", *Irrigation's Impact on Society*.

14. Bortrall (1981) pointed out three factors that determined the extent of boundary or threshold in joint management of a public irrigation system: (i) technological complexity of the water distribution system (this is associated with the system design), (ii) the relative water scarcity (supply-demand ratio which could also be induced by design through rationing), and (iii) degree of social cohesion (collective force) in the community of water users.

15. Examples of differing technologies that impose varying requirements on individuals and organizations, and corresponding emergence of suitable organizational structures can be found in the industrial sector. Although it provides an insight into technology-organization relations, the situation in the industrial production process is different; (raw) materials are transformed from one form to another, and control over technology of transformation is governed by various external factors. Since irrigation water is transported and distributed to its users but not transformed to another form, it remains to be explored whether the technology-organization situation in industrial production process is applicable in irrigation systems.

16. For the usefulness of the case study method see Yin, K.R. (1984), 'Introduction', in *Case Study Research: Design and Methods*. Beverly Hills, Sage Publication, pp.13-26.

2 Canal irrigation in the *tarai*

There is historical evidence that canal irrigation in the *tarai* has been practised by farmers of the country for centuries. But the development of modern canal irrigation systems began in the 1920s, and was initially confined largely to the *tarai*, the southern plains of the country. In the 1970s, most of the large canal irrigation systems in the region were developed with the assistance of external donor agencies.

The purpose of this chapter is to give a broad outline of the development of the government canal irrigation systems in Nepal in general, and in the *tarai* in particular. The land and water resources of a country determine the potential and constraints of irrigation development in that country. The first section of this chapter introduces the history, physiography, and land and water resources. Irrigation systems usually affect the local farming practices and cultivated area. Section 2.2 deals with the farming systems and cultivation practices, and is followed by a historical outline of irrigation development and the current policy in Section 2.3. The last section of this chapter gives the general features of government-built canal irrigation systems in the *tarai* as regards their technology, engineering design, management, and general performance. In this way, this chapter is aimed at providing a background for the three case studies on irrigation systems described in the subsequent chapters.

2.1 History, physiography, land and water resources

Brief history

The Kingdom of Nepal is a small mountainous country situated in South Asia between the longitudes of 80° 04' and 88° 12' East, and the latitudes of 26° 22' and 30° 27' North. The roughly rectangular shape of the country covers an area of about 14.72 million hectares (147,181 km^2) extending approximately 885 km from east to west and with an average width of 193 km ranging from 145 km to 242 km from north to south.[1] The country is landlocked and sandwiched between the two large and most populous nations of the world - India on the east, south and west sides, and China to the north (Figure 2.1).

Historically, Nepal was unified during the second half of the 18th century (1750-1775) by King Prithivi Narayan Shah of Gorkha which was one of the petty states in the western hills.[2] After the unification, five distinct periods of governance can be identified: (i) Post-unification period (1775-1846) when Nepal followed an expansionist policy and confronted the British in India, (ii) Rana oligarchic regime (1846-1951) when the country was effectively isolated from the outer world, (iii) Post-Rana period (1951-60) when the country witnessed democratic experiments, and (iv) Party-less Panchayat regime (1960-90) when the rise of bureaucracy occurred, and international capital in the form of loans and grants began to play a dominant role in the country's development, and (v) Present governance under the multi-party system from 1990 onwards with a policy towards economic liberalization, privatization and an increase in borrowing of international money.[3] Each of these periods showed differences in the nature of irrigation development in the country. (See the following section.)

For political and administrative purpose, the country is divided into 75 districts, 14 zones and five development regions. Each development region extends north-south so that it includes districts from the hills, mountains and southern plains. The present political structure comprises three levels: (i) Village Development Committee (VDC) at the village level, and the Municipality in the town, (ii) District Development Committee (DDC) at the District level, and (iii) Parliament at the national level. A VDC is further composed of nine wards, each ward having a committee.

The current administrative system of the country consists of three tiers: (i) central administration in Kathmandu, (ii) regional administration in the five development regions, and (iii) district administration in the 75 districts. The central administration is composed of various ministries and their departments, constitutional bodies, the parliamentary secretariat, the supreme court, the National Planning Commission, central offices of public corporations and so forth. The regional administration consists of the regional directorate of various departments, the regional office of the National Planning Commission, and the regional offices of some public corporations. The district administration is run by a Chief District Officer (CDO) who is primarily responsible for maintaining law and order in the district, and who acts as the chief representative of the national government at the district level. The CDO is accountable to the Home Ministry.

In each district, the office of the District Development Committee has a Local Development Officer (LDO) who, as the ex-officio secretary to the DDC, coordinates all local development activities of the sectoral offices of the government such as education, health, agriculture, irrigation, transport and communication, drinking water supply and so forth. The LDO is accountable to the Ministry of Local Development. In keeping with the policy of decentralization, the government has been promoting the direct involvement of local bodies or beneficiaries in development projects designed to fulfil local needs.

Agriculture is the mainstay of Nepal's economy providing about 66 percent of the GNP, 80 percent of the export earnings, and employment to more than 80 percent of the country's labour force (MOF 1992). It provides food for almost the entire population. The 1991 census for the country showed an increase in the population from 15.022 million in 1981 to 18.491 million, a rate of 2.1 percent per annum (Central Bureau of Statistics 1994). However, the average annual growth rate of food grain production over the past 28 years was estimated at 2.1 percent (National Planning Commission 1992:3).

The country's industrial sector is at a primary stage. Most industrial production is based upon agriculture. The National Planning Commission (NPC 1992) estimated that the industrial sector, including cottage industries, contributed about 5 percent to the GDP, and provided employment to only about 2 percent of the labour force. The prospects for Nepalese small industries appear grim given India's much higher level of industrial development, transport infrastructure, geographical advantage and open border with Nepal. Agricultural development is, therefore, essential for the welfare of the people and the growth of the national economy.

To appreciate the potentials and constraints in the development of (irrigated) agriculture and to know the diversities in farming system in the country, it is useful to understand the country's physiography and its agro-ecological characteristics.

Physiography and agro-ecological characteristics

Nepal is located on the southern slope of the great Himalayan Mountain range, and about 75 percent of the country is covered by hills and mountains oriented east-west. The country has extreme variations in physiography, geological formations, climate, and vegetation within the short span of its width across south-north. The variations in physiography and geological formations are reflected in the differences in landform, soil types, and the production potential of land.[4] Even within a region, climatic conditions and land potentialities differ from place to place because of the differences in altitude. For these reasons, there are differences in cropping patterns, agricultural input requirements, and crop yields.

The rugged and difficult mountain terrain has a significant impact upon the country's overall development and economic growth.[5] Most parts of the country are isolated, and access is very difficult. The cost of developing access to mountainous areas is extremely high. Inadequate or lack of transport and communication facilities has inhibited farmers of these areas from getting an access to markets for selling their surplus agricultural produce and buying necessary inputs.

The Land Resources Mapping Project (LRMP) identified five physiographic regions, each of which runs across the country from east to west : (i) *Tarai* (southern plains), (ii) *Siwalik* Valleys and Slopes, (iii) Middle Mountain Valleys and Slopes, (iv) High Mountain, and (v) High Himal (Carson et al. 1986; Carson 1986).[6] Hereafter the description and discussion will be mostly focused on the *tarai* physiographic region.

The *tarai*, the southern belt of land adjoining North India and varying in width from 25 km to 32 km, is an extension of the Indo-Gangetic plain. Its elevation ranges from 60 m near the Indian border to 300 m near the *Churia* hills. The climate is sub-tropical and the rainfall is due to the southeast monsoon which occurs during the four months from mid-June to September. The annual rainfall along this region varies from about 1,736 mm in the east to 1,440 mm in the west. In the west, the monsoon occurs about a month later and retreats earlier than in the east. The winter rainfall is higher in the western *tarai* than in the east. This entire *tarai* belt consists of mostly alluvial fertile soil, and forms about 23 percent of the country's land area. It contains approximately 80 percent of the country's irrigable land and produces the major portion of cereal crops, cash crops, fruits and vegetables. The principal crops are paddy, maize and wheat. The Economics Report of the LRMP (Whiting et al. 1986:10) estimated that about 82 percent of the cropped area in this region was cultivated for paddy, producing approximately 80 percent of the country's total rice production. The area is also the major producer of wheat in Nepal which is why the region is called the granary of Nepal. In addition to paddy and wheat, most cash crops which include sugar cane, oilseeds, tobacco, tea, ginger, cardamom, jute and fruits are also grown along this belt in varying amounts. This region contributes the most to the nation's GDP.

The *tarai* presents an unusually interesting case of indigenous economic development (Dahal 1983). Before unification, the region was covered with dense forest and was sparsely populated. Its eastern part was more populous than the western part which had virtually inexhaustible forests (Kirkpatrick 1811: 16-19). After unification, this region became the most valuable acquisition for the rulers of the country, partly because of land revenues, royalty from timber exports, levies on pastures, and the export of elephants (Olyphant 1852: 52). But it was valued more for its large tracts of cultivable land. In the early stage of unification, the state needed to increase revenue to meet the expenditure of the growing military and bureaucratic apparatus involved in the control and administration of the new territories. Given the low population density in this region, the government adopted a policy of encouraging immigrants and promoting land reclamation to obtain revenue from the taxation of agricultural producers (Seddon 1990:16). Immigrants from India were encouraged to settle and to reclaim waste land for cultivation.[7] Efforts in this direction continued even after the halt in the territorial expansion following the war with the British in 1814-16. The Regulations and Acts introduced by the state during the Rana period to encourage the cultivation of land increased Indian immigrants to this region considerably (Dahal 1983; Ojha 1983)). Attempts to control the migration of Indian people to the agricultural land in this region were made, for the first time, through the enactment of the 1963 New Legal Codes (*Naya Muluki Ain*), the 1964 Land Reform Act, the 1964 *Ukhada* Land Tenure Act which put restrictions on the ownership of any form of land by foreign nationals, and the 1964 Planned Resettlement Programme. But, with the control of malaria by the end of 1960s and the growing pressure of population on the land resource in the hills, migration of people from the hilly areas to this region increased tremendously.[8] This is reflected in the increased annual rate of population growth in this region from 3.54 percent in 1961-71 decade to 4.2 percent in the 1971-81 period. While the annual population growth rate for all Nepal in 1971-

81 increased from 2.04 percent to 2.66 percent, in the hills it was only 1.66 percent (NPC 1992: 624). According to the 1991 census, the population density per square kilometre of cultivated land in this region was 635 (Table 2.1).

The second physiographic region which is also called the inner *tarai* or inner terrain occupies land within the *Siwalik* range. In this belt, there are pockets of plain valleys called *Dun valleys* which are about 32 km to 64 km long and 16 km wide. The climate in this region varies from the subtropical to warm temperate. The cropping patterns are similar to those in the *tarai*.

The third physiographic region of Middle Mountain Valleys and Slopes is about 80 km wide, and its elevation ranges from 300 m to 4,000 m. Kathmandu, the capital of Nepal, lies in this belt. The climate in this region varies from warm to cool temperate.

The fourth and fifth regions which lie above 4,000 m elevation, comprise the high mountains of the *Mahabharat* range and the Himalayas in the northern border. These regions are mostly rocky, and at higher altitudes covered with snow and glaciers throughout the year. The climate varies from the cool temperate at low altitudes to the alpine and arctic at higher elevations. These regions are virtually without human habitation except for some isolated settlements in scattered valleys. The agricultural activities in these scattered valleys are limited to the minimum tilling of land. Naturally, with respect to irrigation, the High Mountain and Himal regions have their own unique features, but irrigation here is of little importance.

Though the five physiographic regions described above are very useful for the analysis of agricultural practices and land use patterns in the country, they are not convenient for planning purposes, since most relevant data are collected by administrative districts. For this reason, the Master Plan for Irrigation Development (1990) adopted the commonly accepted division of the country's 75 districts into three almost parallel ecological belts: (i) the *tarai* (including inner tarai), (ii) the hills, and (ii) the mountains.[9] Figure 2.1 presents the three ecological belts. It was claimed that this distribution maintained broad consistency with the distribution by physiographic region, since agricultural lands in the *tarai* districts were primarily located in the *tarai* physiographic region, whereas agricultural lands in the Hill districts were divided between the Middle Mountain Valleys and Slopes physiographic region (CIWEC 1990:8). Only these three agro-ecological belts are referred to hereafter.

Land resource and its potential
The principal agricultural resource, the arable/cultivable land, is severely limited by the topography of the country. According to the Agriculture/Forestry Report of the LRMP (Carson et al. 1986), the cultivable land is estimated to be about 33 percent of the total area of the country. Table 2.1 presents an estimate of the distribution of the land area, cultivated land, irrigable land and population among the three agro-ecological regions.[10] Clearly, the *tarai* region still has considerable irrigable land, while the irrigated area in the Hills and

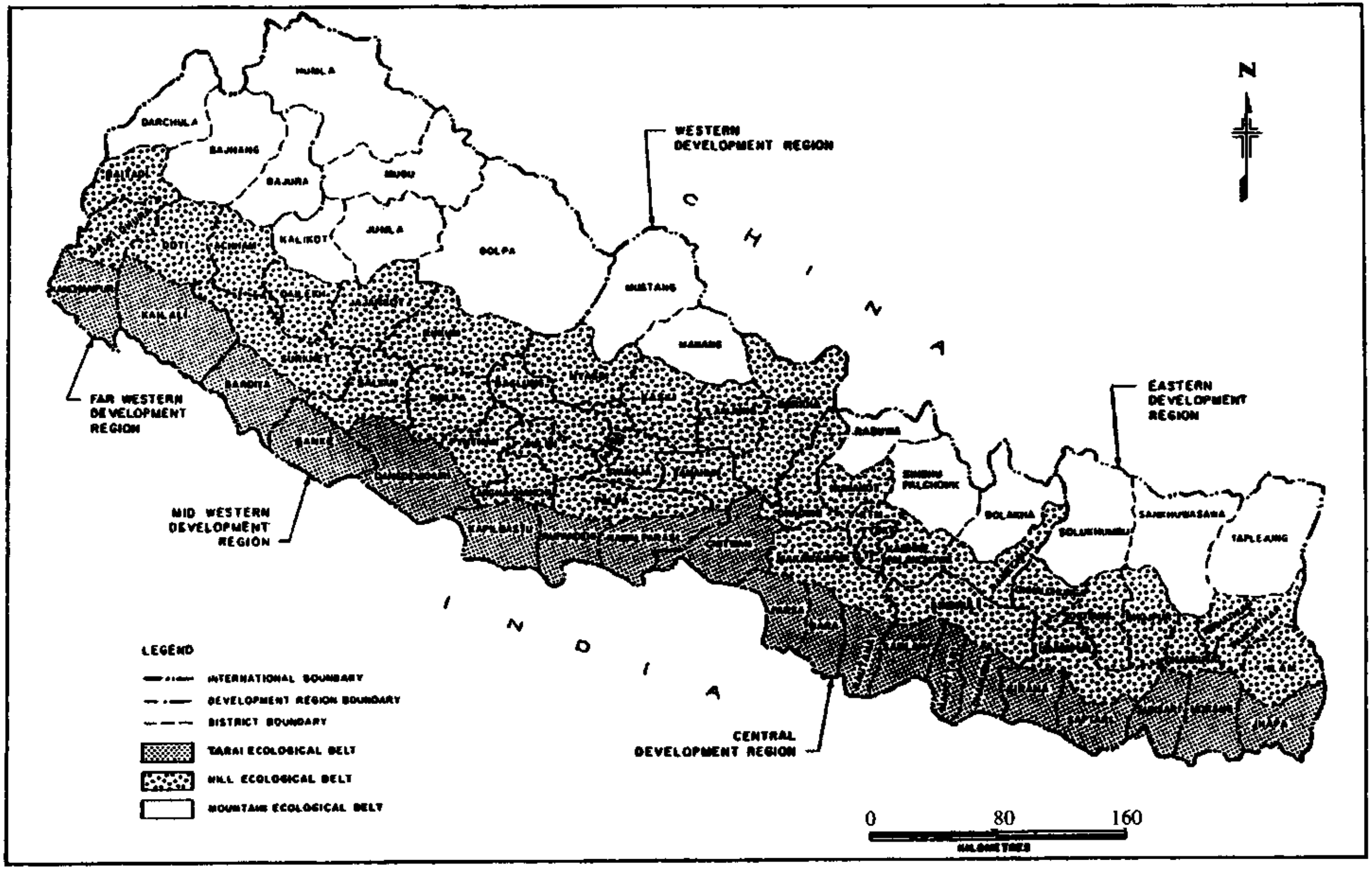


Figure 2.1 Three ecological regions of Nepal (Source: CIWEC, Irrigation Master Plan 1990.)

Mountains has almost reached its limits. The effective cultivation in many parts of the Hills and Mountains have reached its absolute limits owing to steep slopes, poor quality of soils, and population pressure on the cultivable land.

Not all the cultivated land in the country is irrigable. The LRMP (1986) defined irrigable land as the arable land for which a water supply is or can be made available under a specific plan, and which is provided or planned to be provided, with irrigation, land development, drainage, flood protection, and other facilities necessary for sustained irrigation.[11] In addition to the availability of water, the assessment of land for irrigation suitability is based on soil texture and fertility, topography including slopes and micro-relief, groundwater potential, drainage, and climate (Carson 1986: 25-26).

The total irrigable land of 21,780 km^2 (2.178 million hectares in Table 2.1) includes areas under forest cover too, and it is, therefore, the overall upper limit for irrigation development in the country. If the land for forest reserves and the land without access to reliable water supplies are excluded, the actual upper limit of irrigation development falls to 1.6 million hectares. Of this total, about 1.3 million hectares lies in the *tarai*, and the remaining 300,000 hectares are located in the Hill and Mountain districts (CIWEC 1990). A recent estimate of the land utilization situation in the country by the LRMP showed 26.5 percent of land occupied by agriculture, 42.4 percent occupied by forest, 11.8 percent occupied by pasture and 19.3 percent by other land uses (Carson 1980; Hidreth 1986).[12]

The land classification related to irrigation

Various land classification systems such as USDA, USBR classifications, and the like are used by the planners, resource managers, and government agencies in Nepal to meet their diverse needs, but the land classification outlined in the 1962 Land (Measurement and Assessment) Act - with amendments - deserves mention here because of its relationship to irrigation. This classification system which was primarily intended for the purpose of land taxation deals with agricultural land only.[13] In Nepal, it is used much more than other scientifically based land classifications. For example, the cadastral maps used for land registration are marked with the land types under this classification system, and these maps are also referred to for the assessment of irrigation fees. Under this classification, the quality or grading of agricultural land decreases with elevation, steepness and flood hazard. Further, this classification system uses traditional terms. The land classes and the corresponding terms are described below, as these will appear repeatedly in the following chapters.

At the first level, this classification system separates land in the *tarai* from all other land in the country. Then, *khet* (lowland or wetland where paddy cultivation invariably occurs) is separated from *pakho* (upland, maize cultivation without irrigation).[14] These two types of land are further subdivided into four categories based on the extent of irrigation availability and soil conditions. In the decreasing order of grading, the four categories are as follows:

Khet land

Awal	receiving year round irrigation, enabling two or more crops to be grown.
Doyam	receiving supplemental (monsoon) irrigation (5-6 months), enabling two crops to be grown.
Sim	receiving supplemental irrigation (less than 2 months) with only one crop.
Chahar	paddy production, but only in certain years.

Pakho land

Awal	having no soil limitations.
Doyam	having minor soil limitations.
Sim	major soil limitations (sandy soil, and stony and gravelly soils with stones).
Chahar	having severe soil limitations.

Fifth level all land above 2,438 m.

Table 2.1 Land and population distribution among the three ecological regions of Nepal

	Distribution	Ecological region			Nepal
		Tarai	Hills	Mountains	
1	Land area (km²)[a] " (%)	34,100 23	61,530 42	51,850 35	147,181 100
2	Cultivated land (km²)[b] " (%)	13,590 52	10,550 40	2,270 9	26,410 100
3	Population ('000)[c] " (%)	8,628 46.7	8,420 45.5	1,443 7.8	18,491 100
4	Population per km² of cultivated land	635	798	635	700
5	Cultivated land per capita (ha)	0.16	0.12	0.16	0.14
6	Irrigable land (km²)[b] " (%)	17,440 80	3,730 17	610 3	21,780 100
7	Irrigated land (km²)[d] " (%)	7,860 72	2,530 23	520 5	10,910 100

Sources:
a. Land Resources Mapping Project, 1986.
b. Master Plan for Irrigation Development, 1990.
c. Central Bureau of Statistics, 1994.
d. DOI documents, 1992-93.

Both *khet* and *pakho* lands in the *tarai* are taxed higher than those in the Hills and Mountains indicating their higher value. In addition to the higher land tax, a farmer is also charged a fee for the area of land which he has irrigated with the water from government canals.

Water resources and irrigation potential
Nepal is endowed with abundant natural water resources which can be used for irrigation, hydro-power generation, and other related purposes. The major rivers of the country are the Koshi, Gandaki, Karnali, and Mahakali, which are all major tributaries to the Ganges river. In addition to these rivers, there are numerous small rivers and streams. Almost all of these flow from north to south, from the Hills towards the *tarai*. The discharge of all these rivers are influenced by the monsoon rainfall, with the wet season flow being considerably higher than the dry season flow. Some data suggest that the average annual run-off formed within the Nepalese territory is about 174 billion cubic metres. With the average irrigation requirement of 1 lps per hectare, the land area that could be potentially irrigated throughout the year from the available water resources in the country is more than 5 million hectares (Biswas 1989; Pradhan 1990:7).[15]

The average annual rainfall of the country is about 1,600 mm. About 80 percent of this annual rainfall occurs during the monsoon months of June-September. This implies that about the same percentage of the total annual flow in the rivers occurs during this period. In terms of water balance, rainfall is higher than the Thornthwaite evapo-transpiration (Et) during these four months.[16] Maximum water deficits occur in the pre-monsoon months of April and May when highest rates of evapotranspiration can be observed, especially in the central and eastern parts of the *tarai*.

In addition to the surface water, the country has groundwater resources, most of which are also in the *tarai* physiographic region. The actual irrigation potential of the groundwater is yet to be ascertained. A rough assessment showed that about 12 billion cubic metres of groundwater is available. Of this quantity, approximately 50 percent is rechargeable and could, therefore, be safely extracted annually for irrigation and other purposes (Poudel and Sharma 1993: 2.27). Together, the river (surface) water and the groundwater could potentially irrigate 100 percent of all cultivated land in this region.

Before discussing the development of canal irrigation systems in Nepal in general and in the *tarai* in particular, it would be useful to give some attention to farming systems and cultivation practices in the country.

2.2 The farming systems and cultivation practices

Farming in Nepal varies from one agro-ecological region to another due to the variations in topography and climate. The Master Plan for Irrigation Development (CIWEC 1990: 10-13) identified four farming systems in the country: (i) the Main *Tarai* farming system, (ii) the

Dun Valley farming system, (iii) the Middle Mountains farming system, and (iv) the High Mountains farming system.

The Main Tarai farming system

The Main *Tarai* farming system is based on the cultivation of paddy on the heavy alluvial soils of the *tarai* plains. This farming system is practised on about 88 percent of the cultivated area in this area, and approximately half of this cultivated area is under rainfed conditions. Under rainfed farming, paddy is invariably cultivated during the monsoon period, followed by winter crops which are generally grown in a limited area on the residual moisture. Where irrigation is available throughout the year, the most intensive farming is the cultivation of two crops of paddy followed by a winter (*rabi*) crop of wheat. This requires that one of the paddy crops should be an early maturing variety. The other *rabi* crops grown during the period between November and March are rapeseed/mustard, potato, lentil, peas, and maize. The cropping patterns under this farming system vary among the five development regions.[17]

Farmers grow rice in roughly levelled small basins with bunds around the perimeter for ponding water. The average landholding is relatively large (3 hectares) and may consist of a number of such basins. Usually animal (oxen and buffaloes) powered implements are used for land preparation and transport of harvest. The crop residues provide a large proportion of the fodder, and the farms are relatively independent of forest and grazing land.

The Dun Valley farming system

This farming system is based on the cultivation of maize, mostly under rainfed conditions, on the newly deforested lands in the valleys and lower slopes of the *Siwalik* physiographic region. It occupies about 8 percent of the total cultivated area of the country. Landholdings are usually smaller than 2 hectares. Soils in this valley are lighter and more porous than in the main *tarai*. The rainfed maize is sometimes followed by a winter crop of mustard or rapeseed.

The Middle Mountains farming system

The Middle Mountains farming system, which occupies about 38 percent of the country's cultivated area, is practised in the arable areas of the Middle Mountain physiographic region. Cultivation mostly takes place on narrow terraced land on the hill slopes and on the level terraces called *tars* in river valleys. Rainfed agriculture is dominant, due to the shortage of irrigable land and reliable sources of irrigation water. Two types of cropping pattern are distinct in this farming system: (i) a maize and millet based crop pattern under rainfed conditions, and (ii) paddy-based cultivation on lands receiving some irrigation. Sometimes, maize and/or paddy is followed by a winter crop of wheat. The LRMP estimated that about 70 percent of the country's maize production and the cultivation of most millet and barley occurred under this farming system (Carson et al. 1986). In addition, the leguminous crops (soyabean, groundnut, black gram and the like), potato, mustard and rapeseed are also grown. Most landholdings are smaller than 0.5 hectare, and are scattered between small parcels. Therefore, farming is rather intensive. Ox-drawn ploughs are used for land preparation, and cows and she-buffaloes are raised for milk and manure. Forest and public grazing land are used heavily for compost and to supply fodder for livestock.

The High Mountains farming system

This type of farming system is practised in the very limited cultivated areas of the High Mountains and the High Himal physiographic regions. There is a very low potential for crop cultivation, because of the high altitude and unsuitable climatic conditions. Farming essentially consists of raising livestock such as goat, sheep, horses and yak. These livestock provide milk and wool, and are used as pack animals for trading. The livestock are maintained by migratory grazing through the alpine meadows of Nepal and into Tibet in the summer season, and through forest grazing and the utilization of some crop residues at lower elevations during the winter months. In the summer, crops such as barley, wheat, potato, buckwheat, and finger millet are grown at lower altitudes. This farming system occupies about 8 percent of the country's cultivated area.

In each of the farming system described, mostly traditional cultivation practices persist under both rainfed and irrigated conditions. Farmers use local (unimproved) seeds, locally made compost and animal manure, wooden ploughs, simple farming implements, and animal power. All farms in Nepal are family operated with 2-3 family members engaged fully in farming activities.

In the hilly and mountainous areas, farming operations are mostly carried out manually and with the help of animal power. It is hardly possible to use farm machinery, nor is this desirable because of small and fragmented landholdings/parcels, topographic conditions and limited accessibility to the fields. Farm machinery, therefore, has little value in these areas.

In contrast, improved varieties of seeds, chemical fertilizers and other agricultural inputs are increasingly used in the *tarai*, particularly in the areas where irrigation is reliable. Although most farmers having large landholdings increasingly employ farm tractors and power tillers to prepare land, many farmers still use simple farming implements and animal-drawn ploughs.

In summary, farming systems in Nepal have the following general features:

- Primarily paddy-based, especially in the areas where irrigation is available, since rice is the staple food and most valued crop.
- Self-sufficiency oriented traditional farming, mostly under rainfed conditions, in the Hills and Mountains.
- Intensive farming on small landholdings where irrigation is available.
- Integration with livestock and forest for draught power, manure, milk, firewood, fodder and compost.[18]
- Labour-intensive cultivation.

- Market-oriented farming in many parts of the *tarai* where improved seeds, chemical fertilizers, pesticides and other agriculture inputs are available and there are opportunities to sell surplus produce.

Irrigated farming and crop production

The 1990 Master Plan for Irrigation Development estimated that irrigated farming occupied about 36 percent of the country's cultivated area. The remaining area was under rainfed farming which included both rice-based and maize-based cropping, depending on the agro-ecological conditions (ibid: 13). Irrigated farming in Nepal takes place under two irrigation conditions: (i) year-round irrigation, and (ii) supplementary irrigation. The year-round irrigation is characterized by the complete control of the supply of irrigation water, and winter crops also receiving full irrigation. Under supplementary irrigation, water is available only during the monsoon season, and most winter crops are grown under rainfed conditions or are not grown at all. Some recent data suggest that about 72 percent of the irrigated land in the *tarai* is under this condition of irrigation (CIWEC 1990; Poudel and Sharma 1993).

Some estimates show that the cropping intensity in the Hills ranges between 1.75 and 1.8 under irrigated conditions. The intensity varies from 1.09 to 1.15 for rainfed areas. The cropping intensity in the *tarai* under year round irrigation ranged from 1.95 to 2.1, and was 1.42 under supplemental irrigation and 1.1 under rainfed conditions (CIWEC 1990:16; Poudel and Sharma 1993:7.4). In some places in the hills, especially on smaller landholdings having reliable irrigation, the cropping intensity is more than 2, depending upon the local climate such as temperature, humidity and solar radiation. The invariable cultivation of paddy in the *tarai* under both rainfed and irrigated conditions affects the cropping intensity, since most (low) land with paddy remains fallow partly because of the use of late maturing variety, and partly because of the long time taken by the saturated (clayey loam) soil to dry before it can be used to grow some winter crops.

Crop production

Average crop yields in Nepal are considerably below potential and significantly below the levels achieved in the neighbouring countries. As Biswas (1989: 1055) notes, it is not possible to assess the actual impact of irrigation development on crop production on the basis of existing data. Nevertheless, the Master Plan (1990) estimated that more than 50 percent of the country's crop production is from irrigated farming. Table 2.2 shows an estimate of the production of major cereal and cash crops in 1990-91 compared with that of 1981-82.[19]

The planners of the eighth five-year development plan (1992-97) concluded that the modest increase in gross production of major cereal crops in the country was largely due to the increased cropping area rather than to the growth in productivity (NPC 1992:116). The estimated production of the cereal crops in the *tarai* in 1990-91 just exceeded the demand based on per capita calorie consumption, while it showed a deficit for the Hill and Mountain regions (DFAMS 1992:22).

Table 2.2 Estimated production of major cereal and cash crops in Nepal (1990-91)

	Crops	1981-82			1990-91		
		Area cultivated ('000 ha)	Production ('000 MT)	Av. yield (MT/ha)	Area cultivated ('000 ha)	Production ('000 MT)	Av. Yield (MT/ha)
1	Paddy	1,296.53	2,560.08	1.97	1,455.17	3,502.16	2.41
2	Maize	475.49	751.52	1.58	757.71	1,230.95	1.62
3	Wheat	399.89	525.93	1.31	592.74	835.97	1.41
4	Millet	122.10	121.71	0.99	198.57	231.63	1.17
5	Barley	27.02	23.32	0.86	29.61	27.84	0.94
6	Sugarcane	25.17	590.00	23.44	32.96	1,105.96	33.55
7	Oilseeds	113.90	79.12	0.69	156.31	92.14	0.59
8	Potato	52.01	321.10	6.17	84.28	738.03	8.76
9	Pulses	n.a	n.a	n.a	267.72	161.32	0.60

n.a = not available
Source: Food Statistics of Nepal, MOA (1992).

Studies on the agricultural productivity in the country (ADB/HMGN 1982; LRMP 1986; CIWEC, Master Plan 1990) identified six main constraints to the achievement of higher levels of productivity in irrigated agriculture. Most of these constraints also apply to rainfed agriculture. The constraints are:

(i) inadequate supply or non-availability of agricultural inputs, forcing farmers to retain traditional farming,
(ii) inadequate agricultural credit services from formal institutions,
(iii) weak agricultural extension services, inhibiting farmers from adopting new technology,
(iv) lack of financial incentives to many farmers due to poorly developed market conditions,
(v) land tenure situation (e.g. share cropping under informal arrangements) which does not encourage the real cultivators to use improved technology and increase production due to the insecure and temporary tenure arrangements, and
(vi) inadequate and poor irrigation water management.

Whereas the constraints from (i) to (iv) mainly applies to most areas in the Hills and Mountains, those under (v) and (vi) considerably affect the productivity in the *tarai*. The government of Nepal has realized this, and the planners of the Eighth Plan have emphasized the development and improved management of existing irrigation systems to increase crop production (NPC 1992:46).

2.3 Irrigation development and current policy

Historical outline

Most of today's irrigation development in Nepal is the legacy of the past policies and planning at the higher level. It is therefore useful to give some attention to the past development pattern and current planning.

Among the existing canal irrigation systems in the country there are innumerable traditional canal systems built by farmers since time immemorial. Many of these farmer-built canal systems which date back to the pre-unification times are still functioning. The irrigation systems of the pre-unification period have different histories of their initial and continued development (Poudel 1965). They were developed under religious trusts, individual initiatives (mainly of local elites), community efforts, and royal directives. Such irrigation systems, whether state or community built, comprised indigenous technology, and were small in terms of the area irrigated. Each autonomous state had its own way of dealing with the development and functioning of irrigation systems. Some had explicit policies regarding state intervention, others left irrigation systems to function under customary norms. For example, in the 17th century, an edict of King Ram Shah stated that irrigation and its management were the responsibility of the community (Riccardi 1977).

For many decades following the unification of the country, the state followed a policy of using forced labour for the development of various infrastructure. State functionaries mobilized local resources through state-enforced corvee labour for the construction of new irrigation systems and the restoration of existing ones. Although the construction of a number of irrigation facilities was directly financed and carried out by the state, *Raj Kulos* (King's Canals) for example, the day to day operation, maintenance and repairs of such state-built facilities were left to the farmers (water users) and/or the revenue collectors. Their accountability or liability remained in the burden of paying rent for registered irrigated land. In addition to the construction of irrigation systems through direct financing, policies to encourage irrigation entrepreneurs were also formulated by the state.

The enactment of the 1854 Penal Code (*Muluki Ain*) during the Rana period (1846-1951) was a significant landmark in the development and management of canal irrigation systems in the country (Appendices 1 and 2).[20] This Code provided a legal foundation for canal administration in the *tarai* region. It made the Revenue Office (*Mal Adda*) in each *tarai* district responsible for the construction, operation, and maintenance of irrigation systems within the district. The chief of the (District) Revenue Office was legally empowered to mobilize both cultivators and villagers from nearby villages to repair and maintain the irrigation canals within his jurisdiction.

Though the agricultural land in the *tarai* was treated as the main source of revenue, historical evidence suggests that the state did not make a dedicated effort to develop irrigated agriculture in this region until the early 20th century. The first effort of the government towards the development of canal irrigation systems in the *tarai* can be said to have commenced in 1920 when the first international negotiation and agreement between Nepal and (British) India over the sharing of Sarda (Mahakali) river water for irrigation and power took place. However, the construction of the Mahakali Irrigation Project did not get under way until 1971, due to several constraints (See Chapter 5). The unique relationship with the British in India during the Rana period shaped not only the use and sharing of water of the common rivers between Nepal and India, but it also led to modern canal irrigation systems being introduced in Nepal. The first modern canal irrigation system in the country - the *Chandra Canal* in the eastern *tarai* - having a command area of 10,000 hectares was constructed in the years 1922-28 with the assistance of British engineers. In the period 1928-51 a few more canal irrigation systems were constructed by the then Public Works Department (PWD): Jagadishpur in the western *tarai* in 1942 (command area: 1,000 hectares) renamed the Banganga Irrigation System after being expanded in 1978, and Judha Canal in the cental *tarai* in 1946 (command area: 2,000 hectares) which became known as the Manusmara Irrigation System after being expanded in 1976.[21]

The post-Rana period from 1951 onwards was a turning point in the history of canal irrigation in the country. During this period, many of the preconditions for the subsequent irrigation development were created. In 1951 the administrative organ for irrigation development (the present Department of Irrigation) was established. The international agreements with India on the use of the Koshi river water in April 1954 and on the Gandak (Narayani) river water in December 1959, both for irrigation and power, led to the beginning of the construction of large scale government canal irrigation systems in the *tarai*.[22] The irrigation systems constructed under these agreements were essentially constructed in the *tarai*. Further, in 1957, planned development of irrigation works began with the start of the planned economic development of the country. Though the government had recognized the importance of irrigation for increasing agricultural production, at this stage the country did not have adequate technical manpower and financial resources to implement large scale irrigation works (NPC, First Plan 1957). Consequently, only a few medium size irrigation systems were accomplished during the first five-year plan period (1957-62). An estimate of the irrigation development - targets and achievements - by government agencies in each plan period is presented in Table 1 of Appendix 3. The irrigation development targets were, and still are, stated in terms of irrigated areas. The targets and achievements given in the Table also include the areas with shallow and deep tube wells and the existing irrigation systems that received government assistance.

Since the middle of 1960s, government agencies have been active in the construction and management of new irrigation schemes and in assisting farmer groups to construct or rehabilitate low cost irrigation systems. Large canal irrigation systems were constructed with assistance from India, but the government implemented the Minor Irrigation Programme called *Laghu Sinchai* in 1966. Under this programme, many existing farmer-managed systems in the *tarai* received assistance (Poudel and Sharma 1993). The government took on the management of many of the assisted projects.

Minor Irrigation Programme

It is useful at this stage to outline briefly the nature of the Minor Irrigation Programme for a better understanding of the evolution of the Pithuwa Irrigation System which forms a case study in this thesis (Chapter 4). The Minor Irrigation Programme was introduced in the second three-year development plan (1962-65) to provide low-cost irrigation facilities to farmers within a short period of time. The authors of the Plan stated, '... because large irrigation schemes entailed huge amount of government resources and took longer time for their completion thereby delaying the benefits to the people, plans and programme which could use the available small/medium water resources, and which could provide irrigation benefits within a short period are necessary ...'. The programme included the construction of small wells, irrigation tanks and reservoirs, (lift) pumps and other low-cost and short duration irrigation schemes (NPC 1961: 213-214). The construction of gravity canal systems with diversion weirs or check dams, however, was preferred over other types of technology. For the construction of such minor irrigation schemes, places where agricultural development projects were already operating, and where cash crops were cultivated were given priority. The (minor) schemes which would involve relatively large sums of money were planned to be implemented through the Irrigation Department. Some schemes were also planned to be built totally with government resources, whereas some were to be accomplished with contributions from the beneficiaries. Although it was planned to provide irrigation facilities to 4,455 hectares (11,000 acres) by the end of the Plan period under this programme, the actual achievement was insignificant (NPC, Third Plan 1965:85).

The Third Plan period (1966-70) saw the country-wide implementation of the Minor Irrigation Programme with the emphasis on the participation of the beneficiaries. The authors of the Plan stated, '... since farmers who seek to obtain irrigation facilities/services under the minor irrigation programme are required to bear 50 percent of the construction cost, they will pay (due) attention to the proper maintenance and repair of the facilities in order to be continually benefited ...' (NPC, Third Plan 1965: 61).[23] A central Board for Minor Irrigation was created to administer the programme, but investment decisions were mostly made by the district committees. Therefore, some have argued that this programme was the first effort of the government towards the formal recognition of the need for people's participation in irrigation works (Poudel 1986, 1992). The Programme greatly appealed to village and district level politicians because of its nature and the approach used to implement it. Under this programme, many local leaders succeeded in getting (minor) canal systems built in their villages and districts. The Pithuwa Irrigation System is a case in point.

In short, minor irrigation schemes as formulated in the Second and Third Plans had the following salient features:

- small in terms of the area irrigated or commanded
- use of small and medium water resources
- short construction period

- exclusive use of the country's internal resources, with or without the participation of beneficiary farmers
- presumed that beneficiary farmers would take care of the operation and maintenance after the construction

In both the Second and the Third Plans, the government presumed that the operation and maintenance of completed minor irrigation systems would be the responsibility of the beneficiary farmers or water users regardless of their contribution in the construction. But there were no clear directives with regard to this, and the government was therefore obliged to continue, and still continues, to provide assistance in one way or another for the operation, maintenance and repair of such canal systems. This has apparently created a tendency among the users to seek continual technical, financial and material support from the government for running such canal systems.

Large scale irrigation development

After this period of government attention to small scale irrigation, government investment in irrigation development - especially in the large scale irrigation systems in the *tarai* - increased tremendously from 1970 onwards, reflecting the increase in the borrowing of international capital in the form of loans and grants for the country's overall economic development. This is clearly reflected in the surge of irrigation development targets in the subsequent five-year development plans - from the Fourth Plan (1970-75) onwards (Table 1 of Appendix 3). However, as Table 1 shows, the achievements in irrigation development from the Fourth Plan onwards fell far short of the targets. According to the Nepal Agriculture Sector Strategy Study (ADB/HMGN 1982, Vol.II:88-90), the main reasons for the shortfalls in achievements were: (i) ambitious targets, (ii) failure to match budget allocations, and (iii) organizational, management and construction capacity constraints.

Until the middle of 1980s, irrigation development by the government focused largely on the construction of physical infrastructure of canals and structures, and very little attention was given to the effective management of the completed systems. Attention began to be paid to the improved management of government-operated irrigation systems from 1985 onwards, under the increasing influence of donor agencies. This is reflected in the implementation of a number of management-oriented projects in 1985-89: the USAID-funded Irrigation Management Project (IMP) in 1985, the Irrigation Line of Credit (ILC) in 1988 financed by the World Bank, the Irrigation Sector Project (ISP) in 1988 financed by the ADB, and the Irrigation Sector Support Project (ISSP) in 1989 under the co-financing of the UNDP, the World Bank and the Asian Development Bank (ADB). All these projects have specifically emphasized the participatory approach to irrigation development and management of irrigation facilities. Further, following the introduction of the Basic Needs Programme (BNP) in 1987, the 'Working Policy on Irrigation Development for the fulfilment of Basic Needs' was formulated in the early 1989.[24] This was immediately followed by the promulgation of the Irrigation Regulations (IR) in April 1989. These Regulations placed emphasis on the greater collaboration with water users in all phases of irrigation projects - planning, construction, operation and maintenance. The strategy of increasing farmer participation was mainly based on the recognition that government resources alone were inadequate to meet the country's irrigation development objectives and sustain the management of government irrigation systems after their completion. The government expected to increase the rate of irrigation development and develop maximum farmers'/water users' responsibility in the operation and maintenance of completed irrigation systems. The Irrigation Regulations gave water users, for the first time, a legal mandate to form water users' associations in accordance with the 1976 Association Registration Act. It institutionalized the participation of actual water users in irrigation. In 1989, the action plans and policies for the turnover of small irrigation systems and the participatory management of large irrigation systems were formulated.[25]

Irrigation institutions

The history of modern irrigation development in Nepal will remain incomplete without giving an outline of the irrigation institutions involved in the development. The following paragraphs describe briefly the history of the Irrigation Department in Nepal.

The Department of Irrigation (DOI) established in 1951 has been, and still remains, the principal government institution responsible for the planning, development and management of irrigation schemes in the country. Since its establishment, it has undergone organizational reformations a number of times. Initially, it was known as the Department of Irrigation, Hydrology and Meteorology (DIHM), and was under the Ministry of Water and Power. In 1973 the DIHM was shifted to the then Ministry of Agriculture and Irrigation; in 1980 it was again brought under the Ministry of Water and Power which became the Ministry of Water Resources thereafter. In December 1987, following a government decision, the DIHM was split into two departments: the Department of Irrigation and the Department of Hydrology and Meteorology (DOHM), both of them remaining under the MOWR. The DOI operates through its regional directorates in five development regions and District Irrigation Offices in districts.

For about 25 years after its establishment, the DOI carried out irrigation development activities through the Division and Sub-division Offices located at key places in the country until the regional directorates were established during the Fourth Plan period (1975-80). In most of the seventy five districts District Irrigation Offices were not opened until 1987-88. The organizational structure of the central office of the DOI as of 1993 is shown in Appendix 4.

Until December 1987, irrigation works in the country were carried out by three ministries: Water Resources, Agriculture, and Local Development (previously Panchayat and Local Development). There were significant differences in their respective roles in the various categories of irrigation projects, and each ministry had its own implementation procedures and strategies. Whereas the Ministry of Water Resources took (and still takes) charge of the construction of both large scale irrigation and multi-purpose water related projects, the

Ministry of Agriculture carried out the construction of new as well as the rehabilitation of existing small irrigation schemes through its Farm Irrigation and Water Utilization Division (FIWUD) created in 1973. As the name applies, the FIWUD also constructed tertiary or farm level physical facilities and water management extension services in large irrigation systems operated by the DOI. Whereas the activities of the FIWUD occurred in both the *tarai* and hilly areas, the Local Development Ministry was mostly confined to the development of small irrigation schemes in the hill districts. In addition to these two ministries (MOA and MLD), the Ministry of Forestry and Soil Conservation also implemented small scale hill irrigation schemes in limited areas within their project sites. The coordination between the ministries for irrigation activities was poor. In December 1987, under a decision of the government to implement government funded irrigation projects through one government agency, the irrigation division in the Ministry of Agriculture and the irrigation section in the Ministry of Local Development were transferred to the DOI.

In the private sector, the implementation of small irrigation schemes, especially irrigation by shallow tube well irrigation schemes, is carried out by the Agricultural Development Bank of Nepal (ADBN) which is the leading semi-government agency in the country. Through its Small Farmers Development Program (SFDP) the Bank provides technical assistance and credit facilities to individual farmers, village cooperatives and business entities engaged in agricultural production. In addition, the CARE-Nepal and United Mission to Nepal (UMN) - international non-governmental organizations (NGO) - also implement small scale irrigation programmes which essentially require the participation of the beneficiaries. The CARE-Nepal works jointly with ADBN, but the UMN virtually implements such projects on its own.

In summary, canal irrigation systems in Nepal can be categorized into two groups based on their origination and the responsibility for their management: (i) farmer developed and managed systems, and (ii) government developed and managed systems.[26] Table 2.3 presents an estimate of the distribution of irrigated areas under government and farmer-managed systems among the three ecological regions until 1992. The total irrigated area includes the area (15.5 percent of the total) served by shallow and deep tube wells.

The size of farmer-managed irrigation systems in terms of the irrigated area ranges from a few hectares in the Hills to several thousand hectares in the *tarai*. There are few large systems. As shown in Table 2.3, the irrigation systems developed by farmers with their own resources and with the government assistance together covered about 75 percent of the country's total irrigated area. In the *tarai* alone, they occupied 68 percent of the area. Some have estimated that there are about 1,700 such systems in the *tarai* and over 15,000 in the hilly areas (Pradhan 1989: 3; Poudel and Sharma 1993).

Most of the canal irrigation systems developed and managed by farmers are in the hilly areas, but the largest proportion of irrigation systems, especially the large systems, developed and managed by the government is in the *tarai* region where irrigable land and the potential for agricultural output are the highest. Of the 251,000 hectares of total irrigation development by the government (Table 2.3), about 208,600 hectares (83.11%) are served by fourteen large canal irrigation systems with command areas larger than 5,000 hectares (see Table 2 of Appendix 3).

Table 2.3 Irrigated areas under government and farmer developed systems until 1992 (in thousand hectares)

	Irrigation system category	Ecological region			Nepal
		Tarai	Hills	Mountains	
1	Government developed and managed systems	251	15	1	267
2	Government assisted farmer-managed systems	274	48	10	332
3	Farmer developed and managed systems	261	190	41	492
	Total area irrigated " (in percentage)	786 (72)	253 (23)	52 (5)	1091 (100)

Sources: Irrigated land given in Table 2.1; CIWEC, Master Plan for Irrigation Development (1990); and DOI documents (1992-93).

Present policy

For the first two (interim) years after the restoration of a multi-party democratic system in April 1990, the irrigation development activities in the country continued according to the annual plans and programmes. In 1992, the elected government introduced a new Irrigation Policy. The new policy places emphasis on the active involvement of water users in all stages of irrigation development. It focuses on the cost effectiveness of the development, cost sharing by the users, and cost recovery. It also encourages private sector and non-governmental organizations to take part in the development and expansion of irrigation facilities. The salient features of this new Irrigation Policy are as follows:

- emphasis on optimal and sustainable development of irrigation services for increased agricultural production,
- institutional reform for efficient delivery of irrigation service,
- decentralization of the DOI's operations with clear definition of roles and responsibilities at all levels of operation,
- recognition of the need for effective monitoring and evaluation of DOI investments,
- specific reference to the need for agricultural inputs and effective cooperation from agricultural institutions,
- legal recognition of water users as autonomous entities, of the rights and duties of water users and agency, and
- user-managed systems to be under collective ownership; the full ownership of a turned-over system and related structures to be with the water users' organization registered by the government.

Under this policy, irrigation systems (whether canal, tube well or pump) are classified into four categories based on the way they are managed: (i) irrigation systems operated by the users (or users' organizations), (ii) government irrigation systems to be turned over to the users' organizations, (iii) irrigation systems under the joint management of the government and the users' organizations, and (iv) individual (private) irrigation systems (all types of irrigation systems commanding areas less than 10 hectares). The policy then specifies the minimum proportion of the investment cost - the cost sharing - to be borne by the water users in the new construction, reconstruction and/or improvement of each of these categories of irrigation system. This cost sharing principle has already been put into effect in the (ISP and ILC) projects assisting farmers to reconstruct their irrigation systems.

According to this Policy, the management responsibility of government-built and operated irrigation systems are planned to be gradually transferred to water users' organizations. Whereas the irrigation systems with command areas over 2,000 hectares in the *tarai* and 500 hectares in the Hills are planned to be managed jointly by the government and the water users' organizations, the systems commanding areas up to the figures mentioned are to be turned over to the water users' organizations. In keeping with this, the Irrigation Management Transfer Project was introduced in 1993 to turn over to the farmers some selected government-built small and medium irrigation systems in both the hilly and the *tarai* areas.

The present policy makes the involvement of water users' organizations mandatory in the collection of irrigation fees - the cost recovery - in both the systems under (so called) complete government control and the systems under joint management. It encourages the water users to develop self-reliance, since the government will not levy water charges in the turned-over (canal, tube well, and pump) irrigation systems. The responsible water users' organizations may determine the water charges so as to meet all or part of the cost required to maintain, repair/renovate, and operate their irrigation systems. In the case of the systems under joint management, the government may give the water users or their organization a maximum rebate of 50 percent on the water fees collected with their assistance. Although, this policy arrangement for the cost recovery is very encouraging for both farmers and officials of the DOI, unless amended the current government regulations pertaining to revenue collection inhibit its operation. For this reason, this arrangement is yet to be put into practice.

The 1992 Water Resources Act replacing the 1967 Canal, Electricity and Related Water Resources Act was promulgated the same year. Under this Act, the ownership of all water resources within Nepal is vested in the state, and as the state deems fit it allows corporate bodies, communities, or individuals to use the water resources. The people can obtain the right to use the water resources through licenses or permits. The Act authorizes the government to use or develop water resources on its own, and to hand over any of the developed water resources to the water users' organization. It also makes provisions for the principle of beneficial (rational) use of water through the establishment of priorities for various kinds of water use.[27]

The objectives, targets, and implementation strategy of the irrigation development for the eighth five-year development plan period (1992-97) were set within this framework of the new policy. A summary of the irrigation development objectives and targets of the Eighth Plan is given in Appendix 5.

2.4 Physical characteristics and management of government-built canal irrigation systems in the *tarai*

Almost all canal irrigation systems in the *tarai* region have been built primarily to irrigate rice in the monsoon season. Two modes of irrigation system development can be distinguished, based on the extent of physical (canal) infrastructure provided: (i) extensive development, and (ii) intensive development. Clearly, both development modes were influenced by the resources available for development.

In the extensive development, only basic minimum physical infrastructure, such as diversion weirs, main and secondary canals are provided (ADB/HMGN 1982). Irrigation blocks are typically large, their area ranging from 250 to 500 hectares, and irrigation water is mostly available during the wet season only. This type of development is aimed to maximize the number of beneficiaries or the irrigated area. The result is that less than 50 percent of the cultivable command area obtains effective irrigation. Investment costs per hectare are relatively low ($1,450-2,000 at 1981 prices), and the resulting economic internal rate of return (EIRR) varies from 8-20 percent. Until the end of 1960s, the government followed this type of development, particularly to protect the late maturing paddy which is harvested in November-December.

In the intensive development, physical facilities are extended further down to the tertiary or farm level. The size of an irrigation block is reduced to 30-50 hectares. Investment costs per hectare are higher ($2,400-3,200 at 1981 prices) with the EIRR between 12-22 percent. With the increase in the availability of (external) financial resources, this type of development began in the country from 1970 onwards. Examples are: the Narayani Irrigation Project (command area: 34,400 hectares), the Kankai Irrigation Project (command area: 7,000 hectares). Cropping intensities were expected to be higher in such intensive canal system.

The Command Area Development (CAD) is similar to the intensive development. It primarily consists of intensive improvement of the canal systems constructed under the extensive development. The existing physical facilities are rehabilitated, and tertiary and quaternary canals and related structures are constructed to form smaller irrigation blocks of 5-10 hectares. Capital costs per hectare are low ($1,200-1,800), and implementation periods are short. Economic returns lie between 18-30 percent. An important feature of CAD projects is the strong emphasis on the integration of irrigation water management, particularly at the farm level, and agricultural support services to obtain higher agricultural productivity. The implementation of CAD projects started in the country in the early 1980s.

The large and medium canal irrigation systems built by the government in the *tarai* have the following general physical characteristics:

(i) Supply oriented run-of-the-river gravity systems with permanent diversion works.
(ii) Unlined open canals showing little rigid hierarchy of progressively smaller canals, and mostly without provisions for the removal of silt/sediments.
(iii) Relatively simple unsophisticated water control structures; cross regulators in the primary and secondary level canals are either the weir-type free flowing or the undershot, while headgates are invariably the undershot or orifice type.
(iv) Orifice-type (pipe) outlets, with or without gates, at the tertiary level.
(v) Very limited flow measuring structures or none at all.

Understanding the physical features and behaviour of modern irrigation systems of the *tarai* involves taking into account of the technology and engineering design of these systems.

Technology, engineering design, and donor influence

Until the early 1970s, the development of modern canal irrigation systems in the country, especially the construction of large canal systems in the *tarai*, was carried out exclusively with the assistance from the Government of India through the Indian Cooperation Mission (ICM) to Nepal. As a result, the technology and engineering design of government canal systems in this region are derived from the technology and design practised in India, particularly in the North Indian states of Bihar and Utter Pradesh, since the *tarai* is a part of the Indo-Gangetic plain and its geomorphology is similar to that of the adjoining areas of these Indian states. Further, the majority of the Nepalese engineers involved in the design and construction of irrigation systems received their engineering education in India. Interviews with a number of senior design engineers of the DOI revealed that in general the irrigation system design in the country basically followed the criteria and the standards used by the engineers of the Indian Cooperation Mission (ICM), as the department then was in its infancy and did not have standardized design guidelines. Indian text books and handbooks on irrigation engineering virtually became the design guides, and the design engineers commonly used the concept of "water duty" and the irrigation terminology used in India.[28]

From the early 1970 onwards, several other donor agencies - mainly the ADB, the World Bank, the IFAD, the USAID, the FAO/UNDP - have been involved, and are still involved, in providing technical and financial assistance for the construction of new as well as the improvement of existing irrigation systems in the country (see Appendix 3, Table 2). About 75 percent of the ongoing irrigation projects are financed by these external agencies through various grants, loans and partial loans under bilateral or multilateral agreements. By virtue of their substantial share in financial investment, the donor agencies have considerably influenced not only official policies and implementation strategies of irrigation development, but also the technology and engineering design of the irrigation systems developed with their assistance. As a result of (or sometimes as a prerequisite for) the bilateral or multilateral agreements with these donor agencies, various foreign and local consultants are involved at all stages of irrigation projects - from appraisal to implementation. These consultants have introduced different types of water control technology, especially the water control structures, based on the design criteria and the experience in their own country or elsewhere (see Chapters 3 and 5). For example, in the CAD projects financed by the ADB, the consultants have used the USBR-type gated check structures in the main and secondary canals and a single gated orifice type of tertiary outlets (see Chapter 3). Though the foreign consultants have played a vital role in introducing new canal irrigation technology, the appropriateness and effectiveness of such technology and the related structures to the country's socio-economic and agro-ecological setting have so far remained unquestioned.

Organization, management, and water distribution
In principle, the Department of Irrigation is responsible for the management - which is generally referred to as operation and maintenance in the department - of government-built irrigation systems, particularly the large irrigation systems. In the early years, the DOI operated and maintained the completed systems through the Division and Sub-division Offices located at a number of key places in the country. These divisions and subdivisions were removed following the establishment of Project Development Boards for the implementation of externally funded large irrigation projects in the early 1970s, the Regional Directorates in five development regions in the mid-1970s, and District Irrigation Offices in the mid-1980s, and the responsibility of operation and maintenance is gradually being transferred to the latter. But, most District Irrigation Offices in the *tarai* have inadequate management capacity in terms of both manpower and budget to effectively fulfil this new responsibility (see Chapter 3).

From the outset, the DOI has been a construction oriented civil engineering based department, and has looked upon irrigation system management as a matter of secondary importance. This attitude of the department is reflected in the fact that four decades after its establishment and involvement in irrigation development there is no standardized procedure or general specifications in the department for the management of completed public canal systems.

Available evidence clearly show that the allotment of both the field personnel - engineers, overseers and other supervisory staff - and the annual budget for the operation and maintenance have never fully met the design or actual (field) requirements and have been on an *ad hoc* basis (see Chapter 3). As soon as the construction of an irrigation project is completed, the engineers are transferred to other projects under construction; the number of personnel left behind is drastically reduced; a new engineer for operation and maintenance is deployed; and the annual budget allotment slumps. This practice of the DOI gives its engineers and overseers little opportunity to acquire necessary irrigation management skills, does not motivate them to strive for the management for better water distribution upon which intensified agricultural production depends.

In the past, engineering designs of most canal irrigation systems did not necessarily include the manuals or guidelines for their operation and maintenance. Design engineers, who are invariably civil or hydraulic engineers, apparently considered their design task accomplished when the preparation of engineering design and cost estimates were completed. The design engineers rarely stayed on to manage the systems they designed and/or constructed. The operation and maintenance guides began to be produced as a necessary part of the design task when external donor agencies - and along with them foreign engineering consultants - became involved in irrigation development. Clearly, such manuals were prepared separately for each of the donor-funded projects. However, they have not been useful in practice, owing to the technical and financial constraints of the department. In 1990, for the first time, a small manual entitled "Operation and Maintenance" - the thirteenth design manual for irrigation Projects in Nepal - was produced with the assistance of Sir MacDonald and Partners Ltd in association with MacDonald Agricultural Services Ltd and East Consult (Pvt.) Ltd under the UNDP/World Bank funded Planning and Design Strengthening Project.

Given the resource constraints and in the absence of a standardized procedure, a system manager is obviously required to manage the irrigation system under him, based on his experience and understanding of the canal system. In practice, sometimes directions and instructions on the operation and maintenance of a particular system came from the central office or were given by the senior engineers during their canal inspection visits. These instructions, whether oral or written, then became the general rules for running the irrigation system (Agrawal, N.K. 1993: personal communication).

However, a common mode of management can be observed in government irrigation systems in the *tarai*. For the operation of most systems, a simple schedule of opening and closure of main and secondary canals is prepared without making a detailed schedule of water distribution along a secondary canal. During the paddy cultivation period in the summer, the main and secondary canals are operated continuously at their full capacity or full supply level as far as possible. The main canal essentially conveys water continuously, while secondary canals may follow a rotation if necessary. In the winter season, when the demand for water is low, the main canal is usually operated below its design capacity. This is also due to the reduced flow in the river source, as the canal systems are run-of-the-river systems. Water in a secondary or a minor canal is delivered upon farmers' request, and the distribution below the secondary and minor level canals is virtually left in the hands of the farmers. Similarly, the routine maintenance and repair of canals also follow a common regular pattern. The Department of Irrigation cleans most major canals - main and secondary canals - and, if the budget allows, lower level canals too. The cleaning and repair activities usually begin in the months of April-May, and are completed in the months of June-July which are the last two months of the fiscal year in Nepal. The maintenance and repair of tertiary level canals, and sometimes even minor canals, is left to the farmers.

Many of the existing systems have been rehabilitated and improved with an increased number of physical facilities to restore their potential, and attempts are being made to encourage water users to participate actively in the operation, maintenance and management for better water control, mainly at the tertiary level. The irrigation systems constructed under donor funding suffer from a serious draw back: as soon as these systems are completed, the increased requirement of resources (financial input in particular) for the operation and maintenance of the improved physical infrastructure is not adequately available. The management burden of the completed project is immediately transferred to the DOI, which is unable to provide the required resources. This can be seen as poor planning on the part of the Irrigation Department.

Performance of government canal irrigation systems

Most government-built and managed canal irrigation systems in Nepal, as in most developing countries of the world, have generally failed to achieve their desired objectives and goals. At the planning stage, the goals and objectives of the irrigation sector are usually associated with the goals and objectives of agricultural productivity. Irrigation development targets are defined after the agricultural production targets have been set. Whereas production targets are in tonnes per unit of land area, irrigation development targets are set in the hectares irrigated. Thus, in general, the performance of government irrigation systems are judged in terms of the following four indicators: (i) crop yield, (ii) cropping intensity, (iv) area irrigated, and (v) EIRR. The crop yield per unit volume of water is not considered, mainly because irrigation water fees are charged at the flat rate per crop per irrigated area.

As stated earlier, there was no measurable difference in either cropping intensity or yield between command areas receiving irrigation and adjacent areas not receiving irrigation from the project. Though cultivated area has increased, the achievement in terms of cropping intensity has remained insignificant.

Of the 251,000 hectares total irrigated area (Table 2.3) under government irrigation systems in the *tarai*, only about 30 percent receive year-round irrigation. Some data show that even during the monsoon season, the irrigation achievement is only about 57 percent (CIWEC, Master Plan 1990; Table 2 of Appendix 3). This means that the command area of most irrigation systems have both irrigated and rainfed cropping system. In general, the proportion of rainfed areas is higher in the systems providing monsoon irrigation than in those providing year-round irrigation, because of water supply shortfalls on the former. According to the report of the Master Plan (1990), the average EIRR is about 8 compared with the estimated value of 17.

Several reasons have been reported for this state of performance of government canal irrigation systems (WECS 1982, 1983). The general conclusion is that government-built and managed canal irrigation systems in Nepal suffer from the combination of poor condition of physical infrastructure, mainly due to the poor construction and poor maintenance, and deficient irrigation water management.

2.5 Summary

This chapter has explained how modern canal irrigation has developed in Nepal in general, and in the *tarai* in particular, in accordance with the changing policy over time. Although canal irrigation in the *tarai* has been practised by farmers for centuries, the development of modern canal irrigation systems began in the 1920s. Until the end of 1950, there were very few government-built and operated irrigation systems in the country. The Department of Irrigation was established in 1951 and is the principal government institution responsible for the planning, development and management of irrigation schemes in the country. In the 1960s, the government implemented the Minor Irrigation Programme all over the country to provide low-cost irrigation facilities to farmers within a short period of time, because large irrigation schemes entailed huge amounts of domestic resources and took longer to be completed thereby delaying the benefits to the people. The programme focused mainly on the construction of small to medium scale gravity flow irrigation schemes using the small and medium surface water resources. Since 1970, government investments in irrigation development - especially in the large irrigation systems in the *tarai* - has increased, thanks to the increase in the borrowing of international capital in the form of loans and grants for the country's overall economic development. Meanwhile, the country needed to increase its food grain production to meet the growing demand of the increasing population. The irrigation development was focused in the *tarai* region, because this region had the highest potential for agricultural output using the available river water resources.

Until the mid-1980s, irrigation development by the government was confined largely to the construction of the physical infrastructure of canals and structures, and very little attention was given to the effective management of the completed irrigation systems. Since 1985 attention has been paid to improving the management of government-operated irrigation systems, under the increasing influence of the external financing and donor agencies. A number of management-oriented projects have been implemented since then. Further, emphasis has been placed on the participatory approach to the development and management of irrigation facilities. The 1992 Irrigation Policy emphasizes the active involvement of farmers in all stages of irrigation development. The policy also focuses on the cost effectiveness of the irrigation development, cost sharing by the users/farmers, and cost recovery. It also encourages private sector and non-governmental organizations to take part in the development and expansion of irrigation facilities. According to this policy, the management responsibility of government-built and operated irrigation systems is planned to be gradually transferred to water users' organizations. Irrigation systems with command areas over 2,000 hectares in the *tarai* are to be managed jointly by the Irrigation Department and the water users' organization, whereas the systems serving areas up to this size are to be turned over to farmers.

Two modes of irrigation development can be found in Nepal: extensive and intensive development. In extensive development, only basic minimum physical infrastructure, such as diversion weirs, main and secondary level canals are provided, and irrigation blocks are large, ranging from 200-500 hectares. In extensive development, physical facilities are extended down to the tertiary or farm level. The size of irrigation blocks is reduced to 30-50 hectares. In recent years, the emphasis has been placed on intensive development to achieve the irrigation potential. The two development modes have been clearly influenced by the availability of financial resources.

Irrigated agriculture in the *tarai* is primarily rice-based. Paddy is cultivated during the monsoon season, and mainly oilseeds and wheat are grown in the winter season. Whereas paddy covers almost all the land area, the coverage of winter crops is less. Farming is labour intensive, and traditional farming methods are usually employed. Landholdings are fragmented. Where irrigation water is available throughout the year, the most intensive farming is the cultivation of two crops of paddy followed by a winter crop of wheat.

Almost all canal irrigation systems in the *tarai* are run-of-the-river systems and have been built primarily to irrigate rice during the monsoon season. Canals are usually unlined, and types of water control structures vary. The canal operation is upstream-controlled and supply-oriented. In general, the design of irrigation systems has been influenced by the foreign design engineers who are involved because of the agreements with the financing or donor agencies. Most government-built and operated canal irrigation systems in Nepal are reported to suffer from poor maintenance and deficient irrigation water management. The following chapters examine in detail the water control technology, organizational arrangements, and the actual practice of water distribution on three government-built irrigation systems in the *tarai*.

Notes

1. Figures for the total area of the country are inconsistent. Biswas, A.K. (1989) gives the total area as 14.08 million hectares, while the Land Resources Mapping Project (LRMP 1986) estimated it to be 14.75 million hectares. This is not surprising, given the topography.

2. Before unification there were many autonomous petty states. In the Kathmandu Valley alone, there were three kingdoms - Kathmandu, Lalitpur, and Bhaktapur. In the west, from Kathmandu Valley to Mahakali river, there were at least 46 distinct political formations called *Chaubise* (meaning twenty four in Nepali) and *Baisi* (meaning twenty two) principalities. To the south and east of the Valley there were other similar independent states. Although the territories of these petty states were mainly in the hills, some extended into the southern plains, the *tarai*, and several were crossed by trade routes linking India with Tibet.

3. In the early decades of the first period, the rulers of the new state of Nepal focused on the territorial expansion of the country, especially towards the plains of northern India, until checked by the British in India in 1814. The subsequent war with the British East India Company in 1814-16 resulted in the loss of considerable part of the country's territory in the southern plains, and Nepal had to sign a treaty called the "Sugauli Treaty" with the British. This treaty accorded Nepal the status of a "semi-colony" - a politically and economically subordinate but formally an independent state. Nepal had to abandon all territorial acquisitions west of the (Sarda) Mahakali river and east of the Mechi river, and it was effectively forbidden to have direct communication with any western power except Great Britain. With

its external relationship thus "fixed", the role of the state was primarily to ensure the collection of revenues from the taxation on productive land and levies on traders in the major north-south trade routes, and to maintain internal law and order, the latter (law and order) primarily to facilitate the former (revenue collection) (Seddon 1990: 18-19).

Intense political struggle among fractions of the ruling class in Kathmandu during the 1830s and 1840s eventually led to the rise and appointment of Jung Bahadur Rana as Prime Minister. After 1846, the descendants of Jung Bahadur Rana ruled the country with the king as a mere religious figurehead. In 1856, the Ranas then in power managed to obtain a royal decree which allowed them to formally limit the succession to the position of Prime Minister to members of their family thereby establishing the basis for a regime of dynastic rule that lasted nearly a century. During the Rana regime, the country was effectively isolated from the outer world; the social, economic and infrastructural development were insignificant. The Rana rulers also primarily focused on the collection of revenues raised mainly from the taxation on productive land and the retention of ruling power. The people's movement overthrew the Ranas and restored the political power in the monarchy in February 1951.

From 1951 to 1959, the country saw political and administrative instability under the multi-party parliamentary system. In December 1960, King Mahendra dismissed the elected (Nepali Congress) government, dissolved parliament and introduced a three-tier partyless Panchayat System - the village, the district and the national assembly on the grounds that the democratically elected government misused power and resources, posed a threat to national unity, and above all had attempted economic programmes without scientifically examining their viability. Under the Panchayat System, the country was reorganized into five development regions and seventy five districts. The Panchayat System continued until April 1990 when the people's movement once again resulted in the restoration of multi-party democracy with constitutional monarchy.

4. Strictly, the geological subdivisions differ from physiographic divisions. For example, the Plateau of Tibet is a physiographic region, but within this vast area great geological variations are present. Similarly, the Mahabharat, Midlands, and Fore Himalayas divisions may, for the purpose of physiography, be treated as one unit, namely the Middle Mountains Region, while the Siwalik range is both a physiographic unit and a geological division in its own right (LRMP, Water Resources Report 1984: 2).

5. On the other hand, the existing geographical features favour certain types of development, particularly those associated with water resources e.g hydro-electricity the development of which is again extremely costly. The other potential due to the geography is the tourism industry.

6. The Land Resources Mapping Project (LRMP) was funded by the Canadian International Development Agency to produce an inventory and analysis of the land resources, land use and land capability of Nepal as a basis for rational development planning at the national, regional and local level. In the absence of an alternative reliable data source, the LRMP data have been referred to extensively in this text.

7. See Regmi (1978) for a detailed account of the land grant and assignment, land tenure, and land taxation in Nepal. See also Ojha (1982), 'Planned and Spontaneous Land Settlement in Nepal: A study of Two Tarai Settlements in the Kanchanpur District.' Cornell Dissertation in Planning.

8. Before the Malaria Eradication Programme began in the country, the entire *tarai* area was called a '*kala-pani*' (meaning death valley) by the hill people.

9. The Master Plan for Irrigation Development in Nepal was prepared by Canadian International Water and Energy Consultants (CIWEC) in 1989 under the UNDP with the assistance of the World Bank. The reports of the Master Plan documented comprehensively and schematically scattered data related to irrigation development in the country, made assessment of irrigation development potential, and

prepared investment programme options for a decade.

10. The population density of Nepal with respect to the cultivated land (700 persons per square kilometre) is one of the highest in the world (Farrington and Mathema 1991).

11. The LRMP defined arable land as the land which when farmed in adequately sized units for the prevailing climatic and economic setting, and when provided with the essential on-farm improvements of removing vegetation, levelling, soil reclamation, drainage, and irrigation-related facilities, will generate sufficient income under irrigation to pay all farm expenses, provide a reasonable return to the farm family's labour, management, capital, and at least pay the operation, maintenance, and replacement costs of associated irrigation and drainage facilities.

12. In the period when the attention of the state was mainly focused on increasing the revenue from land resources, the classification of land use as either agriculture or forest was basically determined by the amount of revenue accruing to the state from the land. If the total revenue from a land area was less than the expected income to the state from the sale of forest produce, then the land was not permitted to be utilized for agricultural purposes (Regmi 1977: 35).

13. This classification system does not distinguish pasture land, land for fuel and fodder production, nor land for forestry. For tax assessment, agricultural land includes all land that can be cultivated, though not necessarily under cultivation. It may include land that was once cultivated but has since become uncultivated land, such as threshing ground, flower gardens, barns, orchards with no fruit-bearing trees, and waste land adjoining cultivated land.

14. Agricultural land has been traditionally classified on the basis of irrigation facilities, soils, and/or type of crops cultivated. In the hill districts and Kathmandu valley, the terms *khet* and *pakho* are largely used to distinguish between irrigated and unirrigated land. *Khet* land is generally defined as irrigated land situated on the lower areas where paddy and wheat can be grown, while *Pakho* land is unirrigated upland or hill-side land where only dry crops such as maize and millet can be grown (Regmi 1977: 37-38).

15. Because of the erratic climatic patterns, the LRMP suggested that up to 9.69 mm per day (equivalent to 1.12 lps per hectare or 2,900 m^3 per month per hectare) must be planned in terms of crop-water requirements. Considering the present state of irrigation management in the country, with about 39 percent water-use efficiency, the irrigation requirement for a good irrigation system design was suggested to be 7,500 m^3 per month per hectare, that is, about 2.9 litres per second per hectare (Hildreth 1986).

16. Even during the monsoon the rainfall is erratic. Sometimes there are prolonged periods with less than 2 mm rainfall. Under these conditions, even supplementary irrigation can produce considerable benefit to cropping patterns and yields.

17. See Figures 5-9 given in the Economic Report of the LRMP (1986: 51-52) for variations in the cropping pattern in the *tarai* between the development regions.

18. The integration of crop production, livestock and forestry is very prevalent in most areas of the Hills and Mountains where traditional farming is predominant. A simplified schematic diagram showing the complex relationship among agriculture, forestry and livestock is presented in the Land Capability Report of the LRMP (1986:39). It was estimated that such an integrated traditional farming system required about five hectares of grazing and forest land to maintain the fertility of a one-hectare family farm unit (Wyatt-Smith 1982).

19. Agricultural statistics suffer in their reliability, updating, and regularity due to shortcomings in the use of available practical methods of data collection, the efficient management of district level data collection units and the lack of an efficient supervision system. The data presented are, therefore, indicative.

20. This Code laid down the legal recognition of property rights in irrigation and canal systems, and several types of existing customary norms, rules, and practices were endorsed by the state under this code.

21. The Department of Irrigation established in 1951 grew out of this PWD. The department was initially called '*Nahar Vibhag*' (Canal Department).

22. The construction of Chatara Canal (now called Sunsari-Morang Irrigation System which, with a command area of 66,000 hectares, is the largest canal system in the country), West Koshi (21,000 hectares), Narayani (38,000 hectares), and West Gandak (13,000 hectares) irrigation systems was the result of these two agreements with India. The basic infrastructure of these irrigation systems was designed and constructed by Indian engineers.

23. It was planned to provide irrigation facilities to 45,900 hectares under the minor irrigation programme during the plan period (ibid: 61). This in itself reflects the importance given to the programme. For lack of empirical data, it is difficult to say with certainty whether the government was able to obtain the 50 percent contribution to the construction cost from beneficiaries in the minor irrigation schemes implemented.

24. Following His Majesty the King's address in December 1985 calling for the provision of minimum basic needs for a decent living (food, clothing, shelter, health, education and security) for all Nepali citizens to meet Asian Standards by the year 2000 A.D., a Basic Needs Programme was formulated in September 1987. The BNP was soon dropped as a slogan, however, because the country's economic development could not keep pace with the dynamic nature of the Asian Standard.

25. The 1989 Working Policy on irrigation development for the fulfilment of Basic Needs had categorized irrigation systems into three types - small, medium, and large - based on the size of the command area served and the location of the system in the ecological regions. In the hilly districts, irrigation systems serving command areas less than 50 hectares, between 50 hectares and 500 hectares, and over 500 hectares were respectively classified as small, medium and large. For the systems in the *tarai* region, these figures were less than 500 hectares, between 500 hectares and 5000 hectares, and over 5000 hectares respectively.

26. As Pradhan (1989:2) notes, government managed systems are not absolutely managed by the government, since farmers also participate in the management of the system voluntarily or under compulsion. In practice these are jointly managed systems. On the other hand, farmer developed and managed systems in the strict sense, are those which did not or do not receive any agency's assistance.

27. The order of priority is as follows: (a) drinking water and domestic use, (b) irrigation, (c) agricultural uses such as animal husbandry and fisheries, (d) hydro-electricity, (e) cottage industry, industrial enterprises and mining uses, (f) navigation, (g) recreational uses, and (h) other uses. These needs are presumably based on the hierarchy of human needs.

28. In February 1990, for the first time, thirteen technical manuals giving criteria, standards and guidelines for the design of irrigation schemes were issued by the DOI under the Planning and Design Strengthening Project funded by UNDP and the World Bank. These manuals were prepared by Sir MacDonald and Partners Ltd in association with MacDonald Agricultural Services Ltd and East Consult (Pvt.) Ltd. The manuals were distributed to all District Irrigation Offices in 1991.

3 The Banganga Irrigation System

In many irrigation systems in developing countries, engineers have introduced the fully gated water control technology so that an optimal amount of water can be delivered to cropped fields at the right time. Many engineers assume that such a water control technology enables the operation of the irrigation system to be flexible and thereby capable of meeting the different water requirements of crops or cropped areas. They also believe that the technology increases water use efficiency. Whereas this may be true in theory, this technology creates hydraulic instability and requires constant manual operation of a large number of gates in canals.

This chapter presents a case study of the Banganga Irrigation System built and managed by the Department of Irrigation. The irrigation system was rehabilitated under the Command Area Development Project (CADP) in 1982-89. A fully gated water control technology was introduced. The design engineers envisaged that the rehabilitation would improve water allocation and distribution by increasing the system's technical flexibility.

The purpose of this chapter is to examine the flexible technology with gated adjustable structures from the particular point of view of water control. It focuses on how this technology in a particular farming environment affects the water allocation and distribution and how farmers respond to the technology. To do this, a branch canal and three tertiary units within this branch canal and two tertiary units which were directly served by the main canal at the tail end were selected for in-depth field observations. The data are from the field observation of crop cultivation and irrigation practices in these five tertiary blocks in the three consecutive seasons from October 1991 to May 1993.

3.1 The field setting

General

The Banganga Irrigation System is located in the Kapilvastu district of the western *tarai*, Nepal (see Figure 1.2).[1] It has a total cultivable command area of about 6,200 hectares and covers a total of 15 villages (previously village panchayats).[2] Taulihawa, the district headquarters, is in the centre of the command area (see Figure 3.5).

The topography of the command area is characterized by the gentle slope from the north to the south. The elevation varies from 115 m above mean sea level in the north to 90 m in the south. However, there are some low-lying areas which are poorly drained. The soils in the area are alluvial, mostly grey hydromorphic to low humic gley, and more than one metre deep. The soil texture ranges from clay loam and silty clay loam in low lying areas to fine sandy loam in upland areas. In general, the internal drainage of the soils is satisfactory (Land Capability Map 1982: No. 63 M/2; GEOCE 1990).

The Banganga area falls under the sub-tropical humid climatic region. The annual rainfall varies from 1300-1600 mm. The monthly variation of temperature, evaporation and rainfall in the area during the 1991-92 period is presented in Figure 3.1.[3] The variation in rainfall shows that more than 80 percent of the annual rainfall occurs during the monsoon period, from June to September. Isolated showers were observed even during the monsoon season.

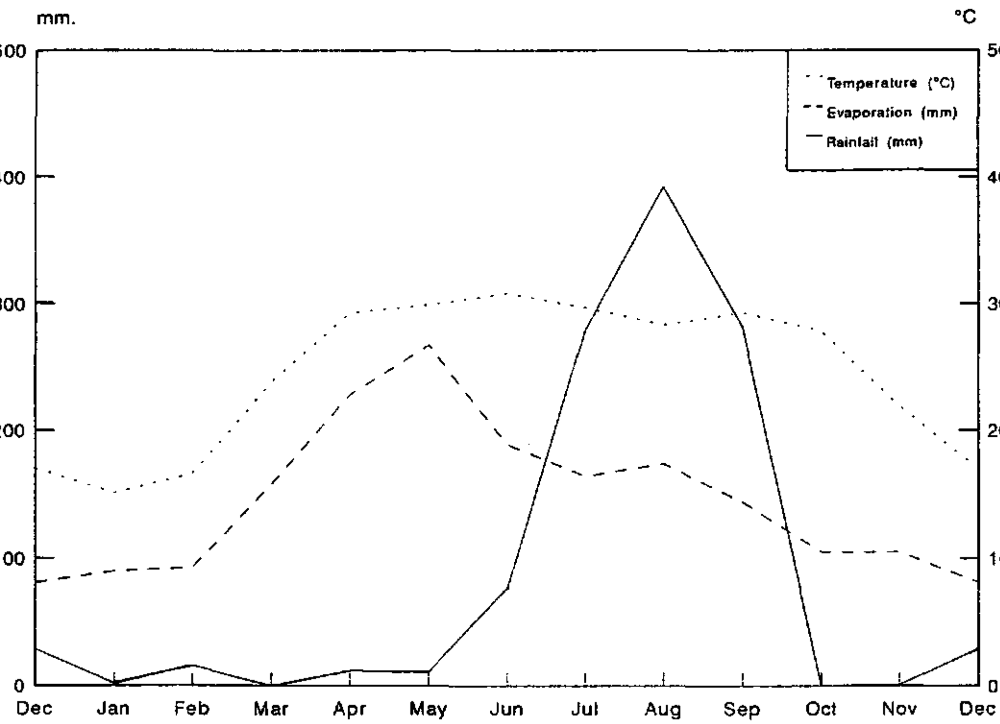


Figure 3.1 Monthly average temperature, evaporation and rainfall in the Banganga area (Sources: Pan evaporation data (1968-78) from the Bhairahawa Meteorological Station, and rainfall and temperature data (1991-92) from the Banganga Meteorological Station.)

The water source of the irrigation system is the Banganga river, a small river with large seasonal variation in its flow. Whereas the river floods its banks during the monsoon season, during the dry season its discharge is extremely small.[4] The low flow in the river limits the intensity of the cultivation of *rabi* crops. Shallow tube wells are commonly used by villagers within the command area for drinking and other domestic purposes. However, there is no evidence that the groundwater resource has been considered for full scale irrigation.

The three gravel roads connecting the district headquarters to the East-West Highway: Gorusinge-Taulihawa road, the Taulihawa-Bhairahawa-Butawal road, and the newly constructed (in 1993) Taulihawa-East-West Highway road, provide access to the command area. These routes are occasionally inaccessible during the monsoon season because there are no bridges across many of the streams crossing the roads. In addition, the Taulihawa-Jagadishpur-Banganga canal road, which also links up with the highway, provides access to the area throughout the year.

The district offices of the Department of Agriculture, Agricultural Input Corporation, Agricultural Development Bank, and the Department of Cooperatives are at the district headquarters. Interviews with farmers suggest that despite the existence of these supporting agencies, the supply of agricultural inputs, especially chemical fertilizers and extension services is poor. Therefore, farmers buy necessary agricultural inputs at the markets across the border.

Villages

As in most part of the *tarai*, the villages in the Banganga command area are clustered. One or more than one such cluster of villages form a *mauja*. The clustered pattern of village has implications on the management of the irrigation system, especially in the formation of water users' organization (see Section 3.3).

Most houses in the villages are temporary, made of bamboo reinforced mud walls and with a thatched roof. These houses clearly belong to small farmers or tenants. The barns are usually attached to the house and form an integral part of it. The few permanent houses with spacious courtyards are owned by landlords, indicating their higher socio-economic status. Most landlords are also the head or the accepted leader of the village communities. The courtyards of the landlords' houses are usually the places where formal or informal meetings of the village community take place. The power and domination of landlords and the people of higher caste groups over small farmers and lower caste groups is clearly visible during village meetings.

Another striking feature of village communities in the area is the common yard known as *khalihan* where villagers stack their harvest, particularly of paddy and wheat, for sun-drying and threshing. There may be more than one *khalihan* in a village, depending upon the size of the village. Such common yards are usually located at the periphery of the village. The harvest is kept in a *khalihan* for several weeks until the threshing and storing is completed.

According to the Provisional Impact Evaluation Study of the Banganga Irrigation Sub-project (GEOCE 1990: 26-27), about 70 percent of the population in the command area belong to Gupta, Kurmi, Yadav, Tharu, Passi, Chamar, and Muslim caste groups. These people originally came from the neighbouring States in India. The remaining 30 percent are of Brahmin and Chhetri caste groups, mostly of whom have migrated from the hill region. The local culture and custom is similar to that in the neighbouring state of India. Even the local language is *Abadhi* which is traditionally used by the people of the area across the border.

The village society is dominated by men. It was observed that only men attended meetings with the irrigation officials, whether at the irrigation office or in the village. Within the village, women are generally reluctant to talk to strangers, especially to researchers or government officials. However, in the field, they spoke openly about irrigation-related problems. On one occasion during the field study, the researcher met a woman who expressed the opinion that the irrigation office in Banganga should also manage the distribution of water in as controlled a manner as in the neighbouring state of India.

Landholding and land tenure

The average size of landholding in the command area is 2.4 ha per family (of 7.7 persons) (GEOCE 1990).[5] Observation shows that farmers' landholdings are scattered. Many farmers had their land located in more than one irrigation block, and some of them away from their residences. Scattered distribution and fragmentation of land have implications on both the management of farming activities and irrigation. Scattered landholding increases the labour input required in farming and constrains effective water distribution at field level. During the winter and summer seasons, most farmers left fields that were far away from the village fallow, as it is difficult to protect crops in these fields from stray cattle.

The household survey of the villages served by the branch canal studied showed three categories of farmers: (i) absentee farmers who owned land within the command area but did not stay in the village or did not cultivate the land themselves, (ii) owner cultivators, and (iii) tenants who cultivated land on lease. It also indicated about 90 percent were owner cultivators, and that the remaining 10 percent either leased out their land or rented land from others. Guptas and Kurmis were the large landholders having holdings greater than 10 hectares. Some absentee large land owners managed their farming through local managers called *sirwars*.

The most common tenure arrangement in Banganga is share-cropping, called *bataiya* in the local language. Usually there is no written or legal agreement made in this arrangement. The tenancy period is generally limited to a year and is often extended at the end of the year, depending upon the wishes of both the landowner and the tenant. Under this tenure arrangement, the tenant provides the seed and the labour required to perform all farming activities, whereas the landowner supplies the necessary chemical fertilizers, pesticides, and pays the land tax and the irrigation water fee. The harvest is shared equally between the two. In most arrangements, straw (*bhusa*) is also divided equally between the landowner and the tenant. The straw is used for feeding cattle, and is of high value during the April-June period when there is a severe shortage of pasture.

In share-cropping, tenants have very little incentive to produce marketable surplus. They lack collateral security to obtain credits from banking institutions. Therefore, a land tenure structure with a high proportion of tenants inhibits farmers from adopting improved farming techniques and from managing water efficiently.

The farming system and principal crops

The farming system in Banganga is similar to the Main *tarai* farming system in Nepal. The cropping pattern is: paddy-oilseeds/wheat-vegetables/fallow. Figure 3.2 shows the cropping pattern envisaged at appraisal of the Command Area Development Project in 1981. Note the 98 percent paddy cultivation which includes 50 percent of a long-term variety. Although there has been no significant change in this cropping pattern since then, observation in 1992 in the five selected tertiary blocks showed an average area of 90 % cultivated with paddy (see Table 3.1).

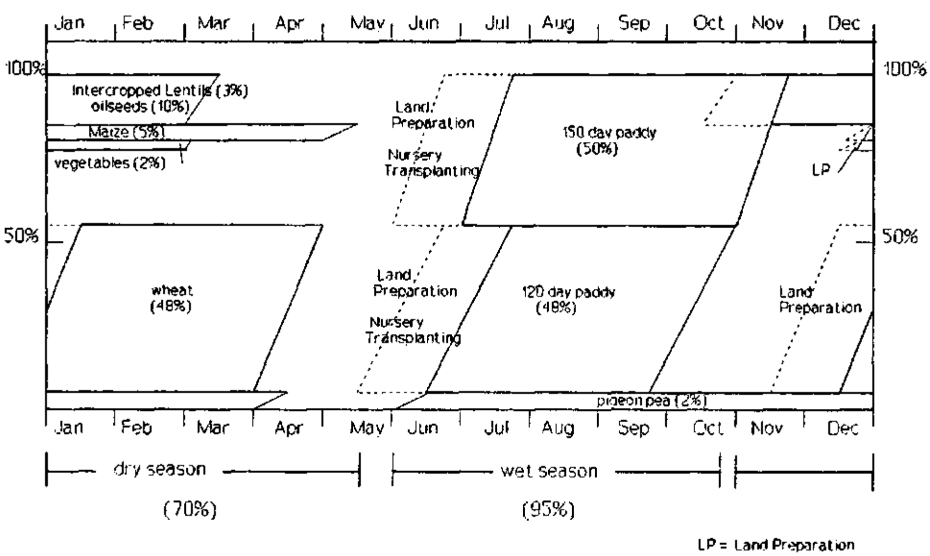


Figure 3.2 Cropping pattern in the Banganga command area (Source: DOI/CADP documents, 1981-89.)

Paddy is the principal crop grown during the monsoon season, and covers more than 90 percent of the command area. Two types of paddy are grown: (i) the long period (150 day) or late maturing variety, and (ii) short period (120 day) or early maturing variety.[6] The long term paddy, called *aghani*, is harvested between the middle of November and early December, and the land is then usually left fallow after the harvest until the next monsoon season. Such fallow land becomes the pasture for cattle. Since many farmers must depend upon (paddy) straw to feed their cattle, particularly during the summer, some local varieties of paddy that produce long straw are grown.

The paddy is cultivated in roughly levelled small square or rectangular basins. As an example, Figure 3.3 shows the pattern of paddy fields within the tertiary block No. 2 (LB 2) of the Laxminagar Branch Canal. These paddy basins in Banganga have remained unchanged for many years, primarily because of the traditional farming practice of the farmers.

Generally, the short period paddy is followed by oilseeds (rapeseed, mustard, linseed) and wheat. The other winter crops grown include lentil, peas, gram, potato and onion. These crops are cultivated in upland (higher-lying) areas which drain soon after the paddy harvest. Many farmers sow oilseeds together with lentil, peas and gram in the same field which require little or no irrigation, and which can be grown with the residual soil moisture from the paddy cultivation.

Observations of crop cultivation in the 1992 and 1993 winter seasons in the tertiary blocks studied indicated that dry season crops occupied an average of about 44 percent of the command area (Table 3.2). As shown in Table 3.2, the percentages of wheat and oilseed cultivation are almost equal. According to the farmers, the introduction of the present irrigation system and its improvement under the CADP later have caused wheat cultivation to increase substantially, but it is not clear that such an increase occurred mainly due to the availability of canal water. Farmers find wheat a less profitable crop than oilseeds, since it requires much more labour input and involves higher risk of yield failure if irrigation is not available on time. The wheat crop usually requires one to two irrigations during February-March due to the increase in evapotranspiration and inadequate rainfall. From April to June, there is virtually no cultivation of crops except for some vegetables and maize which are grown in limited areas that have access to water, e.g land surrounding village ponds. Figure 3.4 presents the typical pattern of winter crop cultivation in a tertiary block within the command area.

Farming activities, from sowing to harvesting and storing, are labour intensive. Observation showed that most labour input came from family members. In the average household (7.7 members) there are usually 4 persons in its labour force. A rough calculation shows a surplus of labour for the annual agricultural activities under the present cropping pattern. However, a shortage of farm labour occurs while paddy is being transplanted and harvested. During these periods, there is a temporary influx of *Tharu* labourers, mostly women, from the neighbouring district of Dang, especially from Deukhuri.[7] Most of these labourers are hired by large farmers. The practice of exchange labour is very limited, less than 10 percent.

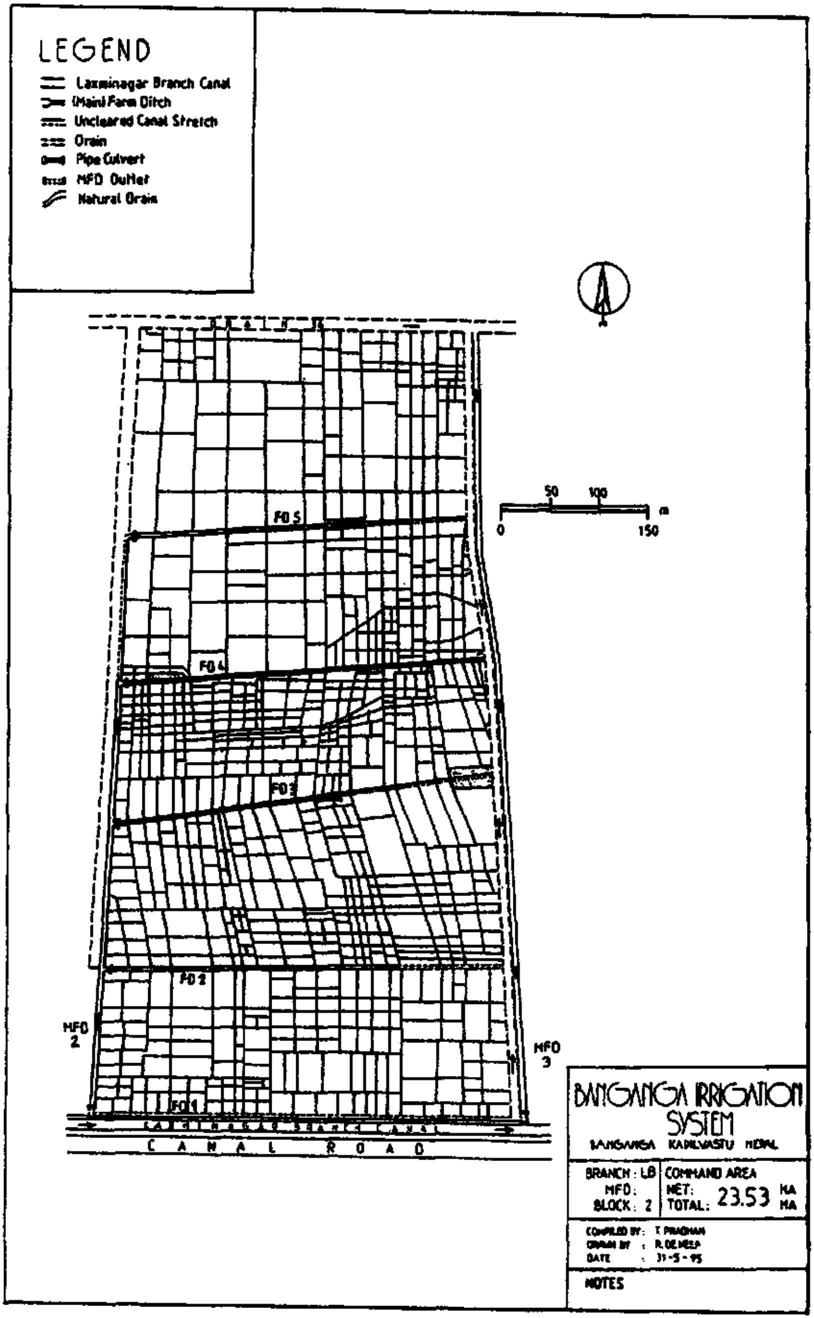


Figure 3.3 Pattern of Paddy fields in the Banganga area (Source: Field measurements 1992-93.)

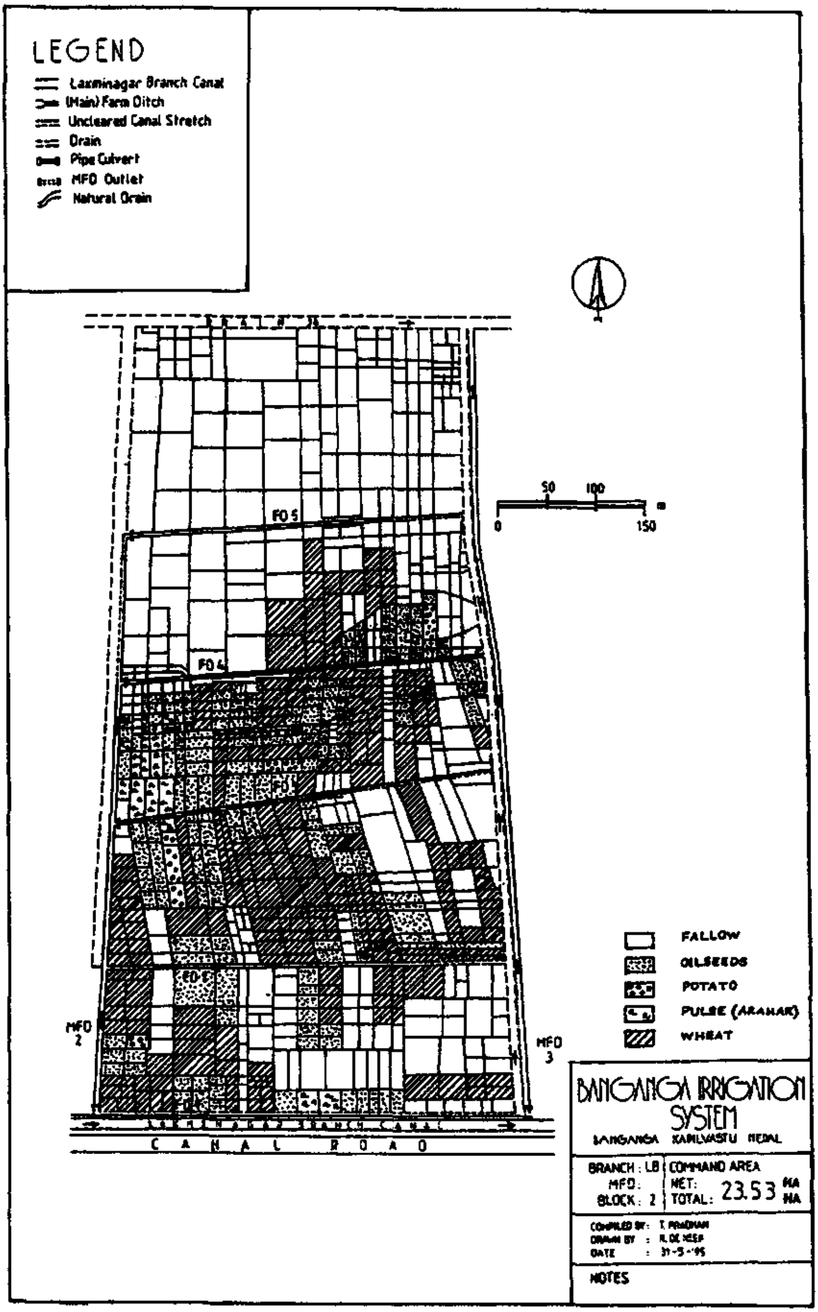


Figure 3.4 Pattern of winter crop cultivation in the Banganga area in Tertiary Block LB 2 (Source: Field observation 1992)

Table 3.1 Cultivation of paddy in the five selected tertiary blocks in 1992 (in percentage of net block area)

	Block	Total cultivation in the block	Paddy		
			Transplanted	Broadcast	Total
1	LB 2	98.4	91.2	4.7	95.9
2	LB 11	94.4	74.3	13.7	88.0
3	LB 12	92.7	70.4	14.7	85.1
4	MC 43	93.2	81.3	10.5	91.8
5	MC 46	92.3	79.9	10.2	90.1
	Average of 5 blocks	94.2	79.4	10.8	90.2

Source: Field observation (1992).

Note: LB 2 = Tertiary Block No. 2 of Laxminagar Branch Canal. MC 43 = Tertiary Block No.43 directly connected to the main canal. Blocks are numbered successively from the headgate downward.

Table 3.2 Cultivation of principal *rabi* crops in the five tertiary blocks in 1992-93 (in percentage of net block area)

	Block	Total cultivation in the block	Crop			
			Wheat	Oilseeds	Vegetables	Total
1	LB 2	47.1 (35.2)	30.6 (25.4)	14.0 (8.8)	1.4 (0.8)	46.0 (35.0)
2	LB 11	67.7 (50.3)	19.8 (14.4)	39.2 (24.7)	4.8 (9.6)	63.8 (48.7)
3	LB 12	47.2 (41.1)	19.7 (12.7)	21.4 (15.4)	0.6 (10.1)	41.7 (38.2)
4	MC 43	28.3 (32.1)	9.1 (11.4)	10.5 (6.6)	6.8 (11.4)	26.4 (29.4)
5	MC 46	44.6 (46.4)	21.7 (21.4)	15.8 (13.4)	4.3 (10.4)	41.8 (45.2)
	Average of 5 blocks	47.0 (41.0)	20.2 (17.1)	20.2 (13.8)	3.6 (8.5)	43.9 (39.3)

Source: Field observation (1992-93).

Note: Figures in parentheses are for the year 1992.

The division of agricultural tasks between men and women is clearly distinguished. Tasks such as land preparation, irrigation, and fertilizing, including the manual spraying of chemical fertilizers and pesticides on fields are exclusively done by men. Women do most of the nursery preparation, transplanting paddy seedlings, harvesting, weeding, threshing, and the storing, assisted by men. Transplanting paddy seedlings is possibly the most desirable task left entirely to women, since the men have to do prepare the land at that time. People of some higher caste groups, Brahmins for instance, do not usually plough the land. They depend upon either wage labour or the people from lower caste groups such as *Tharus*, *Yadavs* and *Kahars* for most agricultural tasks. Women of higher caste family and landlords hardly engage in agricultural activities.

An integral part of the farming in Banganga is livestock raising which provides manure and additional income. Most of the additional income comes from selling milk and milk products.

Since ploughs drawn by oxen or buffaloes are commonly used to prepare land, most farmers try to own at least a pair of bullocks or buffaloes. Only a few farmers having large landholding use farm tractors to prepare land. The use of farm machines is thus very limited. The small size of fields and the availability of relatively cheap labour (because of the lack of alternative opportunities for employment) and of adequate animal power have so far restrained the use of farm machinery.

3.2 The irrigation system: physical and technical characteristics

The Banganga Irrigation System can be said to have developed into the present state in three stages: (i) initial stage (1942-71) when the irrigation system was called *Jagadishpur* system, and provided irrigation to a relatively small area, (ii) the 1972-79 period when the government constructed an extensive irrigation system solely with its domestic resources to increase the irrigated area, and (iii) the 1982-89 period when the extensive irrigation system was rehabilitated and improved under the CADP. The physical and technical features of the irrigation system have been largely influenced by the intensive development under the CADP. The design approaches followed during the three stages are discussed below, beginning with a brief historical outline of the irrigation practice in the area prior to the construction of the present irrigation system.

Oral history suggests that irrigation in the Banganga area using the water from the Banganga river dates back many decades. Prior to the construction of the first irrigation system by the government in 1942, there were a number of scattered small irrigation systems which were built by farmers themselves, either individually or collectively. These irrigation systems were mainly used for irrigating paddy. They consisted of small earthen canals, called *paenes*, and water in these canals was diverted using the traditional technology of building temporary dams of boulders and brushwood every year at various points along the river. Three such traditional irrigation systems managed by farmers still exist near the present headworks, confirming this. Further, a number of similar irrigation systems which used water from the *Jamuwar nala*, the stream forming the eastern border of the Banganga command area, were built by farmers. In addition, there were, and still are, several natural and man-made ponds used for irrigation and domestic purposes.[8] This shows that farmers in Banganga are experienced in irrigation.

The 1942-71 period: The Jagadishpur Irrigation System

The *Jagadishpur* irrigation system which was named after the Jagadishpur village where the reservoir is located was constructed in 1939-42 (Poudel 1986: 20). Its main objective was to enhance the production of paddy crop in the area. Available archives and oral history suggest that the irrigation system was constructed with the corvee labour of local villagers and beneficiaries.

This irrigation system consisted of a simple physical infrastructure and the traditional technology of water control was followed. A temporary dam of brushwood and stones was built every year at a point called *Laxmanghat* on the river to divert water from the Banganga river to the irrigation system. The diverted water flowed through a diversion canal to a reservoir at Jagadishpur. Two canals took off from the reservoir: one at the east and the other at the southwest corner (see Figure 3.5). These were locally called *Rajkulos* since they were built by order of the king. There were only a few secondary level canals which branched off at different points along these two canals. The water supply from the reservoir in the two canals was controlled through the vertical (timber) sluice gates. The larger canal at the southwest corner appears to have supplied water to seven small ponds within its command area. These ponds, which still exist, were used as intermediate reservoirs with similar water control sluices. There were no control structures on canals except these sluices. Farmers used water to irrigate their fields through cuts in the canal banks. Field to field irrigation was practised, with a continuous flow of a small volume of water.

No documents were available on the design of this irrigation system. Interviews with the farmers who could remember the past indicated that the level, gradient, and alignment of the canals were established without using modern survey instruments. The report on the survey carried out by the irrigation department officials in 1973 for the maintenance showed the capacity of the larger *Rajkulo* to be 0.6-0.7 m^3/s. According to this survey, the width of the canal varied from 1.5 to 3 metres and the depth from 0.15 to 0.9 metre. The capacity of the reservoir was estimated to be 1.73 million cubic metres, and the maximum area irrigated by this system was about 645 hectares (DOI 1973).[9]

The 1972-79 period: The Banganga Irrigation Project

The government showed its concern to construct a modern irrigation system or to repair the existing one in the Banganga area from the outset of the first five-year (1957-62) development plan which mentioned that the *Jagadishpur* irrigation system was in a state of disrepair (NPC 1957:36-38).[10] Subsequently, the feasibility study and preliminary design of the Banganga Irrigation Project were carried out by the Irrigation Department during the Second Plan period (NPC 1962: 186-87). At this stage, the project was designed to provide irrigation water for a total area of about 8,000 hectares of paddy cultivation in the wet season and for non-paddy crops on partial areas in the dry season. The project's main objective was to protect the late maturing paddy (*aghani*) which was estimated to occupy about 54 percent of the total command area at that time. The cultivation of the early paddy crop, called *jethuwa*, which is grown in some parts of the *tarai* during the April-July period was not considered possible here because of the scarcity of the water in the source river.

Though planned to implement the project during the Third Plan period (1965-70), the construction works only began in 1971, mainly due to the limited technically trained manpower and financial resources of the country (NPC 1965: 87). The project was completed in early 1979. Like most government irrigation systems at the time, this irrigation system comprised an extensive mode of irrigation development in which only the canals at the main system level and a few tertiary level canals were built. This is largely because the cost of the construction was borne solely by the government.[11] At the end of the project, the total cultivable command area was estimated to be 5,670 hectares of which about 4,860 hectares (86 percent) would be occupied by (monsoon) paddy, and about 2,000 hectares (35 percent) by wheat (DOI 1979). It was presumed that the availability of irrigation water would increase the cultivation of wheat in the area.

Under this project, a completely new irrigation system (hereafter referred to as the Banganga Irrigation System) consisting of a permanent diversion weir and a new network of canals was constructed. The existing *Jagadishpur* irrigation system was abandoned, since its command area came under the new irrigation system. The concrete diversion weir with four vertical steel sluice gates was constructed across the Banganga river at the place where the temporary dam had been built. The canal connecting the headworks and the reservoir (hereafter referred to as the diversion canal) was improved and provided with a head regulator consisting of four vertical steel gates. The Jagadishpur reservoir was reinforced and a new regulator with two screw-type vertical steel gates was built to control the flow from the reservoir in the main canal. Some tertiary level canals (called field channels) were also built.

In summary, the physical infrastructure of the Banganga Irrigation System in 1979 comprised the following:

- a permanent headworks with a gated regulator at the head of the diversion canal,
- a reservoir with a water storage capacity of 1.5 million cubic metres and a gated regulator at its outlet,
- unlined canals,
- a limited number of weir-type check structures in the main and secondary level canals,
- ungated concrete pipe outlets served by weir-type check structures,
- a limited number of tertiary level canals, and
- no field drains.

Figure 3.5 shows the schematic plan of the Banganga Irrigation System in 1979.

The irrigation system of this period was designed and constructed by the (civil) engineers of the Department of Irrigation without the involvement of foreign consultants. The design engineers largely followed the conventional design criteria and standards which were similar to those in irrigation systems in the North Indian States of Bihar and Uttar Pradesh. Apparently, beneficiary farmers were not involved in the design. Farmers and design engineers interviewed indicated that local élites and large landholders were only consulted in setting the alignment of canals. However, the final decision was made by the engineers.

It is useful to note, at this stage, the terminology used to denote the hierarchy of canals in Banganga, which is by and large similar to that used in adjoining states of India. A large capacity canal taking off from the main canal is called "distributary" or "branch" canal, and a canal having capacity smaller than a distributary or a branch canal is called a "minor". A

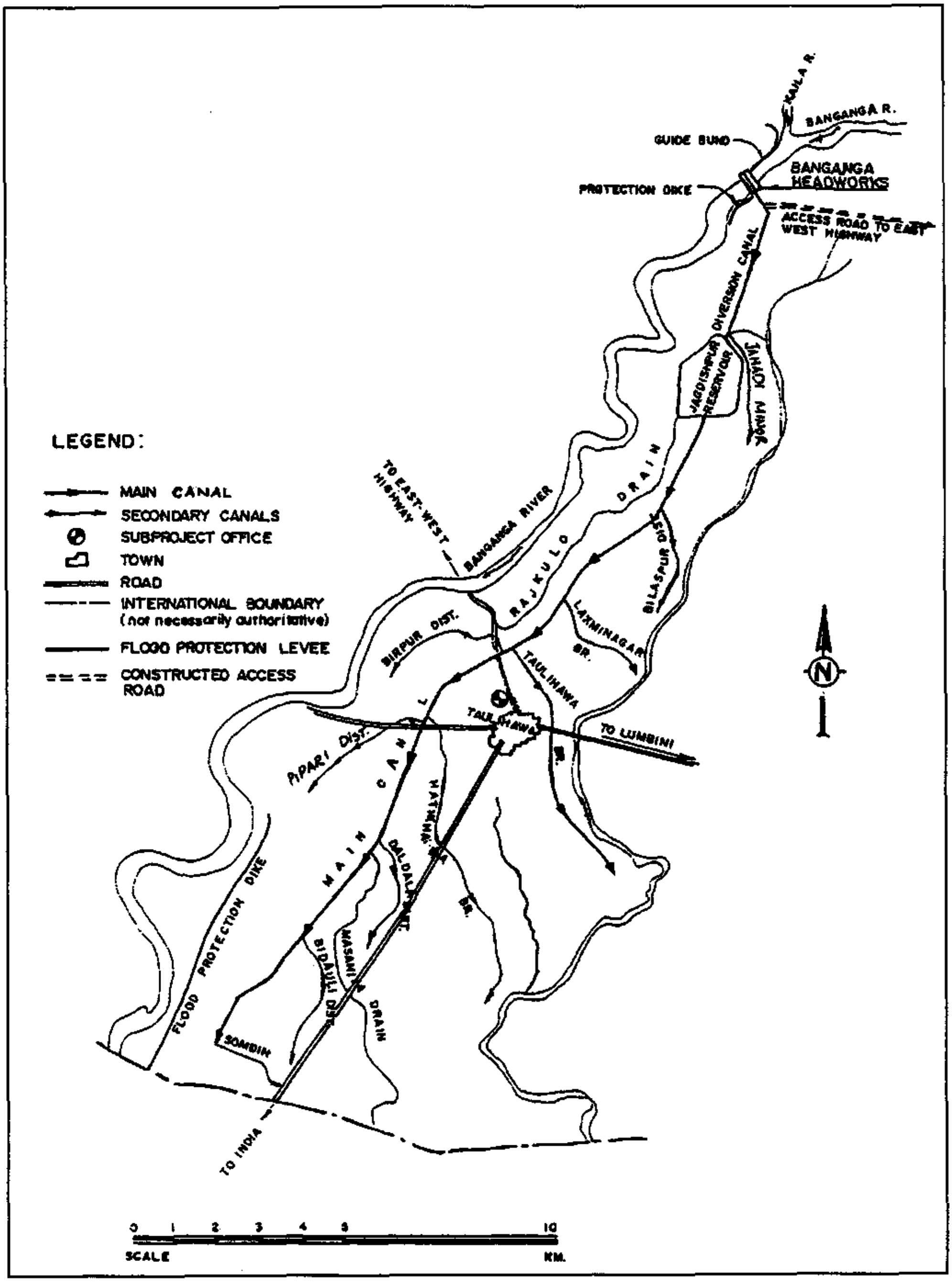


Figure 3.5 Schematic plan of the Banganga Irrigation System in 1979 (Source: CADP/DOI documents 1982)

lower level canal branching off from either a minor or distributary canal is called a "field channel". Some new terms were used to denote small capacity canals taking off from a minor or distributary canal, after the rehabilitation of the irrigation system under the CADP. These are "main farm ditch" which is the synonym for a "tertiary" canal and "farm ditch", the synonym for a quaternary canal in American terminology. However, in this chapter, the term "secondary" is used to denote all canals between the main and tertiary canals unless specifically mentioned.

As mentioned earlier, the irrigation system was built to provide adequate irrigation to the *aghani* paddy and was designed accordingly. Most of this paddy crop is at the flowering (critical) stage during the *hathiya* period in October when the monsoon season is over. Therefore, as one senior design engineer of the DOI said: 'The irrigation requirement during the *hathiya* period governs the capacity of the canal.'[12] According to the design report of this irrigation system, a design water requirement of 0.9 lps per hectare at the tertiary outlet for the paddy crop was used to determine the capacity of the canals (DOI 1972: 4-10).[13] The hydraulic design of canals was based on the Manning's equation. The engineering design of the headworks and other structures on canals is not discussed here since this is not important in the present context.

As shown in Figure 3.5, the main canal which runs along the ridge with lower-level canals branching off on either side divides the command area into two flanks. Note the provision of smaller (minor) canals on the right side of the main canal, with larger canals (called branch canals) on the left side because the strip of land is wider on that side (DOI 1972). For the efficient distribution of water to farmers' fields, tertiary level canals (which were called field channels then) of not less than 0.085 m^3/s capacity were provided (DOI 1976:1). Initially, it was planned to construct such field channels at government cost at the rate of one canal (average length 1.3 km) for every irrigable area of 40 hectares (ibid 1976). But, only 30 such canals had been constructed by 1979 because of the cost involved, most of them in the head reaches of the main canal. The hydraulic boundaries of these field channels were not clearly defined, and were left to the farmers to decide.

The water control structures on canals were selected on the basis of the mode of canal operation. The design engineers presumed that the main and secondary canals would be operated continuously at full supply level or full flow. The 'Sarda-type' falls (drops) were built on the main and secondary canals to maintain the full supply level.[14] The number of such structures was kept at a minimum to reduce the cost of construction. Only 8 such check structures were constructed over the 20 km long main canal.

The secondary canal outlets were provided with a simple screw type vertical slide gate, water from secondary canals was supplied to farmers' fields through ungated pipe outlets. An outlet served a large number of fields. The remains of such pipe outlet structures showed 3-5 cm grooves for stop logs or timber boards at the (inlet) head wall, implying that these outlets were to be operated either "on" or "off".[15] Precast concrete pipes of 15, 23 and 30 cm internal diameter were used in these outlets.[16] The outlets of some small secondary (minor and distributary) canals which took off directly from the main canal were provided with concrete pipes of 45-60 cm diameter. These outlets had been provided with gates. There were a number of ungated tertiary outlets directly connected to the main canal too, but these were either of 15 or 23 cm diameter. Indeed, irrigation systems having minimum ungated control structures was desirable to the DOI, because of the limited technical manpower and budget available for the operation and maintenance.

Interviews with the design engineers indicated that the ungated pipe outlets were placed at 1/3 design depth below the full supply level in the supply canal; this is confirmed by the remnants of old pipe outlets.[17] Within certain limits, an ungated pipe outlet set as such can deliver water proportional to the variation in the water supply canal (Varshney, Gupta and Gupta, 1983: 255-260; Mahbub and Gulati, 1951: 155).[18]

The combination of ungated pipe outlets placed at a 0.3 design depth below the full supply level and the weir-type checks necessitates that canals are operated either fully "on" or "off". Therefore, such a system design is rather rigid in terms of water control and likely to result in water losses.

The 1982-89 rehabilitation under the CADP: an attempt to achieve a flexible irrigation system

In 1982-89, the newly constructed Banganga Irrigation System was rehabilitated under the Command Area Development Project (CADP) financed by the Asian Development Bank (ADB).[19] The objectives of the CADP were to: (i) increase the production of food grains, (ii) increase farm income, (iii) provide rural employment opportunities, and (iv) improve the standards of living of the rural poor in the project area(s). These objectives were to be achieved through: (i) the rehabilitation and improvement of the existing irrigation, drainage and flood control facilities, (ii) the strengthening of the agricultural support services, and (iii) provision of (agricultural) inputs. Clearly, the premise was to follow integrated approach to the development of irrigated agriculture. Nevertheless, the development of physical facilities at tertiary level (also called on-farm development in the literature) through which, '... significant increases in irrigation efficiencies are expected ...' was emphasized (ADB 1981: 19). The project was completed in the middle of 1989 (ADB 1990).[20] Maximum proportion (about 47 percent) of the project cost was spent in the improvement and rehabilitation of the existing irrigation system.[21]

Water being the main constraint in Banganga, it was envisaged by the design engineers that the cropping intensity would increase moderately from 131 to 168 percent at the full project development without any increase in the potential irrigated area (ADB 1981: 19). It was presumed that farmers would increase their wheat cultivation with the availability of irrigation water, and that they would continue to grow the established staple and cash crops with the optimum planting dates for these crops determined by the distinct monsoon and dry winter season.

The construction and repair of all physical facilities including those at tertiary level was carried out by the project. Farmers were not involved, not even in the design and construction of physical facilities at tertiary level. This led to farmers developing a strong feeling that the irrigation system is the government property, and that it is the responsibility of the government to properly manage it.

As in most externally financed irrigation projects in the country, the assistance for the design and implementation of the project was provided by the financing agency through NIACONSULT Inc. of the Philippines in association with International Engineering Company Inc. (IECO) of the USA.[22] In the absence of design standards in the DOI, the consultants freely introduced their own standards, choice of technology, and even terminology.[23] The new water control structures built on canals confirm their influence in the redesign.

The design irrigation requirements adopted for paddy and wheat were respectively 0.93 and 0.45 lps per hectare at the tertiary outlet. Note that these design values obtained using the Modified Penman Equation are almost the same as those followed in the 1972 design. Given these design water requirements, the existing diversion canal, main and secondary canals were found to have sufficient capacity to meet the irrigation requirement of the projected cropping pattern and cropping intensity (NIACONSULT and IECO 1984: 29-35). Table 3.3 presents the designed hydraulic characteristics of the diversion canal, main canal and three large secondary (branch) canals.

Under the CADP, the rehabilitation of the existing physical system comprised the following changes. The diversion canal, main canal and most secondary canals underwent minor repair, since they had sufficient capacity to meet the design water requirements. The headworks, being in good condition, did not require any improvement. Only complementary flood control works were constructed along the banks of the Banganga river upstream and downstream of the diversion weir. A notable change under this rehabilitation is the increase in the storage capacity of the Jagdishpur reservoir from 1.5 to 4.57 million cubic metres to meet the irrigation demand of the anticipated increase in wheat cultivation without increasing the demand at the source river. Another striking feature of this rehabilitation is the introduction of tertiary blocks within the command area. The command area was divided into tertiary blocks of areas not exceeding 50 hectares. However, some tertiary blocks are below (smallest area: 10.5 hectares) and above (110.5 hectares) this limit, for the topographical and economic reasons. These tertiary blocks have clear physical boundaries. Each tertiary block is further subdivided into smaller irrigation units of 5-7 hectares. Each unit is served by a common farm ditch (FD) connected to the main farm ditch (MFD) which takes off either from the main canal or secondary canals. The tertiary blocks are provided with tertiary drains connected to the drainage network of the canal system. Most tertiary drains run parallel to the MFD of the adjacent tertiary block (see Figure 3.3).

Table 3.3 Design characteristics of principal canals in the Banganga Irrigation System

	Characteristics	Canal				
		Diversion canal	Main canal	Laxminagar Branch	Taulihawa Branch	Hathihawa Branch
1	Design discharge (m^3/s)	8.50	5.7 (0.4)	0.31 (0.3)	0.48 (0.29)	1.98 (1.42)
2	Flow velocity (m/s)	0.61	0.6 (0.3)	0.33 (0.24)	0.32 (0.28)	0.46 (0.42)
3	Design water depth (m)	1.39	1.3 (0.5)	0.51 (0.5)	0.56 (0.45)	0.84 (0.8)
4	Canal bed width (m)	8.0	5.4 (1.7)	1.10 (1.0)	1.8 (1.6)	3.9 (3.0)
5	Canal bed slope (m/m)	0.0003	0.0003	0.0003	0.0003	0.0003
6	Side slope (horz.:vert.)	1.5:1	1.5:1	1.5:1	1.5:1	1.5:1
7	Manning's roughness coef. (-)	0.03	0.028	0.028	0.028	0.028
8	Total length of the canal (km)	4.75	20.5	3.35	5.35	8.16

Note: Figures in parentheses are for the tail-end section of the canal.
Source: CADP/DOI documents (1984-85).

In practical terms, the maximum storage of water (4.57 million cubic metres) in the reservoir is approximately equivalent to only about a 10-day supply, starting at full storage capacity, to irrigate paddy in the area of 5,872 hectares below the reservoir outlet at a continuous delivery of 0.93 lps without replenishment. It is estimated that in the winter season the inflowing water or water available in the reservoir can irrigate only about a total area of 3,840 hectares (65 percent of the total command area). In response to these constraints on water availability, the design engineers introduced a water control technology which would allow flexibility in operation and increase water use efficiency.

For greater flexibility in operation and efficient water use, the design engineers introduced gated control structures down to the tertiary outlet. The USBR-type gated cross regulators of reinforced concrete were used on the diversion, main and secondary canals to maintain the desired water level upstream when the canals are operating at less than the design capacity. These cross regulators have one to three rectangular openings with fixed spillway crest on either side, depending on the bed width of the canal and the discharge. Openings greater than 1 metre wide are provided with screw-type vertical slide gates which can be operated manually with a detachable handwheel, whereas those less than 1 metre are provided with grooves for stop logs made of concrete slabs. Photos 3.1 and 3.2 show these cross regulators. The gates are operated from the concrete platform spanning the structures. Despite the provision of new cross regulators, the old weir-type check structures constructed during the 1972-79 were retained for use.

At tertiary level, each tertiary block has been provided with a single-gated pipe outlet of reinforced concrete (Photo 3.2). The size of pipes in these new tertiary outlets varies from 30 cm to 60 cm diameter. The old pipe outlets smaller than 30 cm were either removed or replaced by the new ones. The smallest pipe provided is of 30 cm diameter, irrespective of the area it serves and flow it can carry. At the head-end of each tertiary canal, a rectangular

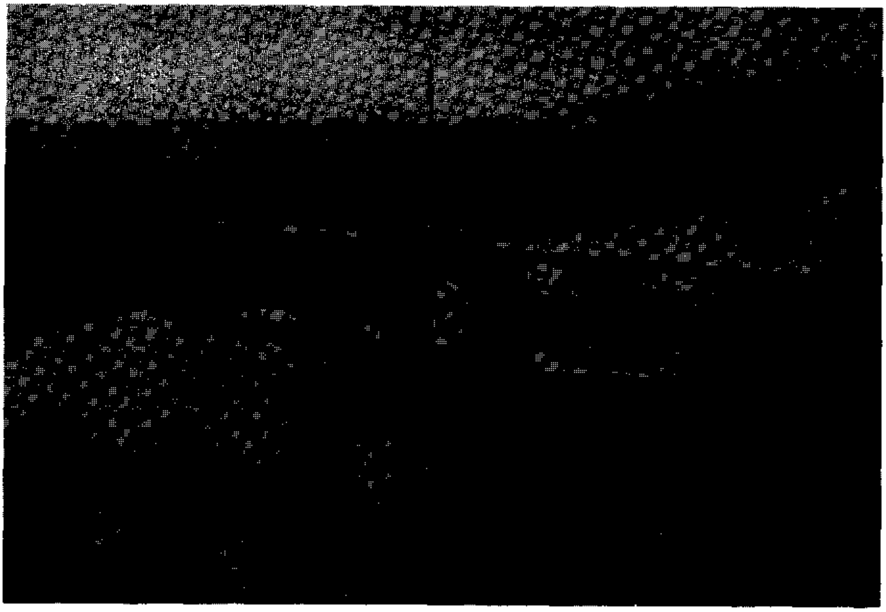


Photo 3.1 A typical USBR-type cross regulator structure on the main canal (1993)

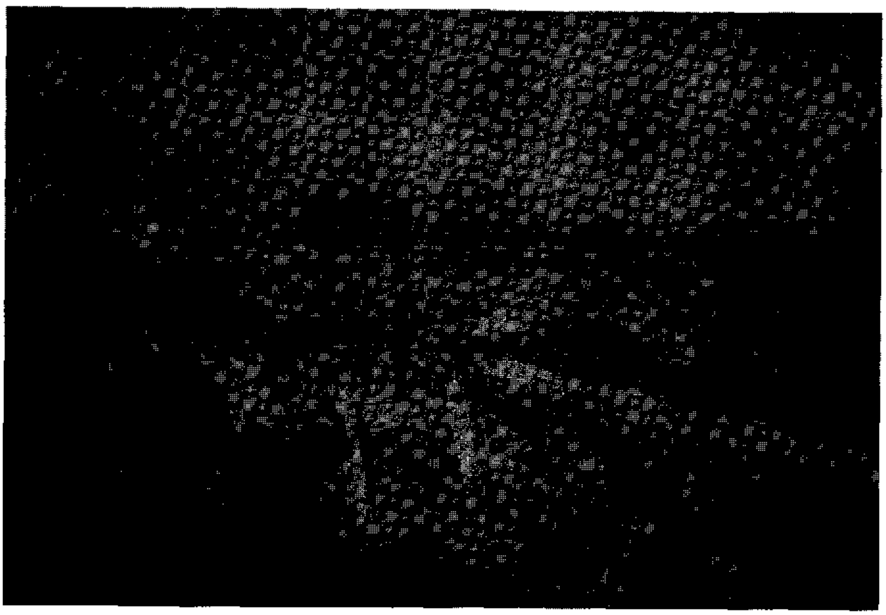


Photo 3.2 A single-gated tertiary outlet and the check structure in a branch canal (Laxminagar Branch canal)

stretch with brick lining has been built to facilitate the measurement of the inflow in the tertiary canal. However, observation show that these stretches have never been calibrated nor used to measure the inflow in the canal. According to the design specifications, the minimum working head for these outlets is 7.5 cm (NIACONSULT and IECO 1984). Observation shows that most tertiary outlets are placed close to the bed level of the canal. The flow through such turnouts is mostly submerged. It was also observed that pipe outlets were not at the same level above the canal bed. This is apparently because of poor control during the construction.

Within a tertiary unit, the flow from the tertiary canal to a farm ditch is to be regulated by means of a set of concrete checks and concrete slabs as flashboards. Similar concrete checks have been provided at the end of the MFD and each FD to control the outflow of water into the tertiary drain. It was observed that most of the concrete flashboards were missing and farmers used soil or mud blocks instead to check or divert water to FDs.

Table 3.4 shows the important canal elements of the Banganga Irrigation System before and after the CADP.[24] Clearly, the technical design and rehabilitation under the CADP increased the number of adjustable structures and permanent outlets on canals tremendously, especially on the main canal, thereby increasing the management burden of the operating agency. Notably, the introduction of tertiary units along the main canal increased the number of outlets directly connected to the canal (hereafter referred to as direct outlets). As a result, a number of cross regulators had to be provided to serve these outlets. Thus, 17 new cross regulators were built in the main canal. Generally, tertiary outlets directly connected to the main canal are not preferred for operational reasons. Yet, according to the design engineers, it was not possible to avoid such direct outlets in Banganga for two reasons: (i) many were already existed, especially in the head reach, and obviously had to be retained, and (ii) without direct outlets a considerable land area adjoining the main canal would have been left without irrigation, and canal breaches might have occurred.

Figure 3.6 presents the schematic plan of the irrigation system showing direct outlets and the areas served by them. Interviews with the design engineers indicated that the implications of such a huge number of direct outlets were not realized by them at design, at least not fully.

Immediate consequence of gated control structures

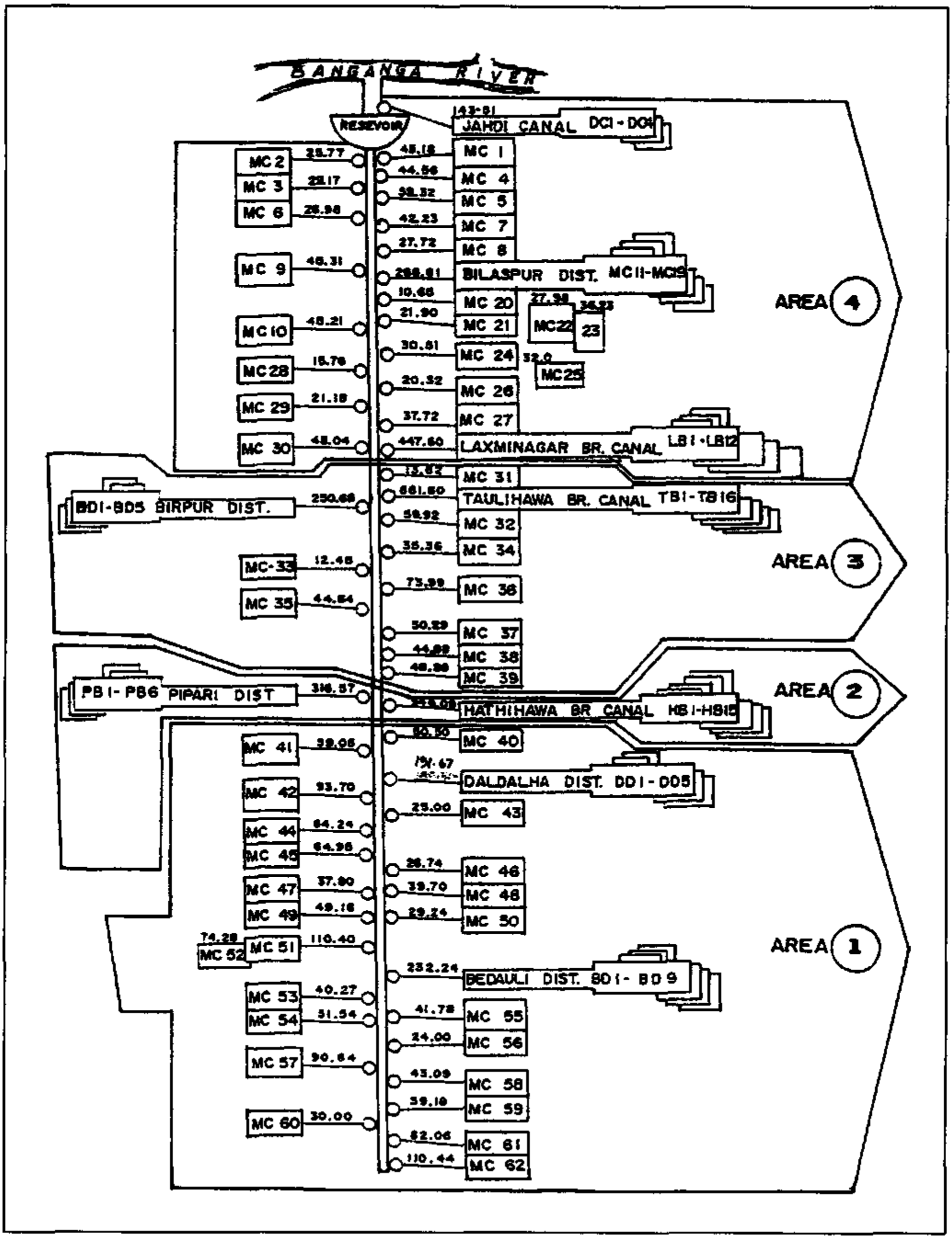
The provision of new gated check structures and gated outlets evoked an immediate response from farmers and villagers of the Banganga area. The gates were vandalized and their parts stolen soon after they were installed, causing '...the sub-project manager of Banganga to defer(ed) the installation of the remaining steel gates ...'(NIACONSULT and IECO 1989:65). In June 1993, the irrigation office had still not repaired the gates, nor did it intended to reinstall them because of the risk of being vandalized or stolen again. This shows that it has been difficult for the irrigation (sub-project) office to manage gated structures from the onset of the project.

Table 3.4 Canal elements in Banganga before and after the CADP.

	Canal element	Under extensive construction in 1979	Under CADP (1982-89)
1	Reservoir		
	a) Surface area (ha)	96	163
	b) Maximum storage capacity (MCM)	1.50	4.57
2	Main canal		
	a) Total length (km)	18.00	20.50
	b) Design capacity (m^3/s)	5.66	5.70
3	Secondary level branch canal		
	a) Number-Total length (km)	3 - 11.00	3 - 16.90
	b) capacity (m^3/s)	0.25-2.00	0.29-2.00
4	Distributary and minor canals		
	a) Number-Total length (km)	not available	6 - 23.50
	b) Capacity (m^3/s)	< 0.14	< 0.14
5	Tertiary canal		
	a) Total length (km)	30*- not available	98.90
	b) Capacity (m^3/s)	not less than 0.08	0.09-0.12
6	Farm ditch		
	a) Total length (km)	nil	301.50
	b) Capacity (m^3/s)	---	0.02-0.03
7	Head regulator: main canal		
	a) Total number of gates	2	2
	b) Type	vertical steel gates	vertical steel gates
8	Cross regulator: diversion/main/secondary canals		
	a) Total number	14	14 + 32**
	b) Type	weir-type	Undershot-type,
9	Tertiary turnout		
	a) Total number	not available	131
	b) Type	on-off type	single-gated type
	c) Pipe size (cm)	15, 23, 30	30, 45, 60

Notes: * These were called field channels.
** Of the 32, 17 cross regulators are on the main canal.
Sources: Field observation (1992-93) and CADP/DOI documents.

This deterioration of gates on check structures and outlets is an indication of the *de facto* control exercised by farmers as a result of the unreliable and inadequate delivery of water by the irrigation office. It is also partly because the irrigation office is not able to control or supervise the physical system with its limited number of field staff. For instance, the gate at the outlet of the tertiary block No. LB 2 was stolen in November 1991, during the researcher's field work and could not be recovered despite the best efforts of the engineer incharge of the irrigation office.[25]



MC 4 = outlet for tertiary block No. 4 directly connected to the main canal.

Figure 3.6 Schematic diagram of the Banganga Irrigation System showing irrigation areas and number of direct outlets along the main canal, 1993 (Source: CADP/DOI documents)

Given such a response to gated structures by both farmers and irrigation officials, it is not difficult to explain the state of large number of cross regulators and outlets with damaged gates or without gates. Table 3.5 presents the situation of direct tertiary outlets, secondary canal outlets, and cross regulators in the main canal from November 1991 to June 1993. Note that out of 61, only 9 (15 percent) outlets have gates that were operable. Only the first cross regulator, which is at km 1+050 from the head gate of the main canal and serves tertiary units MC 1 and 2, has gates that are still in operable condition. In this way, the irrigation system has virtually returned to the same state as it was before the rehabilitation under the CADP in terms of the condition of gates, but with an increased number of permanent outlets and check structures.

Table 3.5 Situation of outlets and cross-regulators on the main canal in 1991-93

	Structure	With operable gates	With damaged gates	Without gates	Total
1	Direct outlets				
	- in number	8#	30	15	53
	- in percentage of the total	15	57	28	100
2	Secondary canal outlets				
	- in number	1*	6	1	8
	- in percentage of the total	12.5	75	12.5	100
3	Cross regulator				
	- in number	1**	13	3	17
	- in percentage of the total	6	76	18	100

Notes: # These are MC 4, 8, 29, 31, 32, 39, 42, and 51/52. These direct outlets are numbered successively from the headgate downstream. Damaged gates include gates with missing spindle and gate plates and broken frame.
* This is the headgate of the Hathihawa Branch Canal which takes off at km 10.79 from the main canal head.
** This is the first cross-regulator from the headgate of the main canal.
Source: Field observation (1991-93).

Characteristics of the irrigation system

The irrigation system has four specific characteristics which have implications for the allocation and distribution of water. Firstly, it does not show the hierarchical rigidity commonly found in large irrigation systems. For example, there are tertiary canals directly taking off from the main canal. This is partly because the design engineers have responded to the topography of the command area. The design of tertiary blocks was primarily based on the topography and made no consideration for the existing pattern of land tenure. In an area with fragmented land pattern, matching the tertiary (canal) boundaries with those of the landholding, community or village would indeed complicate the design. In the present design, a tertiary canal not only cuts through the village or community boundaries which do not necessarily follow the topographical or landscape features, but often separates a landholding into parts such that one part of the landholding lies in the head-end of a tertiary block, while the other part falls at the tail-end of the adjoining block. This design feature has implications for organizing water users' groups at tertiary level (see Section 3.3).

Secondly, there is no provision to prevent the siltation of canals, especially the siltation of the diversion canal. During the rainy season, the Banganga water contains large amounts of silt and sediments which enter the irrigation system with the diverted water. There is, however, no data available on the silt load in the water. Observation shows that most silt deposition occurs in the diversion canal, within the first two kilometres of the head regulator. The silt deposit is maximum just downstream of the head regulator, thereby restricting the inflow of river water in the diversion canal. According to the design engineers, the silt deposition in the diversion canal can be largely checked by shutting the headgates of the canal and opening the under-sluices of the weir during the high flood in the river. The gate operators stationed at the headworks try to follow this simple operational rule. Nevertheless, the diversion canal still faces siltation for practical reasons, such as the gates being lowered only after the flood has occurred and the water not being silt-free immediately after the flood. Observations showed the silt deposition in the canal to average 25-30 cm per year. The irrigation office is responsible for removing the silt in all canals down to the tertiary level. The silt is removed manually during the time of the annual maintenance of canals between April and June. Most of the time, the office only succeeds in partially cleaning the diversion and main canals because of the budget constraint.

Further, silt deposits decrease the discharge capacity of a canal. They enhance the growth of aquatic plants, possibly because of the nutrient contents. Aquatic plants in turn reduce the flow velocity of water, and more silt is deposited followed by increased growth of the plants. Aquatic plants with thin stems and leaves floating on water severely infest the canals, particularly the diversion and main canals. These plants grow rapidly in a short period of time, immediately after the canals are operated for the transplantation of paddy during the June-July period. Although they are removed (uprooted) manually during the annual cleaning of canals, they rapidly grow back. Apparently, the design engineers could not foresee such a fast rate of growth of aquatic plants and the resulting problem in canal operation. Aquatic plants retard the flow of water, increase the water depth for the same discharge, and thereby reduce the flow carrying capacity of the canals. The resistance to flow not only delays the time for water to reach the tail-end of the canal, but the resulting rise in the water level upstream also induces undue increase in flows (hence a loss) through the ungated or open turnouts. The effect of aquatic plant growth in the main canal is such that the design discharge in the main canal cannot be attained, even if the reservoir has enough storage.[26] Observations from 1989 to June 1993 showed that the flow in the main canal never exceeded 3 m^3/s.

Thirdly, the reservoir located 4.75 km away from the diversion weir is a unique feature of this irrigation system.[27] The management of the reservoir, which includes timely storage, release and closure of water supply to the main canal is crucial, especially when considering the demand for water during the period for transplanting paddy in May-June and for growing wheat in the dry season. Effective utilization of the rainfall during the crop cultivation period can lead to increase in the storage of water in the reservoir. The water supply in the reservoir is controlled at the headgates of the diversion canal, that is, at the headwork. At the tail-end of the diversion canal which is the entry point to the reservoir, water flows freely over a weir-type check structure. The reservoir also functions as a sedimentation pond, though it may not have been planned as such in the design.[28] As a result, siltation of the main and secondary canals is minimal, and silt hardly enters farmers' fields.[29] During the rehabilitation under the CADP, a gated cross regulator was built at km 4+000 from the diversion canal head, just below the outlet of the Jahadi minor canal. Although the cross regulator has facilitated the diversion of water into the Jahadi minor canal, it has become a point to be guarded if sufficient inflow of water in the reservoir is to be maintained.

Fourthly, the type of control structures provided on canals gives another important characteristic of the irrigation system. In contrast to the 1972-79 design, the cross regulators and outlets provided during the rehabilitation under the CADP are all undershot-type with screw-type vertical steel gates, with each gate opening potentially having an indefinite number of settings. As mentioned earlier, these structures were provided for the flexibility in operation of the irrigation system. Such a irrigation system design can theoretically respond to the flow fluctuation in canals and enables the irrigation system to meet differential irrigation requirements and to distribute water precisely, if there are adequate number of skilled operating staff. However, irrigation engineers consider such system designs with manually controlled structures to be complicated on the grounds that they may result in a low operational performance (Horst 1983, 1990). The irrigation system discussed here can be considered as a case in point.

The irrigation system as it stands with 61 percent of outlets and 97 percent of cross regulators having non-functional gates (Table 3.5), has become a rather rigid system. Whereas the provision of new control structures and outlets has facilitated access to canal water for farmers along the main canal, the uncontrolled use of these structures has made the delivery of water to the tail-reach of the canal extremely difficult for the operating agency. The water control structures present considerable obstacles to the reliable delivery and even distribution of the available water. Even if gates are operable, the irrigation office cannot distribute the water supply effectively unless head-reach farmers discipline themselves not to practise wasteful use of water. It was observed that farmers easily operated the gates of cross regulator and outlets, with the help of a rope or a bicycle chain and a bamboo stick.

Given these technical and physical characteristics, which are primarily attributed to the design, an efficient organization and effective institutional arrangements is required to manage water distribution evenly. The following section will examine the arrangements made by the Irrigation Department for water control in this irrigation system.

3.3 The organizational and institutional arrangements for water control

Initial management through the District Administration Office and local enterprise

Historical evidence and interviews with elderly farmers of the Banganga area suggest that for about a decade after its construction in 1942 the *Jagadishpur* irrigation system was under the Kapilvastu *Goswara* office, the then District Administration Office located at Taulihawa. This office managed the irrigation system through its public works section which consisted of only a few junior supervisory staff.[30] The small manpower was adequate since the irrigation system was small, and the water allocation and distribution followed a continuous delivery.

Farmers using the irrigation system were required to contribute their labour and skills under corvée in the annual repair and maintenance of the system. Most of their labour input and local resources were naturally used in the main task of constructing the temporary dam on the Banganga river. The secondary canals which delivered water to a village or a group of villages were cleaned and repaired by the respective villagers. The construction of the dam and repair and maintenance of canals had to be accomplished before the onset of the monsoon. The mobilization of villagers and other necessary local resources were done through local *jimidars* and dominant landowners in accordance with the 1935 Revenue Regulations for (canal) irrigation in the *tarai* region (see Appendix 1 and 2).

The consequence of depending upon local *jimidars* and dominant villagers for the annual maintenance and repair of the state-built irrigation system was the increase in the pervasive and lasting influence of these people over common farmers and tenants. Even now, the landlords and dominant villagers have considerable control over the use and distribution of canal water within their village. The fact that most chairmen of water users' groups and committees formed during the CADP period and later in 1992 belonged to this dominant group verifies this.

With little variations over time, the district administration continued to operate the *Jagadishpur* system under this institutional arrangements until some years after the establishment of the Department of Irrigation in 1951. As the irrigation administration of the Department of Irrigation took hold in the country, the management of the irrigation system was transferred to the department.

Management under the Department of Irrigation

Under the Department of Irrigation, the arrangement for the management of the Banganga Irrigation System has changed time and again, with the change in the irrigation policy of the government. Available records show that the DOI managed the *Jagadishpur* system through its *Taulihawa Nahar Sakha* (meaning Taulihawa Canal Section) until early 1973.[31] Despite the considerable length of the period (1952-72), there is an almost total absence of records on how this office managed the irrigation system during this period. Oral history suggest that this office operated and maintained the system in the same manner as the *Goswara* Office did, with a small number of junior level field staff and a limited annual budget.

Following the implementation of the Banganga Irrigation Project in 1971-79, the *Taulihawa Nahar Sakha* was merged into the project in 1973, and the operation and maintenance of the existing system was transferred to the project.[32] Due to the construction of the new irrigation system, the water supply from the existing irrigation system was frequently interrupted. It was not until sometime in 1977 that farmers in Banganga began to receive water from the new irrigation system. From 1979-82, the irrigation system was under the

Kapilvastu Sinchai Subdivision, the then district level office of the DOI. This subdivision office was headed by an assistant engineer and was under the administrative supervision of the Western Regional Irrigation Directorate (WRID).[33] The transfer of the newly built system to the subdivision office was abrupt. Apparently, the subdivision office only managed the main system during this period.

Immediately following the implementation of the CADP in 1982, the irrigation system became the 'Banganga sub-project'. Throughout the project period (1982-89), it was separated from the WRID due to the special arrangements made for the execution of the project. In compliance with the agreement between the government and the financing agency, the CADP had been a central level project directly under the Director General of the DOI.[34]

The consultants of the CADP recommended an organizational arrangement for the operation and maintenance of the improved irrigation system (NIACONSULT and IECO 1989: Appendix 14, Figure 14.3-14.6). This organizational arrangement was derived from the following three major activities involved in irrigation systems: (i) agri-institutional activities, (ii) operation and maintenance of physical facilities and mechanical equipments, and (iii) administrative support services for carrying out the first two activities effectively. It was presumed that the DOI would provide and maintain adequate staff, funds and equipments necessary to ensure desired performance of the irrigation system. This was an over-expectation on the part of the consultants and the financing agency, considering the resource constraint of the government.

The subproject office in Banganga came under the WRID after the completion of the CADP in July 1989. However, as a subproject office it managed the irrigation system for about two years. But its organizational capacity was reduced considerably. The project completion report (ADB 1990:12) noted: 'The project management has retained a limited number of staff who will continue with operation and maintenance of the system up to July 1990 and has adequate budget for this purpose (a total of about Rs 8.0 million for the three subprojects for the 1989-90 fiscal year). [...] The existing staff and transport facilities were inadequate for the operation and maintenance'. This is largely due to the absence of standard guidelines for the operation and maintenance of completed irrigation systems in the DOI. Moreover, the Irrigation Department did not question the operation and maintenance implications of the design by the consultants of the CADP. Its interaction with the (CADP) project office was usually limited to the allocation of the budget. Nor was there supervision on the activities of the subproject from the regional directorate office concerned.[35]

The annual budget allocated by the DOI for the operation and maintenance of the irrigation system dropped substantially in the following years. The budget allocation was not related to the actual requirements of the system. The pattern of the budget requests and approval for the fiscal years 1989-90, 1990-91 and 1991-92 for the Banganga system confirms this. The budget approved for the operation and maintenance for the year 1989-90 was Rs 1.3 million, that for the year 1990-91 was Rs 500,000 (which is 17 percent of the amount requested) and that for the year 1991-92 was Rs 550,000 (16 percent of the requested amount) (IIMI 1992, Vol.IV:7).[36] The reduction in the annual budget not only resulted in deferring the maintenance and repair works, but it reduced the staff strength of the subproject office. For instance, silt deposit in the diversion canal was only removed in June 1992 after a gap of three years. By this time the silt deposits were so large that only partial cleaning was achieved with the available budget. Field level staff like *dhalpa*, gate operators, and supervisors were curtailed. By July 1991, the number of staff in the subproject office had been reduced to 44 from the total of 84 during the CADP. Figure 3.7 presents the organization of the subproject office in 1991. The staff problem was even more critical, given that 39 staff were temporary and only five were permanent.

In November 1991 (effective from November 17, 1991; corresponding Nepali date: *Mansir* 1, 2048), the subproject office was terminated and the irrigation system was transferred to the Kapilvastu District Irrigation Office (hereafter referred to as the District Irrigation Office).[37] This was done following the government's decision to discontinue temporary employees of the development projects in order to reduce the country's financial burden. As a result, all project paid (temporary) staff who were mostly junior field staff such as supervisors, dhalpas, gate operators and the like were dismissed immediately. The acting subproject manager (hereafter referred to as the district irrigation engineer) who had been with the Banganga subproject since the beginning of the CADP was retained as the officer in-charge of the District Irrigation Office.[38]

The Irrigation Department presumes that the District Irrigation Office (DIO) is capable of managing the Banganga Irrigation System, in addition to its other responsibilities. This presumption should be seen from the practical viewpoint because the DIO organization prepared by the department differs significantly from the organizational arrangement suggested by the CADP. According to government policy, the primary function of a DIO is to assist the District Development Committee in the planning and implementation of district level irrigation schemes which are mostly of small scale. Further, the DIO operates on the regular government budget which is stringent. It has inadequate field level technical staff to operate and maintain the system effectively. Figure 3.8 presents the organization of the District Irrigation Office. Note that there is no provision for fieldmen.[39]

Given the limited budget and the operating staff, the District Irrigation Office is only able to focus on the operation and maintenance of the irrigation system at the main canal level. The control of the irrigation office is, in practice, confined to the diversion headgates, reservoir outlets, the main canal headgates, and major secondary canal outlets. At the headworks, two gate operators and a *chaukidar* are stationed to operate and maintain the gates at the diversion weir and the head regulator of the diversion canal. Similarly, there are three persons (reduced to two in the early 1993) deployed at Jagadishpur to control the flow in the reservoir and in the main canal. These persons are also required to monitor the flow in the direct outlets along the diversion canal and the head-reach of the main canal. The gate operators receive instructions either directly from the district irrigation engineer or through his overseers. The engineers and overseers reside in the irrigation office premises at Taulihawa which is about 12 kilometres away from the headworks and give instructions either during their field inspection or when the operators come to report to the office. The assignment of overseers in the system operation is not fixed. Most of the time, overseers are engaged in the survey and estimate of the repair and maintenance works of irrigation systems in the district, including the Banganga irrigation system. The inspection of canal operation by the district irrigation officer is mostly determined by the availability of the vehicle and the fuel. Thus in practice the day-to-day water control along the main canal is left in the hands of a few field staff.

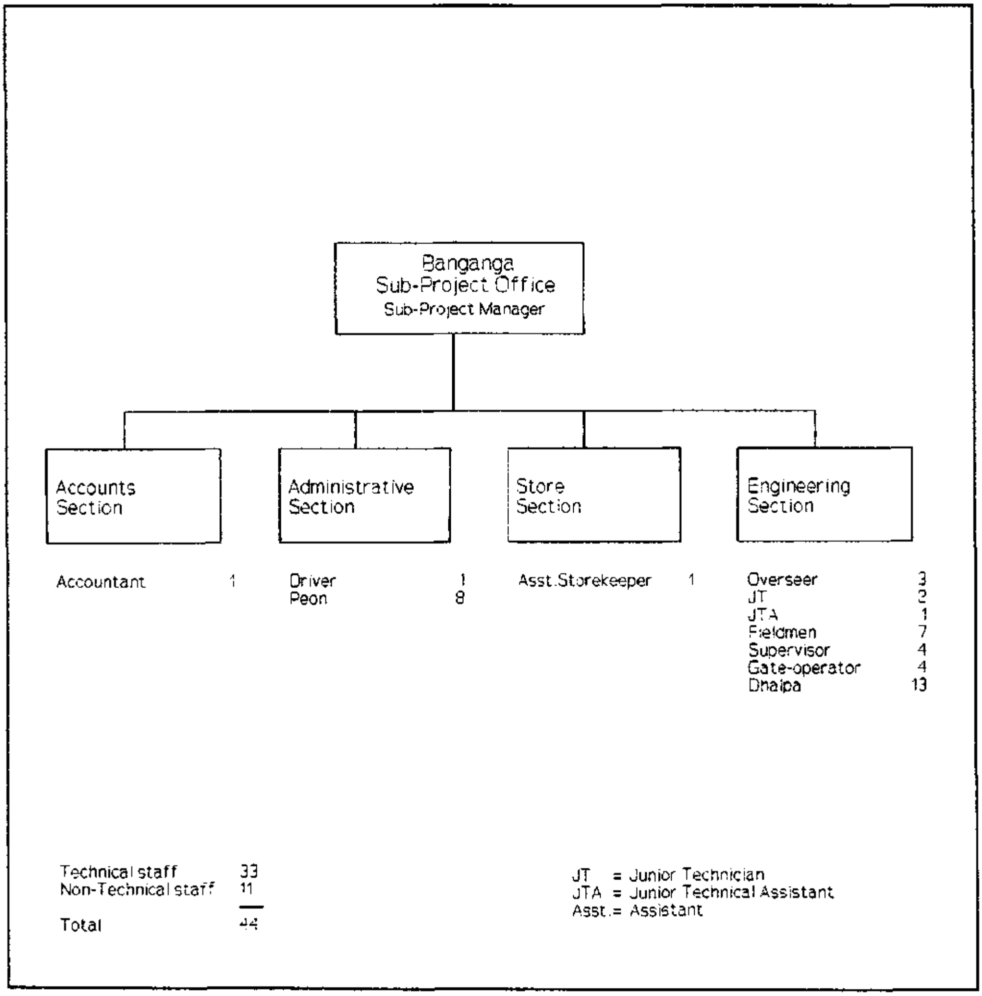


Figure 3.7 Organization of the Banganga Sub-project Office in 1991 (Source: Banganga Subproject Office.)

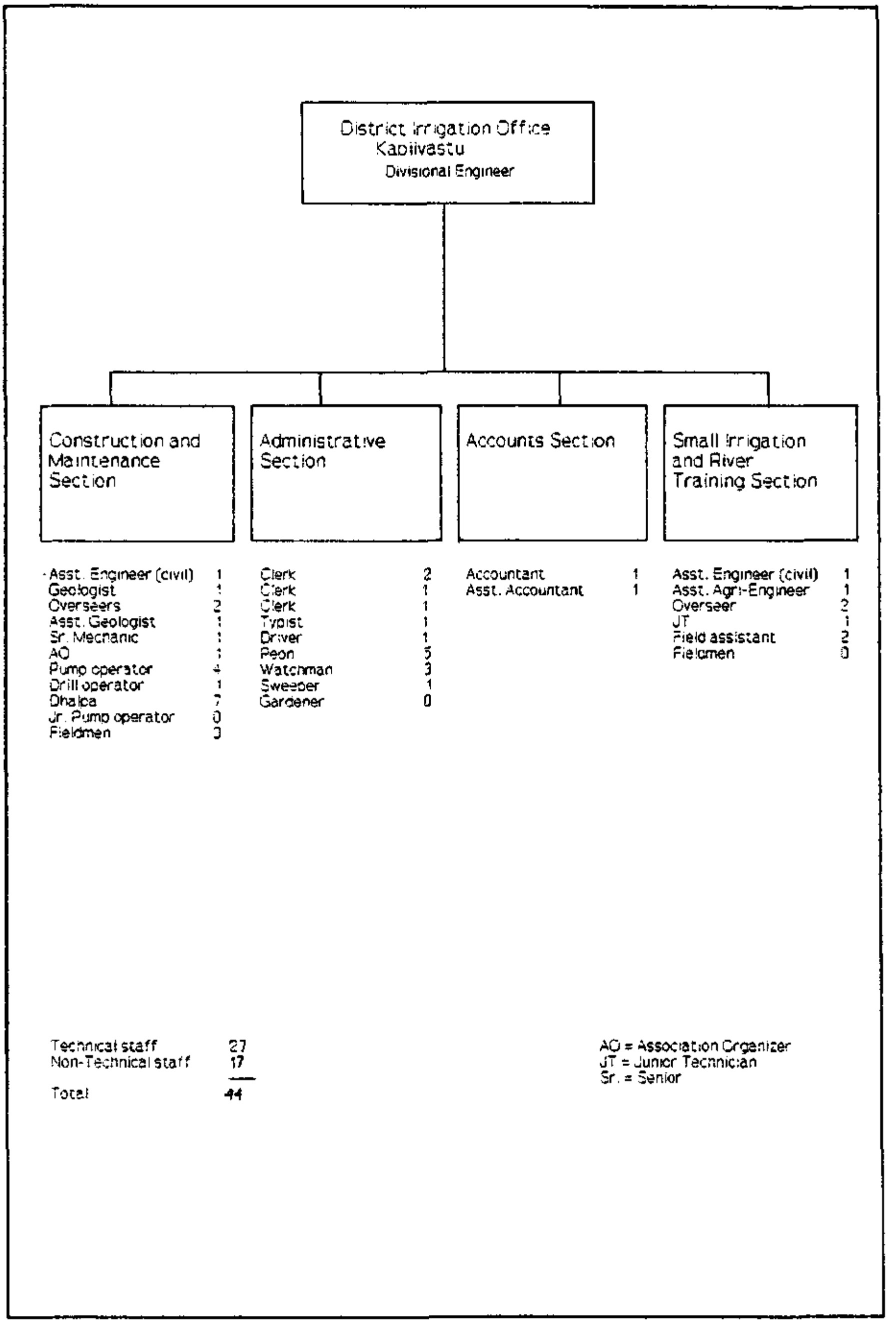


Figure 3.8 Organizational structure of the Kapilvastu District Irrigation Office (Source: District Irrigation Office, Kapilvastu, 1993.)

In 1992-93, a supervisor, three fieldmen and five *dhalpas* tried to manage water distribution along the main canal. *Dhalpas* are under the control of the supervisor, but the fieldmen report directly to the irrigation engineer. Each *dhalpa* is assigned a specific stretch of the canal, and the fieldmen are allotted specific areas. The *dhalpas* are also required to operate the gates at the cross regulators and secondary outlets that have operable gates, as there are no gate operators specifically assigned for the main canal. Thus, with a total canal length of 20.5 km (main canal) the actual field staff density is 3.42 km per field staff (excluding the fieldmen). It is difficult for *dhalpas* to control the flow through the vast number of check structures and direct outlets, especially considering that they have to patrol this distance mostly on foot. By the time a *dhalpa* reaches at the end of his assigned stretch, most of the direct outlets behind him are already open.

Given the limited financial and manpower resources, it was necessary for the government to devise an effective and sustained mode of managing completed large and medium irrigation systems. The government did this by formulating the new 1992 irrigation policy which provides for the institutionalization of farmers' participation in the system operation and maintenance. Whereas farmers' participation in the management of government irrigation systems (projects) has been emphasized at the policy level, approaches to farmers' participation at the implementation level have been inconsistent. The approaches to obtain farmers' participation by the DOI in Banganga illustrate this.

Formation of water users' group under the CADP

Prior to the implementation of the CADP, the Department of Irrigation had not made any effort to organize farmers of Banganga into water users' groups, though such groups were formed on trial basis in a few large irrigation projects elsewhere in the *tarai*, e.g. in the World Bank funded Narayani Zone Irrigation Project. Water users' groups (WUG) were first formally formed in Banganga as an essential institutional activity under the CADP.[40]

The CADP delimited the management responsibility of the irrigation system(s) between the irrigation office and the water users. The operation and maintenance of canals and structures above and including tertiary outlets, and drainage and flood control works was to be the responsibility of the Irrigation Department. Tertiary canals, farm ditches and drains (on-farm facilities), and including on-farm water management were planned to be eventually turned over to the beneficiary farmers organized into WUGs. This division of responsibility seemed justified, considering the numerous gated structures above the tertiary level. By comparison, the operation and maintenance requirement of tertiary level facilities consisting of only unlined MFD, FDs and drains is minimal.

The basic functions of a WUG as stated at appraisal are as follows: (i) to ensure effective water delivery through regular coordinated operation and maintenance of farm ditches; (ii) to provide equitable water distribution among the farmers' fields; and (iii) to act as learning group and communication network for agricultural extension, particularly for on-farm water management practices (ADB 1981: 33). WUGs were planned to be formed during or (soon) after the construction of tertiary canals and farm ditches, and were to be "channel-based", that is along the tertiary canal and farm ditch boundaries (ibid 1981:117).

Two levels of WUGs were created under the CADP: (i) WUG at the tertiary level, and (ii) federation of water users' group (FEWUG) at the secondary canal level. Tertiary level WUGs covered areas between 30 and 70 hectares, and a FEWUG was formed for a group of tertiary blocks of about 200 hectares. The representatives of the WUGs were the members of the FEWUGs, and the fieldman was made the secretary of the FEWUG. Notably, there was no project or system level organization incorporating all FEWUGs.

In Banganga, a total of 134 such WUGs and 28 FEWUGs was formed under the CADP (ADB 1990). It was envisaged that these WUGs would be sustainable to undertake the responsibility of tertiary level water management after the project completion. This did not, however, happen. These WUGs became ineffective immediately after they were created. According to the ADB report, the government agency concerned was responsible for this. The Project Completion Report (ADB 1990: 11,13) noted: 'The irrigation division under DOA did not perform its role as envisaged during the appraisal. It did not provide water management extension staff (JT, JTA, and fieldmen) at all'.[41] Since the DOA failed to provide the necessary field extension staff, the project directly recruited some of them in 1986-87 to begin organizing farmers into WUGs. According to farmers, there was no coordinated participation of water users in the WUG formation process. The WUGs were formed hurriedly in order to meet the project target only. Most WUGs and FEWUGs were formed under the guidance of the expatriate consultant agriculturists and water management specialists, during the first quarter of 1988 (NIACONSULT and IECO 1989: 34,45). Farmers interviewed indicated that there was hardly any interaction between the organizers (the project staff) and water users, nor between the water users themselves in this process. The WUG functionaries - chairman and vice chairman - of most WUGs were picked by the organizing staff after a short discussion with farmers. Most of them were large landholders or dominant villagers who were not interested in the actual task of operation and maintenance of tertiary level canals. The WUGs were not clearly informed of their roles, responsibilities, and rights in system operation and maintenance. They did not have any record of their members and did not know their physical boundaries well. Thus, as the Project Completion Report (ADB 1990:13-15) further concluded, 'The majority of the WUGs have been formally created ...' It was further suggested by the ADB that the DOI should appoint a team of engineering and water management extension staff to encourage the further development of WUGs to improve on-farm water management and its ultimate take over, and that the teams, during the initial period, should be assisted by external agencies such as International Irrigation Management Institute (IIMI).

Restoration of WUGs with IIMI's assistance
Partly in keeping with the ADB's recommendation and in accordance with the 1989 Action Plan for Participatory Management Program, the DOI implemented a pilot project to restore and develop WUGs in Banganga with the assistance from IIMI.[42] Its overall objective was

to develop a set of effective approaches for establishing improved irrigation management practices through increased participation of water users, which can be used by the DOI throughout the country (IIMI 1992, Vol. I). This collaborative project was carried out from May 1991 till April 1992 (extended later up to July 1992) in a total area of about 1,000 hectares distributed over the head-end and tail-end of the command area.

By 1990, all WUGs formed under the CADP had become totally defunct. There were several reasons for this shortfall. As noted by IIMI (1992, Vol.I, II), the reasons mainly relate to: (i) lack of leadership among water users and WUG members, (ii) lack of communication between irrigation staff and farmers, (iii) (physical) defects in the system, and (iv) unreliable and inadequate supply of water. Above all, the feeling that the system belonged to the government (which is of course true) had become stronger than ever among farmers, since to date the government financing and project mode of execution had been predominant. Not surprisingly, farmers made no effort to participate in the system management in a coordinated way. In such a situation, it was important to create an environment that brought awareness amongst uncoordinated and unorganized farmers of the need for an organization. This was done by IIMI, to a great extent, by following the "farmers first" approach.[43]

In contrast to the approach followed during the CADP, the DOI-IIMI project stressed that the formation of water users' groups can be better done by the farmers themselves and that outsiders can only facilitate the process. Emphasis was also placed on the need to properly understand the existing social relations and irrigation practices before any kind of intervention is introduced.[44] This was implemented practically by the two IIMI field-based staff who interacted continuously with farmers of the pilot area to learn about the problems faced by the latter regarding the collective action.[45] By doing so, they were able to gain the confidence and trust of the farmers who expressed the water-related problems to them more openly than to the staff of the irrigation office.

Farmers were constantly chivvied to organize into water users' groups and deal with their irrigation problems collectively. They were encouraged to form their WUGs and choose the WUG functionaries in a general meeting held at their own village premises. Several meetings had to be organized before a WUG could be formed. During such meetings, they were chivvied to define the duties and responsibilities of WUGs and their members, rules and regulations for the cleaning of canals, and sanctions for absentees. They were also advised to keep minutes of their decisions. Each WUG consisted of 5-10 members which included a chairperson, vice-chairperson, secretary, treasurer, and a *chaukidar*. In this process, the IIMI field staff played the following role in assisting the subproject office (later the DIO) and farmers: (i) a catalyst or facilitator during farmer meetings and discussions between farmers and the subproject manager (later the district irrigation engineer), (ii) a rapporteur between the subproject office and farmers, and (iii) an organizer. As a rapporteur, they also interacted constantly with the subproject manager and his field staff.

Further, during this period, twelve farmer representatives and a fieldman were taken to two farmer-managed irrigation systems - the Pithuwa system (Chapter 4) and the Chhattis Mauja system (3,000 hectares) - in the *tarai* for a three-day "farmer to farmer" training.[46] The subproject manager also participated voluntarily. This "learning by seeing" produced an immediate effect upon both the farmer participants and the subproject manager. Impressed by the farmer management of the systems, the farmers and the fieldman became active in the reorganization and strengthening of their respective groups. The subproject manager - a civil engineer - took increasing interest in organizing and motivating farmers and participated actively in almost every meeting with farmers to form WUGs. This resulted in the restoration and reformation of WUGs outside the pilot area also. By the end of this pilot project, 13 WUGs were (re)formed, covering a total area of about 2,000 hectares (IIMI 1992, Vol.II). Of this total seven were outside the pilot area.

Most (10 out of 13) of the new WUGs were village-based. The reason for restructuring the WUGs on the basis of the village boundary against the CADP recommended channel-based was that water users - both landowners and tenants - of the area lived within the same village, and the turnout(s) serving the area was (were) usually located within the village boundary. This made possible easy communication among the members for resource mobilization, decision-making, and control of stray cattle and conflict resolution. Established social relations within the village also facilitated irrigation activities (IIMI 1992, Vol.II: 32). Nevertheless, there were also incidents of conflict among the group members because of the tense social relations.

Despite the short period, this pilot project made a significant contribution in Banganga by making the farmers understand the need and importance of their participation in irrigation system management. It brought considerable changes in the behaviour and attitude of the farmers of the pilot area, and also, to some extent, affected farmers beyond the pilot area. There were three major activities achieved during this project period. For the first time, farmers in Banganga cleaned government-built tertiary canals and farm ditches collectively. In this cleaning activity, labour worth about Rs 96,000 was mobilized by the farmers of the pilot area themselves (IIMI 1992, Vol.II).[47] The cleaning of tertiary canals and FDs by the farmers made the subproject manager obliged to deliver water to these areas. Secondly, each WUG established and executed fines and sanctions for violations of the rules and regulations. For instance, fines were collected from those whose cattle grazed freely along the canal. The subproject manager gave full support to the execution of the sanctions. In this way, social control was tried. Thirdly, the communication and interaction between farmers and the subproject manager was considerably enhanced. For example, a total of 38 WUG representatives participated in the meeting for the preparation of the water delivery schedule at the main and secondary canal level for the 1991-92 winter season. This was a significant improvement over the previous years when the subproject manager prepared the schedule and informed the WUGs. This again can be attributed to the willingness of the subproject manager and commitment of his operation staff to involve farmers and to discuss with them the system management problems. When conflicts occurred within the WUG areas, WUGs turned to the irrigation office or the subproject manager for arbitration.

Despite these achievements, the restoration and restructuring of WUGs came to a halt, and improved water distribution at the tertiary level did not take place after the end of this pilot project in April 1992 as the active subproject manager was transferred two months later. The new chief of the District Irrigation Office had a rather different view towards farmers' participation in the system management. Further, the DOI began the joint management programme in Banganga. As a result, the WUGs formed during this pilot project period could not stabilize or become institutionalized.

Restructuring of water users' groups for joint management
For the third time since 1988, Banganga farmers were reorganized into water users' groups. The reorganization of water users' group this time was a task for the joint management of the system.

In line with the 1992 Irrigation Policy, the DOI began a programme of initiating the joint management to government built and operated irrigation systems over 2,000 hectares in the *tarai* the same year. The main objective of the joint management programme is to gradually build up farmers' capability to manage such irrigation systems through the increased participation of organized water users, and over time, to turn over the system management to farmers (DOI 1993). The Banganga Irrigation System was one of the five systems selected for the programme implementation.[48] The programme is implemented under the direct supervision of the System Management Branch (SMB) of the Irrigation Management and Water Utilization Division (IMWUD) of the department with grant funding from USAID.[49]

The intervention follows the "learning process". The premise is that irrigation systems differ from one another, and that there is no single prescriptive formula for introducing joint management (DOI 1993).

A framework consisting of three phases has been prepared as a general guideline by the DOI (Figure 3.9). As outlined in the framework, the emphasis is laid on the complete organization of the entire irrigation system at the outset, because the usual process of establishing water users' organization in agency-managed irrigation systems at the (tertiary) lower level first and then on to higher levels in the system is considered to be, '... not only a very time-consuming procedure, but also lacks organizational strength because the agency is still in control of the main and secondary canals ...' (DOI 1993:7). The DOI expects that the successful implementation of this process in an irrigation system will result in turnover to the farmers after 2-5 years. This presumption needs careful consideration as Tang and Ostrom (1993:4) have noted, 'Developing irrigation institutions is a long term process that requires the investment of resources and extensive trial and error.'

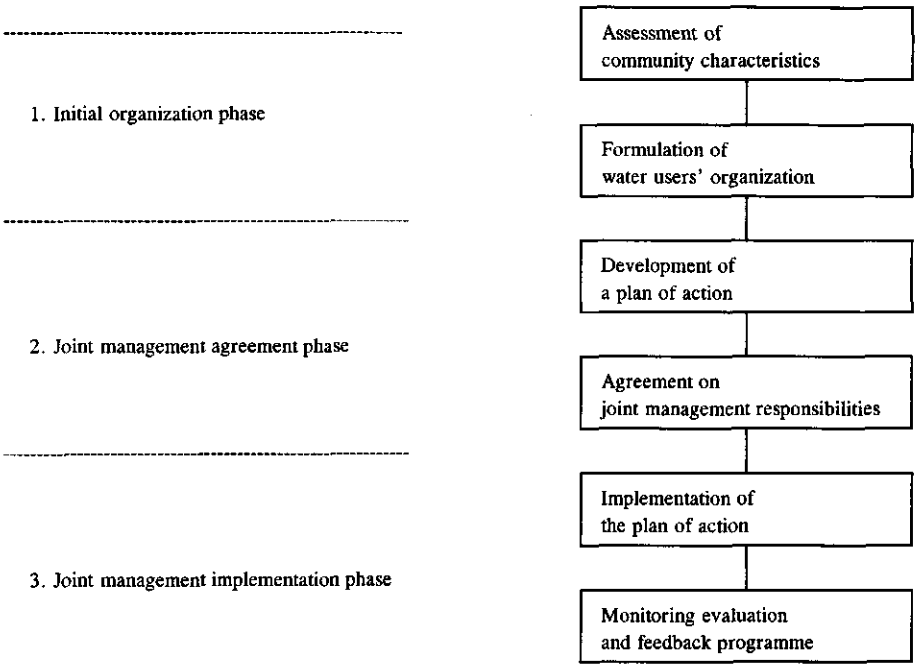


Figure 3.9 Framework for joint management process (Source: DOI, Guidelines for Joint management of irrigation systems, 1993.)

In Banganga, the first phase was accomplished between September 1992 and May 1993. The programme began in late September 1992 with two afternoon pre-sensitization meetings with farmers' representatives within the premises of the District Irrigation Office. In these meetings DOI officials not only informed the farmers the nature, objectives and activities of the programme, but also told them, for transparency sake, of the allotment of about Rs 3.2 million for the repair and maintenance (called essential structural maintenance) of the irrigation system for the 1992-93 fiscal year. The assessment of essential maintenance works was to be done jointly with farmers. As a precondition, water users within the entire command area were required to be organized into water users' groups before the maintenance activity could began. Among other incentives, the availability of the huge budget had immediate effect upon farmers, particularly upon the dominant and influential farmers who became more interested in how to get contracts of the maintenance works than in assisting the office in organizing farmers. These farmers responded immediately by their increased visits to the irrigation office to influence and impress the district irrigation engineer.

The organizing activity was supervised and guided by the engineers and sociologists of System Management Branch (SMB) and Research and Training Branch (RTB) of the Irrigation Department. They tried to follow the learning process.[50] Twelve farmer organizers (FO) - some of them were supervisors and fieldmen under the CADP - were selected from the local community and temporarily employed for three months to disseminate the objectives of joint management and assist in organizing farmers. Each was assigned an area of about 500 hectares in which, apart from motivating and organizing farmers, they collected information, such as number of farmers and their landholding, crops grown, irrigation practices, and other relevant community characteristics. Regardless of this exercise, the district irrigation engineer, supervisors from the SMB, and the influential farmer leaders who saw this programme as an opportunity to maintain their hold and power over their community, dictated the structure of the new water users' organization (here, water users' organization is consistent with the term used by the DOI). The water users' groups established in 1991-92 under the DOI-IIMI pilot project were completely ignored.

The new water users' organization is also a channel-based organization. It is planned to be developed into four tiers as shown in Figure 3.10. In addition, as in some farmer-managed irrigation systems, there is the water users' general assembly for '...the purpose of check and balance ...' (Rajbhandari 1993:43). A the lower levels, are the *upa-toli* and *toli*, the water users' subgroup and group at the tertiary and field ditch levels. The committee at each level invariably has four functionaries: a chairperson, vice-chairperson, secretary and treasurer. The main functions of the general assembly, main committee, block committee, *toli*, and *upa-toli* are given in the Appendix 7.

The 1993 water users' organization began with the three highest levels: (i) block committee, (ii) main committee, and (iii) the general assembly. The irrigation system was divided into six blocks along the canal boundaries (see Table 3.6). The *toli* and *upa-toli* were left to be formed later, as the WUO began to function.

Main committee
Block committee
Toli
Upa-toli

Figure 3.10 Structure of the water users' organization in Banganga (1993)

As shown in Table 3.6, a block committee has 7 to 11 members (including the functionaries), depending upon the size of the block. Blocks up to and less than 500 hectares have 7 members; blocks between 501 and 1,000 hectares have 9 members, and blocks between 1,001 and 1,500 hectares have 11 members. In this way, there are a total of 60 farmer representatives from six blocks. These members are selected or elected by the farmers of the block. The main committee is formed from the farmers representing the blocks. The number of representatives from a block committee to the main committee is based on the member strength of the former: 2 representatives from the block committee with seven members, 3 from the block committee having nine members, and 4 from the block committee having 11 members. Thus there is a total of 21 members in the main committee from the 6 block committees. These members are separately nominated by the water users and do not come from the elected or selected block committee members. In addition to these 21 representatives, the four functionaries of the main committee are elected or selected from among the general assembly members, making a total of 25 members in the committee. The general assembly consists of 122 members, each member representing an average area of 50 hectares. The members for the general assembly are also elected or selected separately. The 21 members of the main committee do not become the members of the general assembly. In this way, there are 199 water users' representatives spread over the three levels of the WUO. The members of the two committees and the general assembly are chosen for the period of two years. This organizational design thus allows a large number of water users' representatives in the organization.

By the end of February 1993, the constitution of the new WUO had been finalized, the registration of the organization processed, and the representative members for the block committee, the main committee, and general assembly had been elected. During the election for the members at all the three levels, political lobbying was seen. In one block, the disagreement between the (political) groups of farmers in the nomination and selection of the candidates was so strong that the election had to be postponed a few times. For the same reason, the four functionaries of the main committee were elected by secret ballot in the DIO premises. Most of the elected members in the committees came either from the dominant group such as large landholders and politically affiliated farmers or the persons backed up by the influential farmers. It is questionable whether such an organization which began with politics would function effectively and sustain for the joint management or turnover of the system. As one farmer honestly said, 'the whole organizing activity was centred around the budget for the year'.

As planned, an assessment of the repair and maintenance required from the headworks to the tail-end of the irrigation system was completed by the DOI engineers and overseers together with farmers' representatives by making a joint "walk-through" along canals in March 1993. Based on this survey, the priority order of essential structural improvement works was set, and the works to be accomplished in the fiscal year were fixed. Both the groups, farmer representatives and the department engineers and overseers, emphasized the repair and restoration of the system capacity. The common agreement was that the main canal should be able to deliver an adequate amount of water to motivate farmers in sharing the management responsibility at secondary canal level and below. But, because of the severe state of disrepair of the main system, only the removal of silt from the diversion and main canals, repair of the regulating gates of the reservoir, and maintenance of the Jagadishpur reservoir dykes could be carried out with the available budget.

Though the capacity of the main and diversion canals was restored to near the design value by cleaning, the damaged and missing gates in the cross-regulators, secondary canal outlets, and direct outlets were left unrepaired. Given the uncontrolled water use by farmers at all levels of the system, the district irrigation engineer believed that the reinstatement of gates is pointless until and unless the irrigation office and/or WUO is capable of managing them. And the new WUO, at this stage, could not guarantee that it would be able to prevent farmers from abusing the gates. Thus, despite the restoration of the canal capacity, the ability of the irrigation system to distribute water evenly along the main canal remains virtually unchanged.

Table 3.6 Division of the Banganga Irrigation System under the new water users' organization in 1993

Block No	Block committee name	Canal boundary	Area (ha)	Total members in the block committee
1	Harnampur-Jahadi	Harnampur minor	143	7
		Jahadi minor	200 (343)	
2	Bilaspur-Laxminagar	MC 1-30	691	11
		Bilaspur distributary	267	
		Laxminagar Branch canal	447 (1,405)	
3	Taulihawa-Birpur	MC 31-39	387	11
		Taulihawa branch canal	662	
		Birpur distributary	251 (1,300)	
4	Hathihawa	Hathihawa branch canal	949	11
		Rangapur minor	200 (1,149)	
5	Pipari-Daldalha	MC 40-48	461	9
		Pipari distributary	317	
		Daldalha distributary	192 (970)	
6	Baidauli	MC 49-62	816	11
		Baidauli distributary	232 (1,048)	
		Total command area	6,215	60

Notes: 1. The two minor canals in Block No. 1 receive water from the diversion canal.
2. Figures in parentheses are the areas in the block.
Source: Field observation 1992-93 and DOI documents.

Although sufficient effort was made by the engineers and sociologists of the District Irrigation Office and the DOI to establish the new WUO and to partially restore the main and diversion canals, there was hardly any discussion between the farmers' representatives and the engineers, nor among the farmers' representatives on actual water allocation and distribution to the six blocks. Given the existing technical features of the irrigation system, water allocation and distribution among the six blocks would be even more complicated, in terms of time allocation, than for the four areas as fixed previously under the CADP.

After the main system has been improved the District Irrigation Office (and the DOI) expect the new WUO to be able to pursue water users to clean the lower level canals, particularly the MFDs and FDs, but farmers are not motivated to do so as they are not sure that the water will be distributed on time and equitably under the current operational practice of the irrigation office.

3.4 Water allocation and distribution

Principles of water allocation and distribution

There is no evidence to show if there were some well defined principles of water allocation and distribution during the period when the (Jagdishpur) irrigation system was under the *Goswara* Office (and later under the *Taulihawa Nahar Sakha*). Oral history suggests that water allocation and distribution during this period was largely left to farmers themselves. The government agency controlled the reservoir sluice only. The main canal ran continuously. Water allocation and distribution among secondary canals and within a secondary canal was decided jointly by farmers. No written rules existed. The (government) officials intervened only when there were water-related conflicts that could not be resolved by farmers. Apparently, this practice of water control was satisfactory to farmers, given the simple features of the irrigation system, irrigation mainly for the paddy crop, and a relatively small area irrigated by the system at that time.

From 1979 onwards, after the construction of the new irrigation system, water allocation and distribution was controlled by the engineers of the Irrigation Department. Available records suggest that during the 1979-82 period the Taulihawa Subdivision Office of the Irrigation Department released water in canals at farmers' request. At the beginning of each cropping season, farmers - either individually or collectively through their village committees - were to submit requests for water to the subdivision office in a format prescribed by the office. They were required to mention the land area to be irrigated, its location and the crop or crops cultivated. The irrigation office then scheduled the time and the duration of water release in the main and secondary canals on the basis of these requests. To the irrigation office, this procedure facilitated the assessment of the areas irrigated with the canal water, and thereby the water charges which farmers promised to pay on their request form. But, it is not clear whether or not farmers received adequate and timely supply of water, since there is no record of the flow delivered and areas actually irrigated. Engineers interviewed indicated that flows in canals were rarely measured. This is partly because a flat (fixed) water levy is charged per unit area irrigated, regardless of the quantity of water applied.[51] In this way, the actual practice of water control differed from the design assumptions. Further, the engineer responsible for operating the system was often not the same person who designed the system. The operating engineer would mostly try to manage the system based on his individual experience, judgement and guidance from his superiors, with the help of the support staff available.

The allocation and distribution of water in accordance with the design considerations was first introduced in 1987 during the implementation of the CADP. Canal operation rules matching the design criteria were prescribed by the consultant design engineers.[52] The design engineers assumed continuous application of water (hence continuous delivery) for paddy during the monsoon season and rotational delivery for the wheat crop during the winter season (NIACONSULT and IECO 1984:ix).

Given the storage capacity of the reservoir and the design capacity of the main canal, the command area was divided into four irrigation areas as shown in Figure 3.6, each irrigation area served by a group of canals.[53] The four areas which vary from 1,300 to 1,750 hectares (21-28 percent of the total command area) were fixed such that the total irrigation requirement in an area would never exceed the design capacity (5.7 m^3/s) of the main canal or water available in the reservoir whichever is lower (NIACONSULT and IECO 1989: Appendix 12, p.3). Under the prevailing cropping pattern, the irrigation requirement is the highest in May, at the early stage of the land preparation (soaking and puddling) for the cultivation of paddy. It is calculated to be about 3 lps per hectare, which is more than three times the design irrigation requirement of 0.93 lps per hectare (at the tertiary outlet) (NIACONSULT and IECO 1989: Appendix 12, p.1). Therefore, the design engineers spread the land preparation period over 8 weeks, since a shorter duration will make water demand exceed the design capacity of the main canal (see Figure 3.2).

In 1987, during the implementation of the CADP, the design engineers introduced a water delivery schedule in which each of the areas was allocated water for a defined period in turn (see Table 3.7).[54] The water delivery schedule was applied at the main canal level only. The water delivery schedule has the following three main features: (i) water allocation to each area is in terms of number of days (ii) a constant flow (presumably at full supply depth) is assumed without taking into account the actual volume of water supplied, and (iii) water is delivered to the tail-end area of the main canal first. Note the numbering of areas in Figure 3.6, beginning from the tail-end area. Further, it is also suggested that the irrigation should began first from the tail-end of the secondary canals served. A similar water delivery schedule was attempted for the winter season also. With some minor variations, the irrigation office has been following such a pattern of schedules ever since (see Tables 3.7 and 3.9).

However, observation of water allocation and distribution during the three consecutive seasons of crop cultivation, from November 1991 to April 1993, showed that the actual water allocation and distribution differed from these schedules. There are several reasons for this difference, and these mainly relate to the design of the irrigation system, the state of the control structures in the main canal (missing gates), and inadequate operating staff. The difficulty faced in managing water distribution along the main canal largely explains why the irrigation office did not attempt scheduled allocation and distribution of water at secondary canal level.

Actual practice
As stated earlier, the District Irrigation Office controls the supply of water in the main canal. A water delivery schedule for each of the two crop seasons is prepared in advance by the district irrigation engineer with or without consultation with farmers' representatives. The pre-determined schedule is then issued to farmers' representatives who are supposed to inform the farmers within their areas. A copy of the schedule is also hung on the notice board of the irrigation office for general information. In addition, the schedule is sent to the village development committees concerned, the District Revenue Office and the district office

of the DOA for information. The fieldmen and supervisor who also carry a copy of the schedule will informally inform farmers while patrolling canals and the command area. The gate operators at the headworks and reservoir sites do not usually get the schedules but are verbally instructed by the supervisor or the irrigation engineer to release, reduce or close water supply in the diversion and the main canals. As mentioned earlier, given the limited number of field operating staff, the irrigation office is confined to controlling water distribution along the main canal.

However, most farmers interviewed indicated that they knew little about the details of the water delivery schedule of the irrigation office, and that they were not informed of the schedule by their representatives. This suggest that farmers' representatives do not carry out their responsibilities and reflects poor communication between the irrigation office and farmers. But the main reason for this poor communication is that water has never been delivered in the canals according to the schedule. Therefore, despite the delivery schedule, farmers tried to irrigate their fields when they saw water in the main or secondary canal. This resulted in uncontrolled use of water both at the main and the secondary canals. As a result, most farmers at the tail-end areas of canals grew their crops under either totally rainfed or partially irrigated conditions. Observation of crop cultivation and irrigation practices in the five tertiary blocks studied confirmed this.

Water allocation and distribution for paddy

Table 3.7 presents the water delivery schedule (English translation) for the 1992 paddy season. Note the number of days - a minimum period of seven days - of water delivery allocated to each of the four areas and the sequence of turn which begins from the tail-end of the main canal. Further the main canal is to run continuously until the end of October.

Observation of water delivery and distribution during this period showed, however, quite a difference from what was scheduled. Table 3.8 presents the actual delivery of water in the main canal. The following observations can be made from this Table. The first is that the water supply in the main canal is not continuous. The district irrigation engineer discontinued the water supply in the canal whenever there was adequate rainfall, and when it was reported to him that the canal water was not being used for irrigation. In the period studied, this was done mainly to increase the storage of water in the reservoir, and was justified. Note the low storage level (106.61 m) in the reservoir at the beginning of the water release compared to the maximum storage level of 109.75 m above msl for the storage of 4.84 MCM of water (See Appendix 8 for the volume of water stored against the water level in the reservoir). Second, since less water was available in the reservoir, the district irrigation engineer tried to supply a small volume of water continuously, which is reflected in the small depth of water at the head of the main canal.[55] Note the average depth of water measured during this period at the head of the main canal was 1.05 m, which is less than the design depth of 1.3 m (see Table 3.3). As a result, the volume of water supplied was far below the design flow of the canal. For instance, the flow measured on July 19, 1992 at km 0+000 of the canal was 0.844 m^3/s at a water depth of 1.15 m and at a water level of 106.73 m in the reservoir.

This small flow rate at a water depth that is near the design depth is partly because of the lowering of the gates at the first cross regulator at km 1+050 downstream and partly because of the growth of the weeds in the canal. Thirdly, of the 140 days (from June 10 to October 28) of continuous supply scheduled, water was supplied in the canal for a total of 101 days, ignoring the supply for 13 days (from October 29 to November 11) that was primarily intended to flush out the uprooted aquatic weeds in the canal. Although the total number of days of water supply might indicate a satisfactory (delivery) performance of the irrigation system, the flow in the main canal shows inadequate supply.[56]

Table 3.7 Water delivery scheduled for the 1992 paddy season in Banganga (June - October)

	Canal	Irrigation block served		Canal Group	Duration	
		Block No.	Area (ha)		Open	Closed
1	Main canal	MC 40-62	1,277			
2	Baidauli Dist.	BD 1-9	232	I	Jun 10-17	Oct 01-08
3	Daldalha Dist.	DD 1-5	192		(8 days)	
	subtotal		(1,701), [27]			
1	Pipari Dist.	PD 1-6	317			
2	Hathihawa Branch and	HB 1-15	949	II	Jun 18-24	Oct 09-14
3	Parsohiya-Rangpur	---	200		(7 days)	
	subtotal		(1,466), [24]			
1	Main canal	MC 31-39	387			
2	Birpur Dist.	BrD 1-5	251	III	Jun 25-Jul 01	Oct 15-21
3	Taulihawa Branch	TB 1-16	662		(7 days)	
	subtotal		(1,300), [21]			
1	Main canal	MC 1-30	691			
2	Laxminagar Branch	LB 1-12	447			
3	Bilaspur Dist.	MC 11-19	267	IV	Jul 02-08	Oct 22-28
4	Jahadi Minor	DC 1-4	143		(7 days)	
5	Harnampur Minor	---	200			
	Subtotal		(1,748), [28]			
	Total area		6,215			

Dist. = Distributary, DC = diversion canal, HB = Hathihawa Branch Canal, LB = Laxminagar Branch Canal, TB = Taulihawa Branch Canal, BD1 = Tertiary Block No. 1 of the Baidauli Dist. Similar notations are used for tertiary blocks under other secondary level canals.

Notes:

1. This schedule was issued by the district irrigation engineer on June 09, 1992 (Nepali date: *Jestha* 27, 2049) with the following note: 'Irrigation shall start from the tail end of the branch/distributary canal as decided during the meeting of the chairmen of WUGs. Any change in this schedule, if required because of some reasons, shall be notified'.

2. Canal groups I-IV represent the irrigation areas 1-4 of Figure 3.6.

3. The figure within the brackets [ ] is the percentage of the total command area.

Source: District Irrigation Office, Kapilvastu (1992).

Table 3.8 Actual water delivery in the main canal during the 1992 paddy season.

	Actual period supplied	Number of days	Water level in the reservoir (m above msl)		Supply in the main canal (at km 0+000)	
			at the start and end of the period	average level	variation in water depth (m)	average water depth (m)
1	Jun 10 - Jul 13	33	106.61 - 106.58	106.59	0.60 - 1.03	0.81
2	Jul 15 - 22	7	106.73 - 106.85	106.79	1.03 - 1.18	1.10
3	Jul 26- Aug 02	7	107.19 - 107.31	107.25	1.17 - 1.28	1.22
4	Aug 04 - 12	8	107.48 - 107.97	107.72	1.14 - 1.33	1.23
5	Aug 24 - 27	3	109.22 - 109.36	109.29	1.00 - 1.00	1.00
6	Aug 30 - Oct 12	43	109.37 - 109.15	109.26	1.00 - 1.51	1.25
7	Oct 29 - Nov 11	13	109.37 - 109.32	109.34	0.65 - 0.90	0.77
	Total	114	Average level	108.03	Average depth	1.05

Notes:

1. There was no flow in the diversion canal from March 30 until the end of May 1992, as the canal was being cleaned during this period.
2. The maximum inflow in the diversion canal between June 10, 1992 and July 05, 1992 was measured to be 0.5 m^3/s. The inflow in the reservoir measured on July 05, 1992 was measured to be 0.473 m^3/s.
3. After the flood of June 23, 1992 in the Banganga river, the headgates of the diversion canal were shut to prevent the inflow of the silt laden flood water in the canal.
4. The monsoon rainfall occurred almost daily from July 09-21, 1992.
5. The maximum monthly rainfall (392 mm) of the year occurred in the Banganga area in August 1992. The highest rainfall of 109.2 mm was recorded at the Banganga meteorological station on August 15.
6. The headgates of the diversion canal was shut once again on October 30, 1992, as the water level in the reservoir reached 109.46 m. The water level in the reservoir for the design storage of 4.57 MCM is 109.65 m (DOI 1984). The full supply level at the main canal head is 106.5 m.

Source: Field observation (1992).

There are two main reasons for the water supply in the main canal being below the design capacity:

(i) The low water storage in the reservoir, which is mainly due to the small inflow of water in the diversion canal. The heavy silt deposits in the diversion canal reduce the inflow of water in the canal and in the reservoir. Further, the inflow of water in the reservoir is not continuous throughout the year. It is sometimes interrupted for a considerable period. Note the closure of the diversion canal in April-May 1992 for cleaning and during the period when there is a flood in the Banganga river.

(ii) The dense weed growth in the main canal that occurs soon after the canal is operated. This significantly reduces the capacity of the main canal.[57]

Measurement of flows at the head of the main canal during the cropping seasons of 1992-93 showed that the amount of water actually released from the reservoir into the canal ranged between 0.5 and 2.23 m^3/s which is about 8.7 to 39.1 percent of the design capacity (5.7 m^3/s). Clearly, this flow is inadequate even to irrigate the head-end areas. The small flow of water in the main canal caused farmers to compete for water during the peak demand period. Farmers responded to this situation by manhandling the gates at cross regulators and outlets.

Observation also showed that most of the time water in the main canal did not advance beyond the weir-check at km 10+840, just below the outlet of the Hathihawa Branch Canal (HBC) which is the only outlet with an operable gate that is still under the control of the irrigation office.[58] There are two main reasons for this. The first is the inadequate flow in the canal, the reasons for which were described above. The second is the design of the physical system. Note that a total of 33 outlets are required to be shut and six gated cross regulators had to be opened over the 12.4 km of the main canal to deliver water to Area 1 which begins from the direct outlet MC 40. Further, Area 1 which comprises 27 percent of the total command area has the longest stretch (about 9 kilometres) of the main canal and has 22 direct outlets serving a total area of 1,277 hectares (see Figure 3.6). Given the state of the structures with the missing or inoperable gates and the limited number of staff, the irrigation office is unable to control water inflow through the direct outlets and the outlets of the secondary canals upstream.

Inadequate flow in the main canal that has a large number of uncontrolled open outlets results in no flow beyond a certain point downstream. Under such a situation, the water delivery to the tail-end area according to the predetermined schedule is difficult in practice. While the few *dhalpas* and operators tried to plug the direct outlets with soil and straw and to open the cross regulator gates that were still operable, farmers at the head-end unplugged the outlets and lowered the gates at the cross regulator or dammed the canal to draw the desired amount of water from the main canal. Not surprisingly, water reached the tail-end of the main canal only twice during the 1992 paddy cultivation period. This was achieved when the irrigation engineer increased the flow in the main canal to its full capacity and maintained a strict patrol by the field staff to prevent water use by farmers at the head-reach areas. However, patrolling of the canal by the irrigation office staff was only effective during the day time. At night, farmers controlled the water in the canal.

Water allocation and distribution for rabi crops

The sowing of oilseeds and wheat follows soon after the harvest of paddy when some moisture still remains in the soil. A water delivery schedule similar to that for the paddy crop season is prepared and issued in advance by the irrigation office for the *rabi* crop season. According to the irrigation office, this scheduled delivery of water is mainly for the irrigation of wheat crop which is usually sown on upland areas soon after the harvest of paddy, although a substantial area of oilseeds is also grown during this period (see Table 3.2). The sowing date for wheat is less critical than for the other crops, and the characteristics of the soil in the area are such that after the paddy cultivation enough moisture remains until the end of December. Together these two factors allow the irrigation requirement for wheat to be on demand.

Table 3.9 presents the water delivery schedule for the 1990-91 *rabi* season. This is the typical delivery schedule established under the CADP for the winter season and has been followed ever since. Note that only about 58 percent of the total command area is intended to be irrigated. This is because of the limited availability of water in the reservoir during the winter season. It is estimated that a maximum of about 65 percent of the total command area can be sufficiently irrigated (See section 3.2). The schedule also assumes gradual decrease in the proportion of the area of irrigation from the head-end downwards, the maximum of 67 percent being in Area 4. This might be justified from the point of view of water delivery.[59] It is also assumed that the main canal will run continuously, but that there will be rotation among the group of secondary canals.

Table 3.9 Water delivery schedule for the 1990-91 *rabi* season (December - March) in Banganga

	Canal	Irrigation block served		Canal Group	Duration	
		Block No.	Area (ha)		Open	Closed
1	Main canal	MC 1-30	490		Dec 01-07, 1990	Mar 02, 91
2	Laxminagar Branch	LB 1-12	310			
3	Bilaspur Dist.	MC 11-19	180	IV		
4	Jahadi Minor	DC 1-4	93			
5	Harnampur Minor	---	100			
	subtotal		(1,173), [67]			
1	Main canal	MC 31-39	271		Dec 08-14, 1990	Mar 09
2	Birpur Dist.	BD 1-5	175	III		
3	Taulihawa Branch	TB 1-16	304			
	subtotal		(750), [58]			
1	Pipari Dist.	PD 1-6	192		Dec 15-21, 1990	Mar 16
2	Hathihawa Branch and	HB 1-15	570	II		
3	Parsohiya-Rangpur	---	62			
	subtotal		(824), [56]			
1	Main canal	MC 40-62	638		Dec 22-28, 1990	Mar 23
2	Baidauli Dist.	BD 1-9	116	I		
3	Daldalha Dist.	DD 1-5	96			
	subtotal		(850), [50]			
	Total area		3,597 [58]			

Note: 1. This schedule was issued by the sub-project manager on November 19, 1990 (Nepali date: *Mansir* 03, 2047) with the following note: 'Irrigation shall start from the tail end of the branch or distributary canals served. Any change in this schedule, if required for some reasons, shall be notified.'

2. The figures within the bracket [ ] indicate the proportion of the area served by each group of canals.

Source: District Irrigation Office, Kapilvastu (1992).

Table 3.10 is the water delivery schedule for the 1991-92 *rabi* crop season. This schedule was prepared by the district irrigation engineer after the meeting with farmers' representatives on November 26, 1991, which 38 representatives attended. Note the change in the duration and sequence of the delivery. But this schedule did not work out, as the irrigation office could not manage to deliver water to the Area II first as scheduled, given the state of the physical system. Therefore, the irrigation engineer then changed the schedules issued on January 26, 1992 and on March 31, 1992 to the same pattern as in Table 3.9, since, in practice, the water distribution along the main canal could not be improved by a change in the schedule pattern.

Table 3.10 Water delivery schedule for the 1991-92 *rabi* season in Banganga

	Canal	Irrigation block served		Canal Group	Duration	
		Block No.	Area (ha)		Open	Closed
1	Hathihawa Branch	HB 1-15	570	II	Dec 01-07, 1991	
2	Parsohiya-Rangpur	---	62	II	Dec 01-07	
3	Laxminagar Branch	LB 1-12	310	IV	Dec 05-07	
4	Pipari Dist.	PD 1-6	192	II	Dec 05-07	
	subtotal		(1,134)			
1	Main canal	MC 53-62	276		Dec 08-11	
2	Main canal	MC 40-52	362	I	Dec 12-14	
3	Daldalha Dist.	DD 1-5	96		Dec 12-14	
4	Baidauli Dist.	BD 1-9	116		Dec 12-14	
	subtotal		(850)			
1	Main canal	MC 1-39	761	I, II	Dec 15-19	
2	Birpur Dist.	BrD 1-5	175	II		
3	Taulihawa Branch	TH 1-16	304	II		
4	Bilaspur Dist.	MC 11-19	180	I		
	subtotal		(1,420)			
1	Jahadi Minor	DC 1-4	93	I	Dec 20-22	
2	Harnampur Minor	---	100	I		
	subtotal		(193)			
	Total area		3,597			

Note: This schedule was issued by the district irrigation engineer on November 30, 1991 (Nepali date: *Mansir* 14, 2048) with the following note: 'It is aimed to start irrigation from the tail end of the branch or distributary canal. A total of three such deliveries will be provided.'

Source: District Irrigation Office, Kapilvastu (1992).

The actual delivery of water during the winter season also differed from that scheduled, as in the paddy season. Table 3.11 shows the actual water delivery in the main canal during the 1991-92 *rabi* season. By comparison, water was supplied in the main canal for a total of only 75 days during the entire *rabi* season from December to March. Note the intermittent water supply in the main canal at an average depth of 0.75 m at the head of the canal. It was observed that most farmers did not have to irrigate their wheat crop at the early stage of growth because of the residual moisture in the soil after the harvest of paddy and occasional rainfall in January and February. In March and April, the wheat crop needs to be irrigated. Note the 40 days of water supply in the main canal during this period. However, the water allocation and distribution to the four areas according to the schedule was not achieved because the irrigation office could not control the inflow of water through the outlets at the head reach of the main canal. Observation showed most outlets at the head reach of the main canal were always kept open to draw scarce water as much as possible.

Table 3.11 Actual water delivery during the 1991-92 *rabi* season (December 1991 to April 1992)

	Actual period supplied	Number of days	Water level in the reservoir (m above msl)		Supply in the main canal (at km 0+000)	
			at the start and end of the period	average level	variation in water depth (m)	average water depth (m)
1	Nov 30 - Dec 25	25	107.51 - 106.97	107.24	0.73	0.73
2	Jan 29 - Feb 08	10	107.92 - 107.18	107.55	0.70 - 1.0	0.85
3	Mar 03 - 10	7	107.61 - 107.20	107.40	0.81 - 0.88	0.84
4	Mar 16 - 22	6	107.25 - 107.20	107.22	0.68 - 0.81	0.74
5	Mar 30 - Apr 26	27	107.22 - 106.48	106.85	0.64 - 0.54	0.60
	Total	75	Average level	107.34	Average depth	0.75

Notes: 1. The inflow in the reservoir measured during the period from December 1991 to March 1992 varied from 0.15 to 0.58 m^3/s. The diversion canal was heavily silted.

2. The flow measured on the main canal head at km 0+000 during this period varied from 0.4 m^3/s to 2.23 m^3/s. The maximum flow was released for only a day, on February 2, 1992.

3. The supply in the main canal was resumed in the month of May for a total of 9 days: May 10-14 and May 21-26 for the irrigation of maize which is grown in a limited area at the head-reach of the main canal. The water supply at the main canal head then was limited to a depth of 0.63 m at the average water level of 106.2 m above msl in the reservoir.

The allocation and distribution of water by the irrigation office for the 1992-93 *rabi* season was similar as described above. There was no change in the allocation plan. The actual distribution practice remained the same because there was no improvement in the physical state of the irrigation system and the number of operating staff.

Clearly, the irrigation office could not manage equitable distribution of water at the main canal level. This had strong impact on the water allocation and distribution at secondary and tertiary canal level.

Water allocation and distribution below the main canal

Although it was initially envisaged that the irrigation office would manage the system down to the tertiary outlet, water allocation and distribution below the main canal level was totally left to farmers, mainly because of the difficulty in managing the main system with a limited number of operating staff. Since the water delivery to a secondary canal was unreliable and inadequate, it was not possible for the farmers to allocate and distribute water evenly within the secondary canal, i.e. among the tertiary outlets served by the canal. Not surprisingly, there was no organized distribution of water within secondary canals. Observation of water supply and distribution in the Laxminagar Branch Canal (LBC), the first large secondary canal which takes off at km 6+100 from the head of the main canal (see Figures 3.5 and 3.6) verified this.

The LBC lies in the head-end area (Area 4 in Figure 3.6) and was therefore selected assuming that water supply in the canal was fairly reliable. It has a maximum discharge capacity of 0.312 m^3/sec and serves a total land area of 447 hectares (see Table 3.3). Figure 3.11 presents the plan of the LBC, including the tertiary blocks, ponds and villages.

As shown in Figure 3.11, the cultivable command area of the LBC is divided into twelve tertiary blocks, Blocks LB 1 to 12. Each tertiary block was provided with a single gated outlet except Blocks No. LB 11 and 12 which share a common outlet. In this way, there are eleven tertiary outlets over the total canal length of 3.35 kilometres (about 3 outlets per km). Figure 3.12 shows the longitudinal profile of the LBC with the location of the tertiary outlets and check structures. Note that pipe outlets are not at the same level above the bed of the canal. Whereas this difference in the level might be because of poor control during construction, it has significant implications for even water distribution, especially when all the outlets are fully open. Table 3.12 presents the size, area covered, and the physical state of the tertiary outlets. Note the use of standard diameter pipes irrespective of the area served. This requires gates to be adjusted so that the flow through the pipe is proportional to the area served.

The flow in the LBC is served by a "Sarda-type" check structure built during the 1972-79 period, at 20 metres below the outlet of the canal. The outlet of the LBC comprises a rectangular orifice 0.5 m wide and 0.75 m high. It is without a regulating gate.[60] The LBC canal bed is almost at the bed level of the main canal. This allows even a small flow in the main canal to be easily diverted to the LBC by closing the drain holes of the check structure.

There are four reinforced concrete check structures in the canal. These check structures have a single ungated opening of less than 0.9 m wide and are provided with the grooves for stop-logs (see Photo 3.2). According to the irrigation office, precast concrete slabs were provided during the CADP to be used as stop-logs. But no such concrete checks were seen during the fieldwork. In place of the concrete checks, farmers used soil from the canal bank to check water. Despite these permanent check structures, farmers built temporary bunds across the canal when the flow was low. Since these temporary checks are built from the soil in the canal banks they have caused damage to the canal. Yet the irrigation office cannot stop farmers from doing this because of its inability to deliver adequate water.

Observation of flow at the head of the LBC during the 1991-92 irrigation period showed that the flow was below 50 percent of the design capacity of the canal for most of the time. Only on one occasion was a maximum flow of 0.24 m^3/s measured. With such an inadequate flow in the canal, water rarely reached the tail-end outlet of Blocks LB 11 and 12, because farmers at the head end tried to use the water first.[61]

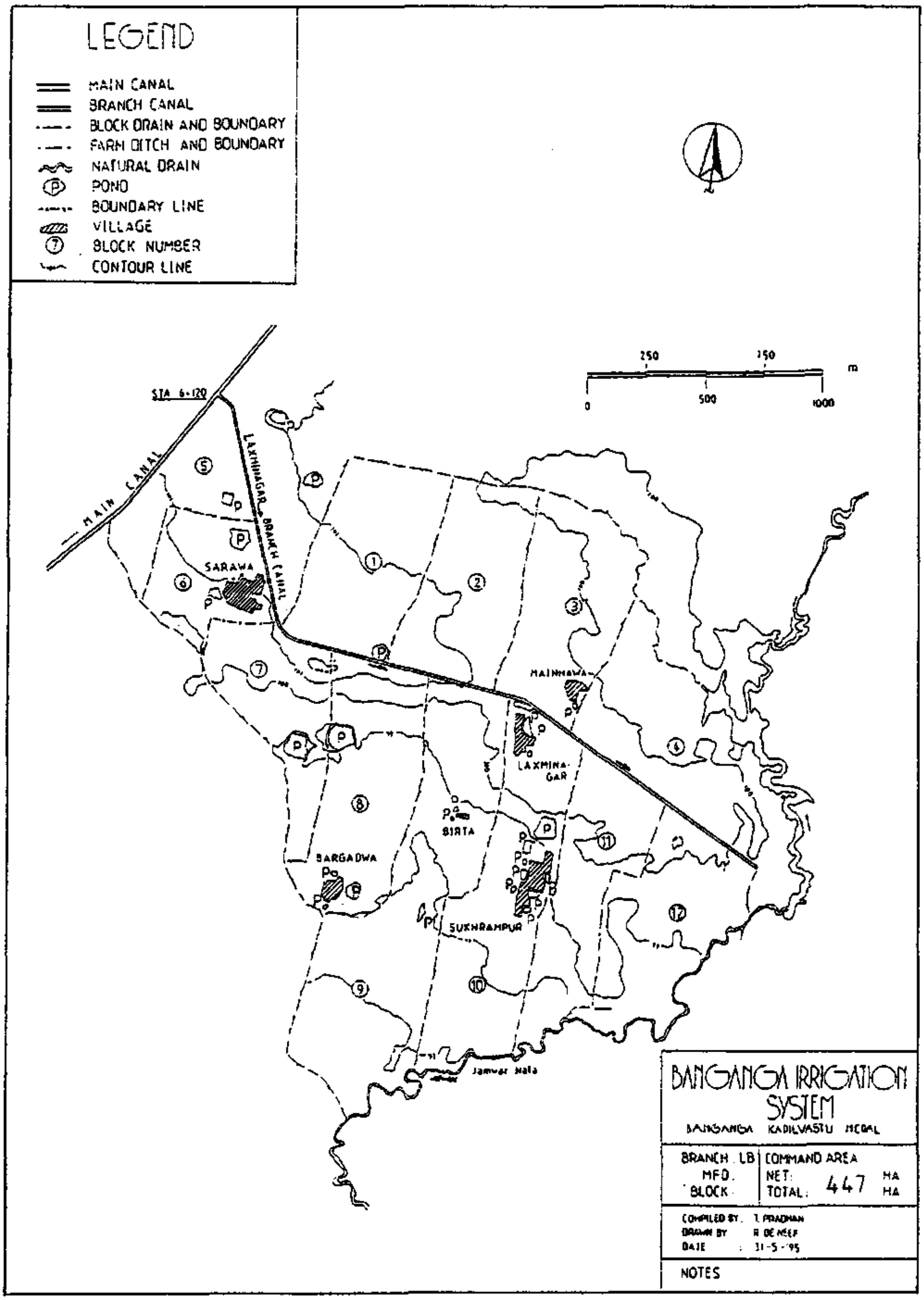


Figure 3.11 Plan of Laxminagar Branch Canal showing the tertiary blocks served, ponds and villages (Source: DOI/CAD Project drawings, 1989.)

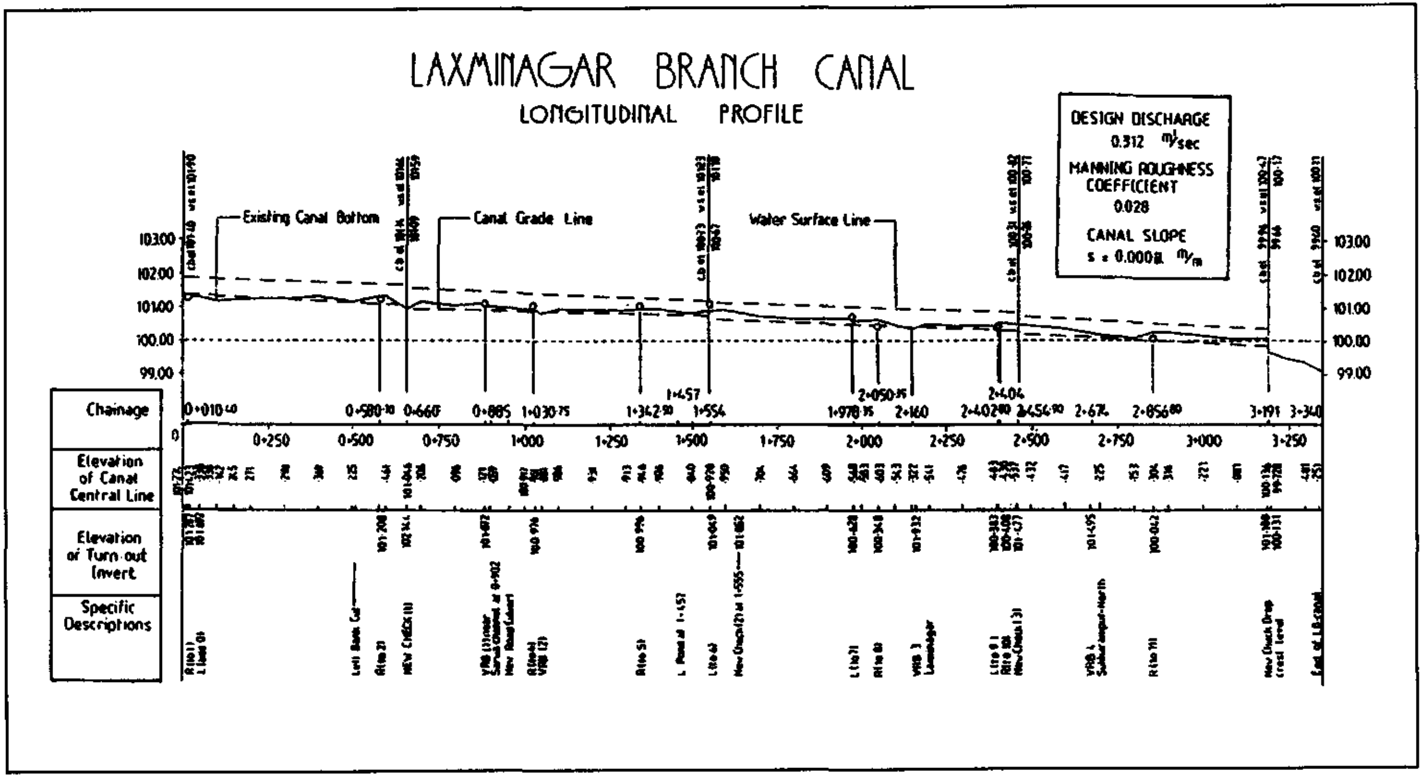


Figure 3.12 Longitudinal profile of LBC (Source: Field measurement 1992)

Table 3.12 Tertiary outlets in the LBC: pipe size, area served, and the physical state of gates (1991-93)

Outlet No.	Pipe diameter (cm)	Tertiary block served		State of the outlet gate		Remark
		Block No.	Area (ha)	Physical	Operational	
1	30	LB 5	14.21	complete set	operable	
2	30	LB 6	36.95	complete set	not operable	jammed
3	30	LB 1	20.23	complete set	operable	
4	40	LB 7	38.76	complete set	operable	
5	30	LB 8	73.54	complete set	operable	
6	40	LB 2	23.53	no gate	n.a	stolen on 01.12.91
7	40	LB 3	36.65	only frame	n.a	
8	40	LB 9	44.83	complete set	operable	
9	40	LB 4	44.21	complete set	operable	
10	40	LB 10	42.37	no gate	n.a	
11	60	LB 11	34.00	no gate	n.a	
		LB 12	38.41			

LB 1 = tertiary block No. 1 in the LBC; Complete set = with the frame, steel plate, and spindle intact; Only frame = without the steel plate and spindle; No gate = gate not installed, removed or stolen; n.a = not applicable.

Note: Outlets are numbered successively from the head of the LBC downward. The areas of the tertiary blocks are from the DIO/CADP documents.

Sources: Compiled from field observations (1991-93).

As shown in Table 3.12, of the eleven gates 6 are in operable condition. But most of the outlets were either fully or partly open, especially the outlets of the tertiary blocks at the head end of the canal. Therefore, farmers of the tail-end tertiary blocks plugged the outlets upstream with soil and straw to allow water down the canal to their area. Sometimes they stayed on guard at these outlets. In this way, outlets upstream need to be watched to ensure the inflow of water into tertiary canals downstream, whether or not there are gates.

Given such a situation of water control along the secondary canal, it was not surprising to find *ad hoc* water allocation and distribution within tertiary blocks. Farmers irrigated their fields when water was available in the canal. Water allocation and distribution was mostly on mutual understanding. In many tertiary blocks within the command area, water use according to "might is right" prevailed, especially during the early stage of the transplanting of paddy. In the two tertiary blocks (MC 43 and 46) studied at the tail end, farmers cultivated their crops largely under rainfed conditions as they could not rely on the canal water. Observation of flow through the flume at the head of the tertiary canals of the two blocks showed water in the canals only six times during the entire 1992 paddy season. The flows never exceeded 30 lps. Farmers of these tertiary units either used water from their village pond or from the natural drainage channel. It was observed that farmers diverted the canal water, when it was available, to the pond for storage.

3.5 Summary and conclusions

This case study has shown how an irrigation system with a fully gated water control technology failed to function under the management of the government agency, the District Irrigation Office. It has also illustrated that in a water scarcity situation it is difficult to allocate and distribute water evenly through this technology. Farmers of Banganga had been used to continuous water supply from the government irrigation system. Then the government built a modern irrigation system, and remodelled it soon after it was built, to achieve the irrigation potential created. The storage capacity of the reservoir was increased. Physical facilities were intensified at tertiary or farm level. Tertiary blocks not exceeding 50 hectares in size were introduced and canals serving an average area of 7.5 hectares were built. Given the limited availability of water supply from the source river, the design engineers provided check structures and outlets with adjustable gates down to the tertiary outlet, for greater flexibility in operation and efficient water use. This system design resulted in an increased number of control points in the irrigation system and increased the operation and maintenance burden of the irrigation office. It was envisaged that the Irrigation Department would manage the irrigation system above and including the tertiary outlet and that farmers would control the operation and maintenance of the system below the tertiary outlet. Attempts were made to organize farmers at tertiary and secondary levels to involve them in the effective operation and maintenance of the remodelled irrigation system. However, farmers did not manage the tertiary system because the irrigation office was not able to effectively operate and maintain such a system even at the main canal level because of limited operating staff and budget. Water delivery by the irrigation office became inadequate and unreliable. In response to this, the gates at the check structures and outlets were vandalized, which is an indication of the *de facto* control exercised by farmers in response to the inadequate and unreliable delivery of water. The irrigation system that was aimed to achieve flexibility and water use efficiency virtually reverted to the technically rigid state within a short period.

The water control technology of manually operated gated structures down to the tertiary outlet, as in this irrigation system, is complicated and creates hydraulic instability in the system. It needs a high management input from the operating agency for effective water control. Therefore, as appeared in this case, this technology does not help improve system performance under the management of an irrigation agency with limited manpower and budget resources.

The benefit of farmer participation in the operation and maintenance of government built and managed irrigation systems has been emphasized, especially at the tertiary level. This case study has shown that organizing sustainable water users' organization at the tertiary level is pointless if the deliver of water from the main system is inadequate and unreliable. As one farmer said: 'Let there be adequate water in the canal in time, then we will organize into water users' groups ourselves.'

Farmers are organized into water users' groups or organization by using social or association organizers. However, evidence from this case study suggests that the engineer incharge of operating the system can play an influential role in organizing farmers into water users' groups.

The water users' organization has been formed by the irrigation office for the joint management of the irrigation system. It has four levels that are parallel to the hydraulic levels of the physical system. Given the design of the physical system, limited availability of water, and the state of the control structures, the organization at the highest level needs to be efficient in coordinating the lower levels of organization. Empirical evidence from this case study suggests that in a government-managed large irrigation system a water control technology with a vast number of manually-controlled structures decreases the willingness of farmers to participate in the operation and maintenance of the system, because the number of points where the decisions have to be executed is increased.

Finally, this case study has shown how operational realities may differ from the design engineers' assumption. In this case, the fully gated water control technology did not improve water allocation and distribution.

Notes

1. Originally, the western *tarai* constituted the districts of Sheoraj-Khajahani, Palhi-Majhkhand, Banke-Bardiya, and Kailali-Kanchanpur. These districts were restored to Nepal as a compensation for the assistance Nepal extended to British in the Indian revolt of 1857 (Regmi 1978:6). Among these districts, Sheoraj-Khajahani and Palhi-Majhkhand were later renamed Kapilvastu and Rupandehi respectively.

   The Kapilvastu district has a total area of 1,738 square kilometres. According to the 1991 census, its population was estimated to be 371,778 from 60,948 households (CBS 1994:5).

2. The Provisional Impact Evaluation Study of the Banganga Irrigation Sub-project reported a total population of 42,998 and 6,662 households within the command area (GEOCE 1990).

3. In 1984, under the Command Area Development Project, a small meteorological station was established within the premises of the sub-project office (now the District Irrigation Office). Temperatures and rainfall have been recorded daily ever since.

4. Some data showed the lowest dry season flow of the Banganga river at the diversion headwork to be 0.6 m^3/s and the average flow during the monsoon season to be 11.3 m^3/s (Poudel, S.N. 1986:75; ADB 1981:7). According to the letter from the Executive Engineer of the Banganga Irrigation Project to the Chief Engineer, the discharge of the river at the diversion point in August 1972, when the monsoon rain failed to occur in time, was 6.4-6.8 m^3/s (225-240 cusec). The *Kaila* river, the main tributary of the Banganga river, contributes the maximum proportion of the flow during the dry season.

5. According to the property inheritance law of Nepal, each son receives an equal share of the parents' property. This practice has also led to the increase in land fragmentation.

6. The varieties of paddy grown in the area in 1992 included *IR-84*, *Sarju-49*, *IR-8*, *B-44*, *Sabitri*, *Mansuli*, *Malisiya*, *Kalanimak*, and *Basmati*. They are all high-yielding varieties except the last two. The wheat varieties were mostly *Lumbini (UP)-262*, *Lumbini-308*, and *RR-21*.

7. There is a general trend among the young men in villages within the command area to migrate to the cities in India for seasonal employment. However, this has an insignificant effect on the availability of labour, since their migration is mostly temporary.

8. The village ponds are multi-functional. Some are privately owned. Apart from their use for irrigation, they provide water to fight fires and for cattle. Although such ponds are still in use for these purposes, the old *paenes* have been abandoned since the construction of the present Banganga Irrigation System.

9. The actual area irrigated by this irrigation system is not consistent because of the lack of records. Some estimates show the command area of this irrigation system to be about 1,000 hectares (Poudel 1986:20).

10. At that time, there were only three government-built and managed irrigation systems: Chandra *Nahar*, Juddha *Nahar*, and Jagadishpur. It was noted in the First Plan that all the three systems were in need of repair or rehabilitation (NPC 1957).

11. Although the initial cost estimate of the project was about Rs 13 million (at 1965 prices), a total of about Rs 23 million had been spent by the end of the project construction in 1979 (DOI 1979).

12. The discharge of a river during the *hathiya* period, which is at the end of the monsoon, is also called "hathiya discharge". The available flow of the source river during this period determines the land area that can be irrigated (Framji and Mahajan, 1969:729). In the 1972 design, the average "hathiya discharge" of the Banganga river at the diversion point was estimated to be 4.2 m^3/s (150 cusec) (DOI 1972).

13. The design irrigation water requirement normally prescribed for paddy crop in the *tarai* region ranges from 0.7-1 lps per hectare (equivalent to a water duty of 100-70 acres per cusec) and that for wheat from 0.35-0.5 lps per hectare. Some DOI design engineers, however, recommend a design water requirement of 0.9-1.2 lps per hectare for paddy and 0.5 lps per hectare for wheat (Agrawal, N.K. 1993: personal communication).

14. See Kraatz and Mahajan (FAO 26/2, 1975: 55) for the details of the 'Sarda-type' fall structure. This weir-type free-flowing check structure, which was developed on the Sarda Canal Project in the Uttar Pradesh State in India to replace the notch fall, is simple and economical. It is usually made of brick masonry and combined with a village road bridge that spans the structure.

15. In general, an outlet is defined as a device at the head of a tertiary canal or watercourse which connects it with a distributing or branch canal. In American terminology, it is called a "turnout". The term watercourse is commonly used in the irrigation terminology in the Indian subcontinent. It is defined as the channel which carries water from an outlet of a distributary to the holding (cultivated fields) of a farmer (Malhotra 1982: 8). It is normally an unlined channel constructed and maintained by the farmers who use it. Its capacity is generally between 30-90 lps. It is thus equivalent to a tertiary canal or a main farm ditch in American terminology.

16. According to Mahbub and Gulhati (1951), the oldest form of a pipe outlet used in canal irrigation systems in Punjab, India comprised an earthenware pipe called *colaba*. The *colaba* was placed in the bank of a distributary or a minor canal. Its standard size was 15 cm (6 inches) diameter, e.g in Sirhind Canal opened in 1872. A standard *colaba* was allowed for an irrigated area of 40 hectares (100 acres) which received annual irrigation from a main distributary, and for an area of 20 hectares (50 acres) receiving water from a minor canal, at that time as the minor canals would run only half the time whereas the distributary would be in constant flow. The size of the pipe was directly related to the area to which water was allowed. The unit of supply was the *colaba* and the efficiency of irrigation was calculated at so many hectares (acres) per *colaba*. The working head of the outlet was not taken into

account and the discharge was an unknown and neglected quantity. Although most outlets were single *colabas*, some outlets had two or three *colabas*. The pipes along the length of a distributary canal were placed at various depths from its bed level depending upon the water depth in the canal. The invert level a pipe outlet was fixed according to the reach of the supply canal in which it lay, the level gradually decreasing from 12 inch at the top reach of the canal to the bed level at the tail reach. Later Kennedy (1893) suggested that all outlets should be place at the bed level of a distributary so as to draw a maximum amount of the silt deposits. Over time concrete pipes replaced steel and cast iron pipes (ibid 1951: 17-23, 49).

17. If the water in the supply canal contains large amounts of silt, the (removal) conduction of the silt load by an outlet can be an important requirement to be considered too.

18. Hydraulically, an outlet is said to be proportional when the rate of change of discharge through the outlet is the same as the rate of change of discharge in the supply canal. That is proportionality occurs when the flexibility is equal to unity. Flexibility is expressed as the ratio of the rate of change of discharge in the off-take canal to the rate of change of discharge in the continuing supply canal (Bos et al. 1978: 94-96).

19. Two other irrigation systems - the West Gandak Irrigation System in the western *tarai* and Manusmara Irrigation system in the central *tarai* - were rehabilitated under the CADP. The International Fund for Agricultural Development (IFAD), and the United Nation Development Program (UNDP) were the co-financing agencies, with the ADB acting as the executing agency. The UNDP provided funds for the technical assistance in the form of grant.

20. The project was scheduled to be implemented over a period of six years, beginning early 1982 (ADB 1990). It was envisaged that the benefits of the project would begin to accrue in the early 1984. However, according to the Final Report by NIACONSULT and IECO (1989), the construction of the civil works actually began in February 1984 due to the delay in the completion of the survey and mapping activities and pre-qualification for tenders. The operation and maintenance phase of the Project started on July 16, 1989.

21. A total of 32 office cum living quarters for water management extension fieldmen and two godowns of 250 MT capacity each for the storage of fertilizers and farm inputs, and canal roads were also constructed to provide farmers with easy access to agricultural inputs and services.

22. The feasibility study of the project was also carried out by a foreign consultant, Ted C. Patterson Inc. Consulting Engineers of New Mexico, USA.

23. See the Project Design Report by NIACONSULT (1984) for the details of criteria and assumptions used in the redesign of the irrigation system, typical hydraulic design of a tertiary canal and the layout of a tertiary block.

24. See the Final Report (NIACONSULT and IECO 1989) and the Project Completion Report (ADB 1990) for the details of the elements of the physical infrastructure improved in Banganga.

25. In November 1992, preparation was being made by the researcher to install a steel cut-throat flume (c-flume) at the head of the tertiary canal of Block LB 2 of the Laxminagar Branch Canal to measure the inflow in the (tertiary) canal. The tertiary outlet had an operable gate which was still in its place until November 30, 1991, the day the c-flume was placed on the canal. The complete gate set was missing the next morning. The flume was, however, left untouched. It probably was too heavy to be taken away together with the gate.

    This tertiary block is situated between the two villages and is within half a kilometre distance from both the villages. Upon inquiry, the villagers of both the villages said they did not know about the theft of the gate.

The stealing of gates and their parts continued. In early 1993, the steel plate of the headgate of the Birpur Distributary was missing. The District Irrigation Office did not know until the researcher informed the supervisor about it. Knowing that its recovery would be very difficult, the irrigation office did not even attempt to inquire about it this time.

26. For instance, a discharge of 2.6 m^3/s was measured for 1.05 m water depth at a point on the main canal 6.4 km downstream for the headgate on June 2, 1991. The same volume of flow was measured at that point for 1.3 m depth on July 21, 1991. The reinfestation of aquatic weeds was almost complete by then.

27. This is the only run-of-the-river irrigation system in the country with an off-channel reservoir.

28. The reservoir presents some additional functions. As a fishing pond, it brings some revenue. Available records showed that the irrigation office made an annual revenue of about Rs 20,000 from selling the fishes in the reservoir. However, there is no direct benefit for the irrigation from it, as this sum has to be deposited in the government treasury. Further, the reservoir is used by (Siberian) ducks which migrate in large numbers during the winter period from December to February.

29. There are no data on the annual rate of sediment deposits in the reservoir. Since its expansion under the CADP, the storage capacity of the reservoir has not been checked.

30. According to the DOI field supervisory staff who once worked with the Public Works Section of the *Goswara* Office, there were only 6 persons (2-*Subedars*, 1-*Bahidar*, and 3-peons) to manage the irrigation system. A retired Indian overseer was employed for some years to supervise the management of the irrigation system.

31. During this period, the government constructed a few small irrigation systems in the district under the Minor Irrigation Program, most of which are still being used. Available records show that all minor irrigation systems together cover a total cultivable command area of about 3,845 hectares (9,611 acres).

32. See the letter No. 89/029-30 of March 5, 1973 (Nepali date: *Falgun* 21, 2029) of the Irrigation Department to the Banganga Irrigation Project.

33. By this time, the regional directorates of the DOI had been established in all the development regions. The Western Regional Irrigation Directorate (WRID) is at Pokhara - the headquarters of the Kaski district - where the regional level offices of various ministries and departments are situated.

34. A central level Project Office was established in Kathmandu, with a sub-project office in each sub-project area. The project manager at the head of the project office was equivalent to the level of superintending engineer who reported directly to the Director General of the DOI. Each subproject had a subproject manager of executive engineer status. These subproject managers were responsible for day to day project activities, reporting to the project manager. The project manager and subproject managers - and most assistant (civil) engineers and overseers - were permanent employees of the DOI. Clearly, these organizational arrangement were created in order to accomplish the project in a prescribed time. The organizational structure for the execution of the CADP at the project and sub-project level is presented in Appendix 6.

The implementation of the CADP followed the integrated approach involving more than one governmental and semi-governmental agency. The DOI was the chief executive agency with the Department of Agriculture (DOA) and Agricultural Input Corporation (AIC) supporting in agriculture related services. The other agencies involved were the ADBN and the DOC. A Central Coordination Committee (CCC) -also based at Kathmandu - under the chairmanship of the Secretary of the Ministry of Water Resources was necessarily formed for the overall coordination, direction and supervision of the project related-activities. The Director General or equivalent officer of DOI, DOA, ADBN, AIC, DOC and other related agencies were the members of the Committee. The project manager was the ex-officio member-secretary. Similarly, a Sub-Project Coordination Committee (SPCC) was established at each subproject area for the coordination of the project-related activities at the subproject level. The members of the SPCC included the chief of the District Agricultural Development Office, the branch/district managers of the AIC, ADBN, and Nepal Food Corporation (NFC), and the District Cooperative Officer. The Chief District Officer (CDO) of the district, where the subproject Office was located, was the chairman of the SPCC.

The Chief District Officer was not included in the initial (at appraisal) list of the SPCC members. But, given his authority to maintain law and order in the district, in practice it was advantageous for the subproject managers to have the CDO as the chairman of the SPCC for the smooth running of the (sub)project. For instance, during the project execution, the subproject manager of the Banganga Sub-Project had to seek CDO's help when villagers did not allow right of way on land for the construction of farm ditches and canals as per the plan. Villagers did not allow the occupation of their land, as they had not received compensation. The District Land Revenue Officer likewise, though not included in the initial list, was made a member of the SPCC.

Whereas the Central Coordination Committee was dissolved after the termination of the Project Office, the SPCC in each subproject area remains - in compliance with the ADB's recommendation - until the full agricultural development which is expected to be achieved by 1995 (ADB 1990:15). The CCC was not found effective compared with the SPCCs (ADB 1990: 10). According to the farmers and the subproject management, the SPCC in Banganga was rather effective compared with other SPCCs, but its contribution to water management activities in the project was minimal.

35. Despite the establishment of the regional directorates in the five development regions, Irrigation Development Boards which operate directly under the DOI are in existence for the development and management of large scale irrigation systems, e,g. Narayani, Mahakali, Sunsari-Morang, Kankai and Chitawan Irrigation Development Boards. Such inconsistent policy of the government has made the relation between the regional directorate and large irrigation systems unclear.

36. The budget has two main components: (i) administrative, and (ii) programme. The administrative component consists of the salaries of the permanent and temporary staff, travel and daily allowances, other allowances, cost of services (electricity, telephone, postal, water) etc. The programme component consists of reconstruction, repair and maintenance of physical facilities. The administrative component of the budget is usually prepared by the accountant (who is essentially a permanent employee of the Ministry of Finance) in consultation with the subproject manager, whereas the programme budget is prepared by the system manager under the general guidelines given by the Regional Directorate (RD). The budget estimate is prepared annually during February-March and submitted by the subproject (system) manager to the RD for approval. After the approval of the total budget for the Irrigation Department, a lump sump is allocated to the Regional Directorate which in turn appropriates to its various units and projects. Although the request for salaries of the permanent government staff are necessarily approved 100 percent, the expenses for other administrative support services are usually curtailed depending upon the amount allotted in the annual budget for this purpose.

37. The District Irrigation Office (DIO) in the Kapilvastu district was established in 1989. The CADP apparently did not foresee the eventual transfer of the Banganga System to the DIO.

The DIOs were established in accordance with the government's plan to implement a decentralization policy towards country's development. The organization and staffing of a DIO was based upon the amount of the irrigation-related works under development or to be developed and managed in the district. Three categories of DIO were created: (i) DIOs with the senior divisional engineer of under-secretary level as the head of the office, (ii) DIOs with the divisional engineer of assistant secretary level, and (iii) DIOs with assistant engineer level. The post of the assistant secretary level, which was created in 1984, was removed in 1993, and all the personnel of that level were automatically elevated to the under-secretary level.

In the organizational hierarchy of the Department of Irrigation, the DIO is placed under the administrative supervision of the Regional Directorate (RD), each of which has an average of 10-15 DIOs. Both the DIO and the subproject office at Taulihawa, were under the same regional Directorate. Yet there was virtually no interaction between the two offices due to the absence of the (horizontal) organizational linkage. The RD dealt with each of them separately.

38. Meanwhile, the International Irrigation Management Institute (IIMI) had began to assist the DOI to restore water users' groups in Banganga. The IIMI office persuaded the irrigation department to retain him, as he was well informed about the system design and the command areas and had begun to take keen interest in organizing farmers into water users' groups. It was advantageous for the IIMI to retain him.

39. This was the first time that the concept of fieldman was introduced in irrigation projects in the country. Each fieldman was assigned 2-3 tertiary canals and 24-30 farm ditches (NIACONSULT and IECO 1987, Vol.II). In the organizational hierarchy, the fieldmen was placed under the JTA. The basic duties and responsibilities of a fieldman were: (i) to assist farmers in the formation and development of the WUGs, (ii) conduct and attend farmers' meetings, (iii) inform the WUGs as regards the water delivery schedule of the project, (iv) inspect, record and report regularly the status of cropped fields and irrigation status to the JT or assistant engineer, and (v) maintain constant dialogue with the farmers to know their irrigation related problems, and report the problems to the superiors (NIACONSULT and IECO 1988). Thus, a fieldmen was the intermediary between the operating agency and farmers. For effective close contact and co-ordination with farmers of the area assigned to him, he was required to stay in the office-cum-living quarters built by the project. Fieldmen were also required to know the technical details such as the areas of the tertiary blocks, area served by each farm ditch, list of farmers of the area assigned to him. They were to be trained in organizing and water management activities by the water management specialist or agriculturist of the project.

40. The term 'water users' groups' (WUG) has been used to refer to the lowest level group of water users, which is not yet registered and has not received legal status in accordance with the 1989 Irrigation Regulations.

41. According to the project planning, the DOA was to provide fieldmen, junior technical assistants (JTA), junior technicians (JT) and a water utilization officer to the subproject office and help farmers form their WUGs. It was also to be responsible for the operation and maintenance of the completed tertiary level physical facilities and for providing technical guidance to farmers and WUGs for about two years. One fieldman would cover an area of about 200 hectares and 100-200 farmers. After the continuous guidance from the fieldmen, the WUGs were expected to be eventually responsible for the sustained operation and maintenance of the tertiary level canals and drains.

The division of the operation and maintenance responsibility of the irrigation system between the two departments was eliminated after the FIWUD was merged into the DOI in 1989. Nevertheless, the DOI still faces the shortage of such extension staff, since they primarily belong to the DOA. At the time of its transfer to the DOI, the FIWUD had limited field extension staff.

42. The main objective of the Participatory Management Program was to share the operation and maintenance responsibility of large scale irrigation systems (greater than 2,000 hectares in the *tarai* and 500 hectares in the Hills) between the water users' organizations and the irrigation agency (DOI 1989).

43. See the final report of IIMI (IIMI 1992, Vol.II) for the details of the approach and process followed in reorganizing water users' groups for improving irrigation management in Banganga.

44. IIMI began its study of the Banganga Irrigation System in the early 1990. This was done to assess the existing water management situation and to understand the evolution of the canal system so as to plan the future activity there. In the middle of 1990, a total of about 500 hectares area was selected for

detail observation and intervention. An area of about 250 hectares in the head reach of the main canal, along the Bilaspur Distributary and the remaining area of 250 hectares in the main canal outlets of MC 40-43 near the tail end of the main canal were selected. This area was further expanded to include an additional 500 hectares distributed in a similar manner at the head and tail end of the main canal following the availability of fund from the USAID and the formal agreement with the DOI in May 1991 to undertake the task. In these selected areas, the IIMI field-based staff studied the farming practices (land preparation, transplanting of paddy, crops, cropping pattern, and crop yields etc) and irrigation practices.

45. Of the two field-based staff of IIMI, one had a Bachelor's degree in agricultural science and was experienced in the research and organization in farmer-managed irrigation systems. The other, who assisted him, was an experienced member of the irrigation organization in the Argeli-Chherlung farmer-managed irrigation systems.

46. Later, two WUG chairmen presented papers in the National Level Workshop on Participatory Management on Agency-managed Irrigation Systems held in April 1992 at Kathmandu. In this way farmers were given an opportunity to express their views on farmer participation in irrigation systems in front of the DOI senior officials.

47. The amount and basis for the labour contributions from each of the WUG varied. Contributions based on both the household and land area were found. Farmers raised questions about the household criterion on grounds of equity.

48. The other four irrigation systems were: Khageri Irrigation System in Chitawan, West Gandak Irrigation System in Western *tarai*, Manusmara Irrigation System in central *tarai* and Kankai Irrigation Project in the eastern *tarai*. However, in 1992-93, the programme was not implemented in the Kankai Irrigation Project because of the difficulty in logistic support.

49. Under this division are the System Management Branch (SMB) and Research and Training Branch (RTB) which were initially created under the Irrigation Management Project (grant) funded by the USAID.

50. The SMB deployed an agricultural engineer and a sociologist to assist the DIO in the formation of new water users' organization. From the DIO side, the assistant (agricultural) engineer was exclusively assigned to the programme. Together the three structured the new WUO.

51. A flat rate of Rs 60 per hectare per crop is charged to farmers who have used water from (gravity) irrigation systems built and operated by the government. This rate was fixed about two decades ago and has remained unchanged. The fee is charged, even if farmers receive water for only one irrigation application. The assessment of water fees and the area irrigated is done by the irrigation office and forwarded to the (local) revenue office which collects the fees from the farmers.

52. Under the CADP, a three-volume operation and maintenance manual was prepared by the consultants (see NIACONSULT and IECO 1987: Vol. I-III). Volume II of this manual gives the detailed calculation of the monthly irrigation requirements for the prevailing cropping pattern in Banganga. None of the Volumes of the manual was in the District Irrigation Office, indicating that the operating engineers did not pay much attention to the operational criteria prescribed since it was difficult to implement them in practice.

53. In some of the project reports, these four areas have been further grouped into head, middle and tail sections, depending upon their relative distance from the headworks. Area No. 4 is considered as the head section, and Areas No. 3 and 2 are taken as the middle section.

54. Such a schedule was first introduced in 1987 for the paddy season in that year (NIACONSULT and IECO 1989: 56). The water delivery according to this schedule began from July 1.

55. During this paddy season, farmers did not begin to plough their land until mid-June, after the pre-monsoon rainfall (total rainfall of the month was 76.8 mm). Paddy nurseries were prepared between June 20 and July 30, 1992. The 1992 monsoon rainfall began rather late, from July 9 onwards. Farmers only began transplantation of paddy seedlings after the onset of the monsoon, though the irrigation office had released water in the main canal from June 10. The transplanting continued until the end of August. Since the water storage in the flow in the main canal was low, most farmers had to depend on rainfall because of the inadequate flow in the canal.

56. Six concrete-lined stretches with gauge marks have been built at various points on the main canal for the measurement of flows. These measuring points are at km 0+000, 6+400, 10+700, 13+400, 15+550 and 17+000 from the head of the main canal. Similar lined stretches have been built at the head of each of the three large secondary canals: Laxminagar, Taulihawa, and Hathihawa Branch canals. But flow (water depth) measurements at these points are rarely carried out by the irrigation office.

57. Even when there are less weeds in the canal the flow in the canal cannot be increased beyond a certain limit because of the obstruction by the jammed gates at a number of cross regulators on the canal. For example, the maximum flow at the head of the main canal during the research period was 2.23 m^3 per second, measured on February 2, 1992. This flow almost overtopped the banks of the canal at some points in its head-reach.

58. There is a single-storey patrol house which was built by the irrigation office next to the HBC outlet during the 1979 construction. A *dhalpa* of the irrigation office resides here. This has apparently enabled the office to keep the gate intact.

59. However, observation showed that the cultivation of *rabi* crops at the tail-end area of the main canal was almost equal in proportion to that at the head end, including the wheat crop.

60. The LBC outlet was originally provided with a vertical screw-type adjustable slide gate. Farmers and engineers interviewed indicated that the gate was destroyed some years later. The absence of a control gate at this outlet structure considerably affected the flow in the (main) canal downstream. A new gate was installed by the district irrigation engineer in February 1992 in order to control the inflow of water in the LBC. This gate was also destroyed by farmers after three months. Since then, the LBC outlet has been without a gate.

61. During the three successive crop seasons from November 1991 to May 1993, inflow of water through the outlet was observed only six times. The farmers irrigated their fields in these blocks by diverting water from the tertiary canal of Block No. LB 10 to the adjoining drain (of Block LB 11). A number of temporary checks (bunds) were built across the drain to divert water to the fields in Block LB 11.

4 The Pithuwa Irrigation System

Many engineers around the world have a bias towards "modern" technology. Their academic and professional training has led them to presume and even conclude that farmers do not have the knowledge or ability required to organize the management and maintenance of irrigation systems once they are built. This may be true under certain circumstances, but under other circumstances farmer-developed simple water control technologies may be superior and may match the farmer's resources better than the modern technology introduced by engineers. The preceding chapter has shown how the technically flexible gated water control technology introduced by the engineers created a complicated physical system which, in practice, was almost impossible to manage for equal and timely water distribution.

This chapter presents a case study of the Pithuwa Irrigation System which was constructed by the government and has been managed by farmers since 1975. Inefficient water distribution by the irrigation agency led the farmers to take the initiative to organize improvements in the distribution. They subsequently remodelled the irrigation system. The purpose of this chapter is to examine how farmers on their own initiative evolved a technical and organizational procedure for water control in an irrigation system built by the government. The principle and the actual practice of water allocation and distribution by farmers are discussed. The data are from the observations of the irrigation practices within three branch canals - one at the head, one at middle and one at the tail end - of the irrigation system, during the two consecutive crop seasons from June 1992 to May 1993. About 120 farmers, within and outside the branch canals, were interviewed.

To an observer, communal action may appear to be something that is understood and perceived as real and routine. As Silverman (1970) has noted, although action presents a routine character it is in fact socially accomplished. In other words, the social arrangement is an outcome of the action and interaction of people. Human action is dependent on a series of stated and unstated assumptions. Careful examination of human actions can reveal many underlying causes for their actions. This case study will show that in an irrigation system farmers act and interact in response to a particular irrigation situation which arises locally or in response to outside intervention.

4.1 The field setting

General

The Pithuwa Irrigation System is located in the Pithuwa village of the Chitawan district in the central inner *tarai*, Nepal (see Figure 1.2). It serves almost all the wards of the village.[1] The net command area is estimated to be 618 hectares.

The command area slopes gently from the north towards the south. The elevations range from 240 metres in the north to 200 metres in the south above mean sea level. The low-lying areas called *ghol* are inundated quickly. The soils in the area are of fine loamy to loamy texture and well drained (Land Systems Map 1982: No. 72 A/10; Nippon Koei 1990). With respect to the land use pattern, most land within the command area can be regarded as *khet* land on which irrigated paddy is cultivated. The land on which a crop is grown without irrigation is treated as *pakho* by farmers.

The Pithuwa area falls under the subtropical humid climatic regime. The annual rainfall in the area varies from 1400 to 1600 mm. Figure 4.1 presents the monthly variation of average temperature, evaporation and rainfall in 1992 measured at the nearest meteorological stations. The variation in rainfall shows that more than 80 percent of the annual rainfall occurs during the monsoon period, from June to September. Observation (amount not recorded) of the daily rainfall pattern during the 1992 monsoon period in the command area showed frequent rainfall of short duration and high intensity occurring more often than the rainfall of long duration and low intensity. The effectiveness of such erratic rainfall is low, especially for growing paddy, due to high percolation.

The water source of the irrigation system is the *Kayer khola*, a small torrential river with large seasonal variation in flow. Maximum flow and flash-floods occur during the monsoon season, but the flow in the stream diminishes greatly during the dry season.[2] The stream is also the source of drinking water for the area.[3] There is virtually no other water resource in the area. The hydro-geology of the area does not permit an economic use of groundwater for irrigation. The low water table and inadequate yield of the (two) wells constructed for drinking water in the village verify this. The combination of extremely low flow in the river and the priority for drinking mean that too little water is available for irrigation in the dry season.

The village

Pithuwa village is situated at about 16 kilometres east of Bharatpur, the district headquarters, and about 2 kilometres north of the *Tadi bazaar*, a market place on the east-west highway. It is connected to the bazaar by an all-weather gravel road and has a well developed market structure.

The village is a recent development.[4] Until the late 1960s it was sparsely populated. Its northern part was a dense forest. Crops were cultivated mostly in the southern part, near the east-west highway, under rainfed condition. According to the elderly villagers, Pithuwa was one of the last places in the Chitawan Valley to be occupied by settlers. Settlement in the village increased substantially in the 1970s, as the land in other parts of the Valley became scarce and costly. Most settlers are from the three neighbouring hilly districts: Gorkha, Lamjung and Dhading districts.[5] About 72 percent of the village population belongs to *Brahmin*, *Chhetri*, *Magar*, *Gurung* and *Tamang* caste groups, and the remaining are *Newars*, *Tharus* and *Kumals* (Neupane 1991: 95).[6] Irrespective of the mixed caste composition, significant social cooperation in the village was observed. Village society is rather open. Women take part in irrigation discussions and even irrigate the fields in the absence of men.

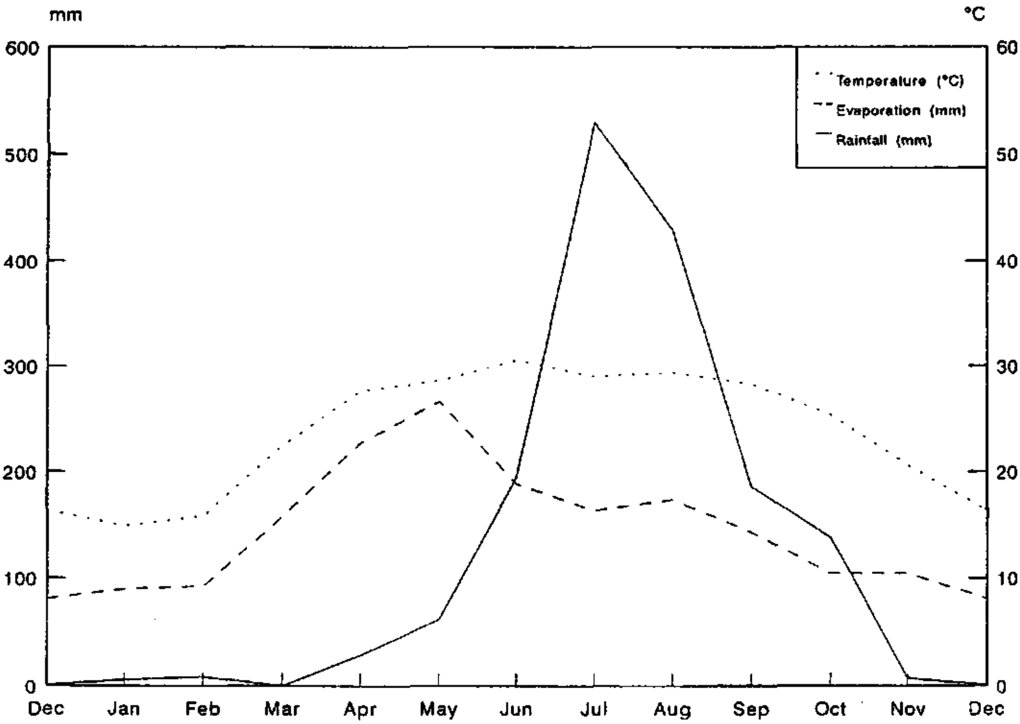


Figure 4.1 Monthly average temperature, evaporation and rainfall in the Pithuwa area (1992) (Sources: Temperature and rainfall data from the Rampur Meteorological Station, and pan evaporation data (1968-78) from the Bhairahawa Meteorological Station.)

An important feature of the village is the pattern of settlement and land distribution. The settlement pattern is such that land parcels are rectangularly gridded by access roads, and farmers have their homesteads along the roadside end of the landholding. Figure 4.2 shows the typical settlement pattern in Pithuwa. This settlement pattern has facilitated the current irrigation management practices, particulary the distribution of water at farm level (see Section 4.4).

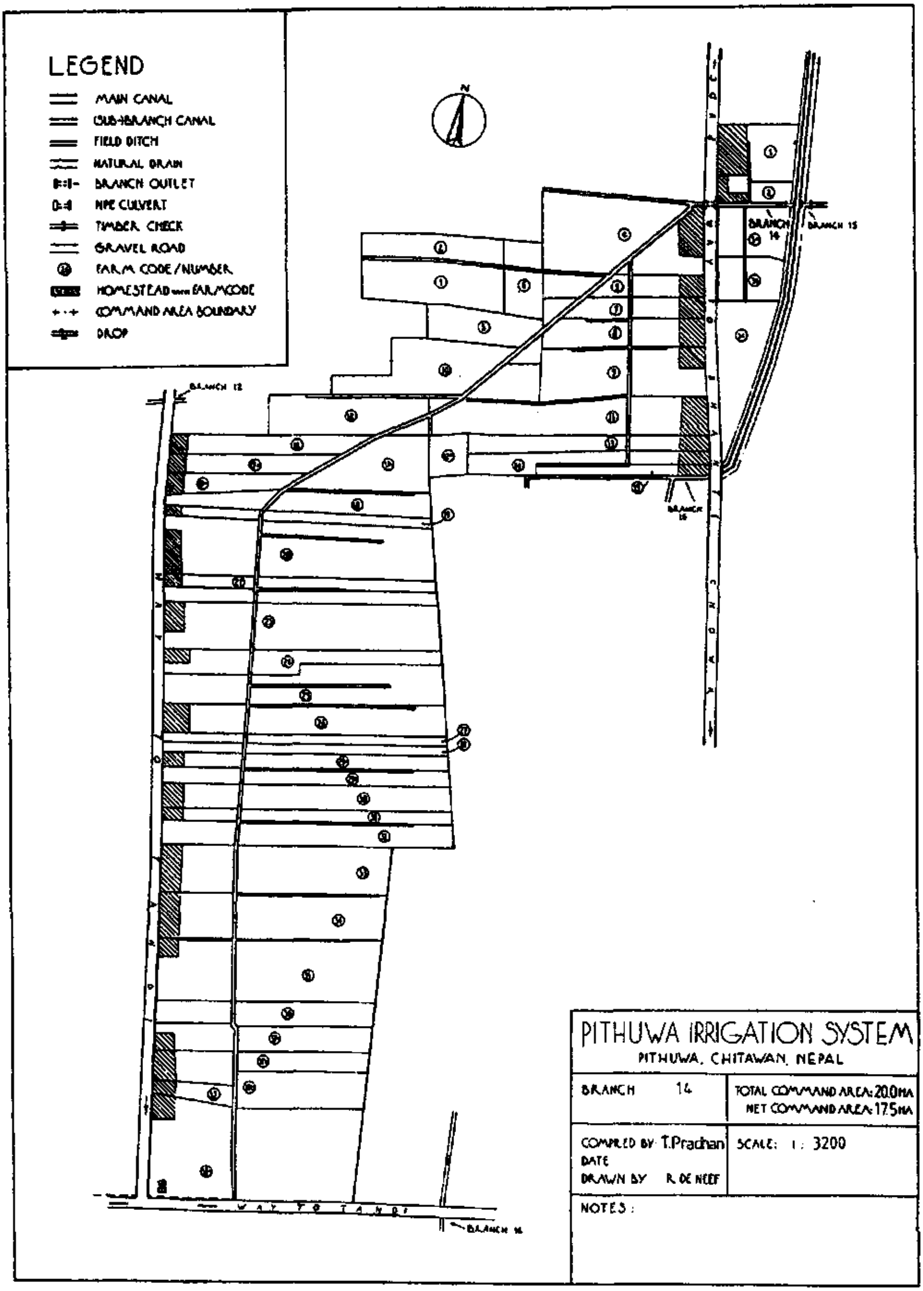


Figure 4.2 Typical pattern of settlement and land distribution in Pithuwa village (Source: Field observation 1992-93.)

Landholding and land tenure

The average size of landholding in the command area is estimated to be 0.56 hectare per household or per family of 4.6 persons (see Table 4.1). Most farmers are owner cultivators. The household survey of the irrigated areas under the three branch canals studied indicated a small proportion of tenants, about 12 percent. There were no landless families in the command areas of the three branch canals studied.[7] In the southern part of the village, the major proportion of land is owned by a few élite who are absentee landlords. This land area lies at the tail end of the irrigation system and is cultivated by tenants, mostly under rainfed conditions.

Table 4.1 Command area, irrigated area and number of farmers under different branch canals in Pithuwa (1993)

Branch Canal No.	Command area (ha)	Number of water users	Irrigated area		Land area per water user (ha)	Irrigated area per water user (ha)
			(ha)	% of command area		
1	20.3	51	17.25	84.98	0.4	0.34
2	61.14	127	35.47	58.01	0.48	0.28
2.1	48.86	157	43.47	88.97	0.31	0.28
3	28.29	56	28.29	100	0.51	0.51
4	19.78	54	19.18	96.97	0.37	0.36
5	28.09	40	19.71	70.17	0.7	0.49
6	26.56	55	23.80	89.61	0.48	0.43
7	8.76	18	7.84	89.50	0.49	0.44
8	64.97	101	50.32	77.45	0.64	0.5
9	40.18	48	34.67	86.29	0.84	0.72
10	52.36	78	43.60	83.27	0.67	0.56
11	42.95	89	36.70	85.45	0.48	0.41
12	26.27	43	19.23	73.2	0.61	0.45
13	33.1	75	31.68	95.71	0.44	0.42
14	20.33	41	18.67	91.83	0.5	0.46
15	40.42	49	23.47	58.07	0.82	0.48
16	55.51	27	32.75	59	2.06	1.21
Total	617.87	1109	486.1	(78.67)	(0.56)	(0.44)

Notes:

1. The command area of each branch canal is the area registered with the "Pithuwa Irrigation Management Committee".
2. Irrigated areas represent the areas cultivated with paddy.
3. Figures in parentheses are average figures.

Sources: Own field data and records of the farmers' committee (1992-93).

The sharecropping, locally called *adhiya*, is the most common form of tenure arrangement in Pithuwa. The terms and conditions under this tenure arrangement are similar to those under the *bataiya* tenure system practised in the Banganga area. However, there are some minor differences. In Pithuwa, the cost of chemical fertilizers and pesticides applied is shared equally between the landowner and the tenant, and in some cases the quantity of harvest that the tenant delivers to the landowner is fixed in advance.

The farming system and principal crops

The farming system in Pithuwa presents a mixture of the Dun Valley and Main Tarai farming systems in the country. Paddy is the principal crop cultivated during the monsoon season. In the dry season, oilseeds, wheat, maize and vegetables are grown. During the April-June period, farmers mainly grow rainfed maize, covering almost the entire area of their landholding. Figure 4.3 shows the current cropping pattern.

Prior to the construction of the irrigation system, most of the crops cultivated were local traditional varieties. During the wet season, traditional varieties of maize were the dominant crop, and only *ghaiya*, a long term (150 days) local variety paddy, was grown in a limited area under rainfed condition. In the winter season, mostly oilseeds were cultivated.[8] Farmers interviewed indicated that paddy cultivation increased substantially and became the staple crop after the availability of irrigation water. Nowadays, early maturing (120 days) varieties of paddy are necessarily grown because these paddy varieties allow the timely cultivation of oilseed crop which is the cash crop. Good management of the irrigation system has made it possible to cultivate early maturing varieties and to cultivate intensively.

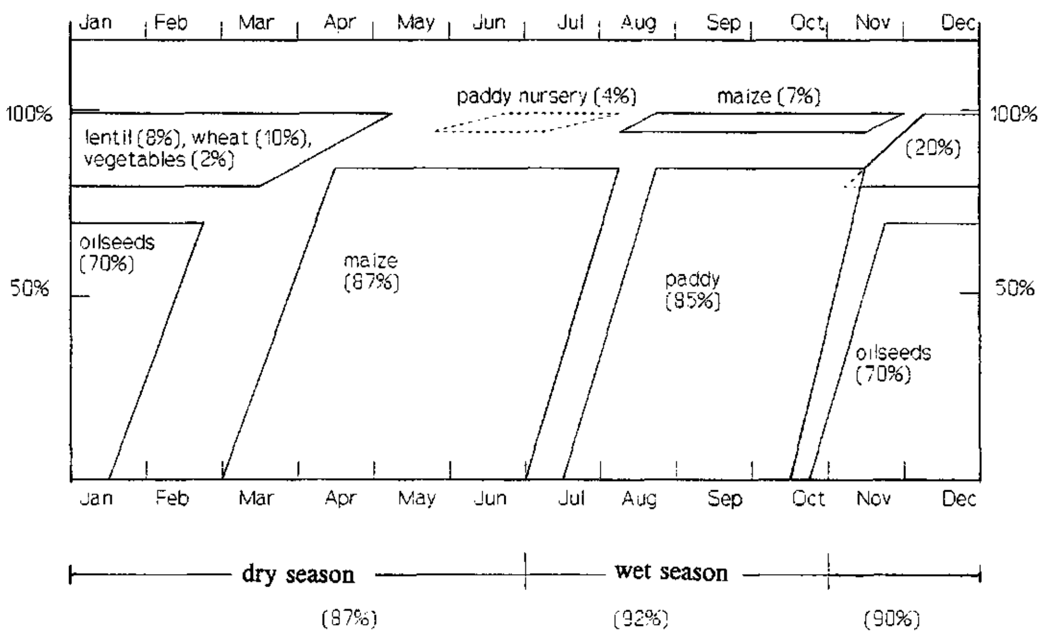


Figure 4.3 Cropping pattern in Pithuwa during 1992-93 (Source: Field observation.)

Table 4.2 presents the proportion of the areas cultivated with principal crops in the three Branch canals studied during the 1992-93 period. Two distinct observations can be made from this Table and Figure 4.3.. The first is that paddy, maize and oilseeds are the principal crops. Second is the intensive farming. Most farmers grow three crops in a year in the irrigated area. The cropping intensity is about 269 percent. Observation of the crop cultivation in the three branch canals revealed that even the temporary bunds surrounding paddy fields are used to grow legumes like soyabean. Farmers practise multiple cropping, mainly because of the small size of the landholding and the dependence on agriculture for subsistence. Some farmers with large landholdings grow only two crops per year. They prefer to leave the land fallow after the maize harvest, to get higher oilseed yields.

As shown in Table 4.2, paddy occupies an average of about 85 percent of the cultivated area during the wet season. Farmers cultivate maize in about 7 percent of their landholding along with paddy, but without irrigation because of the limited availability of water from the irrigation system (see Figure 4.4). In the winter, oilseeds sown immediately after the harvest of paddy occupy about 70 percent of the cultivated area, and wheat is grown in only a limited area (about 11 percent). According to farmers, the cost of oilseed production is relatively less than that of wheat, and oilseed fetches higher price than wheat.[9] The winter crops are grown under partial or no irrigation.[10] The cultivation of maize and vegetables in the April-June period is totally dependent on scarce rainfall. The cultivation of vegetables is very limited and is mainly for home consumption. Potato, onion, garlic, beans, and peas are the commonly grown vegetables. The varieties of paddy, oilseeds, wheat and maize grown in 1992-93 are presented in Appendix 9.

Table 4.2 Areas cultivated with the principal crops in the three branch canals studied during 1992-93 (in hectares)

Branch Canal No.	Command area	Crops					
		Paddy	Oilseeds	Wheat	Lentil	Vegetables	Maize#
3	28.29	25.01 (88.8)	19.1 (67.4)	4.2 (14.9)	2.2 (7.9)	0.97 (3.4)	24.9 (87.9)
8/1	16.12	12.1 (75.2)	10.4 (64.4)	0.9 (5.6)	1.6 (10)	0.17 (1.1)	12.1 (74.8)
14	20.33	17.5 (86)	15.5 (76.1)	2.6 (13.03)	1.9 (9.4)	0.7 (3.3)	20.3 (100)
% average of the three		83.3	69.3	11.2	9.1	2.6	87.6

Note: Figures in parentheses are the percentage of the area under each branch canal.
This maize is grown in the April-June period.
Source: Field measurement.

A striking feature of paddy cultivation is that all paddy varieties are invariably transplanted and are grown totally under irrigation because of the reliability of irrigation water. The cultivation of paddy takes place in small roughly levelled basins. Unlike in Banganga, the topography in Pithuwa is such that every year most farmers have to prepare basins for paddy cultivation by dividing their landholding into small parcels bounded by temporary earthen bunds which are destroyed after the paddy harvest. Figure 4.4 shows the cultivation of paddy (and maize) in the command area of Branch Canal No.14 during the 1992 monsoon season, as an example. Note the high density of temporary bunds and the field channels.

Another feature of farming in Pithuwa is that despite the small landholding size many farmers use hired farm tractors in addition to animal powered ploughs for land preparation, especially in preparing the land for paddy transplanting. This is partly in response to the water allocation and distribution practice, which limits the time for the use of canal water for paddy transplanting (see Section 4.4). Moreover, tractor ploughs are cheaper than animal powered ploughs, in terms of output per unit of time.[11]

Farming activities such as transplanting/sowing, weeding, harvesting, threshing, drying, stacking, winnowing and storing, are labour-intensive. The labour required in these activities is obtained from three sources: family members, neighbours and relatives, and wage labour. Observations show that most labour input comes from the family members themselves, especially women.[12] Neighbours and relatives usually provide their labour on a reciprocal basis without the payment of money. Reciprocity of labour, locally called *parma*, is crucial, as many farmers cannot afford wage-labour which, moreover, is in short supply in and around the area.[13] The farmer community in Pithuwa has devised a way to complement labour to some extent. During the period of paddy transplanting in July-August when the demand for labour is high, all schools in the village have a six-week vacation, beginning from the first day of July. This vacation period, called *barkhe pachaas*, allows both the (local) teachers and the able school children to assist in the farming activities.

An important and integral part of the farming system in Pithuwa is the livestock raising which provides farmers with manure, the main source of fertilizer, and an additional income. Virtually every household in the village has one or more head of cattle. A considerable amount of the family labour of a farmer is consumed in managing the livestock. The livestock commonly raised are buffaloes, cows, bullocks, and goats. Besides manure production, different animals have their own purpose. Most of the income from livestock comes from selling milk and milk products.[14] The intensive cultivation and substantial livestock population have caused farmers to practise controlled grazing of cattle within the village, especially on the canal bank.

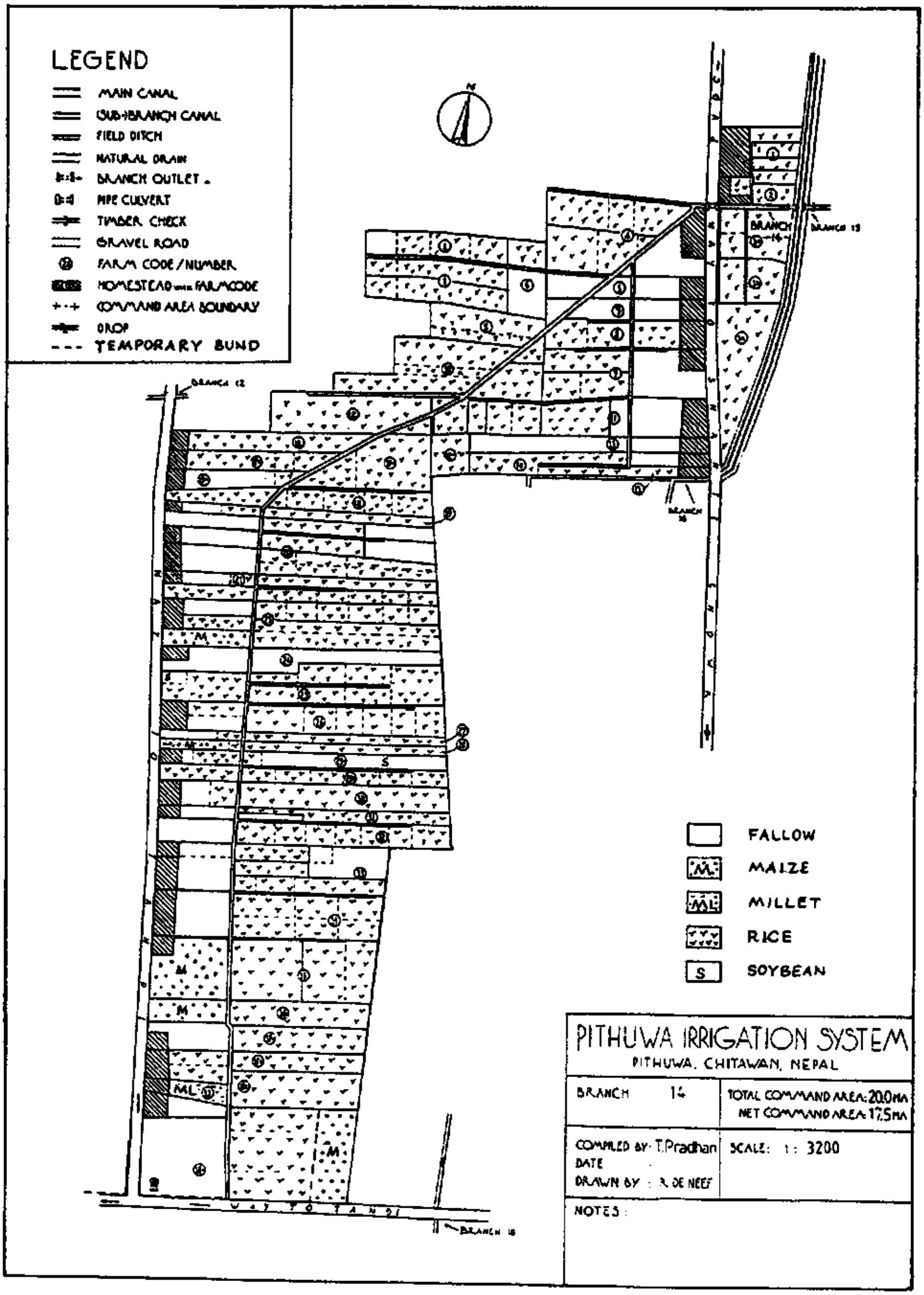


Figure 4.4 Crop cultivation in the command area of Branch Canal No. 14 during the 1992 monsoon season (Source: Field observation.)

4.2 The irrigation system: physical and technical characteristics

The Pithuwa Irrigation System was constructed by the government in 1968 under the Minor Irrigation Programme (Shrestha et al. 1992).[15] Its development to its present state can be said to have occurred in two phases: (i) the 1968-74 phase when the basic canal infrastructure was developed and operated by the Department of Irrigation, and (ii) the 1975-82 period when farmers took over the system and the physical infrastructure was remodelled.

Before discussing the physical and technical characteristics of the irrigation system, it is useful to note the terminology used by Pithuwa farmers to describe the system, as the terms will be used repeatedly hereafter to be consistent with the farmers' description. The main canal is called "*mool nahar*". A secondary level canal branching off from the main canal is called "*sakha nahar*" (meaning branch canal), irrespective of the land area served and the capacity.[16] The lower level canal which takes off from a branch canal and serves several parcels belonging to different farmers is called a "*kulo*".

The 1968-74 design and construction

The physical infrastructure of the Pithuwa Irrigation System (PIS) as originally designed consisted of:

- a temporary diversion dam in the source river,
- a regulating structure with a vertical screw type slide gate at the head of the main canal near the diversion point,
- unlined canals,
- a combination of weir-type check structures and pipe outlets with vertical lift gates, for water division in the main canal, and
- simple water division and check devices in secondary canals.

The main canal and its structures and most of the secondary canals (hereafter referred to as branch canals) were built by the Irrigation Department during this period.[17] Oral history indicated that farmers' contribution in this initial design and construction was negligible.

Given the scope and financial resource limitations of the Minor Irrigation Programme, the irrigation system was designed as a simple and a low cost system without a permanent diversion structure on the source river. Even if it were technically possible, the torrential flow regime of the *Kayer khola* and its load of coarse sediments during the monsoon season would have made a permanent diversion structure economically unfeasible. The risk of such a structure being damaged or becoming non-functional within a short period is great, as can be seen from the severe damage to the head regulator structure and the head-end section of the main canal caused by the heavy flood in the river in August 1974. The DOI repaired the flood damage and improved the irrigation system in that year. The improvements essentially comprised the reconstruction of the damaged head regulator and the protection of the main canal stretch near the diversion point through river training works of boulders in gabion crates.[18] In addition, a service road along the main canal, additional structures in branch canals, and a number of cross drainage structures were built.

The technical design of the basic canal infrastructure - the head regulator structure, the main canal, branch canals and their outlets, and check structures - was prepared by the engineers of the DOI.[19] By and large, it reflects the conventional design of the DOI. The head regulator structure of the main canal is made of reinforced concrete and consists of a vertical screw-type steel gate. The check structures in the main canal are the single opening "Sarda-type" vertical falls of brick masonry. The branch canal outlet structures consist of concrete pipes fixed in brick masonry end walls with grooves for stop-logs or timber boards. The pipes are placed perpendicular to the direction of flow in the main canal. Apparently, all branch canal outlets were initially provided with simple vertical lift gates.[20] The provision of gates implies that the design engineer wished to have a controlled distribution of water to the outlets. No field drains have been provided. In fact, drainage of cultivated fields is not necessary because of the topography and the soil conditions. Natural drainage channels form the drainage network of the command area. For economic reasons and because it is considered as a minor irrigation system, no device has been provided to prevent silt from entering the canal system, nor have devices been built in the canal to flush the silt deposits. As a result, the irrigation system suffers heavily from silting (coarse sand), especially at the head-reach of the main canal.

Although the engineers of the Irrigation Department were responsible for the design, this researcher found no design reports and drawings in the department, nor in the District Irrigation Office concerned, and was therefore unable to trace the criteria and assumptions followed in the design and operation of the system. A brief report by the Central Region Irrigation Directorate on the status of the irrigation system in 1987 shows the capacity of the main canal to be 1.6 m^3/s and the total cultivable command area to be 600 hectares (DOI 1987). These data give a design irrigation water requirement of 1.6 lps per hectare at 60 percent system level efficiency (conveyance efficiency = 80 percent). However, farmers interviewed reported that the irrigation officials usually referred to the main canal as having a capacity of 1.13 m^3/s (40 cusecs). According to the report, the canal system should provide year-round irrigation to the entire cultivable command area. However, this is not possible, given the extremely reduced flow of the source river in the dry season and the temporary diversion dam. Measurements of the openings at the weir-checks in the main canal indicated the variation of design water depth from about 1.1 metres at the head end and 0.75 metre at the tail end. Apparently, the design width of the canal bed varies from 2.1 to 1.2 metres from the head end towards the tail end. Farmers have altered the shape of the cross-section of the main canal to a U-shape by removing silt deposits every year. The slope of the canal between the two (falls) check structures varies from 0.0015 to 0.0025 because of the topography.

It is difficult to discuss of the original design and the capacity of branch canals since the shape and gradient of the canals have been altered during the remodelling and due to regular cleaning by farmers. Apparently, no water distribution structures were built in the branch canals during this initial construction.

The 1975-82 period: remodelling and extension of the physical system by farmers

In 1975, the farmers took over the management of the irrigation system on their own initiative because the Irrigation Department was paying inadequate attention to even distribution of water over the irrigation system (Pradhan 1989). To ensure equity in water distribution within a branch canal and among the branch canals, they adopted rotational distribution. How farmers took over the complete management of the irrigation system and the principle of water allocation and distribution are discussed in further detail in Sections 4.3 and 4.4.

Within a few years after the take-over of the system management, the existing physical infrastructure was remodelled by farmers with technical, material and financial assistance from the DOI. The remodelling mainly comprised changes at and below branch canal level. There was no attempt to build a permanent diversion structure on the river, primarily because of the resource constraint and the nature of the river. The head regulator, the main canal and its structures were not altered. The capacity of the irrigation system thus remained virtually unchanged. Figure 4.5 shows the schematic plan of the irrigation system after the remodelling. The subdivision of areas under branch canals and the number of check structures in the main canal are shown in Figure 4.6.

The changes made in the irrigation system during the remodelling clearly reflect the perception of farmers in the design of the system and the equity in water distribution. The remodelling activities mainly consisted of: (i) re-levelling the pipes in all branch canal outlets, (ii) defining, redefining and fixing the hydraulic boundaries of branch canals, (iii) adjusting the pipe sizes to match the land area served, and (iv) removing gates at branch canal outlets.

The re-levelling of pipes was necessary because pipes at most of the existing branch canal outlets had settled by the time the farmers took over the system operation. This shows the poor quality of the DOI's construction of the irrigation system.

The hydraulic boundary of each branch canal was reestablished on the basis of the capacity of the existing pipe outlets. Available records showed that farmers also considered the convenience of irrigating from a branch canal. For example, through a decision in a general meeting of the main committee, about thirteen farmers in the command area of Branch Canal No.6 were allowed to irrigate from Branch Canal No. 8. Note that these Branch Canals are on the same side of the main canal (see Figure 4.5). The readjustment of hydraulic boundaries necessitated changes in the pipes at the outlets of most branch canals. For example, the outlet of Branch Canal No.6 was initially provided with two concrete pipes: one

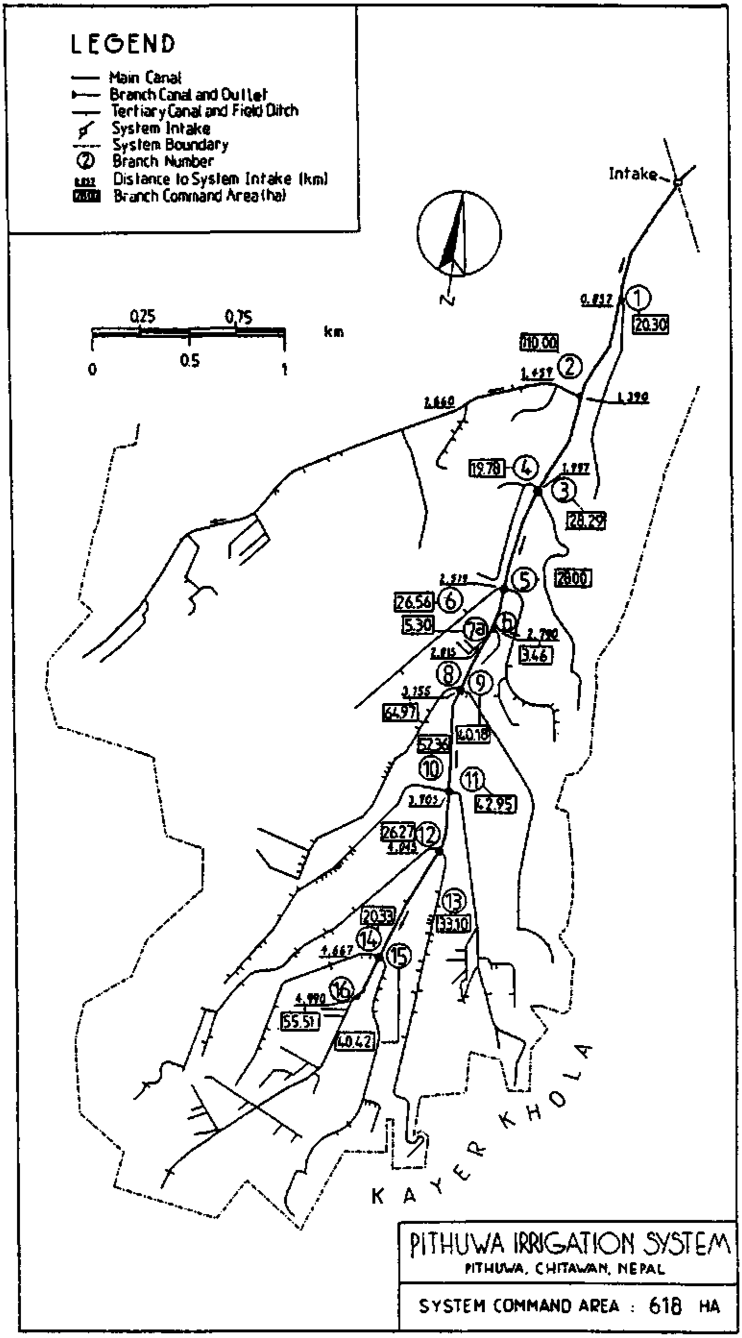


Figure 4.5 Schematic plan of the Pithuwa Irrigation System, 1993 (Sources: Field observation and relevant documents ot the East-Rapti Irrigation Project.)

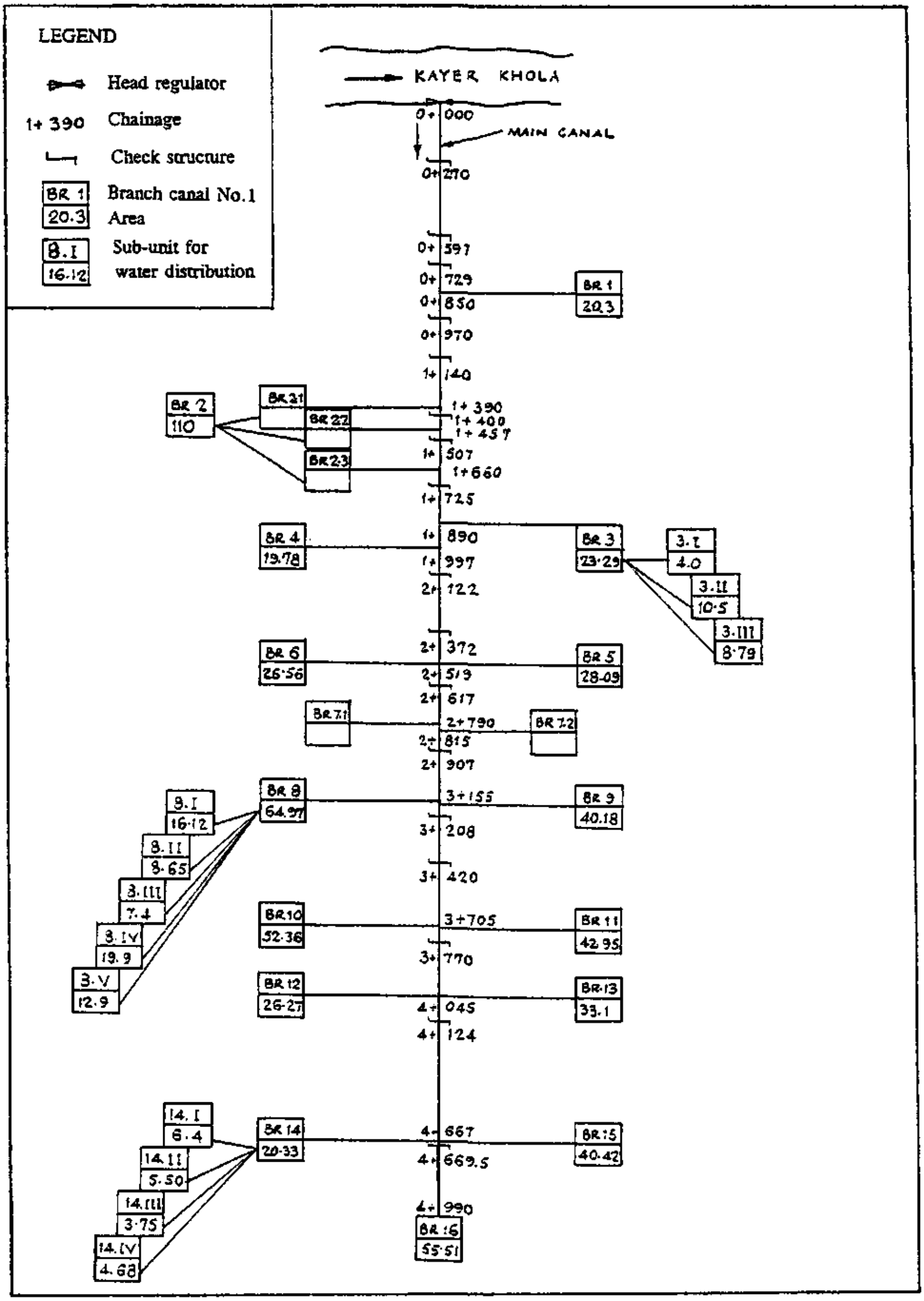


Figure 4.6 Subdivision of areas under branch canals and the number of check structures in the main canal of the PIS (Source: Field observation 1993.)

15 cm diameter and the other of 23 cm diameter. Now it has a single pipe of 30 cm diameter. The outlet of Branch Canal No. 8 had one single pipe of 30 cm, and now it has two pipes: one of 15 cm and the other of 30 cm diameter. Available records also showed that the pipes at the outlets of Branch Canals No. 2, 3, 4, 7 and 9 were altered in a similar manner.

Although there is evidence to show that farmers made requests to the irrigation office for the concrete pipes and other material assistance, there is no evidence of farmers seeking and receiving the technical assistance from the office in redefining the hydraulic boundaries and adjusting the outlet capacity.[21] Both the irrigation boundary of each branch canal and the size of pipe outlet to match the land area served were decided by the farmers themselves based on their convenience and practical experience. Farmers also voluntarily contributed part of the labour required in the remodelling works.

The removal of gates from all branch canal outlets is the most striking feature of the remodelling. Farmers wanted continuous supply of water in their branch canals for effective implementation of rotational distribution of water within the branch canal. The ungated pipe outlets whose sizes have been fixed in proportion to the cultivated land area served allows the water available in the main canal to be divided proportionally under conditions of continuous flow.

By 1982, the main canal was extended further by about one kilometre, and four new branch canals were constructed within this extended stretch. The extension of the main canal and thereby the irrigated area was possible because water allocation and distribution by rotation ensured reliable delivery of water to the tail end of the system. According to farmers, the additional branch canals are Branch Canals Nos. 13 to 16 (Figure 4.5).[22] As shown in Figure 4.5, the main canal runs along the ridge with the branch canals on either side. There are seventeen check structures over the 5-kilometre length of the main canal (on average 1 every 300 m) because of the topography (see Figure 4.6). The total length of all the branch canals considered is about 62 kilometres (Nippon Koei 1990).

Within most branch canals, simple timber-board checks are used to divert water from the (supply) branch canal or the *kulo* to the cultivated fields (Photo 4.1). These timber-board checks belong to individual farmers or to a group of farmers. In some large branch canals, like Branch Canal No.2, simple proportioning water division structures (without a raised sill) of brick masonry are built at bifurcation points. The field ditches connecting individual fields to the branch canal or *kulo* have been constructed by farmers themselves.

The cultivated area of a branch canal varies from 8.75 to 55.5 hectares, except for the area under Branch Canal No.2, which is about 110 hectares (see Table 4.3).[23] Therefore, by comparison, branch canals and the areas served by them in Pithuwa are equivalent to tertiary canals in the Banganga Irrigation System.

Photo 4.1 A typical timber-board check used in a branch canal (Branch Canal No.3, August 1992)

Ungated concrete pipe outlets for water distribution
Water control to branch canals in Pithuwa is through ungated concrete pipe outlets. The hydraulic design of an outlet structure has an important bearing on the equitable distribution of water. Therefore, some important hydraulic features of an outlet structure and the perceptions of engineers and farmers of it are briefly described below, before specifically discussing the features of the pipe outlets in Pithuwa.

In an irrigation canal, variations in water level and flow can occur due to either one or all of these: (i) change in the flow in the higher level canal due to the change in flow at the source itself, (ii) change in the canal dimensions due to silting, aquatic plant growth, excessive cleaning or not cleaning, and (iii) manipulation of regulating structures. Flow through an outlet is influenced by the variations in water supply level in the parent canal and by the hydraulic design of the outlet.

Hydraulically, three outlet devices can be distinguished: modular, semi-modular and non-modular (Bos et al. 1978: 94-96). An outlet is modular if it delivers a constant discharge irrespective of variations in the water level in both the supply canal and the (offtaking) downstream canal. The discharge through a non-modular outlet device depends upon water levels in both the downstream canal and the supply canal. A semi-modular outlet delivers a discharge which depends upon the water level in the supply canal only. Since farmers are interested in receiving adequate water for their growing crops, they would prefer a modular device at an outlet structure.

A non-modular outlet device is not recommended by engineers, mainly for two practical reasons: (i) water levels in a watercourse (tertiary canal) vary considerably, depending on the high or low areas that are being irrigated at any given time, and (ii) farmers can alter the discharge whenever they like by clearing the silt/sediment in the watercourse or downstream in the canal. Thus, in a canal with non-modular devices, there is always surplus water at the tail end when water users at the head-end area do not maintain their tertiary canals during the period of slack demand, and there is a shortage at the tail end during the periods of keen demand when water users clean the tertiary canals so they can draw as much water as possible (Mahbub and Gulhati 1951:140).

Engineers believe that a semi-modular device, if properly designed and constructed, can distribute variations of flow in the supply canal more or less equitably (Mahbub and Gulhati 1951: 140; Varshney et al. 1983: 261; Bos et al. 1978: 94). However, it should be noted that a semi-modular device in the silted and weed infested reach will draw more than its share of discharge, thereby causing shortage of water at the tail-end.

An ungated pipe outlet, which is perhaps the oldest and the most common outlet device used in irrigation systems, can meet most of the requirements prescribed by engineers for a good outlet (Mahbub and Gulati 1951: 13-15; Varshney et al. 1983: 259). Above all, as mentioned earlier in Chapter 3 (Section 3.2), it can deliver flows proportional to the variation in the water supply in the parent canal if placed at a 0.3 design depth below the full supply level. However, a pipe outlet has its limitations and can create problems in the even distribution of water. It functions as non-modular when submerged and as semi-modular when it discharges freely downstream. Therefore, even at a constant water depth and flow in the supply canal, the discharge passing down a pipe outlet can be altered by cleaning or not cleaning the silt deposits in the downstream canal. In the case of siltation in the (supply) canal, outlets of low flexibility help to avoid water shortage at the tail end of the canal.

The original design considerations for pipe outlets in Pithuwa are not available. During the remodelling, farmers fixed the size and setting of pipes based on their own practical considerations and experience about the area irrigated by a pipe outlet in Pithuwa. For a given (design) water depth in the supply canal, the discharge through a pipe outlet is proportional to the cross-sectional area of the pipe. The cross-sectional area of a pipe in an irrigation outlet should be theoretically proportional to the land area served if equity is required.

Three different sizes of pipes are used in Pithuwa: 15 cm, 23 cm and 30 cm internal diameter. Table 4.3 shows the size of pipes, their cross-sectional areas, and the land areas served by them for various branch canal outlets. Figure in Appendix 10 presents the plotting of the ratio of the cross-sectional area of the pipe outlet and the land area served for each branch canal. Two important observations can be made from this Table and Figure in Appendix 10. The first is the large-diameter pipe outlets at the tail end of the main canal. This implies that flow per hectare through outlets increases from the head towards the tail end of the main canal, assuming the same water depth in the canal. Technically, this is justified, when considering seepage losses and higher siltation at the upper reach of the canal. However, farmers gave their own reasons for this. According to them, the large-diameter pipe outlets were provided for the tail-end branch canals to allow some water into these canals as far as possible, even during the low flow in the main canal. The second is that some branch canals, especially Branch Canal No. 7.1, have a share of flow more than the others. Interviews with farmers revealed that an influential farmer on this branch canal managed to install the larger pipe during the remodelling (see section 4.3).

Table 4.3 Pipes used at various branch canal outlets in Pithuwa: number of pipes, size, cross-sectional area and the land area served (1993)

Branch Canal No.	Number of pipes	Pipe size and cross-sectional area		Land area served (ha)	Cross-sectional area (sq.cm)/land area (ha)
		size (cm)	area (sq.cm)		
1	1	30	729.7	20.3	36
2	3	1-23 2-30	1869.8	90.6	20.6
2.1	1	15	182.4	19.4	9
3	2	1-15 1-23	592.8	28.3	21
4	1	23	410.4	19.8	20.7
5	2	1-15 1-23	592.8	28.1	21.1
6	1	30	729.7	26.6	27.4
7	1	15	182.4	10.7	17
7.1	1	23	410.4	8	51
8	2	1-15 1-30	911.4	65	14
9	2	1-30 1-15	911.4	40.2	22.7
10	1	30	729.7	52.4	13.9
11	1	30	729.7	42.9	17
12	1	30	729.7	26.3	27.7
13	1	30	729.7	33.1	22
14	1	30	729.7	20.3	36
15	1	30	729.7	40.4	18.1
16	-	-	-	55.5	

Note: Branch Canal No. 16 is the extension of the tail end of the main canal.
Source: Field observation (1992-93).

As shown in Table 4.3, the outlets of Branch Canals 2, 3, 5, 8 and 9, have more than one pipe of the same size or different sizes. The use of different pipe sizes in one outlet is the striking characteristic of this irrigation system.[24] By combining different sizes of pipes, the design engineers (later also farmers) have tried to provide the cross-sectional area of the pipe outlet close to the design area.[25]

Observations show that pipes at branch canal outlets are not placed at the same (invert) level, that is, at the same level above the bed of the main canal. In most of the branch canal outlets the pipes are at 15 to 30 cm above the bed of the main canal. On the downstream side, they are 20 to 55 cm above the bed of the (branch) canal. Some of the branch canals are cleaned and maintained by farmers such that their bed levels are even lower than the downstream protection apron of the outlet. This is done so that the farmers can see the pipes flowing freely and thereby judge the amount of inflow of water in the canal downstream.[26] The levelling survey of the outlet structures of the three branch canals (Branch Canals Nos. 3, 8, and 14) studied showed that the pipes in these outlets are at about 1/3 depth below the (apparent) full supply depth. However, they were at different levels with respect to the canal bed downstream because of the difference in cleaning by the farmers. Thus, they varied in hydraulic flexibility.

Another interesting feature of the pipe outlets with multiple pipes of different sizes is that the pipes are placed at the same invert level, that is, the bases of the pipes in an outlet are at the same level (Photo 4.2). The provision of multiple pipes at the same level in an outlet has implications for the hydraulic proportionality of the outlet and thereby for the even distribution of water. For the same water depth in the main canal each of these pipes will function differently in terms of the hydraulic flexibility, because the two pipes have different settings. For example, the outlet of Branch Canal No. 3 has pipes of two different diameter: one of 15 cm and the other of 23 cm diameter, both placed at the same invert level. Calculations show that at full supply depth the smaller pipe has unit flexibility, whereas the larger pipe results in flexibility less than unity. Further, the outlets having multiple pipes of different sizes have the smaller pipe placed upstream. An exception is the outlet of Branch Canal No. 9. It is not clear why smaller pipes are placed upstream.[27]

In summary, given the combination of weir-type checks and ungated pipe outlets that are approximately semi-modular, the irrigation system has the following two distinct technical characteristics, especially with respect to water control:

- The system is operationally rigid, as the outlets cannot be adjusted to deliver flows as required.
- The available flow at the (intake) head of the main canal intake is proportionally divided to the ungated outlets.

It should be noted that the flow in the main canal fluctuates rapidly since the irrigation system does not have a storage reservoir and is also without a permanent diversion structure. The degree of variation in flow is discussed further in section 4.4.

The simple technology of water division through ungated pipe outlets gives the impression that the irrigation system should be managed easily. Yet the organization and management effort of farmers shows that even distribution of water depends upon more than merely simplifying the physical system. The following section examines the organizational arrangements farmers have made for effective water control in the irrigation system.

Photo 4.2 An ungated multiple pipe outlet (Branch Canal No.8, 1993)

4.3 The organizational and institutional arrangements for water control

The current organizational and institutional arrangements for water control in the Pithuwa Irrigation System are the result of farmers' own initiative, trial and error, and adjustments made to suit the capacity of the irrigation system and the local farming and socio-political environment. The main driving force behind this development is the negligence in water allocation and distribution by the irrigation agency (Pradhan 1989: 21).[28]

Management under the Department of Irrigation

Until 1974, the irrigation system was managed by the *Khageri* (Chitawan district) sub-division office of the Irrigation Department (DOI 1987).[29] In practice, three *dhalpas* of the department operated the irrigation system and performed the routine maintenance of the main canal.[30] Two of them, both belonging to the village community, were still allocated to Pithuwa as part of the assistance from the District Irrigation Office.[31] One stayed at the intake and operated the main canal headgate, and the other patrolled the canals. Interviews with them indicated that before the farmers' take-over of the system management their task was mainly to release and maintain a continuous flow in the main canal during the irrigation season. The *dhalpas* also preferred to confine their activities to the operation and maintenance of the main canal only. As one of them said: 'Getting involved in the difficult task of distributing water evenly among branch canals and within a branch canal means putting oneself in danger of being unfriendly to many villagers. Since we stay in the village, we do not want to create enmity with the villagers.' Thus, from the outset, the water distribution within branch canals was left totally to the farmers. Farmers interviewed indicated that the maintenance of branch canals was also largely done by the farmers at that time.

Whereas the irrigation agency presumed that farmers would distribute water below the main canal level themselves, farmers considered that it was the responsibility of the government (irrigation) agency to manage water in the irrigation system built by the government. As Pradhan (1989: 19) noted, '... water in the canal was considered as a government resource, and farmers believed that they would be better off by extracting as much of this resource as possible ...'. This difference in perspective between the farmers and irrigation agency resulted in an anarchic use of canal water by farmers. Irrigation was achieved in a total area of about 100 hectares only, mostly confined to the head-end area of the main canal (Shrestha et al. 1992).

Water users' organization

The creation of the water users' organization: farmers' intervention for social control

The formation of water users' organization in Pithuwa was strongly influenced by the need for equitable distribution of water for irrigation. The farmers were aware of the potential of the irrigation system. They understood that the existing irrigation situation could be improved through an organized and cooperative effort. The initiative towards organizing farmers was taken by an enterprising farmer, who had experience of irrigated farming in a large farmer-managed irrigation system in the Rupandehi district.[32] He convinced his fellow farmers that the water distribution problem could be solved if all agreed to the distribution strictly according to the time allotment, the duration of time each farmer uses the canal water being proportional to his landholding. This time-based water distribution principle was first implemented in 1974 in the command area of Branch Canal No.8 where the farmer had his landholding.[33] A water management committee was formed, and rules and regulations for water distribution were formulated and strictly followed. As a result, the water distribution within the branch canal improved tremendously since everyone experienced the benefit by complying with the rules of turn taking they themselves had set (Pradhan 1989: 21). The successful water distribution in this branch canal impressed and motivated other farmers.

Farmers in other branch canals also formed their committees and implemented the time-based water allocation and distribution rule. Eventually an organization of water users at system level, the main committee, came into being in September 1975.[34] This shows that good leadership, especially from the farmers themselves, greatly enhances the organizing activity, and that farmers are more likely to follow and enforce rules they themselves have drawn up than those handed down by an outside authority.

It should be noted that the irrigation agency did not interfere with the governing of the irrigation system and management of the day-to-day water distribution activities by the farmers.[35] The non-interference of the irrigation office encouraged the farmers to develop their irrigation organization. This agrees with the argument by Tang and Ostrom (1993) that farmers should have freedom to develop and enforce their own management arrangements.

The main committee made guiding decisions on the day of its formation. The record of the minutes of the meeting on that day shows that the decisions mainly relate to the following: (i) equal distribution of water among all branch canals from head to tail; the mode of distribution being such that all branch canals are to receive continuous supply so long as there is an adequate flow in the main canal to deliver water up to the tail end, (ii) voluntary contribution of labour based on the households from each branch canal, for the construction of the diversion dam and repair and maintenance of canals, (iii) sanctions for absentees in the repair and maintenance, and (iv) maintaining good linkage with the government irrigation agency for assistance on matters related to the irrigation system. Further, the main committee was empowered to decide the water distribution schedules for branch canals when there is an inadequate flow in the main canal. Clearly, these decisions were based on practical considerations and experience, and they became the general guidelines for the main committee to follow in the subsequent years.

Structure of the organization and its functions at different levels
The two-tier water users' organization is called the "Pithuwa Sinchai Suvyawastha Samiti", meaning Pithuwa Irrigation Management Committee (PIMC). Figure 4.7 shows its organizational structure and the number of committee members at two levels. Clearly, it is a channel-based organization.

In addition, there is a general assembly of farmers. All farmers using the irrigation system are members of the general assembly. The general assembly of farmers meets at least twice a year, in the beginning of the paddy and winter crop seasons, to discuss various matters related to the management of the system. The meeting of the general assembly is held in the premises of the office of the Village Development Committee. Farmers from each branch canal also have their own branch level assemblies.

As shown in Figure 4.7, the main committee consists of twenty three members, including the chairperson called *adhakshya*, vice-chairperson (*upadhakshya)* and secretary (*sachiv*). The three functionaries of the main committee are elected by the general assembly of farmers.

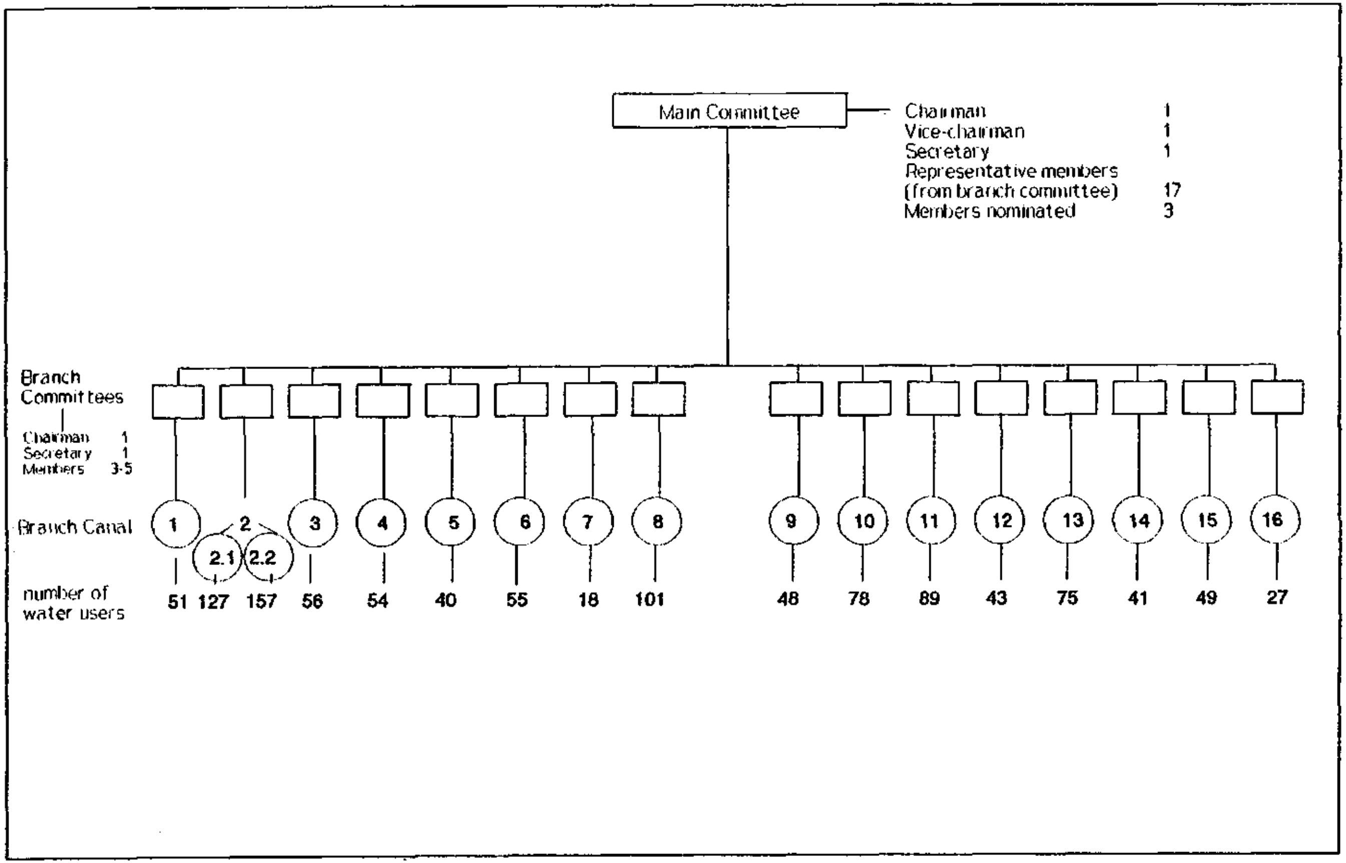


Figure 4.7 Organizational structure of the Pithuwa Irrigation Management Committee in 1993 (Sources: Field observation and records of the PIMC, 1992-93.)

The remaining 20 members include 17 chairmen of the branch level committees (hereafter called the branch committee) and three additional members who are selected from the group of experienced and progressive farmers.[36] The three selected members usually act as advisors to the main committee.

At the branch level committee, there are only two functionaries, the chairman and the secretary. The total number of members in a branch committee, including the chairman and the secretary, varies from 5-7 depending upon the numbers of farmers in the branch canal. The branch committee members are elected by the general assembly of farmers of the branch canal. The executive members at both organizational levels have tenure for two years and perform their duties and responsibilities without any remuneration.

The chairman of the Pithuwa Village Development Committee is usually the chairman of the main committee *ex officio*.[37] This arrangement also shows farmers' practical consideration of the power of politics. Doing so has helped the water users' organization in two ways. First, the support and commitment of local leaders to the water users' organization is obtained and thereby the danger of organizational conflict with the VDC is reduced. Second, dealings with the government agencies, especially the Irrigation Department and the District Irrigation Office, and non-government agencies for obtaining financial and technical assistance are very effective.

Rules, regulations and responsibilities are rational instruments intended to aid task performance. The rules, regulations, and functions of the main and branch committees have been well developed over time to enable the organization to effectively manage the irrigation system. The rules and regulations for the election of committee members, the functions of the general assembly of farmers and the main and branch committees, and the roles and responsibilities of the functionaries of the committees at both levels are laid down in the constitution of the PIMC.[38]

Tasks of the main and branch committee

The primary function of the main committee is to supervise the overall operation and maintenance of the irrigation system. The principal tasks of the main committee are as follows (Shrestha et al. 1992):

- maintaining coordination among various branch committees,
- mobilizing of local (voluntary labour) and external resources (especially government resources) for the construction of the temporary diversion dam in the river and the operation and maintenance of the main canal,
- ensuring the even allocation and distribution of water to all branch canals,
- resolving irrigation-related conflicts that are referred to by the branch canal committees, and
- participating in the irrigation management training programmes conducted for farmers (also for engineers) from other irrigation systems in the country.

Observation show that the main committee is necessarily very active from May to July when resources have to be mobilized to reconstruct the temporary diversion dam and repair and clean the main canal for the coming irrigation (paddy) season. While the chairman is responsible for the arrangement of local and outside resources, the secretary is responsible for organizing the annual cleaning and repair of the main canal, for keeping the records of all income from the fines and fees, budget and materials received from the irrigation office, expenditure on maintenance works etc.[39] He must also keep minutes of meetings.

The main tasks of the branch committee are as follows:

- ensure equal distribution of water to all farmers within the branch command area according to a roster,
- repair and maintain the branch canal,
- penalize the farmers who default or disobey the water distribution schedule and the decisions on repair and maintenance,
- report water related conflicts that could not be resolved at the branch level to the main committee,
- register the farmers' landholding and irrigated land within the branch canal and report to the main committee for water allocation, and
- carry out the decisions of the main committee.

The chairman of the branch committee is responsible for communications between the branch committee and the main committee, and for settling the water related disputes in the branch canal. The secretary of the branch committee keeps the records of the farmers' landholding and is also responsible for preparing and monitoring the water allocation and distribution schedule within the branch command area. Since water allocation to a farmer is based on the landholding, the record of the landholding must be updated every year. The secretary thus needs to be much more active and must interact more with the farmers than the chairman. By comparison, the branch committee is more active than the main committee during the irrigation season, particulary from July to October (see Section 4.4).

Decision making process
Farmers in Pithuwa make decisions jointly. Any alteration or improvement required in the main or a branch canal is discussed and decided by the main committee or the respective branch committee in a general meeting. Modifications to the rules for sanctions and fines are decided similarly. The decisions are recorded in the minutes of the meeting and monitored by a group of persons selected from among the members. How to implement the decision is thoroughly discussed during the meeting. Such collective decision making is likely to bring stability in the changes made in the physical system. This is corroborated by the fact that the hydraulic boundaries of branch canals and the size of pipes in branch canal outlets which were fixed during the remodelling period have remained the same to date.

Further, each branch committee can make its own decisions about the water allocation and distribution within the branch canal, maintenance of the canals and water related conflicts. This decentralized authority to the branch committee is desirable for the flexibility in water management within the branch canal (see Section 4.4).

However, it is difficult for the farmers to decide upon alterations in the physical system built by the government, mainly because the criteria of the system design are not clear to them. Farmers are therefore likely to refer the matter to the District Irrigation Office before making a final decision. For instance, the design engineer's assumptions in fixing the pipe size at the outlet of a branch canal are not known to the farmers. In the meeting of June 26, 1992 when there was prolonged discussion about the excess and deficit of water in some of the branch canals, the chairman of the main committee remarked: 'We do not exactly know what size of pipe can irrigate how many hectares of land. The capacity of an outlet to irrigate the land area should be examined by a technician' (Own field notes: 26.06.92).

Indeed, the size of a pipe outlet is a matter of great concern to the farmers. Making a decision to alter the size of the pipe in an outlet is difficult, since an increase in the size of an outlet upstream would decrease the flow downstream where the flow in the (supply) canal is continuous and the outlets are without gates. The downstream farmers would, therefore, object to the demand of upstream farmers for an increase in the outlet size. Negotiations between the farmers of adjacent branch canals are then most likely to take place. Sometimes, an external factor like the availability of pipe becomes the deciding factor. The alteration of the pipe in the outlet of Branch Canal No. 3 illustrates the influence of the availability of the pipes. This outlet was the first outlet to be altered and was initially provided with a single concrete pipe of 23 cm diameter which, according to the farmers, could not provide adequate water to the cultivable area fixed. Now it has two pipes: one of 15 cm diameter and the other 23 cm diameter (see Table 4.3). The farmers of this branch canal demanded the 23 cm diameter pipe be replaced by one of 30 cm diameter. In the general meeting of September 23, 1975 (Nepali date: *Aswin* 06, 2032), having considered the farmer's demand, the main committee decided to request the irrigation office to replace the existing pipe by a pipe of 30 cm diameter.[40] Eventually, a 15 cm pipe was added at the outlet. Indeed, in this case, the availability of pipes from the irrigation office had influenced the ultimate size of the outlet. Note that the total cross-sectional area of the two pipes of 15 cm and 23 cm diameter put together (592 cm^2) is less than that of a 30 cm diameter (area: 706.8 cm^2).[41]

Therefore, despite the adjustment in the pipe outlets through collective decision, there are inequalities in the pipe sizes per unit land area served by the branch canals (see Table 4.3). The inequality in the outlet size is also caused by the manipulation of the resources (in this case, concrete pipes received from the irrigation office) by influential farmers who can influence local decision making. Farmers of Pithuwa are aware of the inequality in the flow through these outlets and bring up this issue time and again during the general meeting of the main committee. The prolonged discussion among the members of the main committee in the meeting of June 26, 1992 about the oversize of the pipe at the outlet of Branch Canal

No. 7.1 verifies this. Originally, this outlet had a pipe of 15 cm diameter. Now it has a pipe of 23 cm diameter for an irrigated area of 8 hectares (see Table 4.3). Farmers interviewed indicated that during the remodelling period the then main committee secretary who has his land within the command area of this branch canal managed to have the larger pipe installed. But according to this ex-secretary, the present pipe is placed high above the bed level of the main canal and hence discharges less water. (It was observed that the pipe was indeed placed rather high above the bed level of the main canal.) In the meeting, he further argued that the pipe size was selected by the overseer of the irrigation office and not by him.[42] The discussion in the meeting ended with the members agreeing with the proposal to have the flow capacity of all oversize pipe outlets examined by a technical personnel.[43] This implies that technical assistance can help resolve water related conflicts among farmers.

Resource mobilization for operation and maintenance of the irrigation system

Farmers of Pithuwa use both outside and local resources to operate and maintain the irrigation system. The operation of the Pithuwa Irrigation System is dependent upon the construction and maintenance of a temporary diversion dam on the *Kayer* river every year. The temporary diversion dam is constructed just before the monsoon season to enable farmers to grow monsoon paddy. It is difficult to maintain the temporarily built diversion dam during the monsoon season because of the hydrology of the river. The diversion dam is often damaged or washed away by floods a number of times in each monsoon and each time requires an enormous effort to repair when done with manual labour. For some years in the beginning, farmers used their own labour and local resources to construct, repair and maintain the diversion dam.[44] If there was severe damage, it took several man-days to complete the repair. This difficulty led the farmers to seek an alternative means to construct and maintain the dam. In 1980, after constant persuasion, farmers were able to get a bulldozer from the irrigation office (Chitawan Irrigation Project) for the construction and maintenance of temporary diversion. Since then, a bulldozer has been obtained every year in the monsoon season; it is kept at the intake site throughout the season.[45] In addition to the machine, the Irrigation Department allots a nominal amount of budget every year for the operation and maintenance of the irrigation system. The budget is handed over to the main committee. According to the main committee records, the annual budget available from the irrigation office is insufficient even for the construction and maintenance of the temporary diversion dam.[46]

As mentioned earlier, the irrigation system suffers from severe silting, especially in the main canal. Since the limited annual budget provided by the irrigation office is spent on the construction and maintenance of the diversion dam on the *Kayer* river, farmers have to contribute their labour and/or cash to accomplish the routine maintenance and repair of the canals. Every year, at the end of June or just before the rice is planted in July, the main canal is cleaned and repaired. Farmers from all branch canals are compulsorily required to contribute their labour in the cleaning of the main canal. No one is excused from contributing his or her share of labour in the cleaning.[47] For cleaning, the total length of the canal is divided among branch canal committees in proportion to the outlet sizes. The length and the portion of the canal to be cleaned by the farmers of each branch canal is determined on the basis of the sum of the pipe diameter in the branch canal outlet and is decided at the site.[48] The depth (thickness) of the silt deposit in the canal is also taken into account so that the volume of the sediment to be removed is also divided proportionally. Based upon the allotted length to be cleaned, the branch committee secretary then determines the share of the length to be cleaned by an individual person. It is however observed that this rule is not followed by every branch committee. Farmers of some branch canals cleaned their share of the main canal by dividing the allotted length according to mutual agreement.

In July 1992, farmers of a branch canal were allocated stretches of the main canal varying from 3.5 to 4.75 metres per cm diameter of the outlet pipe (9 to 12 metres per inch diameter). This time, farmers were able to obtain an excavator from the District Irrigation Office to clean the main canal.[49] Whereas the thick sediment deposits in the first 2 km of main canal was removed by the excavator on loan from the irrigation office, the farmers cleaned the remaining 3 km stretch.

Branch canals are usually cleaned only once a year. The cleaning of all branch canals is generally completed before the transplantation of paddy begins. In some branch canals farmers have to clean their canals twice a year because of the excessive silting. The labour contribution in cleaning a branch canal is based on the landholding or the land area irrigated. It was observed that in some branch canals the branch committee hired individuals from the village community to clean and repair the canals. The cash required to hire such individuals is raised from all farmers served by the branch canal. In this way, unlike in some farmer managed systems in Nepal, the labour or cash contribution of a farmer in the routine maintenance of the branch canal has no direct relation to the amount of water use.

In addition to the routine maintenance of the irrigation system, farmers have invested in the improvement of the physical system for better water allocation and distribution within their branch canals. The water division structure of brick masonry built at the first bifurcation point in Branch Canal No. 10 is an example. When cash is required for such improvement works, it is collected at a fixed rate per land area irrigated.

Linkage with the irrigation agency: increase in dependence on the government resources
From the outset, the PIMC has persistently interacted and maintained good relations with the Irrigation Department and the District Irrigation Office.[50] The persistent interaction has enabled the farmers' organization to continually receive material, financial and technical assistance from the government for the operation and maintenance of the irrigation system. The main reason for seeking government assistance is the essential construction and maintenance of the temporary diversion dam on the *Kayer* river every year in the monsoon season. Further, the irrigation system is not officially handed over to the farmers yet.[51] Apparently, the government still feels responsible for providing budgetary assistance to the farmers for the operation and maintenance of the irrigation system.

Although the continual assistance from the Irrigation Department has greatly helped the farmers operate and maintain the irrigation system, it has led to the farmers becoming very dependent on the government agency, particularly for machinery. In June 1993, the chairman of the main committee visited the District Irrigation Office to discuss about the bulldozer. He had a letter from the DOI in Kathmandu instructing the irrigation office to arrange the transport of the bulldozer that was at the West Gandak Irrigation Project to Pithuwa because the bulldozer used the previous year had broken down and its repair would have exceeded the budget available for the repair and maintenance of machines.

The dependence on the bulldozer and excavator of the Irrigation Department and the increasing unreliability of these ill-maintained machines is being seriously considered by the progressive farmers of Pithuwa. Interview with these farmers indicated that alternatives like obtaining small earth-moving equipment e.g. farm bulldozers, with the loan from commercial banks or from the government irrigation projects implemented in the Chitawan Valley like the East Rapti Project, which intends to assist farmer-managed irrigation systems in the Valley, are being considered.[52]

The Pithuwa Irrigation System has been operated and maintained by the farmers since 1975 under the organizational and institutional arrangements described above. The following section examines the principles and actual practice of water allocation and distribution.

4.4 Water allocation and distribution

Principles of water allocation and distribution

Basically, water allocation (by farmers) in Pithuwa is proportional to the land area. When the main canal is running at or near its full capacity, the flow in the canal is divided proportionally to each branch canal through the ungated pipe outlets whose sizes have been determined on the basis of the land area served.

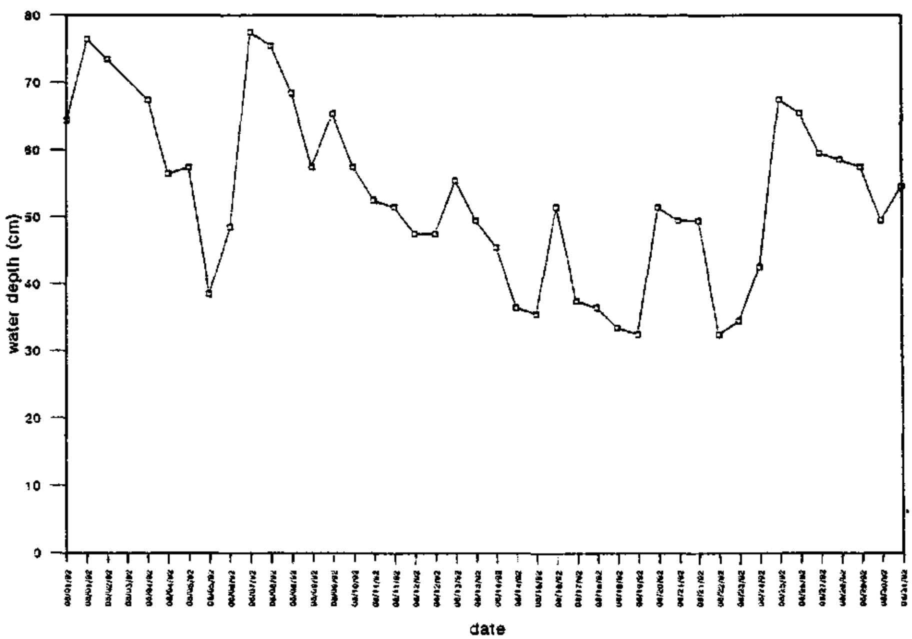
Within a branch canal and at farm level, the allocation of water is in terms of the time share proportional to the landholding.[53] The time allotted to a farmer to use canal water is 90 minutes per hectare (one hour per *bigha*, hereafter called basic time) of land cultivated with paddy.[54] Farmers interviewed indicated that this time period was fixed on the basis of their practical experience in irrigating paddy in the area with the canal water. The basic time share is generally used when the flow in the branch canal is at or near full capacity. It is increased when the flow in the branch canal is reduced. The time share is allotted to individual farmers who have registered their landholding with the branch committee.[55] The allocation of water to a farmer is irrespective of whether he is the owner cultivator or a tenant. The time-share distribution of water is by rotation, usually beginning from head to tail end of the (branch) canal.

All branch canals are to receive water continuously as long as there is adequate flow available to deliver water to the tail end of the main canal. Indeed, a continuous and reliable flow in a branch canal is necessary for the effective implementation of such time-share (rotational) distribution of water within the branch canal. Rotational distribution among branch canals is necessarily followed only when the flow in the main canal has fallen to considerably below the full capacity. The duration of time for a branch canal or a group of branch canals to use water and the order of rotation are decided by the main committee, depending upon the flow in the main canal. Apparently, the rotation usually begins from the tail end and proceeds towards the head end of the main canal.[56]

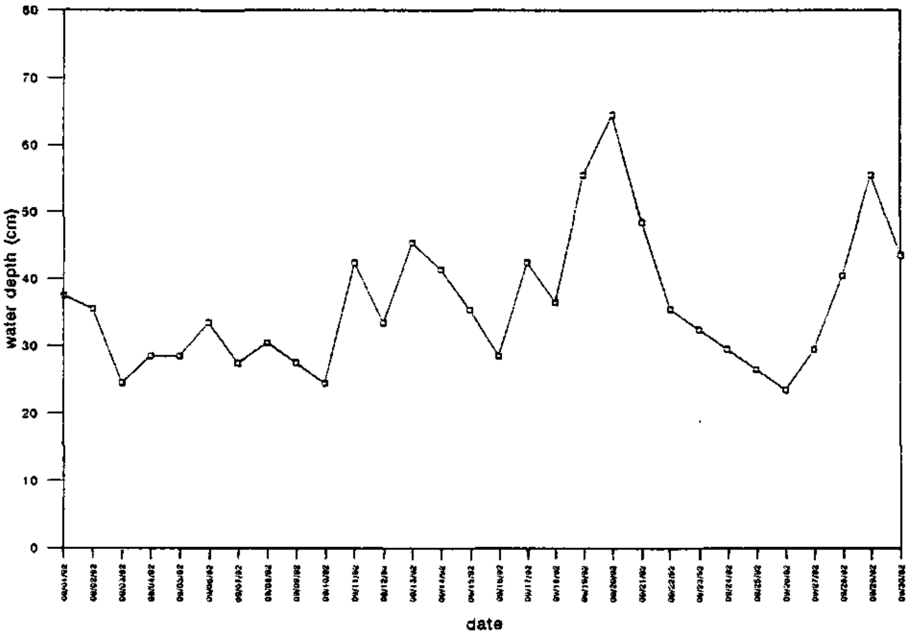
It is useful to know at this stage the degree of variation of flow in the main canal and the resulting flow in the branch canals before discussing the water distribution practised by the farmers.

Flow variation in the main canal and branch canals

The flow in the main canal varies with the variation in the flow in the *Kayer* river, given the design of the irrigation system. Figure 4.8 presents the fluctuation of water level in the main canal during the period from August-October 1992. Note the frequent and pronounced variation of flow in the canal. This is primarily due to the hydrology of the source river. In a situation where water supply changes frequently, a continuous flow in the main canal and rotational distribution within branch canals allow the available flow, whether large or small, at a particular time to be shared by those farmers who are irrigating at that time.



Fluctuation of water level in the main canal in August 1992



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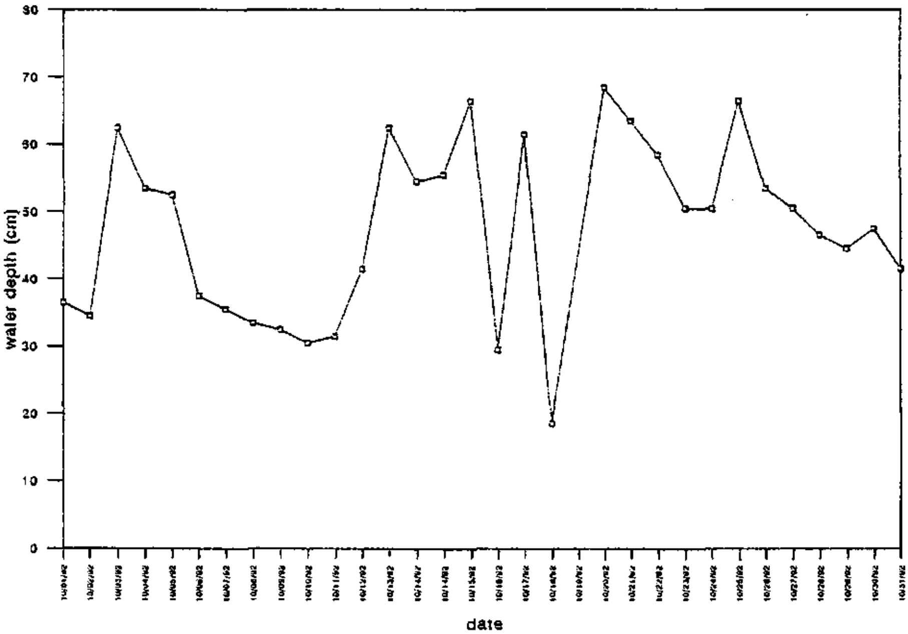


October 1992

Figure 4.8 Fluctuation of water level in the main canal in Pithuwa (near the outlet of Branch Canal No. 8) during August-October 1992 (Source: Field measurement.)

Flow in a branch canal varied with the variation of flow in the main canal, given the ungated pipe outlets. Figures 4.9 through 4.11 show the flow measured in the head of the three branch canals studied in August 1992.[57] The flows measured at these places in the months of September and October 1992 are presented in Appendix 11. The inflow in the main canal was maximum in the beginning of August. Consequently, all branch canals had the maximum flow of the season in that month. The maximum flows in the three branch canals were as follows: 278 lps in Branch Canal No. 3 (area: 28.29 ha); 205 lps in Branch Canal No. 8 (area: 64.97 ha); and 135 lps in Branch Canal No. 14 (area: 20.33 ha). This gives the maximum water actually available as 9.8 lps per hectare, 3.15 lps per hectare and 6.65 lps per hectare for Branch Canals No. 3, 8, and 14 respectively. Such variation of flow rate among the branch canals would be unexpected in an irrigation system in which water allocation in each branch canal is proportional to the area served. The following two factors apparently caused the inequality in flow per unit area in the branch canals. The first is the fixing and re-fixing of the hydraulic boundaries of branch canals by the farmers on the basis of their convenience and practical considerations to irrigate and not on the actual capacity of the outlet. The second is the different setting of the pipes at outlet structures with respect to the design water level in the main canal and the bed level of the canal downstream. For example, the outlet of Branch Canal No. 14 always had water flowing freely downstream because the bed of the downstream (branch) canal was well below the level of the pipe. Whereas, the flow through the other two outlets was submerged at the downstream side, especially when the main canal had large flows.

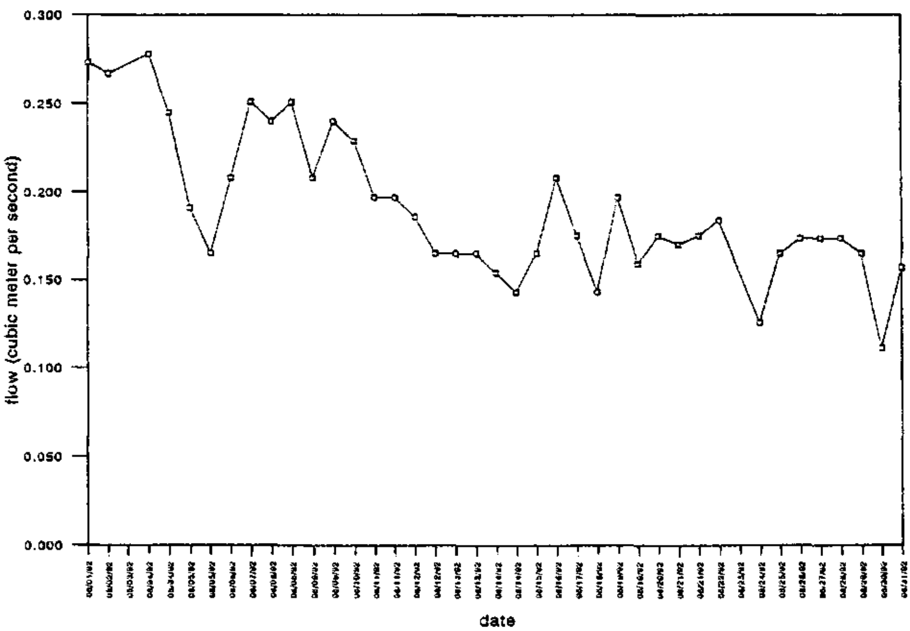


Figure 4.9 Flow variation in Branch Canal No.3 in August 1992 (Source: Field observation.)

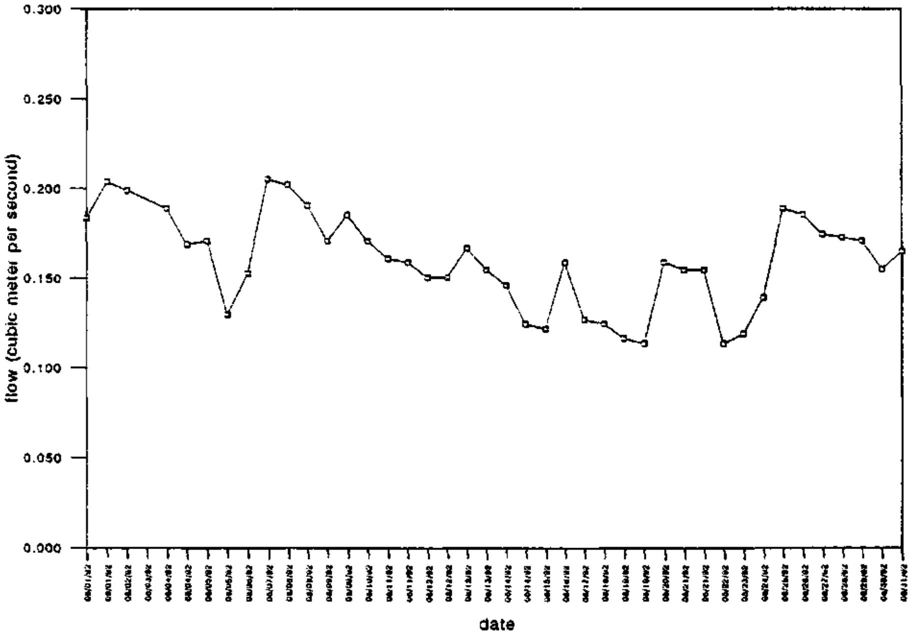


Figure 4.10 Flow variation in Branch Canal No.8 in August 1992 (Source: Field observation.)

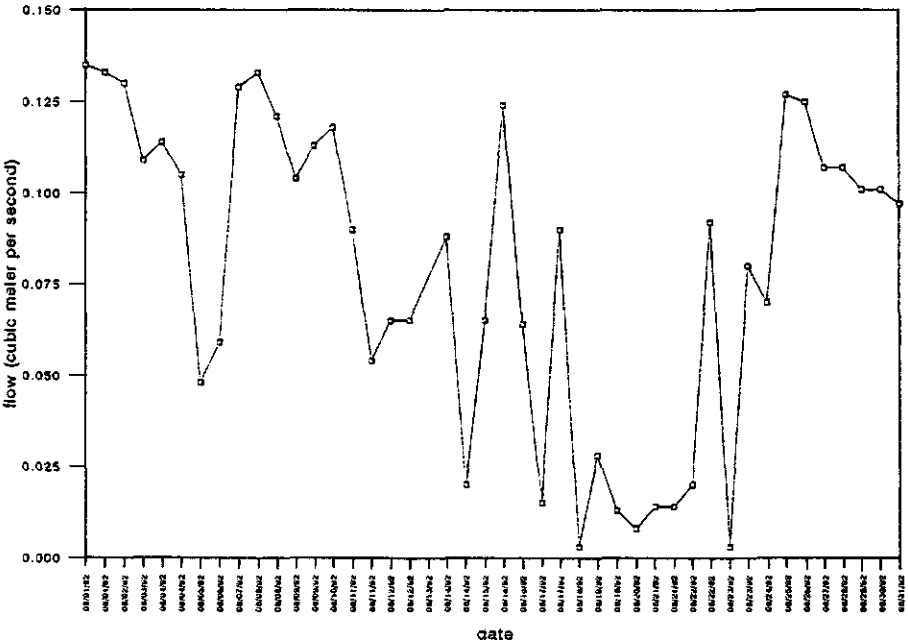


Figure 4.11 Flow variation in Branch Canal No.14 in August 1992 (Source: Field observation.)

The measured flows per unit area are quite high compared to the normal design water requirement of 1 lps per hectare prescribed by the engineers for the *tarai* region. However, observation of standing water in paddy fields showed that a water allowance greater than the conventional design water requirement of 1 lps per hectare is apparently required in Pithuwa to compensate for the high percolation which is observed to be mainly due to the quick puddling of soil during the land preparation. It was observed that some of the paddy fields in the three branch canals studied were without standing water even when there was adequate flow in the canal.

Actual practice
Irrigation in Pithuwa is actively practised during the monsoon season to grow paddy. The cultivation of paddy is completely dependent upon irrigation in spite of the wet season. Throughout the paddy growing period, canal water is only used for irrigating the paddy crop, though a small amount of maize is also grown at the same time as the paddy. Farmers do not (have to) depend upon the monsoon rainfall because they can rely on the water from the irrigation system. The rainfall during the wet season is rather taken as complementary to the canal water. Since farmers depend on the canal water for growing paddy, they are more concerned with the rainfall in the watershed of the source river than the rainfall on their fields.

Water allocation and distribution for paddy
In general, there are two distinct irrigation water requirements for paddy cultivation: (i) water for land preparation and transplantation of paddy seedlings, and (ii) irrigation to maintain the required depth of water after the transplantation. Observation of the cultivation of paddy in Pithuwa, however, showed three types of irrigation water requirements: (i) water for land preparation and transplantation of paddy seedlings, (ii) first irrigation within 24-48 hours after transplantation, and (iii) irrigation for the maintenance of water layer in the paddy field. To meet these three irrigation requirements, farmers in Pithuwa manage the allocation and distribution of water in a systematic and intensive manner.

The main canal continuously runs with water throughout the period of paddy cultivation. Since the flow in the river varies rapidly, the head regulator gate of the main canal is usually kept raised in order to allow water to the maximum capacity of the canal, even though it can be operated to adjust the flow in the canal. The gate is only lowered or shut during the flood in the river to prevent water overtopping the canal bank.

The irrigation activity in the command area of a branch canal begins with the allocation and distribution of water for the transplantation of paddy seedlings.[58] At the end of June every year, each branch committee holds a meeting of the assembly of the farmers to deicide, among other matters, the starting date of transplantation.[59] The secretary of the branch committee decides the place, day and time of the meeting. The meeting is generally held either at the open courtyard of the secretary's or the chairman's house or at a place convenient to all farmers. In the meeting, the farmers who are prepared to begin the transplantation give their names and the land area to be cultivated with paddy in that season to the secretary of the branch committee. The roster of farmers who will transplant first is decided in the meeting. Clearly, the start of the roster is independent of the location of the field in the command area of the branch canal. The day, order of turn and duration of time (when to begin and end) to use water are clearly mentioned in the roster. The secretary then issues the roster to each of the farmers in advance.

The turn to use water for transplantation of paddy seedlings is called "*ropai palo*" (meaning transplanting turn) in the local vernacular. The transplanting is done during the day time, from 6 am to 6 pm. The allotment of time to use water is based on the actual land area to be transplanted. In allocating water for the transplantation, the basic time of 90 minutes per hectare is not applied. The amount of water available in the branch canal on the day determines the total land area that could be transplanted on that day. Often the roster needs adjustments because of the variation in the (supply) flow in the canal.

Observation in the 1992 paddy season showed the total land area that could be transplanted in a day under the current cultivation practice to be about 3-4 *bigha* (2-2.5 ha), when the branch canal had a flow at or near its full capacity. In this way, only 4-5 farmers could transplant their paddy seedlings in one day. Both the land preparation - soaking, tilling, puddling and levelling of the field - and transplantation are accomplished within the time allotted to use water. Since most farmers prepare their land using hired farm tractors and animal-drawn ploughs, the reliability of canal water is very important. Sometimes, because of the reduced flow in the canal or for other practical reasons, a farmer is allowed to continue transplanting until 7 pm, if at the end of the day he is left with a small area to be transplanted. But the farmer must request the secretary of the branch committee for the extension so that the roster of farmers using water at night can be adjusted.

The diversion of water from a branch canal into the cultivated fields is handled by the individual farmers themselves. As a farmer's turn to use water approaches, he goes to his field and diverts the water exactly at the time allotted to him by checking the water with a timber board check and cutting the canal bank. The farmer having the next turn diverts the water to his field similarly. In this way, no separate irrigator is required, and the monitoring of water use turns is automatically done by the farmers themselves. Farmers in some branch canals are so concerned about the leakage of water downstream that they seal the joints between the timber planks in the checks with rubber inner tubes from bicycle tyres.

When the flow in the branch canal is too small for all the farmers in a day's roster to complete transplantation on that day, some of the turns are shifted to the following day.[60] Sometimes, on the days of low flow in the canal, the farmers who have small holdings but have their turns on the following day are allowed to transplant, if they are prepared to do so. The adjustment of turns is decided by the secretary of the committee. If, after the allotment of the water use turn, a farmer decides to continue with the transplantation because there happened to be a good rainfall, he is barred from using the canal water throughout the paddy season. Therefore, farmers prefer to wait until there is sufficient water in the canal to accomplish the transplanting.

The soil in Pithuwa is such that the first irrigation to a paddy field be applied within 24-48 hours after the transplantation. According to the farmers, this is necessary to prevent cracks from developing and remaining permanently thereby making it difficult to maintain the water layer. The quick land preparation (land soaking and puddling) appears to favour the development of cracks.

The first irrigation is called "*maar pani*" by the farmers. (It is not clear why this is called so.) The turns for first irrigation are scheduled at night only, from 6 pm to 6 am.[61] This allows the transplanting to be continued in the day time. The time allotted for the first irrigation is according to the basic time share of 90 minutes per hectare. However, for first few days after the transplanting has started, the farmers who are entitled to first irrigation are few and therefore get more share of time for the first irrigation as the total period of twelve hours is distributed among the few farmers, based on this allocation principle. Thus the farmers who begin transplanting early are likely to get more water for the first irrigation. As more farmers finish transplanting, the time allotted for the first irrigation gradually reduces to the basic time share.

Irrigation is required to maintain the water layer in paddy fields soo after transplantation. Therefore, the allocation of water for this purpose is also arranged at night, maintaining the priority for the first irrigation turn. In this way, the management of three irrigation requirements begins within a few days after the transplanting has started. This method of water allocation and distribution in which the first irrigation and the subsequent irrigation for maintaining the water layer takes place at night continues until all the farmers who wish to grow paddy have finished transplanting. Clearly, this requires intensive management of water.

A new schedule of water use turns is prepared by the secretary of the branch committee when all the farmers growing paddy have finished transplanting. The water distribution begins from the head to tail end of the branch canal. This schedule is then followed until the paddy crop is ready for harvest. The irrigation turn allotted to maintain the water layer in the paddy field is locally called "*palo pani*" (meaning water turn). In this irrigation allotment, the basic time of 90 minutes per hectare is followed. The time and duration of water use is usually issued by the secretary of the branch committee to each individual farmer in writing in a piece of paper. Once a farmer gets his water use turn, he or she must use the water at the time allocated, or must wait until the next turn. However, mutual exchange of turns between the neighbouring farmers also occurs. Such mutual arrangements are immediately reported to the secretary who revises the roster accordingly.

As shown in Figure 4.6, the land areas under some large branch canals are divided into sub-units or sub-areas to facilitate the management of water distribution within the branch canal.

Each sub-unit is allotted a time share proportion to the area of paddy cultivation. The basic time is used to determine the time share of the sub-unit. For instance, in the 1992 paddy season, the sub-unit 1 of Branch Canal No. 8 having a total cultivated land area of 16.12 hectares (see Table 4.2) was allotted a time share of 20 hours and 4 minutes on the basis of the land area cultivated with paddy. Each sub-unit has a representative member in the branch committee. Within a sub-unit area, the member allots the time share to the farmers. The order of rotation is from head to tail end of the canal.

Observations in the three branch canals studied showed each branch committee making its decisions on water allocation and distribution independently of others. Whereas the order of turn followed in each of the branch canal was from head to tail end of the canal, the time share deviated from the basic time allotment of 90 minutes per hectare from one branch canal to another, even at the same period. The basic time share was doubled when the flow in the branch canal had fallen considerably. The increase in the length of the basic time is decided by the branch committee after visual observation of the flow in the canal. The time share used in Branch Canal No. 14 was 180 minutes per hectare throughout the 1992 paddy growing period, whereas the basic time share could be followed in the other two branch canals initially, because flow was adequate. The freedom of decision making about water allocation and distribution has enabled the branch committees to achieve flexibility in operation.

Clearly, such an intensive management of water allocation and distribution is only possible when there is continuous and reliable flow in the branch canal and there is good communication between farmers and the committee secretary (or the member) responsible for organizing the distribution. The water control technology of proportional division of flow through ungated pipes has allowed the continuous and reliable delivery of water to each branch canal. The communication between farmers and the secretary of the committee (and also between the farmers) is facilitated by the close proximity of the farmers' residences to each other and to the irrigation system. Further, the pattern of land distribution has enhanced the rotational water distribution from head to tail end of the canal. Every farmer could directly irrigate from the branch or sub-branch canal without transporting water through the fields of another farmer.

Table 4.4 shows the schedule of water allocation and distribution followed in the 1992 paddy season in Branch Canal No.14 as an example. Note the allotted time share of 180 minutes per hectare. This schedule was applied from August 16, 1992 onwards, after all the farmers who wished to grow paddy in that season had finished transplanting. It was continued until it was time to harvest the crop.[62] Similar water allocation and distribution schedules were followed in Branch Canals No. 3 and 8.

Table 4.4 Water allocation and distribution in Branch Canal No. 14 during the 1992 paddy season

Farmer No.	Area with paddy		Time allotted		Date
	Bg-kt-dh	ha	from to	duration	
1	00-09-00	0.3	06 30 am - 07 30 am	1 h.	August 27, 1992
2	01-04-00	0.8	07 30 am - 10 00 am	2 h 30 min.	
3	01-03-00	0.77	10 00 am - 12 30 pm	2 h 30 min	
4	00-12-00	0.4	12 30 pm - 01 48 pm	1 h 18 min.	
5	00-12-00	0.4	01 48 pm - 03 18 pm	1 h 30 min.	
6	01-04-00	0.8	03 18 pm - 05 30 pm	2 h 12 min.	
7	00-08-00	0.27	05 30 pm - 06 30 pm	1 h	
8	00-05-00	0.17	06 30 pm - 07 00 pm	0 h 30 min	
9	00-15-00	0.5	07 00 pm - 08 30 pm	1 h 30 min	
10	00-10-00	0.33	08 30 pm - 09 30 pm	1 h	
11	00-10-00	0.33	09 30 pm - 10 30 pm	1 h	
12	00-11-04	0.37	10 30 pm - 11 54 pm	1 h 24 min	
13	01-00-00	0.67	11 54 pm - 01 54 am	2 h	August 28, 1992
14	00-05-00	0.17	01 54 am - 02 18 am	24 min	
15	00-10-00	0.33	02 18 am - 03 48 am	1 h 30 min	
16	00-07-00	0.23	03 48 am - 04 30 am	42 min	
17	00-07-00	0.23	04 30 am - 05 12 am	42 min	
18	00-11-00	0.37	05 12 am - 06 18 am	1 h 06 min	
19	00-06-00	0.2	06 18 am - 06 54 am	36 min	
20	01-10-00	1	06 54 am - 09 54 am	3 h	
21	00-07-00	0.23	09 54 am - 10 36 am	42 min	
22	00-10-00	0.33	10 36 am - 11 36 am	1 h	
23	01-04-10	0.82	11 36 am - 02 06 pm	2 h 30 min	
24	01-01-10	0.72	02 06 pm - 04 18 pm	2 h 12 min	
25	00-17-00	0.57	04 18 pm - 06 18 pm	2 h	
26	00-06-00	0.2	06 18 pm - 06 54 pm	36 min	
27	00-08-00	0.27	06 54 pm - 07 42 pm	48 min	
28	00-15-00	0.5	07 42 pm - 09 12 pm	1 h 30 min	
29	00-19-11	0.65	09 12 pm - 11 12 pm	2 h	
30	00-06-00	0.2	11 12 pm - 11 48 pm	36 min	
31	00-15-00	0.5	11 48 pm - 01 30 am	1 h 42 min	August 29, 1992
32	00-12-00	0.4	01 30 am - 01 42 am	1 h 12 min[a]	
33	-	-	01 42 am - 02 18 am	-	
34	-	-	02 18 am - 02 42 am	-	
35	01-00-00	0.67	02 42 am - 04 42 am	2 h	
36	01-02-00	0.73	04 42 am - 06 42 am	2 h	
37	00-10-00	0.33	06 42 am - 07 42 am	1 h	
38	00-10-00	0.33	07 42 am - 08 42 am	1 h	
39	00-12-00	0.4	08 42 am - 09 42 am	1 h	
40	00-10-00	0.33	09 42 am - 10 42 am	1 h	
41	01-00-00	0.67	10 42 am - 12 42 pm	2 h	
1	00-09-00	0.3	12 42 pm - 01 42 pm	1 h	
Total		17.5		54 h 12 min	

Notes: Bg= *Bigha*; Kt= *Kattha*; dh= *Dhur*. 1 *Bigha* = 20 *Kattha*; 1 *Kattha* = 20 *dhur*. 1.5 *Bigha* = 1 ha
[a] This time duration is the total period allotted for the farmers 32, 33 and 34 who divided the land among themselves and distributed the water accordingly. Some differences in the time share compared to the land area is because of the difference in reporting by the farmer. However, these are only a few.
Source: Field observation (1992).

The water distribution schedule in Table 4.4 shows the following. First, the water is distributed from head to the tail end of the canal. Second, the allocation of the time share is rounded to minutes in proportion to the land cultivated with paddy. Thirdly, irrigation occurs day and night, and the day and the time of a farmer's turn varies throughout the irrigation season. In this case, each farmer had his turn after 54 hours and 12 minutes. By comparison, in a "*warabandi*" system of water distribution, the day and the time of a farmer's water use turn remains (theoretically) the same.[63] Fourth, no time is allowed for the seepage and travel time. This is because the canal runs continuously from the first day of the transplantation of paddy seedlings, and also because of the small area served. With such a precise allotment of time to use water, one would expect that farmers would have difficulty in keeping with the schedule. But it was observed that farmers followed the schedule with clock precision.[64] Observations of irrigation in the three branch canals showed the average number of water turns a farmer received during the 1992 paddy season to be 22. This was possible because every farmer strictly followed the roster.[65] Yet, many farmers in large branch canals complained of the long gap of time between the two turns, especially when the basic time had to be doubled due to the reduced water supply in the main canal.

Despite such proportional distribution of time for water use, a few cases of stealing water at night were reported. The conflicts arising from the stealing were, however, immediately settled by either the secretary or the chairman of the branch committee the following day. The water theft occurred during the period of low flow in the main canal implying that scarcity leads to conflict and breaking of rules, even in an irrigation system where water distribution is well organized.

Water allocation and distribution in the winter and summer seasons

The sowing of oilseeds and wheat follow soon after the harvest of paddy when there is still some moisture left in the soil. The water allocation and distribution rules used in the paddy growing period are no longer applied in the winter season, mainly because of the reduced flow in the source river.[66] Further, for the period from December to June, there is a traditional agreement between the Pithuwa and Chainpur villages about the use of water from the *Kayer khola*. Under this agreement, the former village can divert the water for twelve hours, from 4 pm to 4 am, while the latter uses it for the other twelve hours. This arrangement also makes it imperative for the farmers of Pithuwa to irrigate at night, even during the winter season.

Given these conditions of water availability at the source river, the farmers form Pithuwa have devised an interesting rule for allocating water for the winter crops. Usually no rotation among branch canals takes place. Water allocation and distribution occurs at the diversion point itself and is generally left to be managed by individual farmers themselves. A farmer who needs to irrigate his crops has to go to the intake before 4 pm to claim the water.[67] The water is allocated on the basis of "first come first served". This means that the farmer who is at the intake first has the first right to use the water. The distribution of time for irrigation

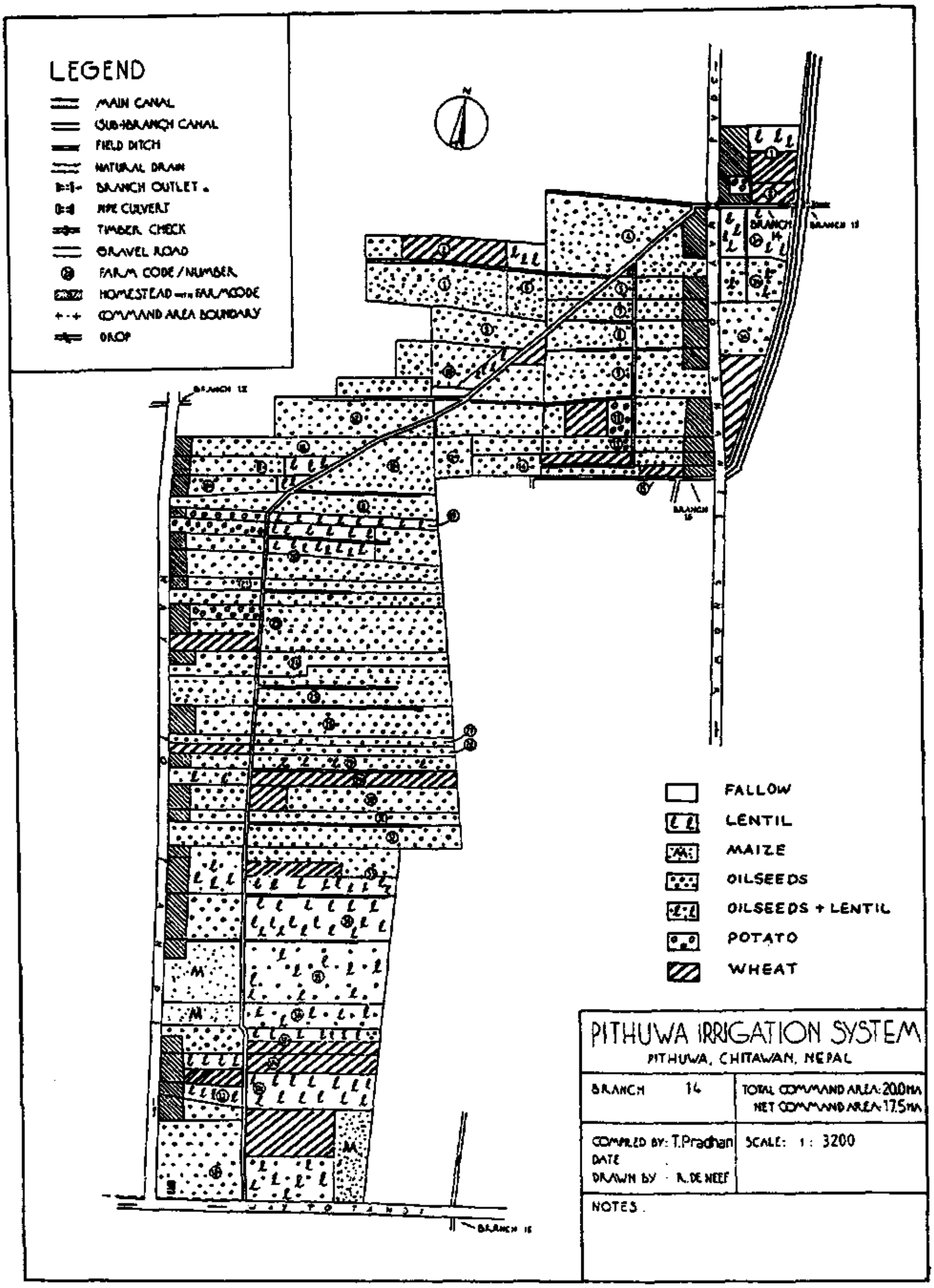


Figure 4.12 Crop cultivation in Branch Canal No. 14 in Pithuwa during the 1992-93 winter season (Source: Field observation.)

is decided mutually among the farmers present at the intake site on the day. However, observation showed that the farmers stayed on guard at the outlets of their branch canals and patrolled the (main) canal at night to ensure that other farmers did not steal water during their turn.

Figure 4.12 shows the cultivation of crops in Branch Canal No. 14 in the 1992-93 winter season. Clearly, the pattern of cultivation has no relation with the location of field in the command area of the branch canal because farmers no longer depend upon the canal water. Note the minor cultivation of wheat at the tail end of the canal. Similar observations were made in the command areas of Branch Canals Nos.3 and 8.

In the summer, virtually all farmers in Pithuwa grow maize which is sown immediately after the winter crops have been harvested (see Figure 4.3). Note the 100 percent coverage by the crop in Branch Canal No. 14 (see Table 4.2). Maize is the choice for the summer or pre-monsoon crop, primarily because of its low water demand. Observation shows that the sowing of maize is usually completed by the first week of April. By this time, the flow in the river is much reduced, and the chances to irrigate the crop are rare, even at the head-end area of the irrigation system. As one farmer said: 'We grow maize as a crop totally dependent on the rainfall that has the least chance of occurring.'

4.5 Summary and conclusions

This case study has shown how farmers on their own can manage an irrigation system built by the government. It has also illustrated that farmers are knowledgable and capable actors, and that they can play an important role in the effective management of irrigation systems. The technical and social order evolved by the farmers in Pithuwa can be regarded as the outcome of their knowledge of the irrigation system, the availability of water at the source, soil conditions of the area, limitations of local (labour and capital) resources, and marketability of the crops. Farmers initially presumed that the irrigation system would be operated and maintained by the Irrigation Department since it was built by the government. Apparently, it was also not clear to the Irrigation Department who should actually take the responsibility of the operation and maintenance, since the irrigation system was built as a minor irrigation scheme. As a result, neither the Irrigation Department nor the farmers paid full attention to the operation and maintenance of the irrigation system. But, the farmers chose to use the existing irrigation system to the best of their abilities, because they have no other alternative for irrigation. They began with an attempt to obtain fair allocation and distribution of water in one of the branch canals at the tail-end area of the irrigation system. Water allocation and distribution by time share in proportion to the landholding and in rotation was applied successfully and within a short period had been implemented over the entire irrigation system. For effective implementation of this water control principle, the farmers remodelled the existing physical system so that the available water could be proportionally shared to the land area. The gates at the outlets of all branch canals were removed, the size of outlets were adjusted and the hydraulic boundaries of each branch canal were clearly defined. In addition, rules and regulations for organizing the allocation and distribution of water down to farm level and imperative maintenance were established and followed strictly. Furthermore, farmers continued to maintain good relations with the district office of the Irrigation Department to obtain the assistance required for the effective management of the system.

The irrigation system in this case presents a simple design with ungated pipe outlets whose sizes are fixed proportional to the land area served. This case study has shown that such technology facilitates the effective implementation of rotational water distribution by time share at farm level, thereby enhancing the equitable distribution of water. This design also reduces the management input in terms of the staff required to operate the irrigation system. In this case, for example, the head regulator of the main canal needs to be operated only occasionally. The minimum staff input required is practical and important in this case, considering the resources available to farmers. This suggest that the simple design of the irrigation system in Pithuwa favoured the turnover of the management to farmers.

The case study has clearly illustrated that despite the simple technology of water control social (organizational) control is equally essential to achieve fair distribution of water, especially when every farmer is totally dependent upon the water from the irrigation system. Note the farmers' dependence on the canal water for growing paddy. Social control minimizes water related conflicts, abuse of physical structures, and enhances fair water distribution. As it appeared in this case, social control can be better managed by farmers themselves.

Water control is a complex process requiring intensive organizational effort. Empirical evidence from this case study has shown that the organizational effort in water control is required most during the period of peak demand for water. The organizational input of the branch committee in controlling water was the highest during the period of paddy transplanting which had to be accomplished within a defined period of time. Indeed the mode of water allocation and distribution largely influences the organizational input required. The irrigation management activities, such as decision making, communication and conflict management described by Uphoff (1986) occur almost simultaneously at field level.

The two-tier water users' organization parallels the hydraulic level of the irrigation system. Given the physical system with ungated pipe outlets and the rotational distribution by time share, the branch level committee has to be more active than the main committee in the actual process of water allocation and distribution. The decentralized authority to make decisions independently has enabled the branch committee to achieve flexibility in water distribution within the branch canal. This suggests that flexibility in the operation of an irrigation system can be achieved to a considerable extent through organizational arrangements.

Finally, the case study illustrates that a large monetary investment is not necessary in the initial construction phase to obtain effective farmer participation. Farmers' participation can come about even after the construction of the irrigation system. But farmers should have the freedom to participate in both the governing and managing the irrigation system. The Irrigation Department's policy of not intervening in the farmers' attempt to manage the irrigation system themselves encouraged them to develop the irrigation organization.

Notes

1. According to the 1991 records of the Pithuwa Village Development Committee, the village has a total area of 1,157 hectares of which the total cultivated area is approximately 1,090 hectares. It has a total population of 6,678 from 1,445 households. This gives an average of 4.6 persons per household (and an average population density of 612.7 persons per square kilometre cultivated area). This figure is noticeably lower than the estimated average family size of 6.95 persons per household reported by Neupane (1991: 67).

2. Since the *Kayer khola* is a small river, its flow is not monitored by the Department of Hydrology and Meteorology (DOHM). There is no hydrological data available.

3. Besides Pithuwa, two other villages - Jutpani and Chainpur - use the *Kayer khola* as the source for drinking water. The Pithuwa and Jutpani villages are served by the same drinking water supply system which has its intake about 5 kilometres upstream from the intake point of the Pithuwa Irrigation System. The Chainpur village situated on the other side of the river has the intake of its drinking water supply system at the same point in the river as the intake of the irrigation system.

   In addition, there are a number of irrigation systems which use the water from this stream at various points. The inventory survey of farmer-managed irrigation systems in the East-Rapti area (Nippon Koei 1990, Vol. III and IV) reported a total of nine such irrigation systems, including Pithuwa. The Pithuwa Irrigation System is the largest of these. The intakes of these irrigation systems are situated within the distance of 10 kilometres upstream and downstream of the intake point of the Pithuwa Irrigation System. Temporary diversion dams made of gravel, boulders and brushwood are used to divert water to all these irrigation systems.

   The irrigation system which has its intake close (about 100 metres upstream) to the intake of the Pithuwa Irrigation System is *Buri kulo* (meaning old irrigation canal). According to villagers, this *kulo* was built on the initiative of an old *tharu* woman (hence the name) many years before the settlement began in the Pithuwa village. Initially it was built to supply drinking water to the village, but some years later it was also used for irrigation purpose. Some parts of the middle and tail-end area of Branch Canal No.2 of the Pithuwa Irrigation System are irrigated from this canal.

   Despite the number of irrigation systems and the drinking water supply systems upstream, there is no conflict over the water rights yet.

4. The village has most basic services, such as electricity supply, a high school, a middle school, two primary schools, health post and so forth. It has also a good network of all-weather gravel roads.

5. Shrestha (1991) describes various reasons for the migration of people from hilly districts to the Chitawan Valley. The reasons mainly relate to: (i) increasing population pressure in hill districts, (ii) government support to settle natural disaster victims and landless migrants from hill districts in the *tarai* by distributing land and thereby enhancing agricultural production, (iii) attaining a better regional

man-land resource balance, and (iv) the success of the Malaria Eradication Program which was started in the valley in 1958 (ibid 1991: 186). Allotment of land in the Valley to the landless people began under the Rapti (Chitawan) Valley Development Project (1955-1961). This project was an extension of the Chitawan Resettlement Project of 1954.

6. *Tharus* and *Kumals* are the natives of the Chitawan Valley. The *tharu* villages between the (East) Rapti river and the east-west highway are evidence of this.

7. According to the estimate of Neupane (1991: 67), about 6 percent of the families in the village are landless.

8. *Tori* (rapeseed) is the early maturing and most commonly grown oilseed in the Pithuwa area. The Chitawan Valley is well known for the production of rapeseed.

9. Rapeseed has exceptionally high oil content, averaging 50 percent (Berry et al. 1974: 113). It is used for the production of cooking oil. For its characteristic pungency, rapeseed oil in Nepal is highly prized for cooking, and therefore has an established market. It enters the trade in the form of three commodities: seed, oil, and cake.

   The cultivation of rapeseed does not involve great risk since it is grown in the winter and is preceded by a monsoon crop of paddy or maize. Rapeseed can grow in a wide range of soils, from silty loam to loam. Its irrigation water requirement is very low. By comparison, wheat crop needs much more intensive care in terms of irrigation and agricultural inputs.

10. This concurs with the general figures in the report of the Nippon Koei Co. Ltd. (1990, Vol. III: Annex II) which shows about 35 percent irrigation for the winter crops in October-January period.

11. It costs Rs 250-300 (about US $ 5-6 at 1992 price) per hour to hire a farm tractor including the operator and fuel, whereas a buffalo/bullock drawn plough can be hired at Rs 300 (Rs 100 for tilling and Rs 200 for levelling) for the entire period of about three hours for the preparation of a hectare of land (soaking, puddling and harrowing) for the paddy transplantation, including the cost of the ploughman.

12. See Neupane (1991: 135-141) for the pattern of female labour use in the irrigated agriculture in the Pithuwa area.

13. The household survey (number of households surveyed: 120) of the study areas showed an average of only two family members engaged fully in farming. These are mostly the elderly people. The young adults strive for higher education and can devote only part of their time to farming activities. The increasing number of both male and female young adults pursuing higher educational qualifications and seeking government or non-government jobs has reduced family labour.

14. The Dairy Development Corporation of Nepal, the only dairy industry in the country, has a centrally located milk collection booth in the village.

15. Farmers interviewed indicated that Mr Ratna Prasad Kharel, a national level politician from the Kavre district, was instrumental in having this irrigation system built. He migrated to the village and became one of the active members of the Pithuwa Irrigation Management Committee.

    Oral history suggest that prior to the implementation of this irrigation system some individual farmers used water form the *Kayer khola* to irrigate their land nearby.

16. By comparison, a branch canal and its command area in the Pithuwa Irrigation System is equivalent to a minor distributary or a tertiary canal and a tertiary unit of large scale irrigation systems in Nepal. By contrast, a minor distributary in irrigation systems in India has a capacity up to 2.5 m^3/s (Varshney, R.S., S.C. Gupta and R.L. Gupta 1983:111).

17. The main canal up to 4 km length, canal structures and Branch Canals No. 1 through 12 were constructed during this time.

18. An interview with the retired senior DOI engineer who had supervised the reconstruction of the PIS revealed that about Rs 900,000 was spent in the flood protection works. This amount was more than twice the amount (Rs 400,000) spent in the initial construction of the system (Amatya, G.L. 1993: personal communication).

19. Opinions vary about who actually designed this irrigation system. According to a senior design engineer of the DOI, the irrigation system was designed by an experienced overseer (Agrawal, N.K 1993: personal communication). Apparently, this was because the irrigation system was smaller in size and did not require the design of headworks. Further, there were not many qualified engineers in the department at that time. Since most graduate engineers were engaged in the design and construction of large irrigation projects, the small irrigation schemes like Pithuwa were designed by experienced overseers.

20. Interviews with farmers and also the remnants in some of the outlet structures indicated that the gates were made of timber board(s). These gates could be raised and lowered in the grooves built in the masonry head wall with the help of a steel rod attached to them. An iron chain was fixed to the rod to secure the gate in raised position.

21. The records of the minutes of various meetings of the main committee showed that farmers made requests to the irrigation office through the water users' organization for the technical and material assistance in the remodelling of the existing physical infrastructure. For example, see Decision No. 4 of the main committee, recorded in the minutes of the meeting of September 10, 1975 (Nepali date: *Bhadra* 26, 2032).

22. According to Pradhan (1989: 19), Branch Canals No. 13 and 14 were built during the 1968-74 period. However, evidence suggests that these two canals were constructed during the second phase of the development.

23. In fact, Branch Canal No. 2 can irrigate only about 80 hectares (75 percent of the irrigable area under its command), mostly at the head and middle sections, because its capacity has been reduced due to heavy silting in the canal near the outlet. The tail-end area of this branch canal is irrigated from the *Buri kulo*.

24. The use of pipes of different sizes in a single outlet structure is rather unconventional, though multiple pipes of the same size in an outlet is not uncommon in irrigation systems in Nepal. An alternative to the use of multiple pipes of large diameter in an outlet structure as in Branch Canal No.2 (which has three pipes - one 23 cm internal diameter and two of 30 cm internal diameter each) would have been to build a rectangular orifice of equal cross-sectional area in brick masonry. This alternative would probably have been discarded by the design engineers because of the time required for the construction. It is quicker to place pipes on the ground than to build a masonry structure.

25. The Neyrpic module is an example of the device with the combination of different sizes of orifices to deliver different discharges to the canal downstream. It requires, however, different hydraulic conditions in the supply canal and is a costly device.

26. This became evident when the c-flume installed by the researcher near the outlet of Branch Canal No. 2 was forcibly removed by the farmers. In the beginning, farmers did not object to the flume being placed since the flow was small and the pipes were discharging freely. They were rather pleased with the installation of the flume which showed small flows in the branch canal. When the flow increased in the canal due to the increased flow in the main canal, the outlet pipes were submerged. The farmers suspected that the submergence had increased because of the flume. To them, the flume obstructed the flow and reduced the water in their canal. It proved impossible to convince them that the head loss in the flume is insignificant to cause the rise of water level upstream of the flume. Eventually, they

removed the flume at night. Although the water level in the branch canal without the flume was almost at the same mark as with the flume and the outlet pipes were still drowned, the flume had to be shifted to a point downstream where it was acceptable to them. This illustrates how farmers look at a pipe outlet. To them, a pipe outlet should discharge freely as far as possible.

27. Observation of flow through these multiple pipe outlets shows that such a configuration of pipes allows an orifice-flow through the smaller pipe for a longer period of time than if the larger pipe were placed upstream.

28. The second reason is that there is no alternative source of water for irrigation in Pithuwa.

29. This sub-division office was later merged into the Chitawan Irrigation Project. Subsequently, the Pithuwa Irrigation System came under the project. With the establishment of the District Irrigation Office in Chitawan in 1989, the irrigation system came under the DIO.

30. In the organizational hierarchy of the Irrigation Department, a *dhalpa* is among the lowest level of operating staff. Because of his lowest status, he does not have the authority to penalize the farmers who misuse water and abuse canal structures.

31. These *dhalpas* were continued in Pithuwa, mainly because they belonged to the village. One of them was transferred to the District Irrigation Office in 1992.

32. This farmer had grown up in the area under the Chhattis Mauja Irrigation System, a farmer-managed irrigation of the Rupandehi district, which has a strong water users' organization. This irrigation system is fed by the *Tinau* river by means of a temporary diversion dam as in Pithuwa (see Pradhan 1989). Besides, he had experience of working as a government functionary in the construction of an irrigation project in the Nawalparasi district. He had also received formal training in community development activities. After migrating to Pithuwa in the early 1960s, he became fully devoted to farming and social works such as establishing the high school, building wells for drinking water and forming co-operatives in the village. He is well known as one of the progressive farmers of Pithuwa.

33. According to Pradhan (1989: 21), water distribution based on time sharing was first implemented in Branch Canal No.14. This contradicts the researcher's finding. According to the record of the minutes of the first meeting of the main committee (September 1975, Nepali date: *Bhadra* 18, 2035), only twelve branch canals existed at that time.

34. According to the records of the minutes of meetings of the main committee, this second-level organization was formed in the beginning of September 1975 (Nepali date: *Bhadra* 18, 2032).

35. Farmers interviewed indicated that the chief of the irrigation office concerned (Chitawan Irrigation Project) at that time had rather encouraged the attempt of the farmers to operate and maintain the irrigation system themselves. To the irrigation office, the take-over of the system management by farmers would have relieved the burden of operating and maintaining the irrigation system.

36. Until 1977, the total number of members in the main committee was 17 because there were only 12 branch canals.

37. The first chairman of the PIMC was the chairman of the Pithuwa Village Panchayat (later Village Development Committee). The interview with past members of the main committee indicated that the reason for deciding to have the chairman of the Village Panchayat as the chairman of the main committee was mainly to avoid confrontation with the then Panchayat government and local politicians who suspiciously looked at such organizing activity as an anti-government activity. This tradition has continued even after the Panchayat regime, because of the benefits farmers gain from this arrangement.

38. This written constitution came into being in 1991 with the assistance from the Research and Training Branch (RTB) of the DOI to help register the PIMC as a corporate body. Prior to this written constitution, the rules and regulations and changes made in them were recorded by farmers in the minutes books.

39. The remuneration received by the individual farmer or the committee member who became the resource person during the field observation or training programmes for outside farmers or engineers is passed on as income to the main committee.

40. See Decision No. 5 in the records of the minutes of the main committee meeting of September 22, 1975 (Nepali date: *Aswin* 06, 2032).

41. Similarly, following the adjustment of the hydraulic boundaries, the sizes of the pipe outlets of Branch Canals No.6 and 8 were adjusted. See Decision No. 4 in the records of the minutes of the main committee meeting of July 31, 1976 (Nepali date: *Srawan* 16, 2033).

42. This ex-secretary was one of the three advisory members in the main committee of 1993.

43. This meeting was attended by the researcher with the permission of the committee chairman. The decision to have the flow capacity of the oversize outlets checked by a technical person might have been influenced by the presence of the researcher who measured flows in the three branch canals selected for his study.

44. Available records showed that in the past when the temporary diversion dam was washed away or severely damaged by the floods, labour from all branch canals was immediately mobilized for the emergency repair. In such emergency situations, the farmers who have already cultivated paddy are necessarily required first to contribute labour for the repair. The amount of labour contribution depended upon the magnitude and urgency of the work involved.

45. The bulldozer is used to prepare a dam, which extends about halfway across the river, to divert adequate water in the main canal. The low dam is made of the river bed material and is not well compacted. Therefore the bulldozer is needed at the diversion point throughout the irrigation season to maintain the dam.

46. For the fiscal year 1991-92, a total of Rs 69,935 was allotted by the Irrigation Department for the operation and maintenance of the irrigation system. This amount is equivalent to US$ 1,413 (at 1992 exchange rate of US $ 1 = Rs 49.50). According to the annual expenditure report of the main committee, about 65 percent of this amount was spent on the repair and maintenance of the bulldozer and excavator used. The remaining amount was spent in the fuel and lubricants for the machines. In addition, an amount of about Rs 9,000 was spent by the main committee on the operation and maintenance of the machines through farmers' contribution. See the letter of May 4, 1993 (Nepali date: *Baisakh* 22, 2050) of the main committee to the District Irrigation Office for the details of the expenses in operation and maintenance of the bulldozer and excavator during July-September 1992.

47. It is observed that women also take part in the cleaning of the canal.

48. Since the contribution of labour for the cleaning of the main canal is based on the diameter of the pipe and not on the cross-sectional area, the farmers from the large diameter pipe outlets have an advantage. This shows inequity in the use of labour resource, and it appears to have been overlooked by the farmers. Yet, farmers of Branch Canal No. 2, which has the large land area to be served, were dissatisfied with this principle of labour distribution for cleaning the main canal. They complained of not receiving adequate water to irrigate all paddy fields in the branch canal command, in spite of their proportional labour contribution. It was observed that the inadequate water flow in the branch canal was because of the huge amount of coarse silt deposited in the canal near the outlet. This branch canal suffers the most from silting up because it is at the head reach (see Figure 4.5). Secondly, it has two large (30 cm) diameter pipes.

49. This was the first time that Pithuwa farmers used an excavator to clean the main canal. Though this may seem to be another step towards dependence on external resources, it is an effort of the farmers to use available resources and shows their progressiveness.

50. In general, the relation between the water users' organization of Pithuwa and the District Irrigation Office is formal. The main committee sends requests to the irrigation office in writing. In addition, the committee members sometimes visit the irrigation office personally to remind the engineers of their requests. Evidence (minutes of the meetings of the main committee, for example) shows that under certain circumstances the farmers even sent delegations to the ministry concerned and the central office of the Department of Irrigation at Kathmandu to pursue their requests for assistance. Such delegations are usually made up of the chairman himself or a group of members of the main committee.

51. According to the district irrigation engineer, the DOI planned to formally hand over the management of the system in 1993. For this purpose, the PIMC was registered with the District Administration Office as a corporate body in 1992.

52. See the request letter of August 14, 1992 (Nepali date: *Srawan* 14, 2049) of the main committee to the East Rapti Irrigation Project. In this letter, the main committee, among other requests, requested a new bulldozer. During the time of this research, the farmers' committee were pursuing this matter seriously.

53. Since branch canals in Pithuwa directly serve cultivated fields, the difference between branch canal level and farm level is not distinct in the context of water allocation and distribution.

54. Farmers call this "*ghante palo*" meaning hourly turn. *Bigha* is the commonly used unit for land area in Nepal. 1 hectare = 1.5 *bigha*.

55. Since access to water is based on the land area, each farmer is required to register his cultivable land with the branch committee. But, the land area recorded by branch committees of the three branch canals studied, and also field observations, show that farmers try to register their total landholding, including the area occupied by their homestead, to obtain more time allotment and thereby more water.

At the time of this research, the main committee was collecting the landholding of all farmers using the canal water in order to assess the actual land area cultivated and irrigated within the command area of each branch canal. Every farmer was required to register his or her landholding with the main committee. A nominal registration fee of Rs 6 per farmer was charged. The fee was received as an income to the PIMC. This updating of the land record was also meant to assess the water allocation to each branch canal.

56. An example of the rotation among branch canals in the early September 1975 is recorded in the minutes of the meeting of the main committee (Nepali date: *Bhadra* 20, 2032), when the flow in the main canal reduced due to the low flow in the *Kayer* river. According to this record, twelve branch canals were grouped to form three rotational Blocks: Block I comprising Branch Canals No 2, 3, 4, and 5; Block II consisting of Branch Canals No. 6, 7, 8, and 9; and Block III had Branch Canals 1, 10, 11 and 12. Apparently, the grouping of canals was done such that the irrigated area in each block were almost equal. It was decided that beginning from Block I, the branch canals in each Block should remain completely closed for 48 hours in turn. This means that the branch canals under Block II and III would receive water first, while the branch canals under Block I would have no water. The time allotment of 48 hours for a Block was decided on the basis of the flow available in the main canal. The canal operation was to be effective from 6 pm that day. This rotation schedule was continued until there was adequate flow available in the canal.

In the 1992 paddy season, rotation among branch canals did not occur as adequate flow was available in the main canal throughout the period. The flow in the main canal in this period was adequate as a result of good cleaning of the canal by the excavator.

57. The flows were measured regularly, at 8 am and 6 pm daily, using c-flumes. Sometimes, the flow varied even within a few hours.

The flows in the canal from November onwards are considerable reduced and are of little importance, since at that time farmers are not keen on using the canal water any more.

58. In 1992, for seed bed preparation, each branch canal was allocated water once in eight days.

59. Other matters discussed are the annual accounts, maintenance works, and election of the branch committee functionaries. Generally, the transplantation of paddy begins around July 1 and continues until the first week of August (see Figure 4.3).

60. Observation showed the transplantation of paddy seedlings beginning from July 11 in all the three branch canals. Throughout the month of July, the flow in the main canal was rather low and fluctuated rapidly. Measurements at selected points on all three branch canals during the transplantation in this period showed flows between 20-120 lps only. Only from the beginning of August did the flow in the main canal increase to its full supply level (see Figure 4.8).

61. The night irrigation in Pithuwa is often not mentioned by researchers studying the irrigation system.

62. The transplantation of paddy in this branch canal began on July 11, 1992 and continued until August 16, 1992. This long period of 40 days for transplanting was mainly because of the varied and inadequate flow in the canal. Note that this branch canal is at the tail end of the irrigation system.

63. See Malhotra (1982) for a description of the "*warabandi*" system of water distribution.

64. Though every farmer did not have a wrist watch, they managed to keep time with the help of their neighbour's watch.

65. The penalty for stealing water out of one's turn is rather high and strictly followed. It was Rs 50. This also controlled the water theft.

66. The flow measured in the *Kayer* river at the diversion point on October 30, 1992 was 1.25 m^3/s. Of this flow, 0.56 m^3/s was diverted to the Pithuwa Irrigation System. This shows the tremendous reduction in the discharge of the river during the winter season.

67. Therefore, during these six months, farmers from both the Pithuwa and Chainpur villages are often seen gathered at the diversion point, the Pithuwa farmers in queue to claim the water turns to divert water into the main canal and the farmers of Chainpur to guard the water until the specified time.

5 The Mahakali Irrigation System (Stage I)

Improvements to the existing physical infrastructure and modifications in organizational arrangements occur during the development of an irrigation system. There are several reasons for this: increase in irrigated area, adoption of a new technology for improved water management, diversification of crops and so forth. Mostly, the changes are situation-specific.

This chapter presents a case study of a government-built irrigation system which has been redesigned and rehabilitated for the implementation of rotational water supply (distribution). The case is of the Mahakali Irrigation Project (MIP) in the far western *tarai*, Nepal. The case study focuses on the changes in technology and organizational arrangements made to improve water distribution. The improvement of water control is sought through "structuring" the existing physical infrastructure and organized participation of farmers in the system operation and maintenance. This case study also illustrates how the external financing agency and the foreign design engineers involved can bring about abrupt changes.

It should be noted here that compared to the field work at Banganga and Pithuwa only a short period of about two months, December 1992 to January 1993, was spent in the field due to the time limit for the research, the difficulty in reaching the study area during the monsoon season and the distance from the other two systems studied. The data used in this case study are mostly from the archives, official and unofficial project documents.

5.1 The field setting

General

It is useful to start with a brief outline of the Mahakali Irrigation Project (MIP) before going on to specific discussions on the improvements in technology and organizational arrangements for better water management. The MIP is planned to eventually provide irrigation facilities to a total land area of about 23,000 hectares in the Kanchanpur district of Nepal (see Figure 1.2). It is an on-going project[1] and is being implemented by the government through the Mahakali Irrigation Development Board (MIDB) in three stages.[2] According to the initial planning, Stages I and II are to provide irrigation facilities to about 6,600 ha net each, and

Stage III to a total area of about 9,800 ha. Figure 5.1 shows the areas under Stages I, II and III. The current development under Stages I and II is financed by the World Bank, and foreign consultants are involved in the design and construction supervision of the project.[3] Stage I (1980-89) comprised improvement and extension of the existing irrigation system built in 1971-79. Stage II is estimated to cover a net irrigable area of 6,800 ha. It is a totally new construction which began in 1989 and is expected to be completed by June 1996. Stage III is currently in the survey and design phase. The Organization of Petroleum Exporting Countries (OPEC) is the financing agency for the engineering survey and design of the physical infrastructure for the Stage III area. Only the irrigation system under Stage I (hereafter referred to as the MIP-I) is currently in operation, and is discussed in this chapter.

The MIP-I covers 18 villages under two village development committees of the district.[4] The net command area is estimated to be about 4,800 hectares. The difference with the planned command area of 6,600 hectares is possibly because of the extension of the Wild Life Reserve (see Figure 5.1). Mahendranagar, the district headquarters, is located centrally within the command area.

The command area slopes gently from an elevation of 185 m above mean sea level in the north to 160 m in the south near the border (World Bank 1980). It can be broadly divided into two main categories with respect to the land use pattern: upland and lowland areas. Traditionally, upland areas are used for the cultivation of wheat, maize, oilseeds, pulses and vegetables, whereas lowland areas are predominantly cultivated with paddy. Some data on the land use within the command area show about 48 percent as upland area (Halcrow 1988b: p.1.3; APROSC 1989: 11-12).

Soils in the command area are primarily of alluvial origin and belong to two types: (i) soils developed under forest cover, which are yellowish and grey brown, coarse to moderately coarse textured and well drained, and (ii) silty clay loam deep alluvial soils, which are less permeable, poorly drained and medium to moderately fine textured. Both soil types are moderately acid to moderately alkaline, and low to medium in organic matter content and fertility. The coarse textured and permeable soils are suitable for the cultivation of upland crops such as maize, wheat, pulses and cotton, while soils under the second type, with some drainage, can be used for both irrigated paddy and upland crops (World Bank 1980:10).[5]

The command area falls within the subtropical humid climatic region. The rainfall pattern is characterized by two distinct seasons: wet (June-October) and dry (November-May). The annual rainfall varies from 1,500 to 1,750 mm. Rainfall during the dry season occurs in occasional showers. Figure 5.2 presents the average monthly temperature, evaporation and rainfall in 1992 recorded at the meteorological station in the premises of the project office at Mahendranagar.[6]

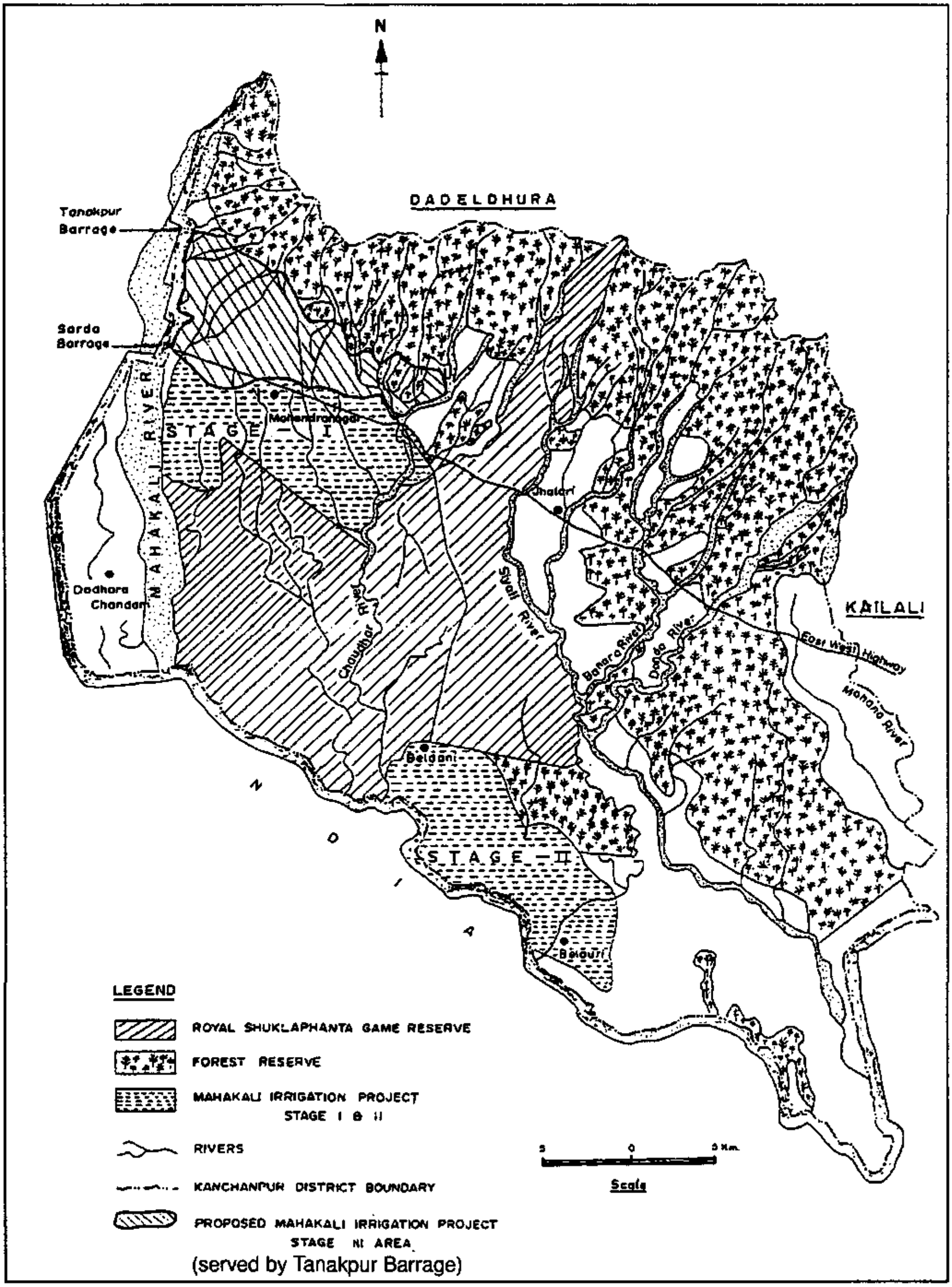


Figure 5.1 Location of command areas under Stages I, II and III ot the Mahakali Irrigation Project (Source: Project documents 1992.)

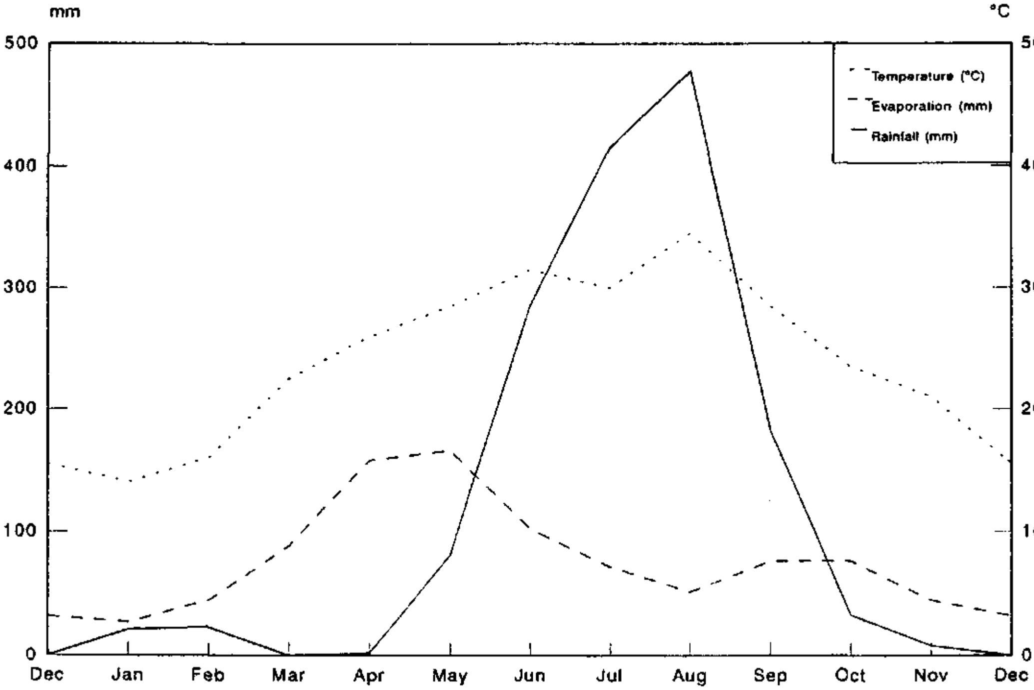


Figure 5.2 Monthly average temperature, evaporation and rainfall in the Mahakali area (Source: Data from the meteorological station at the MIP office, Mahendranagar.)

The water source for the project is the Mahakali river which forms Nepal's western border with India.[7] The river has monthly flows ranging from 130 m^3/s in May up to 11,000 m^3/s in the wet season (World Bank 1980: 11). Sediment concentrations in the water are rather high during the monsoon period when average concentrations in a month range between 1,000 and 4,000 ppm.

Water supply to the MIP is from the Sarda Barrage which lies in India, about 1.1 km west of the border. It is controlled by the Indian irrigation personnel operating the barrage.[8] The water rights of Nepal at the barrage are determined by the 1920 international agreement with India. According to the Agreement, Nepal has the following seasonal water rights:[9]

a) a supply of 13 m^3/s from May 15 to October 15 and, provided a surplus is available and if requested, a supply of up to 28.3 m^3/s, and
b) a supply of 4.25 m^3/s from October 15 to May 15.

The agreement further stipulates that during the period from October 15 to May 15 the water supply to Nepal would be alternately closed and opened for ten days at a time, and that the canal would run at 8.5 m^3/s capacity whenever the canal is open. However, according to the project records, water supply from the barrage during this period has usually been on a continuous basis at about 4.25 m^3/s (Halcrow 1988a).

The water supplies under the Agreement can be attained under almost all flow situations of the river, and can therefore be considered as assured in all years. These supplies are more than sufficient to meet irrigation water requirements of the MIP-I area in all crop seasons. Therefore, the use of alternative water resources such as groundwater and water from small rivers, for irrigation purpose has not been felt necessary yet.[10]

The villages

Most villages within the command area are the outcome of the Kanchanpur Resettlement Project which began in the district in 1977 with the financial assistance of IDA. After 1979, the district began to develop under a comprehensive master plan which includes the resettlement of existing farm population, settlement of landless families and encroachers (mostly from hills) occupying land within the project area.[11] The MIP is an important element in this master plan.

Under the resettlement master plan and project provisions, the settlers who were moved into the project area received a house lot in a village and a parcel of irrigable land equal in size to their initial holding (Word Bank 1980:13). They were also compensated for their old houses, fences, transportation, and were provided with pumps for drinking water and wood to build new houses. The landless received a total land area of about 1 hectare.[12] New settlers are entitled to land ownership only after having cultivated the land for some years, usually minimum of five years. During this period, they are not allowed to mortgage or divide their land. Most farmers have their homesteads within the farm land. In labour intensive farming, homesteads close to the landholding facilitate efficient farm management.

The project area thus consists largely of migrants and re-settlers, mostly from hilly districts. Ethnically, most of the population in the area are *Chetries (Thakuries)* and *Brahmins*. The natives, *Tharus*, are only about 11 percent (Subedi et al. 1992).

At present, access to the project area and the district is difficult because of the lack of road connections with other parts of the country. The main communication routes are the Indian roads and railways along the border. The Kohalpur-Banbasa stretch of the East-West Highway which will eventually link the area with the country's road network is under construction.[13] This has partly inhibited the development of market facilities for agriculture products in the area. Nevertheless, marketing channels through individual traders seem well developed. Private dealers and farmers do petty trade across the border in India. The district headquarters, Mahendranagar, is the major urban and market centre.

Land distribution and land tenure

According to the Agricultural Impact Study by APROSC (1989), the average landholding size per family (of 6-7 persons) in the MIP-I area is 1.45 ha with an average parcel size of 0.5

ha. The same study reported fragmentation of land whereby the number of small holdings is increasing as a result of the division of individual holdings among family members. The country's land tax system, in which farms of less than 1.02 ha are exempted from tax, has also contributed to the land fragmentation.

The same study also indicated that about 93 percent of the cultivated land was being farmed by owner cultivators, and the remaining 7 percent by tenants under tenancy arrangements. Small farmers with landholdings less than 1 ha necessarily try to lease land from farmers with larger landholding in order to meet their subsistence requirements.[14] As in other parts of the *tarai*, the common tenure arrangement in the area is the share-cropping called *adhiya*.

According to the project authority, many re-settlers in the project area have not yet received their land owning certificates.[15] This has not only caused insecurity among the settler farmers and deprived them from obtaining credit facilities for improved farming practices, but it has directly affected the collection of irrigation water fees too. Farmers who have no land owning certificates cannot be expected to pay the water fee.

The farming system and principal crops

The present cropping pattern in the area is paddy/maize-oilseeds/wheat-maize/vegetables. Paddy and maize are the principal crops grown during the wet season. The dry season crops are mainly wheat, oilseeds, pulses and vegetables. The cultivation of pulses and vegetables is primarily for home consumption. Figure 5.3 shows the projected cropping pattern and the intensity at appraisal.

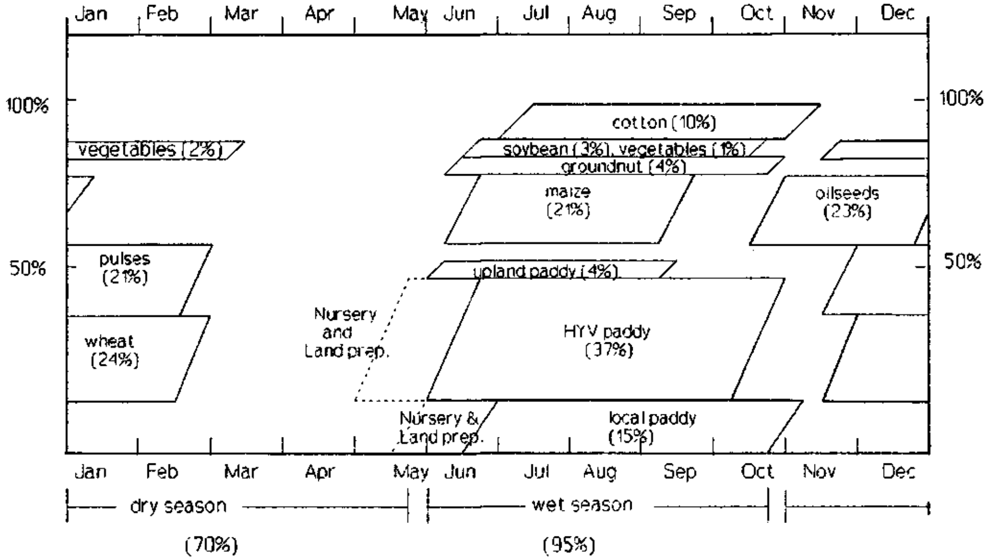


Figure 5.3 Projected cropping pattern and intensity at appraisal for the MIP-I area (Source: World Bank, 1980)

Prior to the improvement of the irrigation system under Stage I, traditional varieties of paddy were mostly grown under both rainfed and irrigated conditions. Some farmers cultivated high yield varieties (HYV) of wheat on a limited area. The cropping intensity was about 132 percent and the crop yields were low (World Bank 1980). The study by APROSC (1989: 14) showed an average cropping intensity in the area at about 185 percent, which is more than the projected cropping intensity of 165 percent. The increased availability of irrigation water after the implementation of the MIP-I enhanced the cropping intensity considerably, particularly for wheat cultivation, which increased from an average 35 percent in 1982 to 55 percent. Presently, most paddy and wheat grown under irrigated conditions are of HYVs.[16] The cultivation of maize, oilseeds and pulses has declined because there is no market for them (ibid: 12). These crops (maize, oilseeds and pulses) are mostly of local varieties which tolerate water stress.

The study by APROSC (1989) also reported significant differences in the cropping intensity between the head and tail-end areas: an average of 192 percent at the head reach area and about 173 percent at the tail-end area. For example, wheat occupied an average of 70 percent of the total cultivated area in the head-end area and only about 40 percent at the tail-end. This is primarily because farmers at the head end area have had longer experience of irrigated wheat (access to irrigation water since 1976) than those at the tail end area. The study also indicated that small farmers usually practised intensive farming to meet their food requirements and had the highest cropping intensity (194 percent).

Farming is labour intensive. Small farmers depend totally upon their family labour. Large farmers accomplish their farming activities through contractual and wage labour. The exchange labour, especially between the *tharu* farmers and settlers, is lacking (Subedi et al. 1992: 15). Animal powered ploughs are commonly used for land preparation and other farming operations. The use of farm machines like tractors and power tillers is very limited.

5.2 The irrigation system: physical and technical characteristics

The MIP-I can be said to have developed in two consecutive periods: (i) the 1971-79 period when the government constructed the main system infrastructure solely with its domestic resources, and (ii) the 1980-89 period when the existing system was improved with the financial assistance from the World Bank. Within these two periods three distinct stages of technical design approaches are observed. These design approaches have influenced the physical and technical characteristics of the irrigation system. They are discussed below.

The 1971-79 design and construction

The physical infrastructure of the main system of the MIP-I was designed and constructed by (civil) engineers of the Irrigation Department during this period. The design engineers used the conventional design criteria and standards (which are similar to those followed in irrigation systems in Uttar Pradesh State of India). Farmers were apparently not involved in the design process.

Evidence shows that Laceys' equations for regime channel conditions were used to design canals conveying flows above 1 m^3/s. For lower level canals carrying discharges between 0.1 and 1 m^3/s, Kennedy's equations (no silting and no scouring in steady flow regime) were applied.[17] The design of tertiary level canals were based on the Manning's equations.

Like most government irrigation systems built at the time, the irrigation system comprised extensive construction of canals at the main system level, and few tertiary level canals. By 1979, it consisted of a 13 km long main canal, eleven distributary (secondary level) canals and several minor canals totalling about 60 km, and some 80 kilometres of tertiary canals (World Bank 1980). All canals were unlined. Undershot-type cross regulators with vertical slide gates were built in the main canal, but weir-type checks without gates were provided in secondary canals. Secondary canal outlets were provided with adjustable vertical gates, whereas water to the cultivated fields was delivered through ungated pipe outlets. There were also a number of pipe outlets directly connected to the main canal. The net command area of the irrigation system at the time was estimated to be 3,400 ha (Poudel 1992: 57).

The irrigation system was first put in operation in 1976. Engineers interviewed indicated that irrespective of the design assumptions the system operation then was such that the main and all secondary canals were allowed to run continuously because water was not a constraint.

It is useful to note, at this stage, the terminology used to denote the hierarchy of canals in Mahakali in order to be consistent with the description of the irrigation system in the archives and reports. A large capacity canal taking off from the main canal is called "distributary". A canal taking off from a distributary is termed as a "branch" or a "secondary" canal. A canal having capacity smaller than a branch or secondary canal but taking off either directly from the main canal or a distributary is called a "minor". "Tertiary" canals are those which take off from a distributary, secondary and minor canal. Clearly, this nomenclature is similar to that used in northern India. The terminology is useful in an irrigation system which has progressive branching of lower level canals. In this chapter, however, the term "secondary" is used to denote all canals between the main and tertiary canals unless specifically mentioned.

Figure 5.4 shows the general plan of the MIP-I. The first 0.6 km stretch of the main canal is in Indian territory.[18] The main canal runs along the contour and is designed to be operated at full supply level in all its reaches throughout the year (except during the short periods of routine maintenance). The first 6.8 km stretch of the main canal has the design capacity of 28.3 m^3/s at a flow depth of 2.14 m. The remaining 6.2 km stretch is designed for a maximum capacity of 12 m^3/s at a flow depth of 1.53 m. These capacities were fixed considering the water to be delivered to the potential areas of Stages II and III. It is not clear why the capacity of the second half of the main canal is less than fifty percent of that of first half.

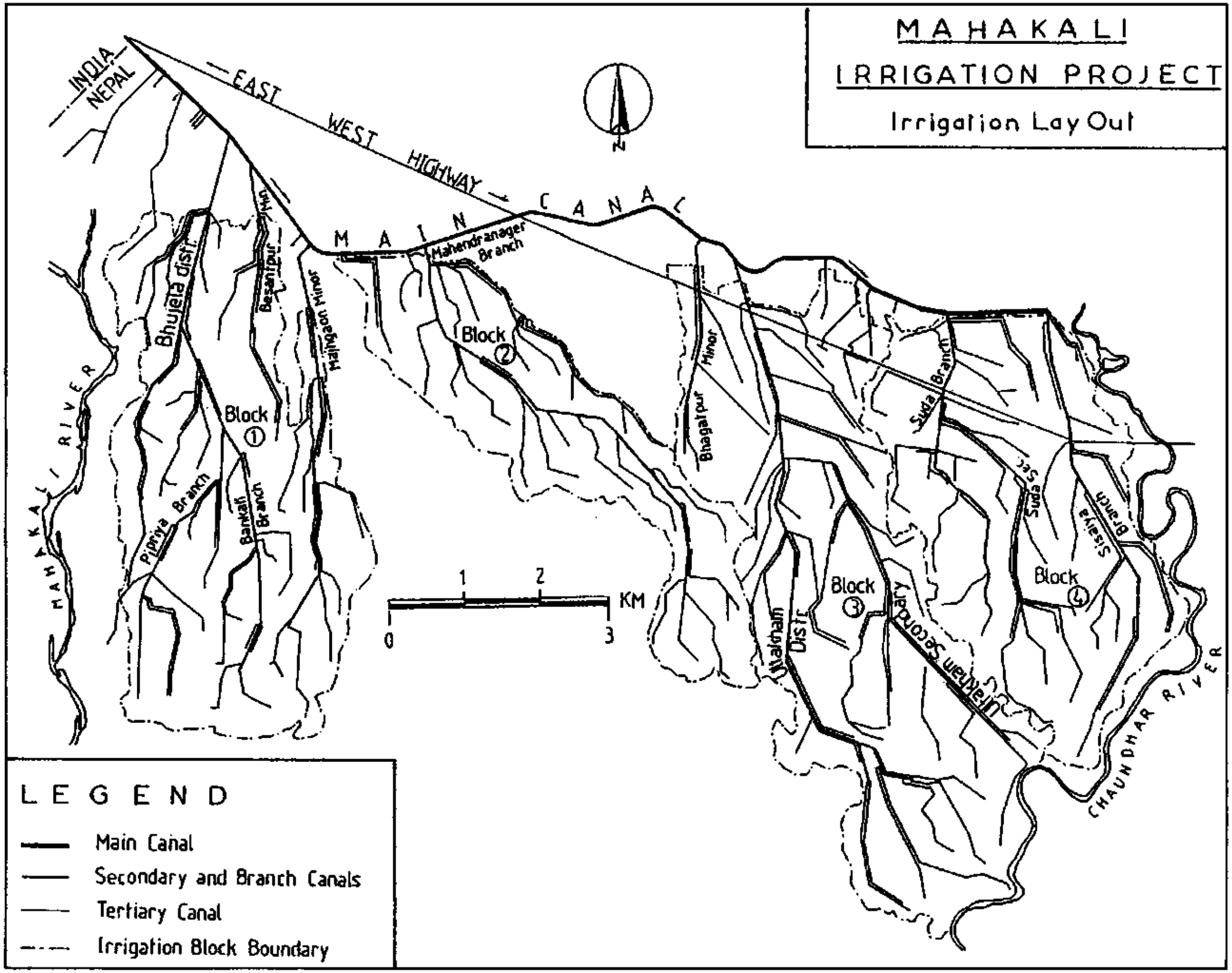


Figure 5.4 General Plan of the Mahakali Irrigation System (Stage I)
(Source: Project drawings, MIP 1989.)

Since the available water supply was much more than the potential irrigation requirements, a feasibility study was conducted in 1979 to increase the irrigated area under the existing irrigation system. In June 1980, the expansion of the MIP (Stage I) was appraised for implementation.[19]

The 1980-89 rehabilitation of the MIP-I

This period can be further divided into two distinct stages with respect to the technical redesign and remodelling of the physical system: (i) 1980-85 period when the existing system underwent rehabilitation based on the design that comprised regulated flow down to the quaternary outlets, and (ii) 1986-89 period when the physical system was redesigned and remodelled for rotational water distribution.

The 1980-85 design and rehabilitation

At appraisal, several (technical and physical) deficiencies in the existing irrigation system were noted (World Bank 1980: 9-10). These were mainly:

- deterioration of the main and secondary level canals due to heavy siltation and steep and unstable side-slopes,
- no silt control devices,
- inadequate number of cross regulators for water level control in the main canal,[20]
- inadequate capacities (generally less than 1.0 lps per hectare) of secondary canals to meet the water requirements for land preparation for paddy transplanting,
- large tertiary units (up to 200 hectares),
- inadequate tertiary level canals and outlets for effective water distribution,
- concrete pipe outlets without control gates,
- no field drainage system,[21] and
- inadequate roads along the main and secondary canal banks for effective operation and maintenance of the irrigation system and access to market for farmers.

It was concluded that the overall water management in the MIP-I area was poor because of the above deficiencies in the existing system. The World Bank also noted: '... so far this has not been a great bottleneck as an abundant supply of water is available. However, this would become a problem as the irrigated area is extended under Stages II and III ...' (World Bank 1980: 9).

Therefore, MIP-I primarily comprised improvements in the existing physical system for better reliability of water delivery to the farmers.[22] Specifically, it consisted of:

- extension of irrigation facilities from 3,400 ha to 6,600 ha,
- increase in the capacity of the existing distribution system,
- improvement of silt control in the main canal,
- construction of additional control structures to improve water control,
- construction of lower level canals for water distribution down to groups of farms of 4-8 ha (net),

- additional escapes (broad crested overflow side weir) at the tail end of secondary level canals, and
- improvement of field drainage.[23]

By these improvements, the project attempted to change the existing irrigation system into a modern irrigation system in which '... a high level of operational efficiency could be achieved ...' (World Bank 1980: 8). In addition, the project included intensification of agricultural extension, research and training, and development of trained technical manpower by providing fellowships for Nepali students to study engineering and agriculture abroad, improvement of communications by providing all-weather access roads within the existing and extended irrigated areas (World Bank 1980: 18-21). These are not dealt with here.

The existing irrigation system was redesigned to achieve the desired operational efficiency.[24] For the redesign, the World Bank specifically laid down a set of design and operating guidelines, right at appraisal. It suggested: '... the design duty for these (existing) canals would be increased to meet the peak water demands. This increase in canal design capacity would require modification of existing structures. Where required, additional control structures would be built for improved water control. Additional tertiary turnouts would be constructed to reduce the size of the tertiary units to a maximum of 40 hectares. Existing turnouts would be replaced by gated structures suitable for discharge measurements. The distribution system beyond the tertiary outlets would be extended down to outlets serving farm groups of 7-8 hectares ... All canals would be unlined. '[...] The canals would be designed for a non-scour, non-siltation situation on average' (World Bank 1980: 18, 22). Further, separate water requirements were recommended for upland and lowland areas because of their presumably distinct use in crop cultivation.[25] It was assumed that only paddy will be cultivated in lowland areas. The consultants followed these criteria literally. The criteria for layout and design for tertiary and quaternary areas outlined in the Design Manual for the MIP-I prepared by the consultants verify this (Halcrow 1984b: 38).[26] This shows that the financing agency strongly influenced the consultants in fixing the design criteria.

The design water requirements at the tertiary outlets for lowland and upland areas for 24 hour irrigation were as follows (Halcrow 1984b: 9, Appendix II/3-5):[27]

a) Lowland areas (paddy as the principal crop) = 2.4 lps per hectare
b) Upland areas (oilseeds as the principal crop) = 1.2 lps per hectare.

Note that these design water requirements are twice as much as those used in Banganga. The main reason for this is that the design engineers assumed that the irrigation system should be able to supply water to the full area during the period of pre-saturation and land preparation for paddy. The design engineers also assumed that there would be sufficient water available for Stage I in any event (Halcrow 1984b: Appendix II, p.3).

Tertiary units of maximum size 40 hectares net (gross area: 47 ha) and quaternary units called *chaks* of 7-8 hectares (net) were introduced. A tertiary unit thus generally consisted of five quaternary units. Based on the above design water requirements, the design capacity of a tertiary outlet (and the tertiary canal) serving a unit of 40 ha in lowland areas was taken as 100 lps and that for an outlet serving the same size tertiary unit in upland areas was taken as 50 lps. The design capacity of a quaternary outlet serving 8 ha farm group in lowland areas was taken as 20 lps.[28] Clearly, tertiary canals were designed such that all quaternary canals within the tertiary unit could be supplied with water simultaneously.

The new capacities of tertiary outlets (and tertiary canals) necessitated modifying (increasing) the capacities of existing secondary canals and control structures. Additional control structures with vertical slide gates were built in the main and secondary canals to improve water control. New tertiary outlet structures with vertical slide gates were provided, and existing ones were replaced by gated structures. These outlet structures are single gated, that is, they have only one gate at the supply end. Within a tertiary unit, concrete water division structures with rectangular openings were built to distribute water to the connecting quaternary canals. These concrete water distribution structures have vertical adjustable steel gates. Concrete water division structures were recommended by the World Bank on the grounds that at the time the local bricks were of poor quality.[29] Photo 5.1 presents such a concrete water division structure.

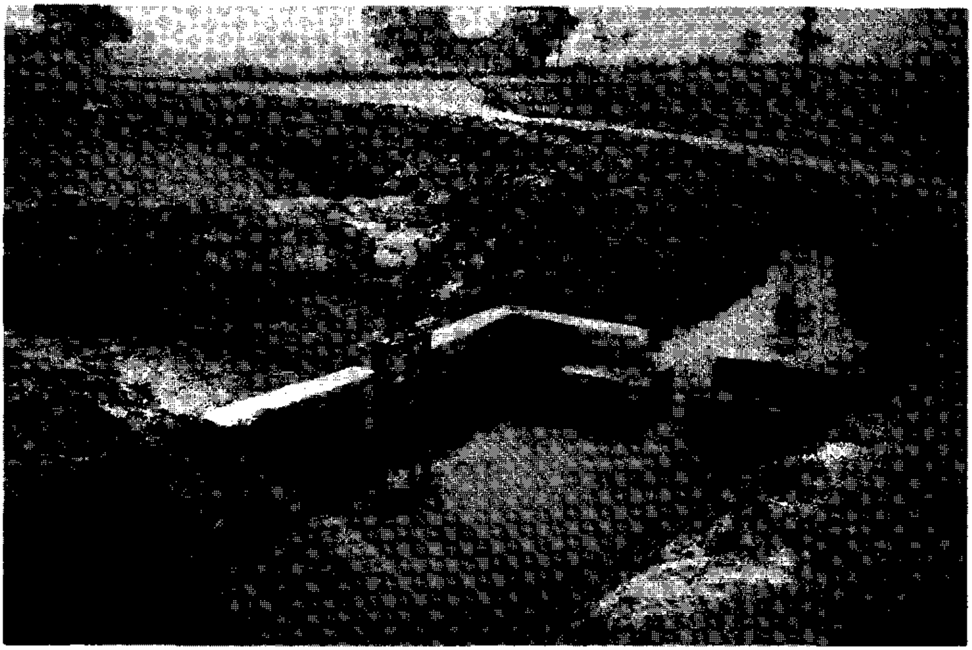


Photo 5.1 Concrete water division structure within a tertiary unit in Blocks 1 and 2 of MIP-I (1993)

The rehabilitation of the existing irrigation system according to the above design began in 1983, and was scheduled to be completed by the middle of 1985. Apparently, the project was behind the schedule and rehabilitation works were still incomplete in 1985, especially the construction of tertiary canals and structures in Blocks 3 and 4. In December 1985, the World Bank reviewed the project and strongly recommended the application of rotational water supply (RWS) in the project to improve equity in water allocation and distribution.[30]

RWS is based on the premise that equity in water distribution can be achieved if the distribution is made on equal water entitlement per unit area wherein each farmer receives an allocation of water proportional to the land area owned or farmed. The recommendation of RWS by the World Bank was based on the successful experience in other Asian countries. Another important argument in favour of RWS is that farm holdings in most developing countries in South Asia are fragmented and mostly less than one hectare. For example, a tertiary unit of about 40 ha will have more than 100 individually owned fields. It is not possible to deliver a small irrigation supply to each individual plot by canal network, and aggregation and rotation of a manageable flow of water is therefore desirable at this level (Albinson 1993).

In the middle of 1986, the Mahakali Irrigation Development Board (MIDB) approved the Bank's recommendation to implement RWS in the project. By this time, the construction of tertiary level canals and structures according to the 1981 design had progressed considerably in the head reach areas, especially in Blocks 1 and 2. However, Blocks 3 and 4 where the rehabilitation works were still far from complete were immediately redesigned for the implementation of RWS (Halcrow 1986). The premise was that RWS should be implemented during the project period itself.

The 1986-89 redesign and remodelling for rotational water supply

The decision of the World Bank followed by the approval of the MIDB to introduce RWS in the project prompted the design engineers to reconsider the criteria used in the previous (1981) design. This decision to modify the design and operation of MIP-I also resulted in the project being extended to 1989.

The consultants followed the new criteria which the Bank at the time was trying to introduce in its irrigation projects in South Asian countries.[31] The new design criteria comprised changes in design water requirements, allocation of flow at the tertiary outlet, size of tertiary and quaternary units, and water distribution procedures in the system. The design water requirements for the tertiary outlets commanding lowland areas and areas with a mixture of lowland and upland soils was reduced from 2.4 lps to 1 lps per hectare. For upland areas, which are considered unsuitable for rice cultivation, it was fixed at 0.7 lps per hectare (Halcrow 1986). A report by the consultants (Halcrow 1990: 4) on the implementation of RWS in MIP gives the following reasons for adopting 1 lps per hectare:

- The previous design water requirement of 2.4 lps per hectare accounted for water supply for land preparation to the full cultivated area. Actually, it is not necessary to supply land preparation requirements to the full area, because most transplantation of paddy takes place between 10th and 31st of July after the monsoon rains have commenced, and only a small amount of irrigation water is required to supplement the rainfall.[32]
- Only about 15 percent of the command area can be planted with early (spring) paddy which is harvested at the mid-monsoon (July-August) season, as the recommended and likely varieties would require 100-110 days from transplanting to harvest.
- A water requirement of 1 lps per hectare would serve any likely *rabi* and other hot season crop requirements.
- The design water requirement of 1 lps per hectare considerably reduced the (canal) capacity of the distribution system, thereby resulting in significant savings in project cost.

The flow at the tertiary outlet for both upland and lowland areas was fixed at 30 lps, assuming that this was the most desirable flow that can be managed by an individual farmer.[33] Based on this allocation of flow, the size of a tertiary unit was reduced from 40 to 30 hectares.

Each tertiary unit was subdivided into seven quaternary units or *chaks*. A *chak* outlet is to have the irrigation turn once a week, that is, an irrigation interval of 7 days. The premise is that a weekly rotation provides an individual farmer with a turn of irrigation at the same time of the day on the same day of the week. This requires that the tertiary outlets receive water continuously.

The size of a *chak* was thus set at an average area of 4 ha net for lowland areas and 5.6 ha for upland areas. Records (Halcrow 1988c) of canals and structures in Blocks 3 and 4 show that many tertiary units have a net size of 28 ha size and have seven *chaks*. Some tertiary units are less than 28 ha and have less than seven *chaks* because of topographical constraints. The *chaks* in these small tertiary units are in multiples of 4 ha.

The design engineers also presumed that RWS should be applied in MIP-I at three levels as follows (Halcrow 1986, 1990: 2):

- Rotation among groups of secondary canals taking off from the main canal. Flow into these secondary canals is to be either full "on" or "off". When "on" the gates at the secondary canal outlets are to be adjusted only to maintain the full supply flow in the offtaking canal according to variations in the main canal flows.
- Rotation (of 30 lps flow) among *chak* outlets within the tertiary unit. Only one *chak* at a time to receive the full flow available in the tertiary canal.

- Rotation among individual farmers within a *chak*. At this level, the flow entering the chak outlet on a day has to be equitably rotated among all the farmers who wish to irrigate their land at that particular period or day.

Since all secondary level canals (distributary, branch, and minor) and tertiary canals are to run at full supply flow (not full supply level), the irrigation system does not require any control structures or cross regulators with adjustable gates in secondary canals. Therefore, flow division between canals branching off from a distributary canal was decided (by the design engineers) to be by proportional weirs, and the flow into tertiary canals through pre-set orifices. Since a *chak* receives the full flow in the (parent) tertiary canal, the distribution of water among the *chaks* within a tertiary unit is to be by "on/off" control structures, that is, the flow through a *chak* outlet is either "on" or "off". The premise is that simple "on/off" outlet structures require minimum management effort for farmers to distribute water within a tertiary unit.

Based on the new design criteria, the distribution systems in Blocks 3 and 4 were modified. The reconstruction of Blocks 3 and 4 were completed by the middle of 1987. The current design capacities of the secondary level canals in these blocks range from 0.25-1.95 m^3/s.

The modification of the canal network comprised the construction and reconstruction of proportional check weirs at the bifurcation point where secondary canals branched off to lower level canals. The tertiary outlets that were already built with adjustable gates according to the previous design were reset to allow the maximum discharge of 30 lps. The gate leaf of these outlet structures which had large pipes of 50 cm diameter was welded to its frame in the required position after the resetting, and the operating handle was removed to avoid unauthorized adjustment of the gate.[34] Within a tertiary unit, the "on/off" outlet device consisting of a precast concrete pipe served by a concrete check structure was provided for each *chak*. The pipes at the *chak* outlets are of 30 cm diameter. A light concrete slab gate is used at both the concrete check and the outlet structure to release or shut the flow. The provision of these precast concrete pipe outlets for individual *chaks* has contributed to significant savings in the cost over the previous design and construction that comprised large concrete division structures with gates. Photo 5.2 shows an "on/off" pipe outlet used in Blocks 3 and 4.

The redesign and remodelling for RWS is an attempt to change the MIP-I into a "structured" system.[35] A structured irrigation system is a system, including operational characteristics of canals, delivering continuous (but fluctuating) flows above a predetermined structured level below which the network operates "on/off" (intermittent flows) and delivers at full supply levels (FSL) when "on" (Shanan et al. 1985, 1992). Engineers advocating this technology argue that structured irrigation systems simplify management by minimizing continuous regulation of a vast number of gates, thereby significantly reducing the number of operating staff (Shanan 1992: 153-155; Albinson 1993). Thus, mismanagement by the operating staff and illegal intervention by farmers is reduced to a minimum because the system below the structured level will require only simple division controls down to the farmer service area (*chak*) level, and farmers are notified of the seasonal schedules in advance.

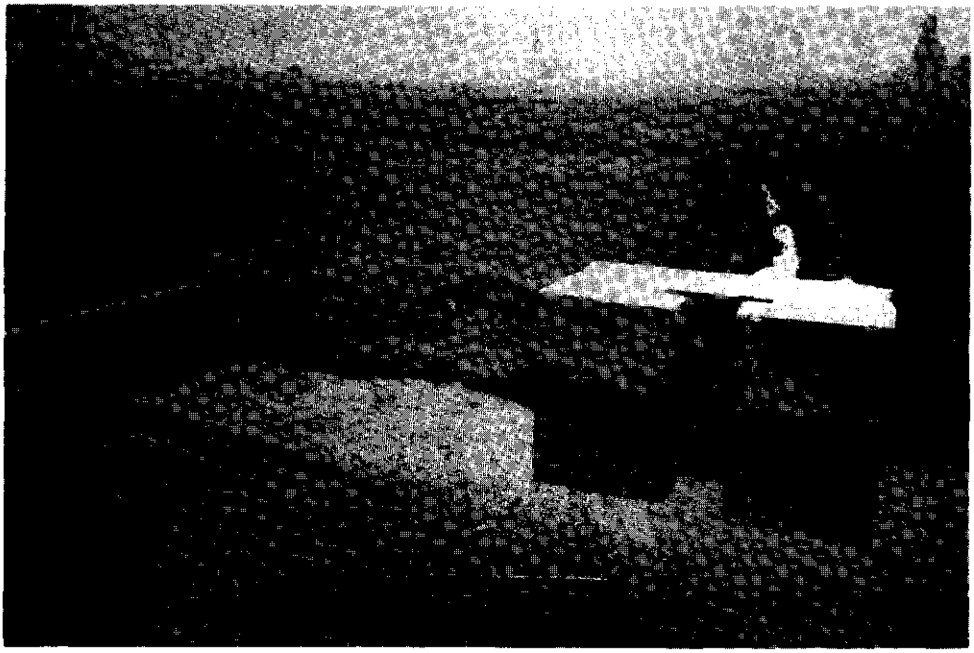


Photo 5.2 An "on/off" pre-cast concrete pipe outlet at the head of a *chak* in Blocks 3 and 4 of MIP-I (1993)

The complexity of the system management is directly related to the structured level. In other words, it is directly related to the number of points (nodes) in the system where control instructions have to be executed. The more the number of regulated control points the more flexibility the system has but more difficult it is to manage, particularly in the case of manually operated gates.

The level of structuring can be fixed at any point above the *chak* outlet up to the headwork of an irrigation system. It is the highest point in the system below which flows are either fully "on" or "off" during an irrigation cycle. Above this point, the irrigation system needs to be fully regulated and actively managed. The level at which an irrigation project (system) is structured depends on system size, village size, prevailing cropping systems and the technical (skills) level of the operating staff.

Shanan (1992) suggests that irrigation projects larger than 10,000 ha should be structured at the 2,000-3,000 ha level. Larger structured blocks mean less internal regulation and easier management, but less flexibility in providing for the needs of individual areas within the block. Often, in practice, a large irrigation block cannot be treated uniformly in terms of soil and crops, and therefore it cannot be structured as a single unit. The existence of upland and lowland areas and the different choice of crops by farmers for these areas in MIP-I illustrates this. In such situations, the level of structuring needs to be lowered.[36] An irrigation system is said to be zero structured, if it is structured at the tertiary outlet and is provided with modular size tertiary units which receive a flow of 0.028 m^3/s, the "modular flow" (Albinson 1993).

MIP-I as a mixture of fully regulated and structured system

According to the 1981 design, all control structures in the irrigation system were provided with adjustable gates.[37] This design results in an unstructured system since it creates a "fully regulated" system (Shanan 1992, Albinson 1993). The redesign of Blocks 3 and 4 of MIP-I in 1986 followed a technology in which flow in secondary level canals is proportionally divided by fixed weirs.

Whereas the distribution system in Blocks 3 and 4 were immediately modified according to the new design criteria for RWS, Blocks 1 and 2 were left, as they had been rehabilitated under the 1981 design. Note that Blocks 1 and 2 were not designed for RWS (Halcrow 1990: 13). As a result (of the two design approaches applied one after another within a short period of time), the physical infrastructure of MIP-I presently comprises two distinct parts:

- Part I consisting of Blocks 1 and 2. This part comprises a total area of 2,268 hectares with gated control structures and has tertiary units up to 40 ha. The maximum number of *chaks* within a tertiary unit are 5, and the maximum size of a *chak* is 8 hectares.[38]
- Part 2 consisting of Blocks 3 and 4. This part comprises a total area of 2,276 hectares with weir-type proportional water division structures at secondary canal level. The tertiary units are sized to 28 hectares, and each tertiary unit has seven *chaks* of maximum size 4 hectares.

With different types of water distribution structures, the two parts of MIP-I require different management arrangements. This presented practical difficulties in the system operation. Therefore, in order to enable the entire irrigation system to be operated on the principle of rotational water supply and distribution, the project began remodelling the secondary and tertiary level canals and the tertiary units in Blocks 1 and 2 under the recommendation of the consultants.

The remodelling of Blocks 1 and 2 consists of the following activities (Halcrow 1992: Appendix B):

- realigning, if necessary, of the existing tertiary canals and drains,
- relocating or modifying quaternary outlets,
- installing new (*chak*) field outlets along the tertiary canal,
- redefining *chak* boundaries,
- computing new discharges at the head of a tertiary canal based on the design water requirement of 1 lps per hectare; minimum flow in a tertiary to be 20 lps and only one *chak* in a tertiary unit to receive water at one time,
- adjusting and fixing gate openings at tertiary outlets for revised discharges; the gate plate to be welded in position on the gate guide to prevent unauthorized opening,
- revising secondary canal discharges, and
- modifying cross regulator structures in secondary level canals; this comprised computing new crest levels at existing gated cross regulators, removing the gate or fixing its position.

According to the project engineers, all gated cross regulators in the secondary canals of Blocks 1 and 2 will be replaced eventually with weir-type check structures, as in Blocks 3 and 4 (Halcrow 1988b: pp. 3.6-3.7).

The remodelling of Blocks 1 and 2 was initially planned to begin before the implementation of the Stage II, i.e., in 1988, and scheduled to be completed by the end of 1991. But it could not begin until late 1991 and was still in progress at the time of the fieldwork.[39] There are several reasons for this. First, there were inadequate field staff like overseer and *amins* (land surveyors) and lack of logistic support (transport), especially in the beginning of the work (Halcrow 1990, 1992). Second, this remodelling work is organized as a part of the routine maintenance of the irrigation system (Aryal et al. 1992). Further, the engineers and other field level technical staff of the project are hardly interested in this remodelling work because of the difficulty of convincing farmers who are used to a particular water supply situation for a considerable period to accept changes in mode of irrigation water delivery. Moreover, there is no incentive for the technical staff to be interested in farmer-oriented works because their performance is not judged by the success in dealing with farmers but by the amount of construction work carried out. Also this remodelling exposes the design weakness of the engineers.

Further, the consultants have emphasized construction of field channels within *chaks*. The emphasis on field channels is based on the design engineers' presumption that given the short period of time the tertiary outlet is "on", efficient and equitable distribution of water within a tertiary unit can be achieved if there is a well laid out network of field channels to deliver water to each individual farmer's field, instead of field to field irrigation (Halcrow 1992: 3). Field to field irrigation results in inefficient and inequitable water use, as uppermost fields are over-irrigated while the lower end fields receive inadequate water. The consultants initially suggested that a field channel should serve a land area of 0.1 hectare maximum. This was amended later so that water should run from individual plot to plot within the 0.1 hectare during an irrigation turn because, in reality, the individual fields within the command area are between 0.01 and 0.025 hectare (Halcrow 1992: 5).

Observations show that the remodelling of the tertiary units in these blocks is carried out with farmers' participation (see also section 5.3).[40] However, the response from the farmers has been poor. Many tertiary units do not have a complete network of proper field channels constructed according to the specifications of the project. Only main field channels of a certain shape and length connected to the group outlets have been constructed. The consultants noted the following reasons for this (Halcrow 1992: 4-6):

- disagreement between farmers on the sharing of water from a common outlet,
- abundant water available for the area,
- reluctance to allow loss of land to field channels serving group of farms within a *chak*, and
- more labour requirement for operation and maintenance of field channels.

The availability of abundant water and loss of land for field channels appear to be the principal factors influencing non-cooperation from the farmers in the remodelling works.[41] On the other hand, it has also attributed to the minimum destruction of the control structures at the tertiary level.

The physical infrastructure of MIP-I as it stands can be said to comprise a part requiring regulation of flows down to quaternary outlets and a part that requires flow regulation at secondary outlets only. The physical system is relatively new and well maintained. Silt deposition in the canals is high because of the high silt content in the water from the Mahakali river, and the project is responsible for removing it up to the tertiary outlet. There is much less infestation of aquatic plants in the canals than at Banganga.

In order to eventually operate the entire irrigation system on the principle of rotational water supply, the project has developed organizational and institutional arrangements which are discussed in the following section.

5.3 The organizational and institutional arrangements for water control

The present organizational and institutional arrangements for the operation and maintenance of the MIP-I are the outcome of both the technical design and the change in the policy of the government towards the management of government constructed irrigation systems. The government decision towards the management of this irrigation system (project) has been influenced by the World Bank.

The project arrangements
Prior to the implementation of the MIP, from 1975 to 1979, the existing irrigation system was operated and maintained by the Department of Irrigation. Not much could be learnt about the department's arrangement for the system operation during this period, due to lack of empirical data.[42] Apparently, at field level, gate operators and *dhalpas* regulated flows in the main and secondary canals. The water distribution below the government-built tertiary outlets was left up to the farmers, as in other government-managed systems in the country at the time.

In 1980, following the implementation of MIP-I, the operation of the existing irrigation system came under the control of the project management. After the completion of MIP-I in 1988, an organizational arrangement for the operation and maintenance of the completed system was suggested by the consultants. An operation and maintenance division under the project management was to be created. This division was to consist of three sections: one section to manage the main canal, one for Blocks 1 and 2, and one for Blocks 3 and 4 (Halcrow 1988b: p.3.5). This organizational arrangement was soon amended to include an additional section which deals with farmer organization. Figure 5.5 shows the reorganization for the project management agreed by the World Bank in November 1992.

As shown in Figure 5.5, the project management has a division called "Irrigation Management and Farmer Organization Division" for the operation and maintenance of MIP-I. The division is headed by a senior divisional engineer (equivalent to an executive engineer in India). It has four sections. The responsibility of operation and maintenance of the irrigation system from the main canal down to tertiary outlets is divided into three sections. Each of these three sections is headed by an assistant engineer supported by two overseers, one supervisor and nine *dhalpas*.[43] Note that the number of support staff allotted to the two sections that are responsible for Blocks 1 and 2, and Blocks 3 and 4 are the same irrespective of the difference in operational requirements.[44] This implies that the field operating staff have been allotted based on the irrigated area only, and not on the actual operational requirements, since the sum of the areas under Blocks 1 and 2 is almost the same as under Blocks 3 and 4.

In addition to manpower, the consultants have emphasized the provision of physical facilities for the operating staff for effective operation of the irrigation system. For instance, they recommended a separate control room in the project office for the operating staff, to facilitate water control (Halcrow 1988b: p. 3.4). A schematic diagram of Stage I canal network was painted on a large metal sheet and was to be installed in the control room. At the period of field research, no separate control room existed yet, and the painted board was lying on the floor in front of the office room of the person incharge of the Operation and Maintenance Division. This reflects the negligent attitude of the (project) division and its engineers towards the system operation.[45] The main reason for this attitude of the engineers of this division is the on-going construction of Stage II. Since the operation engineers are also civil

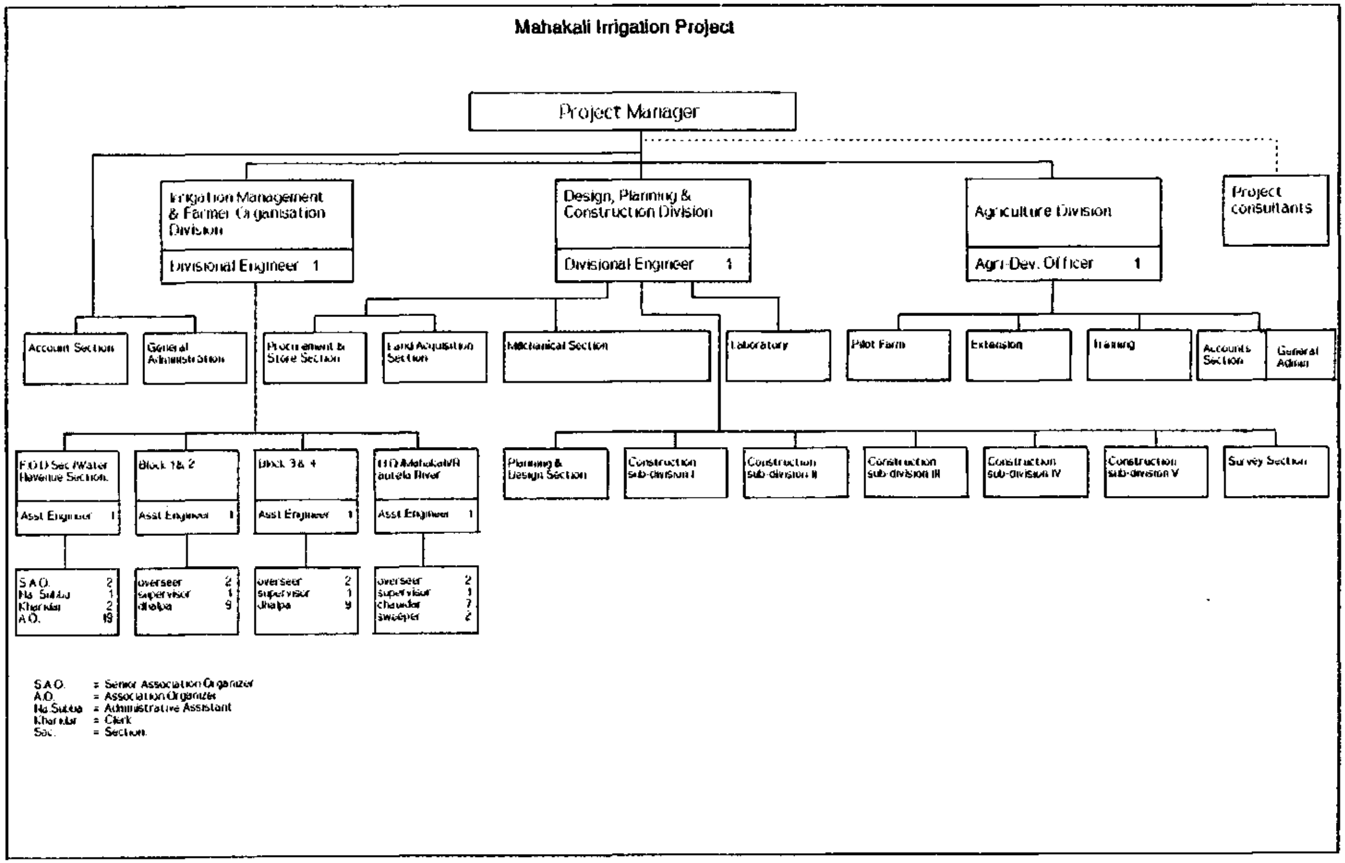


Figure 5.5 Organizational structure of the MIP showing arrangements for the operation and maintenance of the Stage I system (Source: Project documents, MIP, 1993.)

engineers, construction works obviously attract them more than the system operation. In fact, any engineer who is transferred to the project prefers to be assigned to the Stage II area.

One of the four sections under this division is called "Farmer Organization Development and Water Revenue Section" (hereafter referred to as the FOD section). The FOD section has been placed under this division in order to achieve the effective participation of farmers in the operation and maintenance of the irrigation system and facilitate irrigation fee collection.[46] It is charged with assisting the farmers by organizing and training them. Note that the personnel in this section are non-technical staff: 21 association organizers and three administrative assistants. Apparently, an assistant engineer is to be assigned to head the FOD section (see Figure 5.5). But the project did not assign an engineer to this position until 1993. The Farmer Organization Development Coordinator (FODC), who is a non-technical person employed by the consultants, supervised the activities of the FOD section.[47] A professionally trained engineer does not find it interesting to be the head of this section. The scope of activities of the FOD section is further dealt with in this chapter under "FOD section and water users' organization".

The division of responsibility of water control between the project and farmers at different levels of the irrigation system is explicitly mentioned in the occasional reports and the Operation and Maintenance Manual prepared by the consultants (Halcrow 1988c, 1990). In brief, it is as follows:

- Flow regulation in the main and secondary level canals is to be controlled by the project (Irrigation Department).
- Rotational distribution of water within a tertiary unit is to be completely under the control of the farmers.
- Rotation of flow within a *chak* is to be controlled by the farmers within the *chak*.

While this division of responsibility of water control is not new to the Irrigation Department nor to the farmers, the institutionalization of this responsibility is of interest and significance in this case.

Water users' organization

Prior to the implementation of the MIP, there were no formal water users' organization for the operation and maintenance of the existing system in existence. The main reason for this, in this particular case, is that there is abundant supply of water available to irrigate all the lands within the command area in all crop seasons. As Uphoff (1986: 97) has noted: '... where water is abundant there may be little or no need for (farmers to make) collective effort to acquire, allocate and distribute it ...'

Farmers participation through organized water users' groups was strongly emphasized by the World Bank, right at appraisal. The project envisaged that water control at tertiary level could be better achieved by establishing water users' groups and training the water users in water management and agricultural practices. The appraisal report stated (World Bank 1980: 29-30): 'Farmers would participate in the implementation, operation and maintenance of the project through Water Users' Groups (WUG) organized by project staff. A WUG would be established for each tertiary outlet command serving groups of farms of about 40 ha before water is delivered. Each WUG would be represented by a leader and sub-leaders for the 7-8 ha sub-groups elected by the farmers. Their representatives would work with project staff in mobilizing farmers to construct field channels and drains and to operate and maintain the irrigation system below the tertiary outlet. WUG would be legal entities established under the Cooperatives Act and eligible for borrowing from Agricultural Development Bank of Nepal (ADBN).' Further, it was stated, '... water would only be made available on a regular basis to a tertiary unit completed or improved under the project when WUG has been formed for the unit, field channels constructed and satisfactory distribution routines established' (underlining added for emphasis). It was also mentioned that the water distribution programme would be formulated and agreed upon with representatives of the WUGs concerned and water would be released to tertiary outlets according to the agreed programme, and the distribution of water beyond these outlets would be carried out by the WUGs. Herewith the World Bank had the government committed to the farmer participation in the project.[48]

Despite the emphasis by the World Bank, available documents show that the project made its first effort through its Agriculture Pilot Farm to organize farmers into water users' groups only in the late 1987, after Blocks 3 and 4 of the MIP-I had been reconstructed for RWS.[49] This effort was made with the help of field extension staff from the Department of Agriculture (APROSC 1989; Halcrow 1990: 10; Subedi et al. 1992). It was not successful, for several reasons. Firstly, the extension staff available for this work were inadequate and at the same time they were also required to carry out their regular agriculture extension duties. Second, they lacked the skills and the inclination for such group formation work. Third, these extension staff did not understand the RWS concept well. Fourth, they were short of time to organize effective WUGs, since the formation of WUGs, training and orienting farmers and their leadership, and discussing agricultural and irrigation system problems were all attempted within a short period. Further, the WUGs formed and their leadership were largely selected by the project itself, and were seen as a means of regulating the behaviour of farmers rather than as a means of eliciting participation (Halcrow, 1990: 10). As a result, more than 90 percent of the farmers were unaware of the formation of water users' groups in their area. They could not get a clear idea about their roles and functions of their groups, and also failed to understand the RWS concept.

The redesign of the irrigation system for RWS which induced water scarcity is another factor to organize farmers into water users' groups in Mahakali. The effective and equitable water distribution within a tertiary unit, where farmers have to share a common channel and flow, requires farmers to be organized, cooperative and to take appropriate measures for social control if they wish to benefit from the controlled supply made available to them.

Further, in April 1989, the government declared the MIP as one of the three government constructed gravity irrigation projects in which the participatory management according to the 1989 Irrigation Regulations would immediately be implemented.[50] Furthermore, in September 1989, an additional credit fund was made available by the World Bank (under the Stage II development) for the development of farmer organization in Mahakali (Subedi 1989). The policy decision and the availability of fund together had significant impact on the development of water users' organization in the MIP-I area. It accelerated the formation and development process.

Given these conditions, the organizing of farmers in the MIP-I area was resumed in the middle of 1989, with a new approach and strategy. A Farmer Organization Division was established. A Farmer Organization Development Coordinator (FODC), a Supervisory Association Organizer (SAO) and about twenty trained Association Organizers (AO) were deployed on contract.[51] A "coordinating committee" consisting of the project manager, FODC, chief of the Agriculture Pilot Farm of the district, chief of the Irrigation Management and Farmer Organization Division, and chief of the Design Division was formed. Its prime activity was to give the farmer organization a role in all possible project activities and review progress weekly. The process of the formation of the water users' organization in Mahakali is described in detail by Subedi (1989, 1990) and Subedi and Gautam (1992).[52]

The formation of WUGs began from the lowest level of the irrigation system, the group outlet or the *chak*, in ten selected tertiary units (Total area: 300 ha) with AOs helping the farmers to organize. The AOs were continually present in the farmer community to help the farmers. By doing so, they also helped the project to obtain maximum knowledge of farmers in the area. By January 1992, water users' organizations had been formed at different levels of the irrigation system.

The water users' organization (WUO) in MIP-I has four levels: *chak*, tertiary, secondary and main canal or the system level. The lowest level of the organization is called "outlet group". The tertiary level organization is called "tertiary committee", while the secondary canal level organization is called "Water Users' Associations" (WUA) or "Assembly of Representatives". At the projet level is the "Water Users' Association Coordination Committee (WUACC)". This water users' organization was registered with the District Administration Office on March 3, 1993 (Nepali date: *Falgun* 20, 2049) as a corporate body (Joshi 1993). Figure 5.6 shows the four-tier structure of the organization.[53] Clearly, the organizational structure is parallel to the hydraulic levels of the irrigation system.

The members of the higher levels of the WUO represent the water users immediately below. These members are selected or elected at a general assembly meeting. The head of the Irrigation Management and Farmer Organization Division of the project and the chief of the Agriculture Pilot Farm are *ex-officio* members of WUAs. The project manager is the *ex-officio* member of the WUACC. This arrangement of including the project (agency) personnel concerned in the water users' organization allows a linkage to be made between the project and water users' organization.

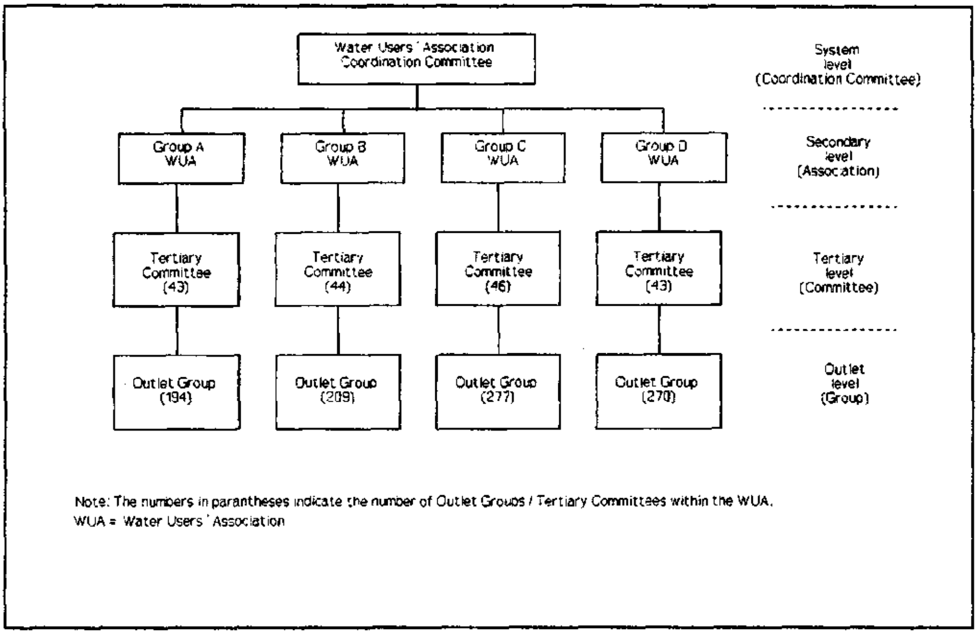


Figure 5.6 Structure of the water users' organization in MIP-I in 1993 (Source: Project documents, 1993.)

The functions of the organization (WUO) at different levels and the tasks and responsibilities of the functionaries are given in the constitution (written in Nepali) of the organization. The principal tasks of the outlet group and the tertiary level committee are water allocation and distribution, maintenance of the canals, mobilization of (labour) resource for the canal maintenance, and resolution of water related conflicts within the tertiary unit. The tertiary committees are empowered to make rules to control stray cattle within their areas, make their own maintenance schedules and sanctions, fines and penalties for the defaulters. The main function of the WUA and WUACC is to coordinate various activities of the lower level groups related to irrigation water and to assist the project in the operation and maintenance of secondary canals and the main canal. In this way, the higher level organizations have only advisory roles. However, the project management expects them to play an active role. Aryal and Sharma (1992:75) wrote: 'The agency (MIP) has been seeking the higher level committees' help to generate people's willingness to protect secondary and main canals from being cut and breached.'

An interview with the chairman of the WUACC indicated that while tertiary committees are encouraged and urged to participate actively in irrigation management activities in their areas of jurisdiction there is no specific division of tasks and sharing of management responsibilities between the higher level organizations (Associations and Coordination Committee) and the project. The specific tasks to be carried out by the higher level organizations are decided during the meetings with the project officials. This is perhaps because the organization is still new. As the chairman reported: 'Since the higher level organizations were formed in January 1992, no major decisions and works have been undertaken' (Bhatta 1992).

The process of the formation of water users' organization in MIP-I shows that the development of institutions like water users' organization is a long term activity, and that "a quick approach" to institutionalize farmers participation in government controlled irrigation systems is not fruitful. Also, it shows that non-technical field level organizers working separately under a section like the FOD enhance the organization of farmers in government irrigation systems where technical officials are dominant.

FOD section and water users'organization

The importance given to farmer participation in the project activities is evident from the fact that the FOD section has been established as an integral part under the project management. The FOD section functions as a bridge (link) between the project and water users' organization. It works virtually as an autonomous unit, and is very active because the engineers of the O and M Division of the project do not interfere much.[54]

The AOs are in constant touch with farmers and assist the farmers in fixing water turns within a tertiary unit, in settlement of disputes on water related matters, and in the selection or election of new outlet leaders, if necessary.[55] They also help plan, schedule and implement monthly and annual programmes for WUGs, depending upon the need of both the project and the water users. Meetings are regularly held with WUGs, and decisions and discussions are recorded in the minutes of the meetings. It was also observed that the AOs held internal meetings at least once a month to discuss matters related to the realignment of field channels, assessment of repair works and so forth, besides the operation of the irrigation system at tertiary level. As stated earlier (in Section 5.2), the project is currently concerned with the remodelling of Blocks 1 and 2 and the construction of field channels within all tertiary units of Stage I. The FOD section assists WUGs in these works. Farmers seem to construct field channels where there is a consensus on the alignment and use of common field channels.

Interviews with the FOD coordinator and AOs indicated that operation and maintenance engineers are hardly interested in farmer organizing activities. The engineers do not even like to attend AOs internal meetings. In the beginning, the engineers attended some of the meetings with farmers, upon request from the FOD section and the consultants. But the engineers gradually began to withdraw from such meetings later, when farmers began to complain openly about the poor quality of construction works and undesirable practices of the engineers and overseers, like allowing influential farmers to have pipe outlets. The practice now is that the divisional engineer will instruct the assistant (Block) engineer responsible to attend the meeting, and the engineer will order the overseer to do so. The FOD coordinator indicated that the attendance by overseers in farmers' and AOs' meetings helps very little since they have no authority to make any commitments on behalf of the project. The result is that the overseers do not attend farmers' meetings either. In this way, farmer organizing activity is totally dealt and supervised by the FOD section alone.

Available records show that the FOD section has been recording the landholding of farmers, the irrigated areas, and crops cultivated in each outlet command within tertiary units as well as organizing farmers. The AOs obtain these data through interviews with the farmers and field inspection. The landholding sizes are marked on the parcel maps. AOs interviewed indicated that these records are used by WUGs for water allocation and distribution, resource (mainly labour) mobilization for the maintenance of the tertiary canal and field channels, and the assessment of irrigation fees. The records of the landholding and the irrigated areas thus obtained are also used to check the *amin*'s assessment of irrigated areas.

The project presumes that farmers lack skill in irrigation water management. The design engineers state: '... the members of WUGs are unlikely to have received any training or advice on how to make best use of the limited amounts of water that are issued to them ...' (Halcrow 1988b: p.3.8). Field demonstration on water management at the Pilot Farm and observation trips to farmer-managed systems like Pithuwa and Chhattis Mauja Irrigation Systems have been conducted for farmers' representatives to improve farmers' skill and motivate them to participate. The observation trips have had considerable impact on the farmers.

The impact of the WUG formation and training farmers is that the project has been able to obtain considerable cooperation in the construction of field channels, in water distribution within the tertiary unit, and in the maintenance of the tertiary canals constructed by the project and the field channels constructed by farmers (Aryal and Sharma 1992). Observations show that most tertiary canals in Blocks 3 and 4 are cleaned well by the farmers. The labour contribution for cleaning tertiary and quaternary canals is usually based on the household, at one person per household irrespective of landholding (See also Subedi et al. 1992). The labour contribution on household basis appears to be equitable here because most farmers are re-settlers and have rather small landholdings. Farmers interviewed indicated that a tertiary canal needs cleaning twice a year, and an average of 20 man-days are required for one kilometre of tertiary canal. Removal of silt is the main cleaning task.

Figure 5.7 summarizes the management regime and the organizational arrangements of the project compared with the physical system. Clearly, given the water control technology, efficient operation of the system by the irrigation agency at the main system level is crucial. In the following section, some observations of the operation of the main and the secondary canals during the December-January 1993 period are described, to illustrate the actual operation of the irrigation system compared to the designers' assumptions.

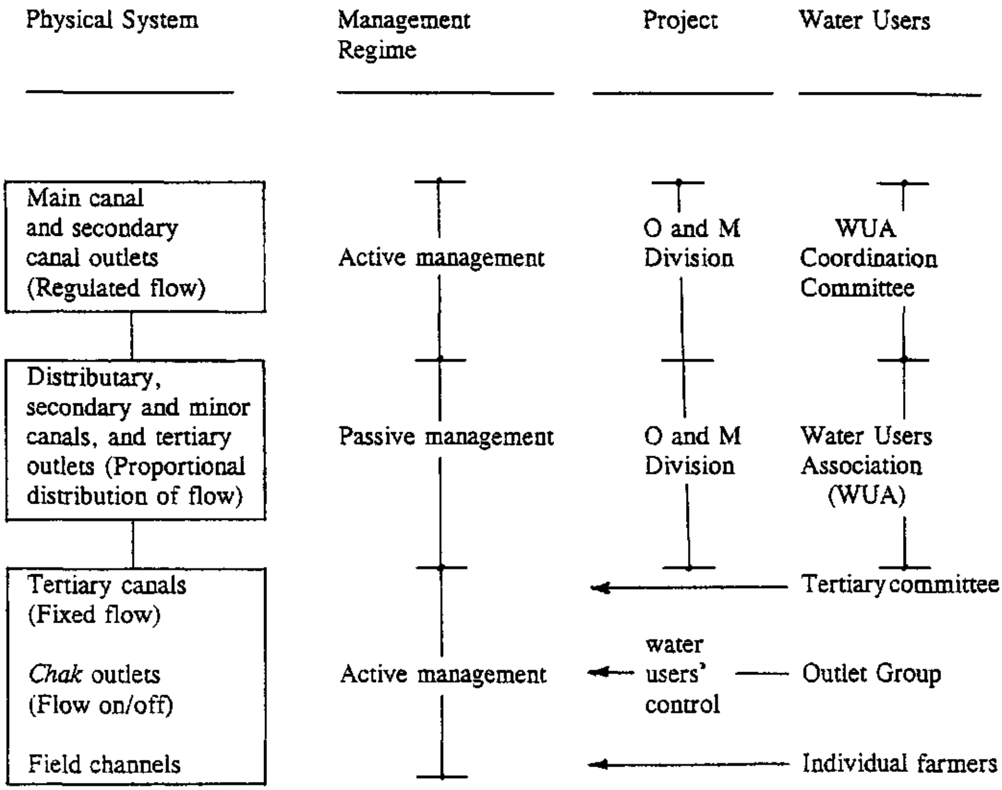


Figure 5.7 Management regime and organizational arrangements of the project compared with the physical system of the MIP-I (1993)

5.4. Water allocation and distribution

As mentioned earlier, water supply to Mahakali is controlled by the Indian authorities at the Sarda barrage. Regardless of the requirement, the project tries to obtain water supplies according to the agreement to avoid the precedence of accepting a reduced supply. The agreed amount of water supplies can be realized only by maintaining a better relationship with the Indian authorities at the barrage. Available evidences show that the engineers of the MIP have indeed maintained good relations with the Indian authorities.

The project tries to monitor the water supplied in the main canal. For this, a concrete broad-crested weir (bc weir) has been built on the main canal near the border (called "border weir"), at about 600 metres from the head regulator at the barrage. The Indian authorities also maintain a measuring gauge on the Nepal (main) canal just below the head regulator, to control flows in the canal.

Measuring flow at the border weir is a problem. According to the consultants, the weir needs recalibration, particularly for measuring discharges above 9 m^3/s (Halcrow 1992: 7). Further, there is another practical problem. In the main canal at 412 m downstream from the weir, there is a cross regulator which serves a minor canal called *Gadda Minor*. This minor canal is at 330 m below the weir. The gates of the cross regulator are mostly lowered because of the farmers' demand for water.[56] Given the flatter gradient of the main canal (which is a contour canal), the lowering of the gates at this cross-regulator influences the water level at the border weir, giving apparently higher discharge.[57] Since the border weir is not reliable, records of the water supply are obtained by the project engineers from the Indian authorities.

The design assumptions

Water allocation (by design) in the MIP-I area is based on the design water requirement of 1 lps per hectare at the tertiary outlet. The irrigation system under Stage II is also designed based on this design water requirement (Halcrow 1988a: 33-34). It is assumed that the main canal will have a continuous supply of 13 m^3/s in the high flow season and 4.25 m^3/s in the low flow season. The design engineers have allocated water to Stage I area considering simultaneous operation of Stages I and II, the amount of water being proportional to the irrigable area (Halcrow 1988a, 1988b).[58] Based on this apportion principle, Stage I is allocated a supply of 5.25 m^3/s during the high flow season and a supply of 1.71 m^3/s during the low flow season (Halcrow 1988b: p.1.4).

Under these water share and operation criteria, the water allocated in the high flow season can irrigate only about 75 percent (i.e. 3,570 ha) of the total irrigable area under Stage I at a time, considering the 68 percent delivery efficiency.[59] In the low flow season, only about 25 percent (i.e. 1,160 ha) of the total area can be irrigated at a time (Halcrow 1988b: pp. 2.6-2.8). These conditions necessitate rotational distribution of water between secondary canals or between groups of secondary canals taking off from the main canal. Therefore, the design engineers have divided the irrigable area of Stage I (also of Stage II) into four irrigation (rotational) blocks of almost equal size.[60] Each rotational block is served by a group of secondary canals which are to be operated either "on" or "off" at full supply flow. The grouping facilitates the operation of the canals at full supply flow during the low flow period. It is presumed that rotational distribution will be applied at three levels (Halcrow 1990: 2): (i) rotation among groups of secondary canals taking off from the main canal, (ii) rotation among the *chak* outlets within the tertiary units, and (iii) rotation among individual farmers within a *chak*. Figure 5.8 presents schematically the grouping of canals and the rotational distribution to be followed at three levels of the irrigation system.

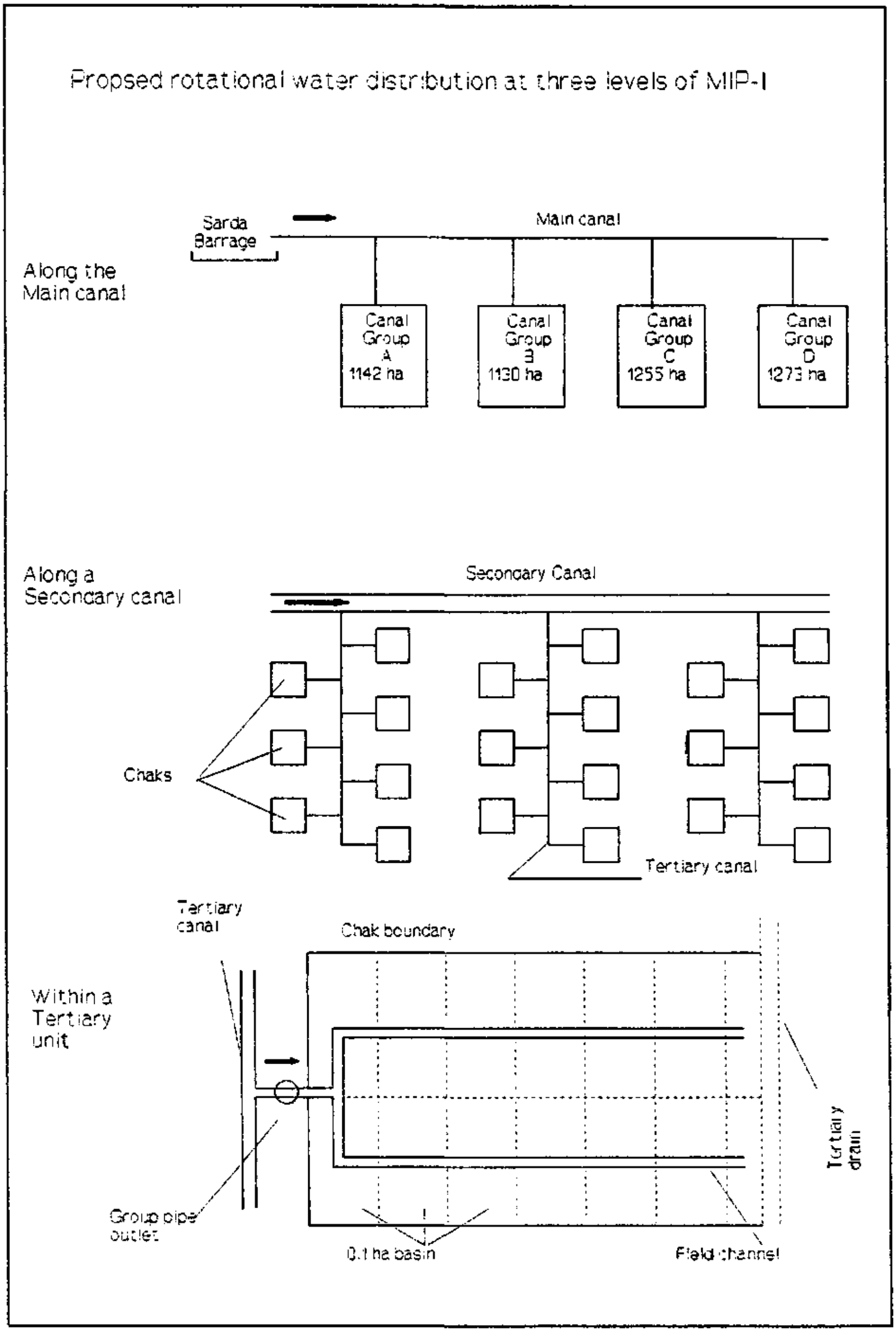


Figure 5.8 Schematic presentation of the proposed rotational water distribution at three levels of MIP-I (Source: Project documents, MIP, 1993)

Since the irrigable areas under each group of canals are almost equal, the water allocated for Stage-I during the high flow season allows three out of the four groups of secondary canals to be operated at a time (called 3:4 operation). Water distribution among the four groups of canals is to be in successive rotation e.g. ABC, BCD, CDA, DAB and so on. However, if the maximum supply of 28.3 m^3/s (see Section 5.1) is available, a continuous full supply flow to all secondary and tertiary canals of the Stage I and II areas is possible throughout the high flow season (Halcrow 1990: 7). In the low flow season, only one out of the four groups of canals can be operated (1:4 operation) at a time, with each group of canals receiving water in succession, usually beginning from A towards D.

Further, the irrigation system, Blocks 3 and 4 in particular, is designed such that when a secondary canal is "on" all tertiary outlets in the canal automatically draw the fixed or design flow because the gates at the tertiary outlets are fixed or welded. Therefore, if all or most farmers along a secondary canal do not wish to use water during the "on" period (for instance, after heavy rain), the secondary canal will be closed and water will not be supplied in this canal until the next turn. Within a tertiary unit, the *chaks* will draw water from their parent tertiary canal in turn. The order of turn among the *chaks* and the scheduling of the periods of flow to each *chak* within the tertiary unit will be determined by the farmers through their tertiary committee and the WUGs. Within a *chak*, an individual farmer will not be obliged to use the water in each "on" period. He may instead irrigate on two or three occasions only, during the season.

Initially, the canal operation was planned such that during the high flow season groups of secondary canals would be operated 21 days "on" and 7 days "off", and during the low flow season 7 days "on" 21 days "off". This canal operation plan was modified by the consultants shortly afterwards, even before it had been tried out, after considering the local farming practices and farmers' demand. The consultants noted that rice nurseries which are usually planted between May 25 and June 25 - the early period of the high flow season - could only stand a maximum of 4 days without water because of high temperature and evapotranspiration. Also, during the *rabi* (low water supply and rainfall, from October 16 to May 15) season farmers need water twice a month instead of once a month for winter crops like wheat and vegetables on certain soil types (Halcrow 1988b: p.2.9; 1990: 6). The modified canal operation plan is now as follows: in the early high flow season, each group of secondary canals will be operated 12 days "on" and 4 days "off" during the critical period of planting paddy nurseries (from May 16 to July 2), and in the low flow season 4 days "on" and 12 days "off" instead of 7 days and 21 days.[61] At other periods of the year, the water distribution schedule is to remain as initially planned. This modification in canal operation plan clearly shows that uniform canal operation does not apply in practice.[62]

This operation procedure was planned to be implemented in the entire MIP-I area, beginning from 1989 (Halcrow 1988b: p.1.7). Furthermore, the design engineers emphasize the methodical allocation and distribution of water as follows: (i) budgeting (volumetric allocation of water in litres per second to each offtake points), (ii) issuing (supply of the volume allocated by adjusting gates or water level above weir crests), (iii) monitoring (measurement of flows), and (iv) adjustments (maintenance of flows) (Halcrow 1988b: p.3.4).[63] With water allocation fixed to each area under a predetermined schedule, the design engineers expect that farmers will develop cropping patterns to allow full utilization of the area, matching the supply.

It was presumed that farmers in Blocks 3 and 4 would practise rotational distribution of water within the tertiary units because the canal infrastructure in these blocks were designed for this. In contrast, it was planned to impose water scarcity in Blocks 1 and 2, which were designed for continuous flow, in the first year, to educate the farmers of these blocks about the need to rotate water among *chaks*. The design engineers suggested that water supply in Blocks 1 and 2 be fixed at 1.5 lps per hectare in order to give the farmers time to adjust to a system of rotational distribution (Halcrow 1988b: p.5.3). This did not, however, materialize.

Actual operation

Both farmers and engineers interviewed indicated that rotational water distribution among secondary canals has not been implemented yet in MIP-I as planned. The main reason is that the Stage II irrigation system and the remodelling of Blocks 1 and 2 are still incomplete. The incomplete condition of Stage II allows abundant water to be available for the Stage I area. Interviews with AOs and AO supervisors revealed that rotational distribution is not practised within most tertiary units, particularly in Blocks 1 and 2, because of the abundant water available. For the same reason, farmers in these two Blocks could irrigate their crop when they need and prefer to do so with a continuous flow. Water users' groups and tertiary committees in these blocks have been formed, but they are not distributing water as envisaged by the project, because farmers are particularly aware of the adequate water supply in the main canal.

However, available records show that a seven-day rotational distribution is practised occasionally by farmers in many of the tertiary units of Blocks 3 and 4. This is partly because farmers in these two Blocks have been constantly persuaded by the project to practise rotational distribution (see Section 5.3). Water allocation and distribution within a tertiary unit is organized by the tertiary committee. The allocation of (available) water to each *chak* is proportional in terms of time to the area of the *chak*. A water distribution schedule is prepared based on this principle and the schedule is issued to the leader of each outlet group. The WUG leader then distributes the time allotted for his outlet to the individual farmers. The water use turn within a *chak* is usually decided by mutual understanding. The order of water use turn varied among the tertiary units.

Table 5.1 presents water allocation and distribution followed by farmers in a tertiary unit in Block 3, as an example. Figure 5.9 shows the plan of this tertiary unit with seven outlets and the individual fields. The tertiary unit has a total irrigable area of 32.3 hectares and therefore the time allotment per hectare of irrigable area is 5.2 hours, considering a 7-day week (168 hours) turn. Three distinct observations can be made from this Table. The first is the time allotment rounded to full hours. Since the *chaks* are not equal in size, the allocation of time period to them is also unequal, either less than or more than one day. The second is the head to tail distribution of water. The third is that the last outlet, outlet No.7, has about one and half hours less time allotted than it is entitled to. One would assume that the tail-end outlet should be allotted more time because of the seepage losses.[64] According to farmers, the less time allotted for the last outlet is because the last outlet gets all the left over water in the canal when the rotation is resumed from the outlet No.1. Note that the length of the tertiary canal in this tertiary unit is 1.36 km and the bed width is 30 cm.

Farmers interviewed indicated that it was the responsibility of the outlet leader who has the next turn to shut the outlet upstream and divert the water to his outlet. While farmers still use the pre-cast concrete gates in some *chak* outlets, in many outlets they use straw balls or mud blocks to plug the outlet pipes.

Table 5.1 Water allocation and distribution schedule in a tertiary unit in Block 3 (1991 paddy season)

Outlet No.	Area served by the outlet (ha)	Time allotted to use water (h)	Time period
1	4	22	Sunday 0800 to Monday 0600
2	4.9	26	Monday 0600 to Tuesday 0800
3	4.7	24	Tuesday 0800 to Wednesday 0800
4	4.6	23	Wednesday 0800 to Thursday 0700
5	4	22	Thursday 0700 to Friday 0500
6	4.8	25	Friday 0500 to Saturday 0600
7	5.3	26	Saturday 0600 to Sunday 0800

Notes: This distribution schedule was applied in the tertiary unit No. UL 5/L1/2 of the *Ultakham* distributary canal. The (*chak*) areas under the outlets are actual areas and have been fixed by the WUGs and FOD section together.
Source: Records of the FOD section, MIP (1993).

In the winter season, rotational water distribution is not followed at any level of the irrigation system. The project does not prepare a water delivery schedule. Water is delivered to secondary canals upon request. Observation of the canal operation in December 1992 and January 1993 showed that while the main canal is operated continuously, many secondary canals are closed. The secondary canals in operation had water below the FSL. This was because there was hardly any demand for canal water at the time. Farmers, AOs and engineers interviewed informed that farmers mostly irrigate their wheat only once during its entire growth period because of sufficient residual moisture in the soil after the harvest of paddy and the intermittent winter rain. Wheat on some upland soils requires more than one irrigation. Even in areas needing more than one irrigation, rotation within *chaks* is not followed in the current situation of adequate availability of water and the relatively small proportion of the area cultivated with wheat. Farmers arranged their water turns informally since they were few and the area of cultivation was small.

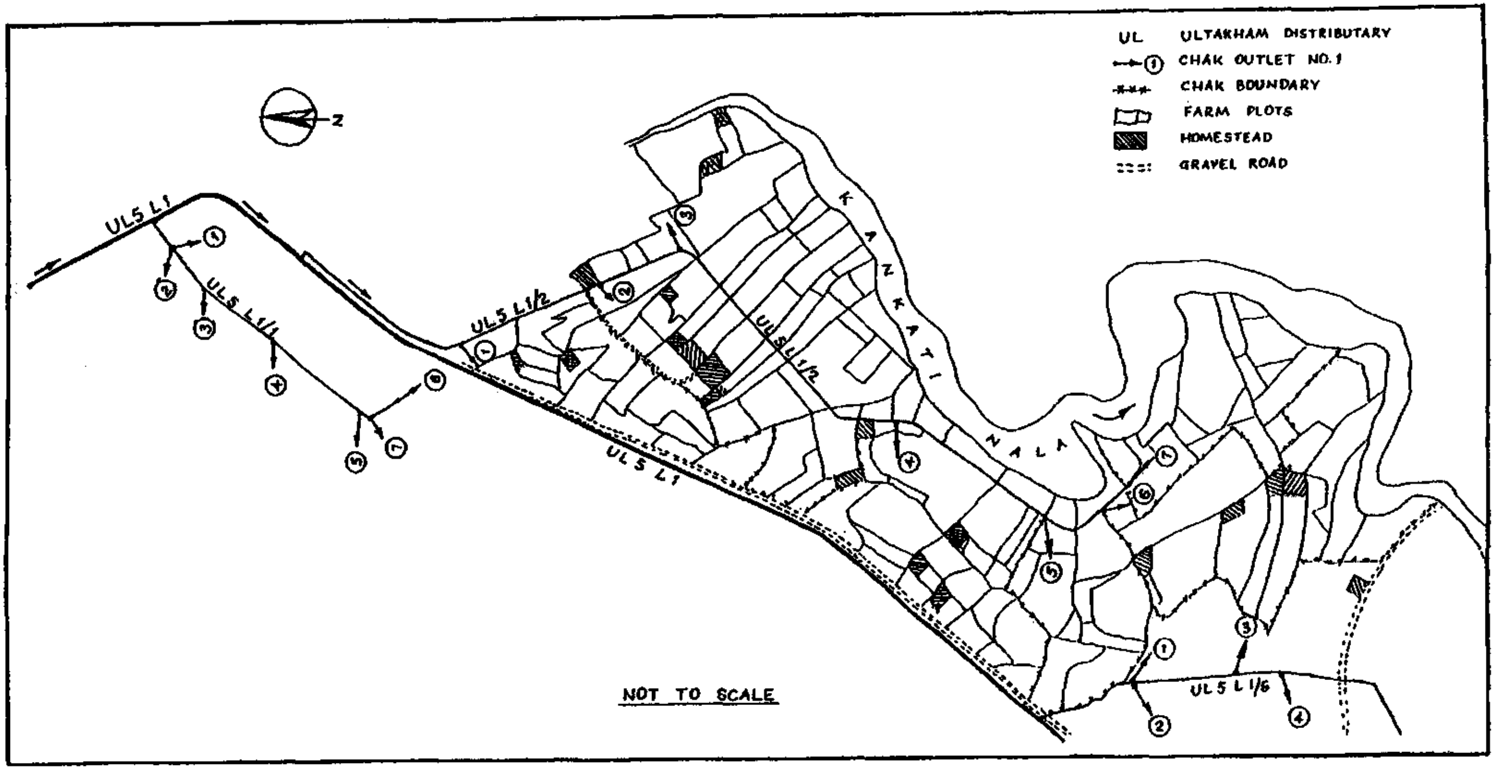


Figure 5.9 A typical tertiary unit with seven outlets in Blocks 3 of MIP-1 (Source: Project drawings, MIP, 1993.)

Farmers verbally request the engineers at the project office or overseers and operators for the release of water in the canals in the winter season. Observation shows that farmers seem to request water to the gate operators or *dhalpas* in the field rather than going to the project office. This results in the informal operation of secondary canals, that is, without the approval from the project office. Gate operators interviewed indicated that many times water is released or closed in secondary canals only on farmers' request. Nevertheless, the operators reported such unscheduled or unauthorized operation of canals to the project office later.

An informal operation of a distributary canal was observed by the researcher in January, and is narrated below to illustrate the methodical steps followed by the gate operator and his knowledge of the control structures in the canal. The canal in operation was the "Mahendranagar Distributary" which takes off at 5+172 km from the main canal headgate. This distributary canal is in Block 2 and is about 5.9 km long. It has a design capacity of 1.06 m^3/s. Its head regulator structure consists of a single rectangular opening and has a sluice gate of 1.5 m wide and 0.75 m high.

A cold and foggy morning of January 5, 1993. The time was 0905 h. There were hardly any farmers in the field. The cropped fields were mostly cultivated with wheat. A diesel water pump stood on the right bank of the main canal, a few metres downstream of the cross regulator serving the distributary. Its suction pipe was immersed in the canal water. The water supply in the main canal was well below the full supply level.

The distributary canal had water below the full supply level. Its regulator gate was secured in place with a chain and a padlock.[65] The gauge mark at the bc weir below the distributary outlet showed a water depth of 20 cm, with a free flow over the weir (Time: 0925 h). The discharge for this water depth is equivalent to 0.45 m^3/s.[66]

The gate operator appeared at 0930 h. He saw me, greeted and went towards the one-storey house at the right bank corner of the distributary head.[67] He seemed to be in a bit of hurry. When asked, the gate operator said that his colleague, the other gate operator assigned to the tail-end of the distributary canal, had come to him the previous night to request an increase in the flow in the distributary as the tail-end farmers wanted to irrigate their wheat crop. He had promised his colleague to increase the flow next morning. He said: 'if I do not increase the flow in the distributary my colleague will be in trouble.'

He picked up a bunch of keys from the key board in the store-house and went to lower the gates of the cross regulator in the main canal. This cross regulator located only a few metres (at km 5+175) below the headgate of the distributary canal has two openings, and each opening has a sluice gate of 5.34 m wide. From the operating bridge of the cross regulator structure, he looked at the gauge marked on the abutment wall of the structure below, opened the lock, unwrapped the chain around the hand wheel of left gate, and started lowering the gate. The screw threads of the hand wheel and spindle rod of the gate were well greased. After a few turns of the hand wheel, he looked again at the gauge to see the position of the gate. He did not seem satisfied with the position of the gate. He brought a big boulder from nearby and dropped it at the left corner of the gate plate. This he did because the gate did not move in the groove smoothly. He said that the gate always tilted towards one side while raising or lowering. Apparently, he could operate only this gate in such crude way because the right gate is jammed at a few cm above the bed of the canal, and has been in this position for a long time. 'The project engineers also know about this. But nothing has been done yet', he said.

The gate was lowered by about 4 cm. The decision to lower the gate in this position was based on his practical judgement and experience. He estimated that under the discharge in the main canal at the time it would take about 30 minutes to build up presumed storage in the canal and stabilize the water level after the gate had been lowered.

He wrapped the chain around the hand wheel and tied the chain with the padlock to fix the gate in position. This shows his confidence on the operation of the structure.

We returned to the store house and waited for the water level in both the main canal and the distributary canal to stabilize.[68] About half an hour later, he checked the water level in the distributary canal. The water level at the bc weir on the distributary canal had increased by only one centimetre. Since it was not sufficient, he raised the gate at the distributary outlet by turning the handle three complete turns. After some time, the water level in the distributary stabilized at 23 cm on the bc weir, which is equivalent to a flow of 0.57 m^3/s. He had increased the flow in the distributary by 0.12 m^3/s. He was satisfied with the increased flow and therefore secured the gate in position with the padlock. It appeared that he could translate the water depth on the canal to the discharge from the experience. He did not, however, record the discharge in the distributary.

Since there were cross regulators to be adjusted down the distributary canal, he collected the keys of the gates to be operated. We walked on the canal road along the left bank of the distributary. He wished that he had a bicycle from the project, which would have saved time in the gate operation.

The first cross regulator, a drop structure, to be adjusted is at 0.228 km from the distributary head, just below the first secondary canal, MN1/L1, which branches off from the distributary. He stopped for a moment to look at the flow in the secondary canal MN1/L1. He did not need to change the flow in this secondary canal and went ahead to adjust the cross regulator gates. This cross regulator is a drop structure with a free flow of water over the structure. It has two openings, each one with a vertical slide steel gate of 1.25 m wide. He opened the locks, unwrapped the chains from both handles of the gates, and raised both the gates by two complete turns to each handle. The spindle rods of these gates were also well greased.[69] The water level on the distributary canal upstream fell by about 5 cm. The gates were secured in position with the chain and the lock. This operation took him about 7 minutes.

The second cross regulator (also a drop structure) is at 1.307 km from the head of the distributary canal and has a single gate 1.8 m wide. He raised this gate by turning its handle to complete four revolutions. The water level in the distributary canal upstream of the cross regulator fell by 5 cm, from 70 to 65 cm in the gauge. The gate was secured in place. This was the last cross regulator to be adjusted. Below this point, he left it up to his colleague to take care of the rest. His part of the canal operation was complete (Time: 1100 h).

This complete gate operation had taken him about one and half hours including the time for walking and the conversation with the researcher. The conversation did not really affect his gate operation work since we continued to talk while he operated the gates.

The above observations show the following. Most farmers find it more convenient to approach gate operators than the project office. Firstly, because gate operators can be approached at any time, day or night. These operators come from their own community and have some landholding within the command area. For example, the above gate operator also had a piece of land in nearby village in Block 2. Secondly, they can be relied on. Communication with them is easier and the response is quick. Thirdly, they do not seem to interfere with what farmers do with the canal water below the tertiary outlet. Thus, a gate operator performs a crucial role in meeting the water demands of farmers, though an employee of the project or the Irrigation Department. He is thus a front line worker, like a *canalero* in the El Operado Irrigation System in Mexico (Zaag van der 1992: 100), maintaining the flexibility of the gated irrigation system. He tries to and has to satisfy both the project or department engineers and the farmers. In the words of the gate operator: 'Engineers ask me whether I am releasing water in the canals as per the demand of farmers, and when I answer yes, they are satisfied.' This also implies and supports the fact that measurements and recording of flow in distributary, secondary and minor canals are given little importance by the operating engineers.

The interview with the gate operator also verified that rotational distribution of water between secondary canals had not been implemented yet. In the 1991 summer, during the planting of paddy nurseries and transplantation of paddy seedlings, the consultants had tried to enforce water allocation and distribution to secondary level canals according to a rotational schedule. But it proved almost impossible for the operating staff to implement the schedule. Farmers were able to influence the project authority to stop the rotational water distribution on the grounds that there was enough water available for a continuous delivery.

Further, other operators and farmers interviewed indicated that engineers responsible for the operation and maintenance rarely show up in the field during the canal operation. Overseers are required to actually supervise and monitor water allocation and distribution at field level, but they are mostly engaged in the survey, estimate and supervision of repair and maintenance works. Moreover, most overseers in the project are new and have little experience in canal operation. Therefore, water distribution has to be trusted to gate operators who seem to know the operational features of the gates very well. This virtually gives a gate operator an authority and power over water control at operational level.

Although gate operators are still required and seen around operating the gates in secondary canals in Blocks 1 and 2, no gate operator can be seen in Blocks 3 and 4. The provision of fixed check weirs to distribute the water proportionally and the welding of tertiary outlets gates or sizing of the tertiary outlets to deliver a fixed flow of 30 lps have eliminated the need for gate operators in secondary canals and below in Blocks 3 and 4. There is only one point of water regulation or control in these two Blocks, the point at which the distributary (secondary, minor) canal takes off from the main canal. Gate operators are required only to operate these secondary canal outlets.

5.5 Summary and conclusions

This chapter has shown how, in an externally financed large irrigation development project, the donor or the financing agency (in this case the World Bank) and the foreign consultants can play important roles as agents of change. It has also illustrated how they can bring about changes abruptly. According to the guidelines of the World Bank, the existing irrigation system was first redesigned and rehabilitated to change it into a "modern" system with gated technology which allowed full regulation of water flow down to the quaternary outlets. This technical improvement was aimed to deliver water to farmers on demand. It was also to enable the delivery of adequate water to the total irrigable area of Stage-I during the period of land preparation for planting paddy. But, as it had meanwhile been decided to implement Stage II of the project, the available water supply had to be shared between the irrigable areas of the two Stages, and water scarcity in Stage I was anticipated. As a response to this, the design engineers necessarily chose rotational water supply and distribution to be applied, extended to the secondary canal level. Design criteria were revised. The water control technology through proportional division of water in secondary canals was introduced in place of gated controls, and the concept of "structured" system design was adopted. In this way, two design approaches were followed within a short period of five years. Such abrupt changes in the technical design of the physical system were possible because of the lack of design standards in the Irrigation Department and the weak position of the department engineers *vis-à-vis* the World Bank and the foreign design consultants. The technological intervention became consultant driven and thus unidirectional. The unidirectional intervention in turn resulted in repeated revisions in the design and operation procedures later.

The water control technology through proportional water division structures at secondary canal level and a fixed delivery of flow (in this case 30 lps) to tertiary outlets has reduced the management input required from the project to operate and maintain the irrigation system. Therefore, this technology appears to be useful for an operating agency which has limitations of skilled man power and financial resource. However, it should be looked upon as undesirable where there is large spatial variation in soils and crops.

The premise of introducing rotational distribution in MIP-I was to enforce and formalize the process of water rationing in the water-abundant irrigation system so that irrigation can be extended to the areas which are in need of water. But, empirical evidence from this case study has shown that farmers are unlikely to be motivated to accept and adopt forced water scarcity where an abundant water supply is available. While the project insists on the rotational distribution of water from secondary canals down to farmers' individual fields, farmers wish to wait until Stage II is in operation.

The benefits of farmer participation in the operation and maintenance of government built and managed irrigation systems in South Asian countries have been discussed by many authors (Uphoff, 1986; Lowdermilk, 1985; Bagadion, 1985). In this case, the project has made continuous efforts to motivate and organize farmers to achieve their effective participation in the system operation and maintenance. Water users' organization in the project has been formalized through institutional and legal arrangements. Yet, as this case study shows, whereas it is possible to induce farmers' participation through constant effort, it is not very effective for water control where water is not a constraint.

The water users' organization has been formed by the project such that it has four levels that are parallel to the hydraulic levels of the physical system. Given the proportional division control structures in the secondary canals, the lower two levels - the tertiary committee and outlet groups - have to be relatively more active in actual allocation and distribution of water to farmers than the higher levels of water users' organization. This (hydraulic) channel-based organization appears to be effective here because the project area is a newly settled area with most of the farmers having their homesteads within the farm land. Further, the boundaries of the tertiary units and of the *chaks* have been defined with the help of the farmers.

This case study has also shown how operational realities can be different from the design engineers' assumptions. In this case, the availability of abundant water did not allow the implementation of rotational water distribution as planned.

Finally, the choice of proportional division of water at secondary level canals seemed to have encouraged the farmers towards taking over water control at secondary level canals. The chairman of the WUA Coordination Committee said: 'We believe that we can handle the distributary canals too.' This shows that the type of the technology has strong influence on farmers' willingness to participate in water control. In this particular case, however, it will remain a wishful speculation until Stage II is put in operation and sharing of water between Stages I and II actually begins.

Notes

1. Since the MIP is an on-going project, and improvements in the Stage I area are still in progress, the term "project" has been used in this chapter.
2. The Mahakali Irrigation Development Board (MIDB) was created for effective implementation of the project, under the 1956 Development Board Act. The establishment of the MIDB was one of the conditions for credit effectiveness (see World Bank 1980: 43, Section 9.02). The chairman of the Board is the Secretary to the Ministry of Water Resources. The MIDB is a semi-autonomous agency. The Project Manager is selected from one of the senior engineers of the Irrigation Department, equivalent to a superintending engineer. Most engineers, overseers and other technical staff of the project belong to the Irrigation Department.
3. Sir William Halcrow and Partners Ltd. of England is the principal consultant to the project. Under the principal consultant, two local engineering consulting firms were also involved in the engineering design of the irrigation system under Stage I.
4. According to the 1991 census, the district has a total population of about 258,000 and a total area of 1,610 km^2. It includes The Royal Shuklaphat Wild Life Reserve Forest (15,500 ha) which extends up to the Nepal-Indian border in the south. The arable land in the district is about 29,400 hectares.
5. According to the USBR standards for soil classification, over 95 percent of the command area falls into the Class 2 and 3 for irrigation. See also World Bank (1980: Annex 1, p.46) for the land use and soil characteristics in the command area,.
6. This meteorological station was established under the Project. At appraisal and in the subsequent design, the climatic data recorded at the Dhangadhi meteorological station, which is 40 km east of the project area, were used.
7. In India, the Mahakali river is known as the "Sarda" river.
8. The Sarda barrage (built in 1928) and the Sarda Irrigation System in India were constructed in the 1920s during the British rule, but the MIP in Nepal only began in 1971, mainly due to resource and communication constraints. The Sarda Irrigation System in India has a main canal capacity of 396 m^3/s.
9. See also Gyawali (1991) for the water rights according to the 1920 international agreement with India.
10. There are some small rivers running north-south, but their discharges are unreliable. For instance, the Chaudhar river at the end of the Stage I area (See figure 5.4) has significant flash floods during the monsoon season, but its base flow in the dry season has been observed to be about 1 m^3/s only (World Bank 1980, Halcrow 1988a).

Studies of groundwater resources and their potential in the district were started by the Irrigation Department in 1973 with the technical and financial assistance of the United States Geological Survey and the USAID. According to these studies, a considerable part of the Stage I area contains aquifers. The uppermost aquifer consists of a phreatic alluvial zone 10-20 metres thick and is located at about 2-3 metres below ground level. This aquifer provides water to a number of open wells and shallow tube wells in the area. A semi-confined to confined aquifer of new alluvial sediments descending to a depth of 150 metres lies under this phreatic alluvial zone. The water from both aquifers has been found to be suitable for both drinking and irrigation purposes.

11. This comprehensive Master Plan for the development of the Kanchanpur district was approved by the government in December 1979. The Plan delimits the areas to be maintained as agriculture land, commercial forest, wild life reserves, areas for reforestation, resettlement, and settlement of landless people.

    At appraisal, a total of about 1,000 hectares land in the project area was occupied by encroachers. The implementation of the project required clearing a forest area of about 2,200 hectares (World Bank 1980: 11-13).

12. According to Ojha (1983), the size of land allotment was initially fixed at 1.53 ha (2.25 *bighas*) per family in the resettlement projects implemented under IDA financing.

13. The Royal Nepal Airlines has weekly flights from Kathmandu to Mahendranagar via Nepalgunj. These flights take place only if the weather conditions permit.

14. The classification of small, medium and large farmers in terms of the size of landholding is inconsistent. Apparently, at appraisal, the World Bank (1980: 12) classified farmers with landholdings less than 5 hectares as small farmers, and 5-10 hectares as medium. Landholdings greater than 10 hectares were classified as large. By contrast, Aryal and Sharma (1992) classify the three as follows: landholding less than 2.4 hectares is small, between 2.4-5 hectares as medium, and above 5 hectares as large.

15. According to the 1989 Agricultural Impact Study of MIP-I by APROSC, about 36 percent of farmers in the project area had not received their land owning certificates. This situation had hardly improved in 1992.

16. The APROSC (1989) study also reported substantial increase in the yields of paddy (from 2 to 3 tons per hectare) and wheat (0.8 to 1.8 tons per hectare). It also showed that the non-traditional crops, such as cotton, groundnut and soyabean have not been adopted by the farmers as projected at appraisal. This is mainly because there are no processing facilities available in the project area. The same study further noted: 'Sugarcane cultivation is a recent introduction in the project area, and only a small proportion of farmers (3 percent) are growing this crop, mostly under rainfed conditions. While the establishment of a few sugarcane mills in Mahendranagar have encouraged farmers to plant sugarcane, the project authority presently does not encourage irrigation water for sugarcane because of the high water requirement. Cotton is presumed to fit in well with the existing cropping system. With the establishment of a cotton ginnery in the Stage II area, increase in cotton cultivation is expected in the future, given adequate support services from the Cotton Development Corporation.'

17. The old design documents could not be found. These design bases are mentioned by the consultants (Halcrow 1984b: 12).

18. See Gyawali (1991) for how this land area became Indian territory.

19. The feasibility study of all the three stages of the MIP was done by the Tahal Consulting Engineers Ltd. of Israel in 1979, financed by the UNDP.

20. There were only two cross regulators over the 13 km long main canal and there was no proper regulator at the tail end of the canal (World Bank 1980: 9).

21. While the fairly dense existing natural drainage channels form the drainage system, field drainage, especially in the lowland area, is required.

22. The MIP-I, as defined by the World Bank at appraisal, was a project to provide the necessary irrigation, drainage and road infrastructure with the objective to increase agricultural production.

23. The improvement of the main canal was initially limited to the minimum rehabilitation and new works necessary to provide adequately for the conveyance of Stage I discharges (Halcrow 1984: 1). Only minor improvements such as side escapes for excess flow, small control structures, measures for sediment control and a duckbill weir at the tail end of the canal were built, as there were still uncertainties about when Stage II and III would be implemented, particularly regarding water supply and size of command area for Stage III. Another reason was that the capacity of the existing canal, although reduced due to siltation, could still deliver adequate flow to Stage I area.

24. To speed up the design work, the Stage I area was divided into four Blocks based on the topographic conditions. The cultivable command areas under Blocks 1, 2, 3 and 4 were 1593, 675, 1284 and 993 hectares respectively. See Figure 5.4.

25. See World Bank (1980: 79-80, Annex 3) for the engineering design criteria for irrigation systems. The design water requirement at the tertiary outlet for low land areas (paddy cultivation) was estimated to be 2.25 lps per hectare, while for the upland areas it was 0.75 lps per hectare. These water requirements were calculated using Vand der Goor and Zijlstra's formulae which are based on the field trials in Indonesia.

26. See Halcrow (1984b: 7-20, 39-45) for the details of the criteria followed by the consultants for the design of water control structures such as cross regulators, gated outlets, and side escapes. In general, the consultants followed the British Standards and Codes of Practice for the design.

27. These values differ from those recommended at appraisal because 200 mm instead of 140 mm of water for land preparation, and 10 days instead of 15 days as duration of the supply were adopted. See Halcrow (1984b: Appendix II, pp. 1-7) for detailed calculation of the design water requirements.

28. The water efficiencies in this derivation were assumed as 80 percent for the tertiary conveyance and 85 percent for the farm application for lowland areas. For upland areas, the efficiency at farm level was assumed to be 70 percent. The overall efficiencies for upland and lowland areas were taken as 34 percent and 41 percent respectively (Halcrow 1984: 10).

29. The large capacity tertiary canals and the massive concrete water division structures within the tertiary units occupied a considerable area of land.

30. Most government managed irrigation systems in Nepal face three basic problems: (i) equitable water allocation to all water users within the command area, (ii) development of a system which would provide each farmer with the minimum water necessary for double cropping thereby maximizing the area that can be irrigated, and (iii) (technical) simplicity in the system to ensure that farmers assume responsibility for operation and maintenance of the project after its completion in a sustainable manner. The World Bank believes that these problems could be dealt with by implementing the RWS. A report by the consultants (Halcrow 1990: 1) later noted, '... based on experience elsewhere in Asia rotational water supply was considered the most suitable system [to fulfil these objectives]'.

31. The fact that the Design and Operating Guidelines for Structured Irrigation Network (Third draft) by Shanan et al., South Asian Projects Department, World Bank, October 1985 was an important part of the consultants' design guidelines verifies this.

32. The consultants reported that the computer program of the World Bank for the determination of crop water requirements showed that a design water requirement of 1.0 lps per hectare would meet the peak demands of any practicable cropping pattern with no more than 50 percent of pre-monsoon rice. The World Bank consultant who reviewed the redesign of the distribution system of Blocks 3 and 4 later also confirmed that this design water requirement was adequate and acceptable (Halcrow 1986).

33. According to the design guidelines prescribed by the World Bank a flow of 28 lps (one cusec) at the tertiary outlet is considered ideal and is called a "modular flow". This flow value have been used in many of the World Bank funded projects in South-Asian countries. For example, Mula Command Area Project at Maharastra, India (see Patil 1988).

34. To save the cost, the tertiary outlet structures already built according to the first design were used.

For the tertiary outlets in Stage II, the consultants have designed an adjustable proportional module (APM) instead of the conventional outlet structures with manually operated gates. The APM contains a steel plate fixed on to the structure to give an opening to the pipe that would allow the required flow e.g., 30 lps through it. Hence it is named adjustable, and is adjusted by the project, and not by the water users (Trimble 1993).

35. See Design and Operating Guidelines for the Structured Irrigation Network (Fourth draft) by Shanan et al. (1986), World Bank, for the structured system concept.

36. Based on the analyses of most of the World Bank funded irrigation projects in Asia, it is hypothesized that if the lower level physical facilities are destroyed or damaged, it is usually a sign that the system is structured at too low a level (Albinson 1993: 4).

37. The irrigation system designed as such was considered by the consultants later as '... demand oriented with water distribution controlled by gates in all structures ...' (Halcrow 1990: 1).

38. According to the consultants' records (Halcrow 1988c), the tertiary units actually range from 6.8 to 42 hectares.

39. The remodelling work was rescheduled to be completed by June 1993. This was optimistic, considering the rate of progress of the remodelling activities. According to the report of the 1992 Review Mission of the World Bank, the remodelling of a total of 27 tertiary units out of 87 in Blocks 1 and 2 was completed by that time.

40. See also Halcrow 1992: Appendix B, p.5 for the project's emphasis on farmers' participation for this work.

41. To a smallholder farmer with one hectare of land or less, the construction of field channels means a loss of precious land. By design (for RWS) the capacity of a field channel should be such that it can carry the full (tertiary) discharge of 30 lps. The project engineers have specified certain dimensions for a field channel, bearing in mind farmers' concern about the loss of land. According to the specifications, the maximum strip of land occupied by a new field channel of 35 cm bed width and a side slope of 0.5 to 1 is 135 cm (Halcrow 1992: Appendix A, p.2). For a maximum length of 500 m of such a field channel, the land occupied is 675 m^2, which is nearly 2 percent of the 4 hectare *chak*.

42. The consultants later reported that the irrigation system was operated in such a way that water was delivered infrequently (Halcrow 1990: 12).

43. In October 1988, the consultants prepared a three-volume Operation and Maintenance Manual (O and M Manual) in English. The O and M manual Vol.I gives the procedures of canal operation at different levels in the irrigation system. It also presents a number of proforma to facilitate the collection of data and information on water demand, supply available in the canal and the water level at different points in the distribution network. These proforma are required to be filled in by the canal operating staff prior to and during the canal operation. The same Volume also describes the duties, responsibilities

and authority of various canal operating staff of the project, such as main canal engineer, Block engineer, main canal overseer, Block overseer, supervisor, canal inspector and gate operator. Among the proforma, there is only one format (also translated into Nepali) for collecting information from farmers regarding their cropping intentions for each season. The information collected is expected to help project staff in planning irrigation (supply) schedule at the tertiary level. However, the prescribed operation procedures have not yet been followed in practice.

44. These allotments were made after the laying off of about 100 project temporary staff in 1992, following the government decision (see also Chapter 3). Interviews with on-the-job operating staff indicated that there were a total of 28 *dhalpas* for the operation and maintenance of the MIP-I before the lay-off.

45. Interviews with the operating engineers indicated that there was sufficient budget for the routine maintenance of canals and structures. This implies that budget is not a constraint in the project.

46. At appraisal, this was placed directly under the project manager as Farmer Group Development Division, showing the importance given to the development of farmer organization for system operation and maintenance (see World Bank 1980: 73).

47. Association organizers (AO) are like social organizers. AOs were first used to organize farmers into water users groups in the three pilot irrigation projects of the Irrigation Management Project (IMP).

This person in the MIP is one of the first group of AOs trained in the country under the IMP. He worked as an AO for about three years in the IMP before joining the Mahakali Irrigation Project. He comes from one of the villages within the command area of Stage I.

48. See also World Bank (1980: 42-43, section 9.01): 'Assurances received from the government of Nepal' for the implementation of the project.

49. Unlike other irrigation systems in the country, the MIP has its own Agriculture Pilot Farm with several agriculture officers and a consultant agronomist.

50. See Notice No. 2 of the Ministry of Water Resources published in the Gadget of April 2, 1989 (Nepali date: *Chaitra* 21, 2045).

51. The AOs of the MIP were trained in April 1989 under a special training programme organized for them by the Research and Training Branch of the Department of Irrigation.

52. See Manzardo et al. (1990) for the process of the formation of water users' groups and water users' organization in the MIP-I area.

53. The Nepali terms used in Mahakali to indicate the water users' organization at different levels in the irrigation system are similar to those suggested in Article 3 of the 1989 Irrigation Regulations. For example, the WUG at the outlet level is called "*samuha*", and the tertiary level water users' group is called "*samiti*" and so forth.

54. Unlike the office room of the divisional engineer of the O and M Division where only a calendar hangs on the wall, the room of the FOD section displays charts and photographs showing glimpses of various training activities and farmers' meetings held. This reflects the activeness of the FOD section.

55. Apparently, prior to the formal organization of water users into WUGs, farmers were not even aware of their own *chak* boundaries and were trying to draw water from the field outlet which was not supposed to serve their area (Subedi et al. 1992: 17).

56. Engineers interviewed indicated that the *Gadda Minor* was built under the pressure of the local leaders. Most of the time, this minor canal has to be kept open at the demand of the farmers of the area.

57. This problem of flow measurement at the border weir is also mentioned in the O and M Manual (Halcrow 1988b: p.4.4). Further, if the amount of flow is large, the effect reaches up to the head regulator at the barrage and has consequences in the supply from the barrage. Engineers interviewed

indicated that the apparent increase in the water level at the gauge below the head regulator (of the main canal) provokes the Indian authorities at the barrage to alter the water supply to the Nepal canal.

58. The consultants propose that the main canal will be operated continuously to deliver water to both Stages I and II simultaneously, even during the low flow season, to avoid higher water conveyance losses that would occur if canals were operated repeatedly "on" and "off" (Halcrow 1988b: p.2.7).

59. The overall water efficiency in the project is estimated to be 54 percent (Halcrow 1988b: p.2.7).

60. In this grouping, the canals under Blocks 1 and 2 mentioned in Section 5.2 fall respectively under the Groups A and B, while canals under Blocks 3 and 4 are under Groups C and D respectively.

61. Similarly, there have been changes in the maintenance period of the main canal also. Initially, the Agriculture Division of the Project proposed that the maintenance of the main canal should be carried out in the first half of January. The maintenance period was later shifted to May to match the maintenance of the Sarda headwork by the Indian authorities (Halcrow 1988b: p.1.7). In 1993, farmers requested the project to maintain the main canal between January 15 and February 14 so that they can cultivate spring paddy with canal water. Accordingly, the project made a request to the Indian authorities. However, the project records showed that a notice had been issued to farmers stating that the water supply in the main canal will be closed from March 7 to 28, 1993. Apparently, it was not convenient for the Indian authorities to comply with the project request.

62. See Halcrow (1988b: Table 2.4) for the canal operation schedule for one complete year for Stage-I groups of canals, as an example. The engineers also suggest: 'Water should be distributed to arrive at tertiary tails by midday on the first day of each rotation period, and to be cut off by midday on the first day of the following rotation period' (ibid: p.3.4).

63. In such a system design as in Mahakali, it is essential to ensure a supply of correct discharge at the head of each secondary canal and tertiary canals. To monitor this, broad crested weirs (bc weirs) have been built on secondary canals below their head regulators to monitor the incoming flows. In Blocks 1 and 2, bc weirs were constructed at the head of tertiary canals because the original design assumed variable flows in the tertiary canals.

64. The water efficiency of tertiary canals has been estimated to be at 89 % for design purposes. However, the flow measurements by the project with portable bc-weir flumes have indicated a much lower efficiency than this. The consultants reported: 'The method of maintenance which greatly oversize the canal, more than doubling the wetted perimeter, is considered the major factor for the increased losses and lower efficiency (Halcrow 1988b: p.2.7).' The same report stated that 15 % water losses have been assumed in field channels.

65. Each gate at cross regulators and secondary canal outlets is secured in required positions with a chain and a padlock. Each padlock is supposed to have three keys. One is for the gate operator. The second key should be with the supervisor or overseer on duty so that the gate can be adjusted in the absence of the gate operator, if necessary. The third key is to be in the control room of the project (Halcrow 1988b: p.4.9).

66. See Table 12 in Halcrow (1992) for the equivalent discharge.

67. Small one-storey houses have been built at key locations along the main and secondary canals to store tools and materials for the operation and maintenance of gates and canals. These house premises are also sometimes used for meetings with farmers. One such house has been allotted to the WUA Coordination Committee to use as the office. This also shows the importance and the encouragement given to farmers' participation.

68. Further conversation during this waiting period revealed that he was one of the old gate operators in the MIP, working since 1972. Though appointed as a *dhalpa*, he was currently assigned to operate the cross regulator in the main canal, most of the minor canals served by the cross regulator, and the head

regulator of the Mahendranagar Distributary including all control structures up to the half way along the distributary. The tasks of a gate operator as outlined in the O and M Manual (Halcrow 1988b: p.3.13) are:

- to operate head and cross regulator gates according to instructions received from the overseer,
- to maintain water levels upstream of cross regulator gates, and over weir crests,
- to keep gate lifting well greased,
- to keep the gate guides free of weeds and debris,
- to remove trash with the special rakes provided, and
- to keep staff gauges clean.

69. According to the gate operator, the gates are greased or lubricated twice a year, in June and in December. By comparison, water control gates in Banganga are hardly lubricated, except for the gates at the head regulators of the diversion canal.

6 Comparison of water control in the three irrigation systems

Now that the technology, organizational arrangements, and actual water control in the three irrigation systems have been examined in detail, the three case studies are compared in this chapter. In recent years, the concept of "structured irrigation system" has been advocated and used by some engineers in the design of new irrigation projects and in the remodelling of existing irrigation systems, especially in those financed by the World Bank (World Bank 1986; Shanan 1992; Burns 1993). It is claimed that the structured irrigation system minimizes complexity in the management of the system, particularly larger irrigation systems. The scope of this chapter is to discuss the technology, organizational and management features, and water allocation and distribution mechanism in the three irrigation systems from the "structured" system concept.

6.1 Technology in the three irrigation systems

The three irrigation systems have a number of technical features in common. Each of them is a run-of-the-river system and is thus subjected to inter and intra-seasonal variations in the water supply.[1] Basically, all of them are designed to provide supplemental irrigation for the monsoon season paddy. Their operation is upstream-controlled and supply-oriented. Water delivery is according to predetermined schedules and a combination of continuous and rotational flows. Canals in all the three systems are unlined. The head regulators of the main canal of each system are orifice-type with manually operated vertical slide gates. Outlet structures of tertiary level canals in all the three systems consist of concrete pipes with or without adjustable gates.

However, these three irrigation systems differ from each other in the water control technology.[2] This difference is because the three systems were designed by three different groups of engineers who followed different design approaches. The involvement of different groups of design engineers is largely the result of the government's position in irrigation development in the country *vis-à-vis* external donor or financing agencies. Most of the irrigation systems presently managed and controlled by the government in the *tarai* have been constructed and rehabilitated with external grants and loans in the 1970s and 1980s (see

Appendix 3: Table 2). The donor or financing agencies have played a crucial role in the involvement of foreign consultants. The government has to commit to involve foreign design engineers at the time of loan or grant agreements. The design of externally financed irrigation projects is therefore essentially done by foreign consultants from different countries with different experiences. Further, the consultants are placed at an authoritative position right from the appraisal to design and implementation of such projects. For example, note the consultants' place just below the project manager in the organizational hierarchy in Figure 5.5 (see also Appendix 6). The consequence of the involvement of foreign consultants on the choice of technology could not be foreseen.

This situation is aggravated by the fact that the Planning and Design Division of the Irrigation Department (Appendix 4) is not strong enough to discuss, check and question the compatibility and appropriateness of the designs of the consultants.[3] The department accepts and implements the consultants' design without considering the operational consequences. Absence of design standards in the department allows the consultant design engineers, especially the foreign consultants, to introduce freely their own choice of technology.[4] Moreover, in view of field allowances and fringe benefits, engineers of the department are more interested in being engaged in the construction of new irrigation projects or the rehabilitation of existing irrigation systems than keeping to the design. This gives foreign consultants further scope to implement their choice of technology.[5] The consultants hardly involve the farmers in the design process, mainly because the time given for the design is limited and the communication with local farmers is time consuming. The Banganga and Mahakali Irrigation Systems illustrate this.

Different designs and their implications on the management

In Banganga, the redesign of the existing physical system was strongly influenced by the NIACONSULT design engineers who were concerned about how to regulate water in the entire irrigation system during the period of low supply in the (Banganga) river or low storage in the Jagadishpur reservoir and the period of low demand. Given the limited capacity of the reservoir (water availability), the design engineers emphasized the efficient use of the available water *vis-à-vis* flexibility in the system operation. As a response to these considerations, gated check structures and gated outlets were provided in the main and secondary canals, including tertiary outlets. While this fully regulated technology potentially enables an irrigation system to supply and distribute differential water requirements to the canals and outlets under the conditions of varied water availability, it considerably increases the operation and maintenance burden of the agency operating the system. Above all, it requires relatively frequent resetting of gates at each variation of flow.

By comparison, the Pithuwa Irrigation System designed initially by the DOI engineers and remodelled later by the farmers is a non-flexible system. It does not have a permanent diversion structure on its source river. The water supply in the main canal is unpredictable because of fluctuating river flows. There are no adjustable control structures except the head regulator of the main canal. The check structures in the main canal are free flowing weir-type. The available flow in the main canal is distributed to all branch (secondary) canals through open pipe outlets whose sizes are proportioned to the land area served. Within a branch canal, the incoming flow is rotated among the farmers according to a pre-agreed water distribution schedule. The farmer who has the irrigation turn diverts the flow using a temporary timber-board check. The combination of open pipe outlets and weir-type checks has enhanced reliable and uninterrupted supply of water to all branch canals, facilitating effective rotational water distribution at individual farm level. In this technology, the management input in terms of the operating staff is reduced to the minimum: the operation of the main canal headgate. Interference by people (including farmers) in the distribution of water along the main canal is reduced.

The redesign of the Mahakali Irrigation System (Stage I) is based on the "Design and Operating Guidelines for Structured Irrigation Networks" of the World Bank. The irrigation system is "structured" such that flow regulation in the main canal is only required to operate secondary canals at full supply flow, given the seasonal variations in the water supply from the Sarda barrage. On secondary canals, proportional flow division weirs are built at bifurcation points where lower level canals take off, and tertiary outlets are set (by welding the gates) for a fixed discharge - in this case 30 lps. Within a tertiary unit, the fixed flow is rotated among the irrigating farmers. This "structured" system design thus eliminates flow regulation in secondary and tertiary canals and makes the management of the irrigation system relatively easier, as compared with Banganga. But it reduces the flexibility in water distribution in the irrigation system.

The three irrigation systems as structured systems

The "structured" design deviates from the notion that operational flexibility and water efficiency in an irrigation system has to be achieved using control structures with manually adjustable gates down to the lowest possible level of the system. Shanan (1992: 153) and Albinson (1993) argue that "structuring" an irrigation system simplifies management by minimizing continuous regulation of a large number of gates. Mismanagement by the gate operators and unauthorized handling of gates by farmers are minimized because only a limited number of gates will be in the main system, and the canals below the structured level will be supplied with either full (design) flow or zero flow, down to the *chak* level.

If the three irrigation systems are compared from the "structured system" concept, each of them is found to be structured at a different level in the canal hierarchy. Figures 6.1 through 6.3 present the schematic diagrams of the three irrigation systems as structured systems.

As shown in Figure 6.1, the Banganga Irrigation System can be said to be structured at the tertiary outlet. This low level of structuring is the result of the design engineers' emphasis on operational flexibility and water use efficiency. According to Albinson (1993), this irrigation system is a zero structured system as it is structured at the lowest level. It illustrates the considerable number of control points with manually operated gates and the resulting difficulty in management.

Technically, the Pithuwa Irrigation System can be said to be structured at the highest level, i.e., at the headgate of the main canal (Figure 6.2). In practice, the water supply in the main canal is not regulated, because the gate is only operated occasionally to prevent flooding the main canal.

In Mahakali, the level of structuring is clearly at the headgate of the secondary (including the distributary or minor) canal which takes off from the main canal, as there is no regulation of the flow below this point (Figure 6.3).[6] The flow in the secondary canal in operation is divided by fixed weirs with proportional openings, and all the tertiary outlets in the secondary canal automatically draw the design flow because the outlets gates are pre-set or welded.

Thus, the structured design divides an irrigation system into two distinct zones: active management zones with fully regulated flow, and passive management zones with non-regulated or fixed flow. Table 6.1 presents the type of management and the flow regime in a structured irrigation system.

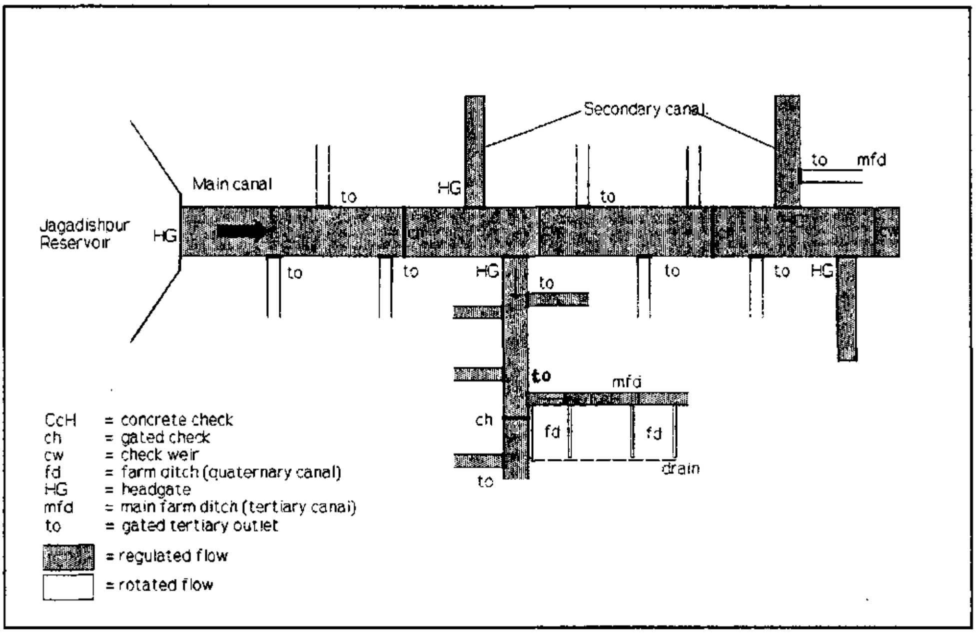


Figure 6.1 Schematic diagram of the Banganga Irrigation System as a structured system

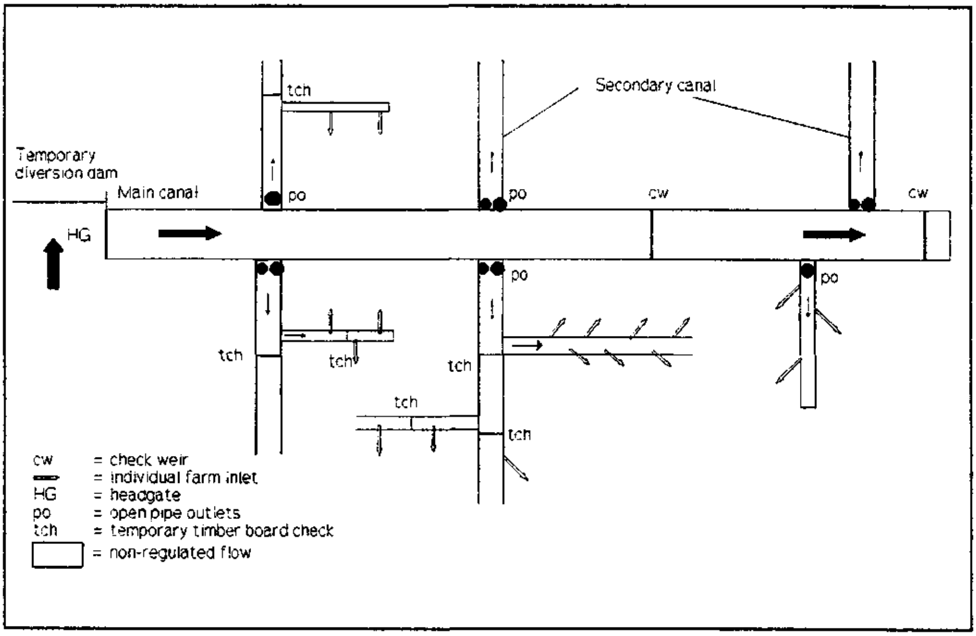


Figure 6.2 Schematic diagram of the Pithuwa Irrigation System as a structured system

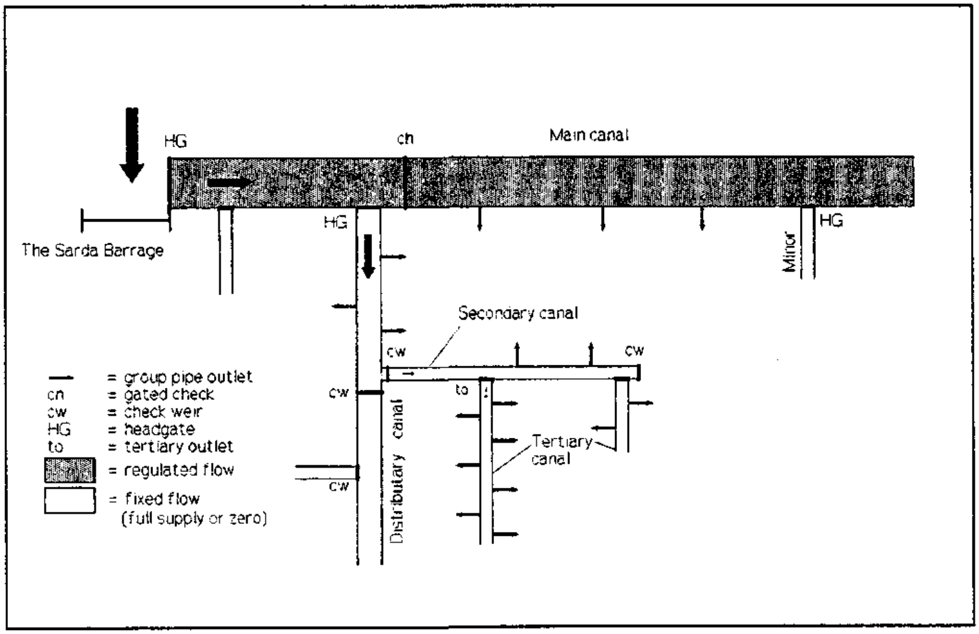


Figure 6.3 Schematic diagram of the Mahakali Irrigation System as a structured system

Table 6.1 Type of management and flow regime in a structured irrigation system

System location	Type of management	Hydraulic characteristics
Above structured level Below structured level	Active management Passive management	Regulated flow Non-regulated flow

Therefore, the level of structuring in an irrigation system is crucial and has considerable impact on management of the system. The higher the level of structuring in an irrigation system, the fewer are the number of points where control instructions have to be executed or the number of gates to be adjusted, and the more reduced is the management burden of the operating agency. Table 6.2 compares the mode of management at different levels in the three irrigation systems. Note that there is no secondary level in Pithuwa because of its small size.

Table 6.2 Management mode at different levels in the three irrigation systems

System level	Banganga (6,000 ha)	Pithuwa (618 ha)	Mahakali (5,000 ha)
Main canal	Active management	Passive management	Active management
Secondary	Active management	n.a.	Passive management
Tertiary	Active*	Active*	Active*

n.a. = not applicable

* Active management is required for effective rotational distribution of water.

Table 6.3. summarizes the level of structuring, the type of physical control structures provided below and above structured levels, and the agency controlling water at the two zones in the three irrigation systems. Generally, in government constructed and managed irrigation systems, the government agency is responsible for the management of the system above the structured level. Water control below the structured level is usually left to farmers or farmers' organization.

6.2 Intensity of adjustable control structures

An important outcome of the different design approaches is the intensity of adjustable control structures in the irrigation system. The intensity of these structures, such as cross regulators and gated outlets in the main and secondary canals has considerable impact upon water control. In water-constrained irrigation systems, the greater the number of adjustable control structures, the greater the risk of failure to deliver water downstream because of possible abuse and misuse of these structures, especially during the peak demand periods.

Table 6.3 Level of structuring, type of control structures and controlling agencies in the three irrigation systems.

	Banganga (6,000 ha)	Pithuwa (618 ha)	Mahakali (5,000 ha)
Level of Structuring	Tertiary outlet	Headgate of the main canal	Headgate of the secondary canal
System operation@: - above str. level - below str. level	 Varied flow continuously delivered. Constant flow rotated among groups of farms.	 Uncontrolled flow from the river. Varied flow continuously delivered (proportionally distributed among secondary canals and rotational distribution at farm level).	 Varied flow continuously delivered. Intermittent flow on rotation.
Type of control structures: - above str. level - below str. level	 Adjustable gates On-off checks at farm level	 Uncontrolled flow. Proportional division through open pipe outlets; on-off temporary checks at farm level.	 Adjustable gates. Proportional weir checks on secondary canals; on-off structures at farm level.
Controlling agency - above str. level - below str. level	 Irrigation Department Farmers.	 Farmers' organization at both levels	 Irrigation Department Irrigation Department and farmer organization.

Str. = structured

@ The system operation considered here is as designed for irrigating paddy.

Sources: Field observations (1992-93) and relevant project documents.

Table 6.4 shows the intensity of adjustable control structures in the three irrigation systems. Among the three irrigation systems, Banganga has the highest number of adjustable check structures and outlets.[7] Given such a large number of control points, a small number of operating staff and limited budget for the operation and maintenance, it is difficult for the irrigation agency to effectively operate even the main canal (see Section 6.3). As a result, the tail-end areas do not receive irrigation water adequately and timely.

In Pithuwa, the number of adjustable structures is kept to a minimum (0.16 per 100 hectare). The combination of ungated proportional pipe outlets and fixed weir-type checks allows dependable and uninterrupted water supply to all branch canals and effective rotational water distribution at farm level. In Mahakali, the adjustable control structures has been provided only in the main canal, as the irrigation system has been as redesigned as a "structured" system. The small number of adjustable check structures is mainly because the canal is aligned along the contour and has a flatter gradient.[8]

It is observed that in the Banganga and Mahakali irrigation systems there are a large number of pipe outlets directly connected to the main canal, irrespective of the difference in design approaches used (Table 6.4). The provision of direct outlets, though not preferred by design engineers, is fairly common in irrigation systems in the *tarai*. Although such direct outlets are inevitable due to the small and fragmented landholding and the topography, evidence from Banganga and Mahakali suggests that one or both of the following reasons also contribute to the increased number of such outlets: (i) pressure from local leaders, and (ii) personal favour to influential farmers by the engineers during the construction period.

Table 6.4 Intensity of adjustable control structures in the three irrigation systems.

Intensity of adjustable control structures	Banganga (6,000 ha.)	Pithuwa (618 ha.)	Mahakali (5,000 ha.)
Main canal length:			
Total (km)	20.50	5.0	13.75
Per unit of the command area (m/ha)	3.4	8.1	2.7
Check structures (No.):			
Main canal	18@	nil	3
Secondary canal	14	nil	nil
Total	32	nil	3
Per 100 ha of the command area	0.53	nil	0.06
Outlets (No.):			
Main and secondary	9	1	10
Tertiary	131#	nil	22*
Total	140	1	32
Per 100 ha of the command area	2.3	0.16	0.64

@ This includes the cross-regulator in the diversion canal.

This includes 52 tertiary outlets which are directly connected to the main canal and serve 10-110 hectares.

* These 22 tertiary outlets are connected directly to the main canal and serve 4-40 hectares.

Sources: Field observations (1992-93) and Table 3.4.

The pipes in tertiary outlets, including those connected directly to the main canal, are relatively large, 30 cm diameter or more. In modern rice-based irrigation projects, design engineers generally provide large pipes at tertiary outlets and large capacity tertiary canals to accelerate the land preparation (Plusquellec et al. 1994:18). In Banganga, for example, ungated and small size pipe outlets have been replaced by gated and large size pipe outlets (See Table 3.4). Observations in Banganga show that the large pipe outlets enable head-reach farmers to draw more water than their share under uncontrolled management. By contrast, in Pithuwa, different sizes of pipes are combined to apportion water to the area irrigated. The combination of different pipe sizes has minimized the chances of head-reach farmers withdrawing excess water at constant and full supply level. This implies that the design engineers should reconsider the use of large pipes at tertiary outlets. Further, a high density of direct outlets and cross regulators as in Banganga makes it virtually impracticable to deliver water to the tail-end area of the main canal, under low degree of management.

6.3 Organizational and institutional arrangements

Irrigation Department and District Irrigation Office

The organizational capacity of the operating agency also has a bearing on the effective functioning or non-functioning of a given technology. It depends on several factors. Below, the organizational arrangements in the three irrigation systems are compared in terms of the pattern of the organization operating the systems and the allocation of operating staff for water control. Institutional arrangements here are considered in the light of the division of management responsibilities between the irrigation agency and water users' organization.

Every irrigation system has its operation and maintenance requirements inherent in the design. Accordingly, a particular pattern of organization and the number of staff required are prescribed by the design engineers for effective operation and maintenance of the completed system, as in Banganga and Mahakali.[9] But, in government constructed and managed irrigation systems, the organizational arrangement of the agency operating the irrigation system is determined by the Irrigation Department. It is normally governed by the overall objectives of the department, and not by the actual or specific requirements of the irrigation system. The organization of District Irrigation Offices illustrates this (see Figure 3.8).

The Irrigation Department is often unable to comply with the organizational pattern or to fulfil the number of operating staff recommended by the design engineers, mainly because of limited financial resources of the government. Consequently, the irrigation agency cannot meet the specific requirements of operating staff presumed in the design. The Banganga Irrigation System clearly illustrates this.

Table 6.5 presents the number of field level operating staff recommended by the NIACONSULT design engineers for the effective operation and maintenance of the Banganga system, the number engaged immediately after the project completion, and the number allocated to the District Irrigation Office which presently controls the irrigation system. The technology in Banganga requires full regulation of flows down to the tertiary outlets, and therefore needs a large number of skilled operating staff. Clearly, this technology is unrealistic, when considering the limited number of skilled operating staff available in the Irrigation Department.

As shown in Table 6.5, the DIO not only has limited number of field operating staff, it has no supervisors and fieldmen as envisaged at design. Initially, the DIO was not meant to operate the Banganga Irrigation System, which explains the small number of field operating staff. With such a few operating staff, the DIO is not even able to control water distribution along the main canal.

Table 6.5 Number of operating staff recommended and actually allocated for the operation and maintenance of the Banganga Irrigation System (1991-93)

Operating staff	CADP Recommendation (in 1989)	Staff employed in 1990-91	Allocated to the DIO* (1993)
Gate operator	5	3	None@.
Dhalpa	28	13	7
Fieldman	28	7	None
Supervisor	4	4	None
Overseer	8	3	4

* These are permanent staff.
@ Posts are mentioned only for four pump operators and one drill operator.
Sources: Field observations (1991-93) and the District Irrigation Office, Kapilvastu.

By comparison, in Pithuwa, two *dhalpas* are assigned by the (Chitawan) District Irrigation Office. They have very little to contribute in the operation of the system because of the technology. There is virtually no need for any operating staff in Pithuwa since no flow regulation is necessary below the headgate of the main canal.

In Mahakali, the project has 6 overseers, 3 supervisors and 18 *dhalpas* for the operation and maintenance of the irrigation system (see Figure 5.5).[10] The operation of the irrigation system below the main canal level does not require any skilled operating staff.

The above figures on the number of operating staff available in the three irrigation systems show *ad hoc* distribution of operating staff by the Irrigation Department.[11] The main reason for such inconsistent allotment of operating staff is that the Irrigation Department has not yet developed a set of operational standards.[12] Another reason is that the department has not made it clear as to which level the agency should manage government-constructed irrigation systems.

Clearly, different technologies have different implications on the requirement for operating staff. The three irrigation systems with three different technologies show that the number of operating staff increases with operational flexibility.[13]

Water users' organization in the three irrigation systems

In all the three irrigation systems, water users' organizations have been established to acquire farmers' participation in the management of the systems. These water users' organizations were created under different conditions. Observations show that they have varying degree of authority, tasks, responsibilities and control over the management of the irrigation systems.

In Banganga and Mahakali, the establishment of formal water users' organizations was initiated by the government. The financing agencies - the Asian Development Bank and the World Bank respectively - also strongly pursued the formation of water users' organization. By contrast, the "Irrigation Management Committee" in Pithuwa was developed totally by farmers themselves. Regardless of how they were formed and developed, the water users' organizations in all the three irrigation systems have a similar pattern. The levels of the organization are parallel to the hydraulic levels of the irrigation system. This clearly shows the impact of physical system on the structure of the water users' organization.

In Banganga, the water users' organization was introduced under the CADP. The pattern of the organization and the tasks and responsibilities at different levels of the organization were formulated by the project. The project divided the responsibilities and control over the system such that farmers organized into water users' groups were expected to allocate and distribute water below the tertiary outlet. Accordingly, a two-tier water users' organization was formed. The WUGs had no control over the water supply to the tertiary outlets. It was presumed that the irrigation agency would be able to supply and distribute water adequately and in time, down to the tertiary outlet. Given the limited water supply, a complex technology with too many gated structures and inadequate number of operating staff, the irrigation agency was unable to fulfil its responsibility of delivering water in time and in adequate quantity. Consequently, water users' groups did not function as envisaged. Farmers' informal control extended to the handling of gates at the check structures in the main canal and the tertiary outlets. The recently introduced joint management programme has changed the pattern of the water users' organization from two to four tiers (see Figure 3.10). Under this programme, the Irrigation Department intends to clearly divide the management responsibilities between the irrigation agency and water users' organization. Yet, at the time of the research, farmers were reluctant to share the responsibility for water control at higher level in the irrigation system because they were not confident of the reliability in the water supply by the agency which will continue to operate the main canal for many years in the future. This shows that the reliability of water supply from the main system has strong impact on the development and continuity of water users' organizations.

By contrast, the farmer-developed "Irrigation Management Committee" in Pithuwa has full control over the irrigation system. The Irrigation Department does not interfere with the farmers' management. The functions of each level of the (water users') organization are clearly defined. The tasks, responsibilities and authorities of the functionaries of the committee at each organizational level are clearly stated and known to all farmers. The main committee at the system level is charged with the arrangement and mobilization of both local and outside (government and non-government) resources for the operation and maintenance of the irrigation system.[14] The branch committee is empowered to make decisions about water allocation and distribution independently and resolve water related conflicts within its hydraulic boundary. Water allocation and distribution decisions are made collectively during the general meetings. This organizational arrangement by the farmers allows flexibility in the operation of the irrigation system and is responsive to the irrigation need of the farmers. The reliability of water supply to the branch canals is also due to the social control exercised by farmers themselves.

In Mahakali, which is eventually expected to be operated jointly with the water users according to the government's declaration in 1989, the project management has meticulously developed a four-tier water users' organization. In this development process, AOs of the project organized and assisted farmers to form water user' organizations. Farmer representatives were taken to the farmer-managed irrigation systems like Pithuwa for observations and training on water management. The method of rotational water distribution was demonstrated to them. The functions of each level of the organization and the tasks, responsibilities, and authorities of the functionaries at all levels of the organization have been defined. Yet farmers will have to be confined to the management of water within the tertiary units because the actual control over water supply will remain with the agency for many years in the future. However, water users' organizations (at tertiary level) are active here and farmers cooperate in operation and maintenance of the tertiary system because they receive water when they require. The availability of abundant water at present has enabled the project to meet the water demand of farmers as and when required.

Institutional arrangements

Since 1989, following the enactment of the 1989 *Irrigation Regulations* and the 1992 Water Resources Act, the government of Nepal has been trying to institutionalize water users' organizations in the development and management of irrigation systems. In line with this, the water users' organizations of Pithuwa and Mahakali have been registered as corporate bodies under the *Association Registration Act*. The new water users' organization formed under the joint management programme in Banganga was also in the process of registering in 1993. In this way, these water users' organizations are given legal status.

Further, the new 1992 Irrigation Policy provides for the water users' organizations that assist the irrigation agency in the collection of irrigation fees to retain a maximum of 50 percent of the amount collected. For the first time in the country, the MIP has tried to implement this policy. The project has agreed in principle to allow the tertiary committees which assist in the collection of irrigation fees to retain 25 percent of the collection. The committee can use the amount in the maintenance of the physical infrastructures within their hydraulic areas. The premise is to motivate farmers to participate in the operation and maintenance of the system.

6.4 Water allocation and distribution at different levels

By design, water allocation in all the three irrigation systems is on the basis of amount of water per unit of irrigated or cultivated area for the projected or prevailing cropping pattern. Table 6.6 shows the design water requirements in the three irrigation systems. Clearly, there is no significant difference in the design water requirements between Banganga and Mahakali, for paddy crop. The difference in the design water requirement for rabi crops is partly because during the *rabi* season wheat is the main crop in Banganga, whereas in Mahakali oilseed is the base crop.

Table 6.6 Design water requirements and irrigation mode in the three irrigation systems

Water requirements and irrigation mode	Banganga (6,000 ha)	Pithuwa (618 ha)	Mahakali (5,000 ha)
1. Design water requirements at the tertiary outlet (lps)			
- for paddy	0.93	Not available*	1
- for wheat and other *rabi* crops	0.45	Not available	0.7
2. Irrigation mode	24 hours	24 hours	24 hours

* Design water requirements for Pithuwa are not available. Considering the design criteria in use at the time the irrigation system was built, it can be assumed that the design water requirements used here should be in the same order of magnitude as that in Banganga and Mahakali. Observation of flows at the three selected branch outlets in August 1992, however, showed maximum water actually available between 3-10 lps per hectare (see Figure 4.9).
Sources: Relevant project documents and field observation (1992-93).

Actual water allocation and distribution in all the three irrigation systems is a result of management decisions made by the irrigation agency and/or the water users' organization, and their capability to implement the decisions. In Banganga and Mahakali, where the irrigation agencies - the District Irrigation Office and the Project respectively - control the system operation, the actual water distribution deviated from what was planned and presumed in the design. By contrast, the water users' organization in Pithuwa successfully implemented the principle of water allocation and distribution that evolved from field experience.

In Banganga, the command area was divided into four irrigation blocks (later six under the joint management programme) of almost equal area. In the beginning of the monsoon and winter crop seasons, the district irrigation engineer prepares a water delivery schedule, generally without consulting the farmers. Water allocation to each irrigation block is in number of days. Generally, a week is allocated for each irrigation block (see Table 3.7). This weekly turn has been fixed for easier system operation and not according to actual water demands of farmers, nor to actual crop water requirements. Limited water supply to or limited storage in the reservoir has prompted the irrigation agency to (try to) distribute water in the main canal in rotation, even during the wet season (paddy cultivation period) when the river has abundant discharge.[15] This rotational distribution for paddy during the monsoon season is contrary to the continuous water delivery to the tertiary blocks as presumed in the design. Water distribution is intended from the tail towards the head of the main canal (see Table 3.7 and Figure 3.6). However, this is not achieved in practice for two main reasons. The first is the limited availability of water. Second, control by the District Irrigation Office is usually confined to the headgates of the diversion canal and the reservoir outlet because of inadequate number of operating staff. This has resulted in water distribution along the main canal virtually under the informal control of farmers.[16] Maximum proportion of the flow in the canal is used in the head-reach area, resulting in the shortage of water at the tail-end area. The irrigation agency has no control over water distribution among branch canals and within tertiary units. Because water supply into the tertiary units is unpredictable and unreliable, the water users' groups are not functioning, and farmers do not have any definite rule for water distribution at farm level.

In Pithuwa, water allocation is by fixed time slot, 90 minutes per hectare of cultivated land. This time allocation is for the irrigation of wet season paddy and is actually applied at individual farm level. Unlike in Banganga and Mahakali and most government irrigation systems in the *tarai*, farmers here grow their paddy totally dependent on irrigation. The canal water is, therefore, highly valued. Flow in the main canal is continuous, though it varies. The continuously available flow in the canal is distributed to all branch canals through the ungated pipes which are approximately proportional to the irrigated area served. Only when the flow in the main canal reduces considerably, is the rotation among branch canals followed as decided by the main committee. The continuous flow of water to all branch canals allows the branch committees the autonomy to make decisions on water allocation and distribution within their command areas. Within a branch canal, each individual farmer is allocated in writing a definite time and the period to use the available flow in the canal, proportional to the cultivated land. Therefore, each farmer must have separate inlets to irrigate his/her cultivated fields, resulting in high density of field irrigation ditches (see Figure 4.4). Large branch command areas are subdivided into small rotational blocks in which the same principle of water allocation and distribution is followed. The subdivision into smaller units allows the branch committee to maintain effective water control. Also, farmers strictly observe their water use turn. Since the number of water users in a branch or sub-branch canal is limited, between 13 and 45, each individual farmer knows the other's turn to use the water. Water distribution within a branch or sub-branch canal, after every farmer has completed transplanting paddy, is from the head towards tail of the canal. The water user having the next turn downstream checks on the one using water currently as he cannot afford to miss his turn. If he/she does not use the water during his period, he/she must wait until the next turn, and there is no alternative source of water, such as tube wells. During the winter season, flow in the source river is reduced to only a few hundred litres per second, and Pithuwa must share this water with the neighbouring village, Chainpur. Irrigation in this period becomes supplementary, and the procedure of water allocation and distribution changes. Farmers who want to irrigate their wheat or oilseed crops gather at the diversion (intake) point to claim their turn. The turn to use water is on the basis of "first come first served", and the time distribution is agreed mutually.

In Mahakali, water allocation and distribution basically follows the equal entitlement per unit land area farmed, as in Banganga. The canals and outlets taking off from the main canal are grouped to form four irrigation blocks of almost equal areas (1,130 - 1,142 hectares). During both the summer and winter seasons, water flow in the main canal is variable but continuous. The flow available in the main canal is to be distributed to the four irrigation blocks by rotation, proceeding from head towards the tail. These canal groups are to run either full "on" or "off". When "on", the full supply flow is to be maintained. The Project operates the main system, while the water distribution within the tertiary units is left to the water users. The tertiary outlets are to receive a fixed flow of 30 lps. Within a tertiary unit, this full flow is (or should be) rotated among the individual farmers. Because the water supply currently available in the main canal is abundant, the rotation among the four groups of canals at the main canal level is not practised at present. The continuous and abundant supply from the Sarda barrage makes it possible for the project to deliver water to the farmers when requested.

6.5 Impact of technology choice and social control

The choice of a particular water control technology and a specific pattern of social control (organizational arrangement) in an irrigation system will have an impact on the performance of the system. Irrigation system performance is problematic. Different professionals have different views regarding irrigation system performance and use different indicators of performance, depending upon their objectives and interest (Abernethy 1986; Chambers 1986; Small and Svendsen 1990; Murry-Rust and Svendsen 1992). It is therefore accepted that no single assessment of performance can involve all the facets of an irrigation system. However, cropping intensity which is commonly used as one of the targets at design has been taken here to show the impact of the technology choice and water control in the three irrigation systems.

Table 6.7 compares the cropping intensities projected and achieved in the three systems.[17] The variations in the cropping intensity achieved reflect, among others, the impact of the different water control technologies. In Banganga the cropping intensity lower than projected can largely be attributed to the fully gated technology and a low degree of agency control over the system. Given the limited availability of water and inadequate operating staff, this technology was ineffective in the timely and equal delivery of water as intended at design. By contrast, farmers in Pithuwa achieved the higher cropping intensity because of the technology they adopted.[18] The ungated physical system, the water allocation by time slot and rotational distribution, and the high degree of organization for the effective water distribution made the intensive cultivation possible. The reliability in water delivery due to this technology enabled the farmers to harvest paddy and cultivate oilseeds in time. In Mahakali, abundant water availability has apparently increased the cropping intensity beyond the project target.

Table 6.7 Projected and actual cropping intensities in the three irrigation systems (1992-93).

Cropping intensity (%)	Banganga (6,000 ha.)	Pithuwa (618 ha.)	Mahakali (5,000 ha.)
Projected at design	168	Not available	165
Achieved	145	275	184

Sources: Field observations (1992-93) for Banganga and Pithuwa, and relevant project documents for Mahakali.

Water efficiencies as measures of performance are used by most engineers. Recently, "relative water supply" has been used by engineers as an alternative indicator of the irrigation system performance because it is said to incorporate management aspects also (Levine 1981; Oad and Levine 1985; Yoder 1986). However, in this study these water efficiency indicators have not been considered for two reasons. First, these indicators are very technical and are useful from the engineering point of view only. Second, efficiency and equity in an irrigation system do not usually go together. In Banganga, although the Provisional Impact Study of CADP (GEOCE 1989) reported an average of about 92 percent water efficiency in the main canal, observation in 1992-93 showed less than 50 percent of the required flow in the main canal and practically no flow was delivered at the tail-end of the canal. Further, actual water delivery to secondary and tertiary outlets was so unpredictable and inadequate that it was difficult to arrive at a valid water efficiency by regular measuring of flows at these outlets were (Chapter 3: section 3.4). Furthermore, farmers were using water from the secondary and tertiary drains. By comparison, in Pithuwa, farmers receive water equitably, given the time allocation of water proportional to the cultivated land and the effective social control which allows regularity in scheduled distribution of water, even if the water efficiency in branch canals and at farm level appears to be low. In Mahakali, water supply is more than the demand. The relative water supply might show a high degree of performance (Flow measurements were not taken because of time limit). Available records (Halcrow 1988a: p.2.6) show about 91 percent conveyance efficiency in the main canal.

6.6 Summary and concluding remarks

Comparison of the three irrigation systems show that although they have some common technical characteristics, they differ from each other in the water control technology. The difference in the technology is the result of the different design approaches followed by the design engineers. In externally financed irrigation projects, foreign design consultants are necessarily involved because of the conditions for loan agreements between the government and the financing agencies. Empirical evidence from Banganga and Mahakali show that external donor/financing agencies and foreign consultants use different design approaches, depending upon their notions about water control and experiences. The technology is largely dictated by the financing agencies and dominated by the foreign consultant engineers involved. These external agents emphasize the "modern" technology. The compatibility of the technology with local farming and socio-economic environment is usually disregarded. Neither are the management implications of the technology considered. By contrast, the technology developed by farmers in Pithuwa is simple, and management implications are accounted for.

Compared in terms of the "structured" system concept, the three irrigation systems have different level of structuring. Accordingly, they show different operational flexibility. Whereas the operational flexibility is potentially high in the fully gated technology in Banganga which has the lowest level of structuring, it is low in the ungated technology in Pithuwa with highest level of structuring. The high intensity of adjustable control structures, as in Banganga, makes the delivery of water to tail-end areas of the irrigation system virtually impracticable.

The Irrigation Department determines the organizational arrangements for all the government constructed and controlled irrigation systems. Because the government has limited manpower and limited financial resources, the department cannot provide the relatively high operational and maintenance requirement of a fully gated irrigation system.

Water users' organizations in all the three irrigation systems are parallel to the hydraulic levels of the systems. The reliability and adequate delivery of water to farmers have strong influence upon the continuity or stability of the water users' organizations. The legal recognition and institutionalization of water users' organizations enhance the continuity of the organizations, but they do not necessarily motivate farmer participation in government controlled irrigation systems.

Water allocation and distribution differ from that intended in the design because of management decisions and capability of the agency to execute the decisions. Three observations are of interest in the water allocation and distribution in the irrigation systems studied. The first is the strong influence of the availability and value of water in the allocation and distribution. The second is the requirement of a strong organization and effective institutional arrangements for effective water control. The third is that water distribution at farm level by fixed time slot provides an effective and verifiable means of monitoring the water allocation, though this requires strict discipline and time synchronization on the part of the farmers. Whereas in Banganga and Mahakali, the irrigation agency tries to stick more to the rules of engineering than the actual field situation, farmers irrigation committee in Pithuwa have flexibility in their water allocation and distribution rules and choose the cropping pattern to fit the (water) resource constraint, e.g., low water requirement crops like oilseed and lentil in the winter, and maize in the dry season period.

Finally, the three irrigation systems show that the technology that consists of numerous adjustable structures for water efficiency and operational flexibility actually creates problems in water management, especially in government-operated irrigation systems having the limitation of an inadequate reserve of skilled manpower resource. Conversely, the technology that constitutes the least number of adjustable structures allows most effective water management. The structured system design, as used in Mahakali, could possibly minimize problems associated with water control in government-managed irrigation systems.

Notes

1. In view of the small capacity of the Jagadishpur reservoir, which is an intermediate reservoir, Banganga Irrigation System might also be considered as a run-of-the-river system.

2. The three irrigation systems also differ from one another in the physical pattern of their canal network and, to some extent, in the intensity of water control structures in the main and secondary canals because of the differences in topography, land distribution pattern, soil types, hydrology and size of the command area.

3. One may ask why local engineering consultants are not used. Generally, local engineering consultants in Nepal at individual capacity cannot fulfil the qualifying standards for the design works of financing agencies like the World Bank. The current practice is for foreign consultants to collaborate with or take competent local engineering firms on sub-contract for the design works. Nevertheless, the financing agencies and the foreign consultants have retain control.

4. In many externally financed irrigation projects, engineers from the DOI also work with the consultants in the design of the physical system. But they are usually young graduates with little or no design experience and, therefore, could hardly influence the design. Interviews with some of the DOI design engineers who were involved in the design and redesign of irrigation systems indicated that the foreign consultants dominated the design.

5. Whereas foreign consultants were freely allowed to implement the designs of their choice, design engineers of the irrigation department continued to use the conventional technology of ungated pipe outlets with weir-type checks for government constructed projects.

6. In this Figure, it is anticipated that Blocks 1 and 2 of the MIP-I will eventually be remodelled to "structured" design.

7. Most of these structures have been damaged and have non-functioning gates or no gates at all (see Table 3.5).

8. Unlike in Banganga, the gates at check structures and outlets in Mahakali are still operable because the project has adequate operating staff and financial resources to operate and maintain them and because water supply is still adequate enough.

9. The operating staff recommended by the consultants, however, are the estimates which are often based on the judgement or experience of the design engineers, rather than the given technology of the project.

10. In fact, an irrigation system does not operate fully during its construction or rehabilitation because of the construction work. The number of operating staff actually required is therefore estimated by the consultants.

11. The number of operating staff in Mahakali seems to be on the high side compared to that recommended for Banganga by the design engineers. This might be because Blocks 1 and 2 still have to be remodelled into a "structured" system.

12. Relatively adequate manpower, such as overseers and other field level operating staff are employed where financial resources are not a constraint. For example, in on-going projects like Mahakali.

13. For example, *dhalpas* allotted in Banganga, Mahakali and Pithuwa are at 1 for 215 hectares, 277 hectares and 300 hectares respectively. In view of note 11, a realistic estimate for Mahakali should be much higher than 277 hectares.

14. Because government resources are continually involved in the operation and maintenance, engineers of the Irrigation Department do not agree that this irrigation system is a totally farmer-managed system.

15. As described in Chapter 3, most of the time the reservoir does not contain full storage level of water in the beginning of the paddy season, as the supply to the reservoir is either low or withheld for a considerable period, from May to June, for the cleaning of the diversion canal. Further, the main canal cannot carry full discharge because of the quick growth of aquatic plants, even if the reservoir has full storage of water.

16. As Burns (1993) noted: 'A little water in gated canals is an invitation for farmer manipulation of the gates and checks and their frequent destruction.'

17. It should be noted that these cropping intensities also include the monsoon paddy which usually covers more than 90 percent of the cultivated area. This paddy is grown under partial irrigation (except in Pithuwa).

18. The design cropping intensity for the Pithuwa Irrigation System is not known, but it is clear that farmers have been able to increase the irrigated area more than anticipated in the design by remodelling the existing physical system and effective social control.

7 Conclusions and implications

7.1 Conclusions

This study presents the three case studies on water control in government-built and controlled irrigation systems in the *tarai* Nepal. This final chapter attempts to formulate conclusions and implications by tying together the findings from the case studies with respect to technology, organization and water control.

Irrigated agriculture in the *tarai* Nepal is basically rice based. Paddy is grown in the monsoon season which lasts only a few months (from July until the mid-October), and the monsoon rain is erratic. Farmers need water to prepare paddy nurseries, for land soaking and puddling, and to complete transplantation of paddy seedlings before the onset of monsoon season. Further, different farmers use different transplanting techniques and hence require different amount of water at different times. Water demand is high during the transplanting period, and canals need to supply large amount of water (therefore require larger capacities) to ensure that land preparation is accomplished in time. During the monsoon, irrigation water demand is influenced by rainfall. Water demand is reduced. In the dry season, crops requiring less water are grown, and the irrigation system needs to match the demands for water at short intervals.

As Plusquellec et al. (1994: 17-18) and Burns (1993) have noted, the design of (monocrop) rice-based irrigation systems in monsoon areas of South Asian countries, where small (land) holders are predominant, presents special problems and challenges. In large irrigation systems, heavy rainfall in one area (localized rain) might require that water supply to the canals in the area be closed temporarily. The irrigation system needs flexibility to match the seasonal variations in water demand and supply due to the change in weather conditions and cropping patterns.

Technology and operational flexibility
We saw three different types of technology in the case studies: flexible technology in Banganga, non-flexible technology in Pithuwa, and semi-flexible technology resulting from the structured system in Mahakali.

Whereas the flexible technology of fully gated (manually operated vertical screw-type gates in cross-regulators and tertiary outlets) systems, as in Banganga, can potentially fulfil time and spatial variations in water demand of farmers, in practice the continual and complicated operation of numerous gates at control structures inhibits the intended operational flexibility. It requires a large number of skilled operating staff. Moreover, it does not guarantee reliable and adequate water supply because of the complicated technology and hydraulic instability. The Banganga Irrigation System illustrates the failure of this technology to attain flexibility in water allocation and distribution as intended.

The non-flexible technology comprising fixed weirs as check structures and ungated pipe outlets whose size is based on the irrigated area served, as in Pithuwa, allows the water available at the intake of the irrigation system to be distributed fairly and proportionally down the system. However, this technology providing simple equity presents some water distribution problems. First, it is not possible to alter the distribution ratios of flow. Second, the outlets in use will not receive their proportional share under reduced flows because this technology results in gradual reduction of flows from head towards tail. Thus the equity in water distribution may not be achieved under varied flow conditions in the supply canal. Thirdly, such rigid design inhibits the effective use of rainfall, especially where rotational water distribution is applied. Even when there is good rainfall it is difficult to stop the water supply because this will disturb the rotation. Therefore, high water efficiencies may not be achieved. Further, because it incorporates very little or no flexibility, this technology might not match water deliveries to crop need; rather the farmer must match his planting and other farm management activities to the water deliveries. Nevertheless, as evident from Pithuwa, this technology is also highly effective for rice cultivation.

The "structured" irrigation system in Mahakali has a combination of undershot gated cross-regulators and gated outlets in the main canal, fixed weir-checks at bifurcation points in secondary canal, fixed-gated tertiary outlets and "on/off" outlets to the farms. This technology is semi-flexible. The secondary canals and tertiary canals either run full flow or are empty. Only a limited number of gates in the main canal need to be operated. This technology allows water supply to the part of the system to be cut off if necessary, because of rainfall.

Conclusion
The extensively gated technology for operational flexibility needs to be reconsidered, if effective water control is to be achieved. The semi-flexible technology like that in Mahakali might be appropriate for government-controlled and managed large irrigation systems, given

the resource (operating staff and budget) limitations of the irrigation department on the one hand, and rice-based agriculture on the other.

Technology and organization

In Banganga, organizational arrangements of the District Irrigation Office are such that the operational decisions are centralized. Release and closure of water supply in the main canal is decided by the district irrigation engineer who is not accountable to farmers. In contrast, in Pithuwa the authority to make operational decisions has been devolved to the branch committees. This decentralized control has enabled the Pithuwa Irrigation Management Committee to distribute water evenly through the entire system. The simple technology of continuous flow proportionally divided facilitated the organizational and institutional arrangements towards decentralized control.

In government constructed and controlled irrigation systems, organizational arrangements are determined by the Irrigation Department, and also by the technology. The organizational arrangements are such that the management decisions are centralized. Organizational and institutional arrangements oriented towards decentralized control enhance operational efficiency more than the centralized authority.

A strong organization is needed to ensure even distribution of water at all levels of the irrigation system. A strong organization also encourages effective cooperation and coordination between farmers and between farmers and irrigation agency for mobilizing resources required for the operation and maintenance of the irrigation system. Full cooperation from farmers in the system maintenance can only be obtained when they are assured of adequate and reliable water supplies.

The fully gated technology, as in Banganga, enhances unreliable water distribution and conflicts at the outlets. When water supply becomes unreliable, farmers lose respect for the rules and regulations governing the water usage and water users' associations or groups at tertiary or farm level become passive, uncooperative or totally defunct. This in turn leads to unauthorized control over the outlets and damage to canals and control structures upstream. Farmers discontinue to clean the tertiary canals and the farm ditches within tertiary units.

Reliable water supply to the branch canals is possible in Pithuwa because of the choice of the technology which does not require flow regulation in the main canal, and which allows continuous flow to all branch canals simultaneously. It is difficult to steal water because of the transparency of the technology. Farmers at the tail-end area contribute fully to the maintenance of the main and branch canals because they receive the share of water they are entitled to.

The "structured" technology in Mahakali can be expected to be successful compared to fully gated technology. However, the availability of abundant water has until now hampered the introduction of rotational water distribution as anticipated in the "structured" system design.

Conclusion

Water control technology is related to organizational requirements. Simple inflexible proportional division technology complemented with strong organization for social control is more effective in equitable water distribution than flexible adjustable systems that make it difficult to establish organisation because of unreliable delivery.

Technology and water control

Water control involves making day-to-day allocation and distribution decisions at the operational level. Operational decisions are made within constraints set by controlling or governing agency structures. Therefore, well-designed control mechanism is necessary for effective water control management (Tang and Ostrom 1993). The physical infrastructure with extensive gated control structures, as in Banganga, which requires close monitoring and guarding during the canal operation, prevents water from being effectively allocated and distributed.

Pithuwa shows that farmers should have full control over the entire irrigation system for effective water allocation and distribution. At farm level, a farmer must know when the water is supplied, when it is his turn to use water. This enables him to insist on water delivery to meet his entitlement. Farmers can have flexibility in cropping decisions when they are involved in the complete operation of the system, including the establishment of the water allocation principles and water distribution procedures. In Pithuwa, every farmer knows the exact time and period of his or her water use turn and can exert some control over the timing. The ability of each farmer to explicitly identify the allocation of water he is entitled to receive was seen to be one of the essential factors for the high cropping intensity achieved.

In government-built and managed irrigation systems in Nepal, farmers have no direct control over irrigation water supply, nor can they directly influence decisions on water allocation and distribution by the irrigation office or its operating staff. Where farmers have little or no input into water allocation and distribution decisions and where they are seldom required to directly contribute resources for the system maintenance, there is no incentive for them to organize. Banganga clearly illustrates this. The irrigation agency determines the water delivery schedules which it cannot comply with, and farmers are not sure that water will be delivered according to the schedule. In such cases, promoting formal water users' groups at the tertiary level is unlikely to have much impact on water use efficiency. Farmers in Mahakali are motivated to participate in the system operation and maintenance because of the technology evolved from the "structured" design.

Conclusion

Farmers' involvement enhances effective water control in government-controlled irrigation systems. Technology that allows reliable water supply motivates farmers to participate.

7.2 Implications for turnover

Since 1989, the government of Nepal has been strongly pursuing participatory management in government-built and managed irrigation systems in the country for improving the system management. Under the 1992 Water Resources Act, the Irrigation Department has recently introduced a programme to gradually transfer the management responsibility of government built and controlled irrigation systems which irrigate areas below 2,000 hectares to the farmers and to manage irrigation systems larger than 2,000 hectares jointly with the farmers. In view of the complexity in operation and management input required, the fully gated technology, as in Banganga, is clearly unsuitable for turnover to farmers who have limited resources.

For joint management of government-controlled irrigation systems, the fully regulated technology is unlikely to favour farmers' participation in the system maintenance and operation. This technology is not conducive to effective water management by farmers at tertiary or farm level because it is too complicated to guarantee reliable and adequate water supply. Without considerable confidence upon the capability of the technology to deliver reliable and adequate water, farmers will have little incentive to participate in collective efforts in operation and maintenance. As demonstrated in Banganga, efforts to improve water management through farmers' participation hardly succeed in irrigation systems with gated technology.

The non-flexible technology like that in Pithuwa seems to be appropriate for complete turnover to the farmers. This water control technology needs to be reconsidered and utilized if the investments in the future irrigation development in Nepal and in countries with similar natural and socio-economic environments are to realize their potential.

Considering the size (618 hectares) of the Pithuwa Irrigation System which is about the average irrigated area under a branch canal in Banganga, the question is whether it should not be appropriate for the Irrigation Department to turn over the operation and maintenance of branch canals or a group of canals serving less than 2,000 hectares to the farmers, in the case of government-managed large irrigation systems. Farmers within these branch canals should be allowed (institutionally) to define and develop their own rules and regulations of governance.

7.3 Issues requiring further research

In recent years, the "structured system" design has been strongly advocated by a number of irrigation design engineers and used as an alternative technology for effective water control. Research on actual water control in structured irrigation systems like Mahakali is required to understand the operational flexibility of structured systems.

Apart from technology, several factors enhance or inhibit effective water control in irrigation systems. Further research is needed to identify factors that contribute to effective or ineffective organizational control.

More methodological tools need to be developed to facilitate the analysis of the technology-organization-control relations in gravity flow canal irrigation systems.

Summary

The control, allocation and distribution, of water is the core process of an irrigation system. It is the process by which the available water is divided and distributed to the smaller irrigation units within the system, which in turn is distributed further down to the individual water user who must control it to place it in the crop root zones in particular fields. This study is based on the thesis that water control is a function of both technical/engineering, and organizational and institutional arrangements (social) controls. The combination of the physical system and organizational arrangements in an irrigation system determines how much water goes where. An analysis of both aspects in the context of the local farming system should lead to the better understanding of the more general issues and complexities of water control in irrigation systems.

This study presents three cases studies on water control in government-built and managed irrigation systems in the *tarai* Nepal. Water allocation and distribution practices during the consecutive crop seasons in the three irrigation systems located in three different places in the *tarai* region were studied from October 1991 to May 1993. There were two principal reasons for focusing research on the *tarai* irrigation systems. The first is that this region has the greatest number of and the largest area covered by government-built and managed large to medium scale irrigation systems. The second is the challenges and complexities in water control in the government-built and managed irrigation systems. An integrated approach which combined the study of the technical design and of organizational arrangements was followed. The historical development of the irrigation systems has also been traced to see the change or evolution of technical pattern and management practices over time. In addition to the study of the technical design of the irrigation systems, the concept of practice, which in this study refers to the visible actions and undertakings of people, has been used to understand how a certain type of water control technology provokes particular activities of water allocation and distribution. Both quantitative and qualitative data have been used.

There is historical evidence that canal irrigation in Nepal has been practised by farmers for centuries, but the development of modern canal irrigation systems in the country began only in the 1920s. The Department of Irrigation, established in 1951, is responsible for the planning, development and management of government irrigation schemes in the country. It consists mostly of civil engineers and is largely construction-oriented.

Government investment in irrigation development - especially in the large irrigation systems in the *tarai* - has increased tremendously since 1970, with the increase in the borrowing of international capital in the form of loans and grants. The development of irrigation facilities has been focused in this region because it has the largest area of irrigable land and the greatest potential for agricultural output using the river water resources. Until the mid-1980s, irrigation development by the government was largely confined to the construction of

physical infrastructures of canals and structures, and very little attention was given to the effective management of the completed systems. From 1985, attention began to be paid to the improved management of government-operated irrigation systems. This move was also influenced by the external donor agencies involved in the irrigation development. Further, the Irrigation Regulations promulgated in 1989 emphasized the participation of farmers in all phases of irrigation projects, the operation and maintenance of the government-built and controlled irrigation systems in particular. The premise of increasing farmer participation was that government resources alone were inadequate to meet the country's irrigation development objectives and sustain the management of government irrigation systems after their completion. The same year, action plans for the turnover of small irrigation systems and the participatory management of large irrigation systems were formulated. Subsequently, in 1992, the government adopted a policy under which the management responsibility of the government-built and operated irrigation systems are to be gradually transferred to farmers who are organized into water users' organizations. Under this policy, the irrigation systems serving command areas over 2,000 hectares (in the *tarai*) are to be jointly managed by the government and the water users' organization, and the management of the irrigation systems commanding less than this area are to be totally turned over to the water users' organizations.

Two modes of irrigation system development can be distinguished in Nepal: extensive and intensive development. In extensive development only basic minimum infrastructure, such as main and distribution canals, are provided and irrigation blocks are typically large, from 250-500 hectares. In intensive irrigation development, physical facilities are extended further down to the tertiary or farm level. The size of an irrigation block is reduced to 30-50 hectares. In recent years, emphasis has been placed on intensive development with farmer participation, to achieve the irrigation potential as envisaged in the design. In Nepal, these two development modes have been influenced by the resources available.

Irrigated agriculture in the *tarai* is basically rice based. Paddy, the staple crop, is cultivated during the monsoon season, followed by the cultivation of mainly oilseeds and wheat in the winter season. Whereas paddy covers almost all the land area, the coverage by winter crops is less intense. However, the cropping intensity varies from one place to another within the region. Farming is labour intensive and traditional methods are generally employed. Landholdings are fragmented and farmers practise intensive farming on smallholdings. Where irrigation water is available throughout the year, the most intensive farming is the cultivation of two crops of paddy followed by a winter crop of wheat.

The irrigation systems in the *tarai* region are run-of-the-river systems and have been built primarily to irrigate rice in the monsoon season. They are therefore subjected to inter and intra-seasonal variations in the water supply. Their operation is upstream-controlled and supply oriented. The canals in most irrigation systems are unlined.

However, the three irrigation systems studied show that the government-built and managed and controlled large canal irrigation systems in the *tarai* have varied technical design and operational features for water control. The difference in the water control technology is mainly because of the different design approaches followed by the design engineers, especially foreign consultant engineers. The involvement of different groups of design engineers is largely because of the government's position in irrigation development in the country *vis-à-vis* different external financing or donor agencies, such as ADB, World Bank, USAID and so forth. The government has to commit to involve foreign design engineers at the time of loan or grant agreements. The consultants are placed in an authoritative position. This situation is favoured by the fact that the Planning and Design Division of the Irrigation Department is not strong enough to discuss, check and question the compatibility and appropriateness of the designs of the consultants. The consequence of the involvement of foreign consultants on the choice of technology could not be foreseen.

The first case study, the Banganga Irrigation System, comprises a fully regulated water control technology with manually adjustable gates down to the tertiary outlets. The design engineers emphasized the efficient use of the available water *vis-à-vis* flexibility in the system operation, given the water constraint. Whereas this fully regulated technology potentially enables an irrigation system to deliver and distribute differential water requirements to the canals and outlets under the conditions of fluctuations in water availability, it considerably increases the operation and maintenance burden of the agency operating the system. It requires frequent resetting of gates at each variation of flow and is therefore complicated and the control structures become the targets of vandalism.

The second irrigation system, the Pithuwa Irrigation System, which was designed initially by the engineers of the Irrigation Department and later remodelled by the farmers, is a non-flexible system. It does not have adjustable control structures except for the head regulator of the main canal. The available flow in the main canal is distributed to all branch canals through open pipe outlets whose sizes are proportional to land area served. In this technology, the management input in terms of the operating staff is reduced to the minimum: the operation of the main canal headgate. Interference by people (including farmers) in the distribution of water along the main canal is reduced.

In the third case study, the Mahakali Irrigation Project (Stage I), the water control technology is based on the "structured" design concept. In the "structured" system design, regulation of flow is only required above the structured level. The level of structuring can be fixed at any point above the *chak* outlet up to the headgate at the diversion point. The "structured" system design thus makes the management of the irrigation system relatively easier, as compared to the fully gated controlled technology as in Banganga. But it reduces the flexibility in water distribution in the irrigation system. The Mahakali Irrigation System (Stage I) is "structured" such that flow regulation in the main canal is only required to operate secondary canals at full supply flow, and the flow in secondary canals is divided through the fixed weirs with proportional openings and all the tertiary outlets are set for a fixed discharge.

Compared in terms of the "structured" system concept, the three irrigation systems differ in their level of structuring. Whereas Banganga has the lowest level of structuring, at the tertiary outlet, Pithuwa has the highest, at the headgate of the main canal. Accordingly, they present different operational flexibility.

Many engineers have a bias towards "modern" technology and operational flexibility in irrigation systems. From the case studies presented in this thesis, it is concluded that the extensively gated technology for operational flexibility needs to be reconsidered, if effective water control is to be achieved. The semi-flexible technology based on the "structured" concept, as in Mahakali, might be appropriate for government controlled and managed large irrigation systems, given the operating staff and budget limitations of the Irrigation Department. The simple water control technology as that in Pithuwa appears to be appropriate for complete turnover of the irrigation system to the farmers. This water control technology needs to be reconsidered and utilized if the investments in the future irrigation development in Nepal are to realize their potential.

Water users' organizations are created for farmers' participation in the operation and maintenance of the systems. The reliability and adequate delivery of water to farmers greatly influence on the continuity or stability of the water users' organizations. The legal recognition and institutionalization of water users' organizations enhance the continuity of the organizations, but they do not necessarily motivate farmers' participation in government controlled irrigation systems. This study suggests that the fully gated water control technology does not guarantee reliable and adequate water delivery because of the complexity in operation, especially in government-operated irrigation systems having the limitation of an inadequate skilled manpower resource. The non-flexible technology of fixed weir check structures and open pipe outlets, as in Pithuwa, allows the available water to be distributed fairly and proportionally down the system. However, the limitation of this technology is that it is not possible to alter the distribution ratios of flow, and it inhibits the effective use of rainfall, especially where rotational water distribution is applied. By comparison, the semi-flexible water control technology, as in Mahakali, allows water supply to part of the system to be cut off if necessary, because of rainfall. However, this technology should be looked upon as undesirable where there is large spatial variation in soils and crops.

Farmers' participation enhances effective water control in government-operated irrigation systems. Farmers will have little incentive to participate in collective efforts in the operation and maintenance activities if they have no confidence in the capability of the technology to deliver reliable and adequate water. The empirical evidence from Pithuwa show that simple inflexible proportional division technology complemented with strong organization for social control is effective in ensuring reliable and fair water distribution.

Water control is a complex process requiring intensive organizational effort. Social control strongly influences the water allocation and distribution in irrigation systems. It minimizes water related conflicts and vandalism of physical control structures and enhances fair water distribution. As the case study of Pithuwa shows, social control is more effectively developed by farmers themselves than imposed by an external agency like the Irrigation Department.

Finally this study has shown how operational realities can be different from the design engineers' assumption. Water allocation and distribution differ from that intended in the design because of management decisions and the capability of the operating agency to execute the decisions. The availability and value of water also has strong influence upon this. In Mahakali the attempt to introduce rotational water distribution for efficient water management has had little impact because the water supply is abundant.

Samenvatting

De essentie van een irrigatiesysteem is het beheersen, toewijzen en distribueren van water. Het is een proces waarbij de beschikbare hoeveelheid water wordt verdeeld en verspreid over de kleinere irrigatie-eenheden in een irrigatiesysteem en vervolgens verder wordt verdeeld over de individuele watergebruikers, die er voor moeten zorgen dat het op de verschillende velden in de wortelzones van de plant terecht komt. Deze studie is gebaseerd op de these dat de controle over irrigatiewater een functie is van zowel technische, organisatorische als institutionele ordening. De combinatie van het fysieke systeem en de organisatorische ordening in een irrigatiesysteem bepaalt hoeveel water waar terecht komt. Een analyse van beide aspecten binnen een lokaal agrarisch bedrijfssysteem zal leiden tot een beter begrip van meer algemene vraagstukken en problemen met betrekking tot waterbeheer in irrigatiesystemen.

In deze studie komen drie voorbeelden aan bod van waterbeheer in een door de overheid gebouwd en beheerd irrigatiesysteem in de *tarai* in Nepal. Tussen oktober 1991 en mei 1993 is gedurende de opeenvolgende groeiseizoenen onderzoek gedaan naar de toekenning en verdeling van water in drie verschillende irrigatiesystemen in het *tarai* gebied. Aan de bestudering van de *tarai* irrigatiesystemen lagen twee redenen ten grondslag. Ten eerste heeft dit gebied de grootste bevloeide oppervlakte en tevens de hoogste concentratie door de overheid aangelegde en beheerde grote en middel-grote irrigatiesystemen. De tweede reden betreft de complexiteit van en de uitdagingen in het waterbeheer in de irrigatiesystemen in overheidsbeheer. In het onderzoek is gebruik gemaakt van een geïntegreerde benadering waarin zowel het technisch ontwerp als de organisatorische ordening werd onderzocht. Tevens is onderzoek gedaan naar de historische ontwikkeling van de irrigatiesystemen om inzicht te krijgen in de veranderingen en ontwikkeling van de techniek en beheerspraktijken over een langere periode. Naast een analyse van het technisch ontwerp van de irrigatiesystemen is het concept 'praktijk' gebruikt, dat verwijst naar de zichtbare handelingen van mensen, waarmee kan worden begrepen hoe een bepaalde vorm van beheerstechnologie aanleiding geeft tot bepaalde activiteiten van watertoekenning en verdeling. Hierbij zijn zowel kwantitatieve als kwalitatieve gegevens gebruikt.

Historici hebben aangetoond dat boeren in Nepal al eeuwenlang irrigeren met behulp van kanalen. De ontwikkeling van moderne systemen van irrigatiekanalen begon echter pas in de jaren '20. Het Irrigation Department van Irrigatie, opgericht in 1951, is verantwoordelijk voor de planning, ontwikkeling en het beheer van staats-irrigatiesystemen in het land. Aan het departement zijn merendeels civiel-ingenieurs verbonden die zich vooral richten op constructie.

De overheidsinvesteringen in de ontwikkeling van irrigatie - in het bijzonder de grote irrigatiesystemen in de *tarai* - zijn sinds de jaren '70 enorm gestegen, tezamen met een groei van het buitenlands kapitaal in de vorm van leningen en giften. De ontwikkeling van irrigatie faciliteiten zijn geconcentreerd in deze regio aangezien de hoeveelheid bebouwbare grond en de potentiële opbrengst met gebruik van rivierwater er het grootst is. Tot halverwege de jaren '80 was de ontwikkeling van irrigatie door de overheid grotendeels beperkt tot de constructie van fysieke infrastructuur in de vorm van kanalen en kunstwerken. Er was slechts geringe aandacht voor de effectiviteit van het beheer van de aangelegde systemen. Sinds 1985 begint er aandacht te komen voor de verbetering van het beheer van de staats-irrigatiesystemen. Deze verschuiving kwam mede tot stand onder invloed van externe donoren, betrokken bij de ontwikkeling van irrigatie. Bovendien werd in de Irrigatie Verordening, afgekondigd in 1989, de nadruk gelegd op de participatie van boeren in alle fasen van een irrigatieprojekt, in het bijzonder de bediening en het beheer van de staats-irrigatiesystemen. De vooronderstelling bij meer participatie van boeren was dat de overheidsmiddelen niet voldoende waren om de landelijke doelstellingen met betrekking tot irrigatie te halen en te voorzien in het beheer van de staats-irrigatiesystemen na hun voltooiing. Nog hetzelfde jaar werden plannen geformuleerd voor de overdracht van kleine irrigatiesystemen en het gezamenlijk beheer van grote irrigatiesystemen. In 1992 ging de regering over op het beleid de verantwoordelijkheid van de staats-irrigatiesystemen geleidelijk over te dragen naar de boeren, georganiseerd in watergebruikersorganisaties. Met dit beleid moeten irrigatiesystemen welke (in de *tarai*) meer dan 2000 ha. omvatten, gezamenlijk worden beheerd door de overheid en de gebruikersorganisaties en komt het beheer van systemen kleiner dan deze oppervlakte geheel in handen van de gebruikersorganisaties.

In de irrigatiesystemen in Nepal kunnen twee vormen van ontwikkeling worden onderscheiden: extensieve en intensieve ontwikkeling. Bij extensieve ontwikkeling wordt alleen in de belangrijkste infrastructuur voorzien, zoals hoofdkanalen en secundaire kanalen. De geïrrigeerde eenheden zijn hierbij groot, tussen de 250 en 500 ha. Bij intensieve ontwikkeling wordt de infrastructuur opgezet tot op het tertiaire- of bedrijfsniveau. De grootte van een geïrrigeerde eenheid is beperkt tot 30 à 50 ha. Recentelijk wordt bij de intensieve ontwikkeling de nadruk gelegd op de participatie van boeren om het geplande irrigatiepotentieel te benutten. Deze twee vormen van ontwikkeling zijn in Nepal afhankelijk van de mate waarin middelen beschikbaar zijn.

De geïrrigeerde landbouw in de *tarai* betreft voornamelijk de verbouw van rijst. Paddy, het ruwe produkt, wordt verbouwd gedurende het regenseizoen, gevolgd door de verbouw van voornamelijk oliezaden en tarwe in het winterseizoen. Voor de verbouw van paddy wordt vrijwel het hele areaal gebruikt, maar de verbouw van de wintergewassen is minder intensief. De gewasintensiteit is echter per plaats binnen de regio verschillend. De landbouw is arbeidsintensief en meestal wordt gebruik gemaakt van traditionele middelen. Het grondbezit is gefragmenteerd en op kleine stukjes wordt intensief geboerd. Indien het hele jaar door irrigatiewater beschikbaar is, bestaat de meest intensieve bebouwing uit twee oogsten paddy en één oogst tarwe.

De irrigatiesystemen in de *tarai* zijn 'run-of-the-river' systemen en zijn in eerste instantie gebouwd om rijst te bevloeien in het regenseizoen. De watertoevoer is derhalve afhankelijk van fluctuaties in het seizoen en tussen de seizoenen. Het systeem wordt bovenstrooms gereguleerd en is aanbod-gericht. In de meeste systemen zijn de kanalen niet bekleed.

Het onderzoek in de drie irrigatiesystemen toont aan dat het technisch ontwerp en het beheer van de staats-irrigatiesystemen in de *tarai* variëren. De verschillen in de technologie zijn voornamelijk een gevolg van de verschillen in de ontwerpbenaderingen die de ingenieurs hebben gehanteerd, in het bijzonder ingenieurs van buitenlandse instellingen. De bemoeienis van verschillende groepen ingenieurs is voornamelijk het gevolg van de positie van de overheid in de ontwikkeling van irrigatie *vis-à-vis* verschillende externe financierings- of donorinstellingen, zoals ADB, Wereldbank, USAID enz. De overheid verplicht zich buitenlandse ingenieurs aan te stellen bij een lening of een gift. De externe deskundigen komen op invloedrijke posities terecht. Deze situatie wordt in de hand gewerkt doordat de afdeling Planning en Ontwerp van het Irrigation Department niet krachtig genoeg is om te overleggen, te controleren en te kritiseren in hoeverre het ontwerp van de externe deskundigen aansluit bij en geschikt is voor de situatie. De consequentie van het betrekken van externe deskundigen bij de keuze van de technologie kon niet worden voorzien.

In de eerste casus, het Banganga Irrigatie Systeem, is de controle over het water geheel gereguleerd middels met de hand in te stellen schuiven tot op het tertiaire niveau. De ingenieurs hebben, gezien de beperkte hoeveelheid water, de nadruk gelegd op het efficiënt gebruik van het beschikbare water in plaats van flexibiliteit in het gebruik. Hoewel deze geheel gereguleerde technologie het in potentie mogelijk maakt verschillende hoeveelheden water aan te leveren en te verdelen bij een variërende aanvoer van water, legt het een sterke last op de schouders van de instantie die het geheel moet bedienen. Het is noodzakelijk om herhaaldelijk de schuiven bij te stellen bij iedere variatie in de waterstroom en het systeem is daarmee gecompliceerd en gevoelig voor vernieling van de kunstwerken.

Het tweede irrigatiesysteem, het Pithuwa irrigatie Systeem, dat in eerste instantie was ontworpen door de ingenieurs van het Irrigation Department en later is aangepast daar de boeren, is een inflexibel systeem. Het heeft geen verstelbare regelwerken met uitzondering van het inlaatwerk aan het begin van het hoofdkanaal. Het beschikbare debiet in het hoofdkanaal wordt over alle secundaire kanalen verdeeld middels open buizen waarvan de doorsnede gerelateerd is aan de hoeveelheid land. Bij deze technologie is het beheer in termen van menskracht beperkt tot het minimum: het bedienen van de hoofinlaat. De bemoeienis van mensen (inclusief boeren) bij de verdeling van het water over de kanalen is tot een minimum beperkt.

In de derde casus, het Mahakali Irrigatie Project (Fase I), is de technologie van het waterbeheer gebaseerd op het 'gestructureerde' ontwerpconcept. In het 'gestructureerde' ontwerpconcept is het regelen van de waterstroom alleen noodzakelijk boven het gestructureerde niveau. Het niveau van structurering kan worden vastgesteld op ieder punt boven de *chak* inlaat tot aan de hoofdinlaat op het verdeelpunt. Het 'gestructureerde' systeemontwerp maakt het beheer van het irrigatiesysteem relatief gemakkelijk, vergeleken met het geheel gecontroleerde Banganga systeem. Maar het reduceert de flexibiliteit van de waterverdeling in het irrigatiesysteem. Het Mahakali Irrigatie Systeem (Fase I) is zodanig 'gestructureerd' dat de regulering van de waterstroom in het hoofdkanaal voldoende is om de secundaire kanalen te bedienen bij volledige toevoer. De waterstroom in de secundaire kanalen wordt verdeeld door vaste stuwen met proportionele overlopen en alle tertiaire inlaten zijn ingesteld voor een vast debiet.

De verschillende irrigatiesystemen hebben een verschillend niveau van structurering. Het Banganga systeem heeft op het tertiaire niveau het laagste niveau van structurering, het Pithuwa het hoogste niveau van structurering bij de hoofdinlaat. De systemen vertonen als gevolg hiervan verschillen in flexibiliteit van het beheer.

Veel ingenieurs neigen naar 'moderne' technologie en operationele flexibiliteit in irrigatiesystemen. Uit de drie casussen van het onderzoek valt te concluderen dat het verband tussen veel reguleringspunten in het systeem en een flexibel gebruik herzien moet worden indien effectief waterbeheer wordt nagestreefd. Gezien de personeelsbezetting en het beperkte budget van het Irrigatie Departement kan de semi-flexibele technologie, gebaseerd op het 'gestructureerde' concept, zoals toegepast in Mahakali, adequaat zijn in grote irrigatiesystemen in overheidsbeheer. De eenvoudige technologie waarmee het water wordt gereguleerd zoals in het Pithuwa systeem blijkt geschikt bij een algehele overdracht van het irrigatiesysteem aan boeren. Deze beheerstechnologie moet opnieuw worden bekeken en toegepast om investeringen in de toekomstige ontwikkeling van irrigatie in Nepal te doen renderen.

Watergebruikersorganisaties worden opgezet voor de participatie van boeren in de bediening en het onderhoud van de systemen. Een betrouwbare en adequate waterverdeling heeft een sterke invloed op de continuïteit en stabiliteit van de gebruikersorganisaties. De formele erkenning en institutionalisering van watergebruikersorganisaties verbeteren de continuïteit van de organisaties, maar zijn niet noodzakelijkerwijs ook een motivatie voor de participatie van boeren in systemen die door de overheid worden beheerd. Deze studie geeft aan dat het geheel gereguleerde waterbeheer niet garant staat voor een betrouwbare en adequate verdeling van water door de complexiteit in het gebruik, met name in staats-irrigatiesystemen met onvoldoende geschoold personeel. De inflexibele technologie van vaste overlaten en open buizen, zoals in het Pithuwa systeem bieden de mogelijkheid het water proportioneel en eerlijk te verdelen over het systeem. Echter, de beperking van deze technologie is dat het niet mogelijk is de verhouding in de waterverdeling en de toevoer te veranderen en het werkt een effectief gebruik van de regenval tegen, met name bij het gebruik van roterende waterverstrekking. Met de semi-flexibele verdeeltechnologie zoals toegepast in het Mahakali systeem is het daarentegen wel mogelijk om de watertoevoer in bepaalde delen af te sluiten bij regenval. Deze technologie is echter minder wenselijk indien er een grote variatie is in bodemsoorten en gewassen.

De participatie van boeren verbetert het effectieve waterbeheer in staats-irrigatiesystemen. Boeren zien er weinig in om te participeren in gezamenlijke bediening en onderhoud indien ze geen vertrouwen hebben in de technologie om het water betrouwbaar en adequaat te verdelen. Het Pithuwa systeem bewijst dat eenvoudige inflexibele proportionele verdeeltechnologie gepaard aan een sterke organisatie voor sociale controle er in slaagt een betrouwbare en eerlijke waterverdeling te bewerkstelligen.

Waterbeheer is een complex proces waar een intensieve organisatorische inspanning voor vereist is. Sociale controle beïnvloed in sterke mate de toewijzing en verdeling van water in irrigatiesystemen. Het werkt conflicten over water en vandalisme tegen en bevordert een eerlijke waterverdeling. Zoals uit de casus van het Pithuwa systeem blijkt is de sociale controle effectiever wanneer deze wordt gehanteerd door de boeren zelf dan wanneer dit gebeurt door externe instanties zoals het Irrigation Department.

Tenslotte heeft deze studie aangetoond hoe de werking in de realiteit kan verschillen van de uitgangspunten van de ingenieurs. De toewijzing en verdeling van water verschilt van de manier zoals die was bedoeld in het ontwerp, door beslissingen in het beheer en de capaciteiten van de uitvoerende instantie. De beschikbaarheid en de waarde van het water heeft hierop ook grote invloed. In het Mahakali systeem heeft de poging een roterende waterverstrekking voor een efficiënte verdeling te introduceren weinig effect gesorteerd door een overvloedige watertoevoer.

References

Abernethy, Charles L., 1986. Performance Measurement in Canal Water Management: a discussion. ODI/IIMI Irrigation Management Network Paper 86/2d, London.

Agricultural Projects Services Centre (APROSC), 1978. Irrigation Impact Evaluation Study. Kathmandu, Nepal.

Agricultural Projects Services Centre, 1982. Farm Economics Survey of Selected Public Sector Intensive Irrigation Development Projects. Kathmandu, Nepal.

Agricultural Projects Services Centre, 1989. Agricultural Impact Study: Mahakali Irrigation Project (Stage I). Nepal.

Albinson, Brian, 1993. Unpublished notes and papers on practical guidelines for the design of a structured system. North Vancouver, Canada.

Ali, Syed Hasim, 1983. One Season of Integrated Water Management in Andhra Pradesh. ODI, Irrigation Management Network Paper 7d, London.

Aryal, M. N. and S.R. Sharma, 1992. Main System Management, Mahakali Irrigation Project. In *Proceedings of the National Workshop on Participatory Management in Agency-managed Irrigation Systems in Nepal*, DOI and IIMI/Nepal, April 29-30, pp.71-77.

Asian Development Bank, 1981. Appraisal of the Command Area Development Project in Nepal. Manila, The Philippines.

Asian Development Bank, 1982. Nepal Agriculture Sector Strategy Study, Vol.I and II. Manila, The Philippines.

Asian Development Bank, 1990. Project Completion Report, Command Area Development Project, Nepal. Manila, The Philippines.

Bandaragoda, D. J. and Carlos Graces-Restrepo, 1992. Crop-Based Irrigation in Pakistan: Initial Efforts in the North West Frontier Province. ODI, Irrigation Management Network Paper 18, London.

Barker, R. et al., 1984. Irrigation Development in Asia: Past Trends and Future Directions. Cornell Studies in Irrigation, Cornell University, Ithaca, New York.

Baxter, C. J. and W.R. Laitos, 1988. Water Control and the Maintenance Imperative: Evidence from Nepal. *Agricultural Water Management*, Vol.15, pp.115-130.

Berkoff, D.J.W., 1988. Irrigation Management in South India: The approach of the National Water Management Project. *WAMANA*, Vol.III (IV: 19-231), October, India.

Berkoff, D.J.W., 1990. Irrigation Management on the Indo-Gangetic Plain. Technical Paper 129, World Bank, Washington, D.C.

Berry, M.J. et al., 1974. Development Potential of Nawalparasi Area of Nepal, Land Resources Study. Overseas Development Adminstration, England.

Bertalanffy, von Ludwig, 1993. *General System Theory: foundations, development, and applications*. George Braziller, New York. Reprint of the 1968 edition.

Bhatta, Raghunatha, 1992. Participatory Management: farmer's viewpoint. *Proceedings of the National Workshop on Participatory Management in Agency-managed Irrigation Systems in Nepal*, DOI and IIMI/Nepal, Kathmandu, April 29-30, pp.119-122.

Bijker, W.E., 1990. Do not despair: there is life after constructivism. In *Kennis en Methode, Tijdschrift voor wetenschapsfiodofie en wetenchapsonderzoek*, jrg. XIV, No.4, pp.324-325.

Biswas, A.K., 1989. Irrigation in Nepal: Opportunities and Constraints. In *Journal of Irrigation and Drainage Engineering*, Vol.115, No.6, pp.1051-1064.

Blaikie, Cameron and D. Seddon, 1980. *Nepal in Crisis: growth and stagnation at the periphery*. Oxford University Press, Oxford.

Bos, M.G. (ed.), 1978. *Discharge Measurement Structures*, ILRI Publication 20. ILRI, Wageningen, The Netherlands.

Bottrall, Anthony, 1981. Improving Canal Management: The role of Evaluation and Action Research. In Asit K. Biswas (ed.), *Water Supply and Management: Social and Economic Perspectives on Irrigation Management*, Pergamon Press, Oxford.

Bourdieu, Pierre, 1977. *Outline of a theory of practice*. Cambridge University Press.

Burgess, Robert G., 1985. *In the Field: an introduction to field research*. Contemporary Social Research Series.

Burns, Robert E., 1993. Irrigated Rice Culture in Monsoon Asia: The Search for an Effective Water Control Technology. In *World Development*, Vol. 21, No.5, pp.771-789.

Callon, M., 1987. Society in the Making. In Bijker et al. (ed.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. MIT Press, Cambridge, Massachusetts. pp.83-103.

Campbell, Donald E., 1995. Design and Operation of Smallholder Irrigation in South Asia. Technical Paper 256, World Bank, Washington, D.C.

Canadian International Water and Energy Consultants, 1990. Master Plan for Irrigation Development in Nepal, Main Report, Cycle 2. Department of Irrigation, Nepal.

Carson, Brian et al., 1986. Agriculture/Forestry Report, Land Resource Mapping Project, Nepal (Prepared by Kenting Earth Sciences Ltd., Canada for HMG of Nepal).

Carson, Brian, 1986. Land Capability Report, Land Resource Mapping Project, Nepal (Prepared by Kenting Earth Sciences Ltd., Canada for HMG of Nepal).

Central Bureau of Statistics, 1992. Statistical Pocket Book, Nepal.

Central Bureau of Statistics, 1993a. National Sample Census of Agriculture (1991-92), Nepal.

______________, 1993b. National Sample Census of Agriculture (1991-92), District summary, Nepal.

______________, 1994. Statistical Pocket Book, Nepal.

Chambers, Robert, 1980. Basic Concepts in the Organization of Irrigation. In Walter E. Coward Jr. (ed.), *Irrigation and Agricultural Development in Asia: perspectives from the social sciences*, Cornell University Press, Ithaca, New York, pp.28-50.

Chambers, Robert, 1991. *Rural Development: Putting the Last First*. Longman Scientific and Technical. England. Reprint of the 1983 edition.

Chambers, R., A. Pacey, and L. A. Thrupp (ed.), 1991. *Farmers First: Farmer innovation and agricultural research*. Intermediate Technology Publications, London. Reprint of the 1989 edition.

Chambers, R., N.C. Saxena, and T. Shah, 1991. *To the hands of the poor: Water and trees*. Oxford and IBH Publishing Co. (Pvt.) Ltd., New Delhi. Reprint of the 1989 edition.

Chambers, Robert, 1992. *Managing Canal Irrigation: Practical Analysis from South Asia*. Oxford and IBH publishing Co. (Pvt.) Ltd., New Delhi. Reprint of the 1988 edition.

Chambers, Robert, 1993. *Challenging the Professions: Frontiers for rural development*. Intermediate Technology Publications, London.

Chyurlia, Jerome P., 1984. Water Resources Report, Land Resource Mapping Project, Nepal (Prepared by Kenting Earth Sciences Ltd., Canada for HMG of Nepal).

Collingridge, David, 1980. *The social control of technology*. Frances Printer Publishers Ltd., London.

Coward Jr., Walter E., 1980. Irrigation Development: Institutional and Organizational Issues. *Irrigation and Agricultural Development in Asia: perspectives from social sciences*, Cornell University Press, Ithaca, New York.

Coward Jr., Walter E., 1985a. Technical and Social Change in Currently Irrigated Regions: rules, roles and rehabilitation. In Michael Cernea (ed.), *Putting People First: Sociological variables in rural development*, a World Bank Publication, Oxford University Press.

Coward Jr., Walter E., 1985b. State and Locality in Asian Irrigation Development: the property factor. In *Current issues in and approaches to irrigation water management in developing countries*, Westview Press, Colorado State University, International School for Agricultural and Resource Development.

Dahal, Dilli R., 1983. Economic Development Through Indigenous Means: A case of Indian migration in the Nepal *Tarai*. In the Contribution to Nepalese Studies, *Journal of the Research Centre for Nepal and Asian Studies*, Vol. II, No.1, Tribhuvan University, Kathmandu, pp.1-20.

Department of Irrigation, 1972. Design and Estimate of the Banganga Irrigation Project, Nepal.

______________, 1973. A Brief Report on the Status of *Rajkulo* in the Banganga Command Area, Nepal.

Department of Irrigation, 1976. Design and Estimate of the Field Channels in the Banganga Irrigation Project, Nepal.

______________, 1979. A Brief Introduction to the Banganga Irrigation Project: an introductory note issued on the inaugural day of the project, Nepal, January.

______________, 1987. A Brief Report on the Pithuwa Irrigation Scheme, Department of Irrigation, Nepal.

______________, 1989a. Action Plan for Participatory Management Program, Department of Irrigation, Nepal.

______________, 1989b. Action Plan for Turnover Program, Department of Irrigation, Nepal.

______________, 1993. Guidelines for Joint Management of Irrigation Systems, Department of Irrigation, Nepal.

Dusseldorp, van D.B.W.M., 1981. Participation in planned development influenced by governments of developing countries at local level in rural areas, In *Essays in rural sociology*, Department of Rural Sociology of the tropics and subtropics, Wageningen Agricultural University, Wageningen.

Farrington, J. and S.B. Mathema, 1991. *Managing Agricultural Research for Fragile Environments: Amazon and Himalayan Case Studies*, AAU Occasional Paper No.11, ODI, London.

Framji, K.K. and I.K. Mahajan, 1969. Irrigation and Drainage in the World: A global review. *International Commission on Irrigation and Drainage*, Vol. II.

Freeman, David M., and Max L. Lowdermilk, 1985. Middle-level Organizational Linkages in Irrigation Projects. In Michael Cernea (ed.), *Putting People First: Sociological variables in rural development*, a World Bank Publication, Oxford University Press, pp.91-118.

Geertz, C., 1980. Organization of the Balinese Subak. In Walter E. Coward Jr. (ed.), *Irrigation and Agricultural Development in Asia: perspectives from social sciences*, Cornell University Press, Ithaca, New York.

GEOCE Consultants (Pvt.) Ltd., 1990. Provisional Impact Evaluation Study of Banganga Irrigation Sub-project, Vol.I-II, Kathmandu.

Giddens, Anthony, 1987. *Social theory and modern sociology*. Polity Press, Cambridge.

______________, 1992. *Sociology*. Polity Press, Cambridge. Reprint of the 1989 edition.

Groenfeldt, David, 1988. The Potential for Farmer Participation in Irrigation Systems Management. *Irrigation and Drainage Systems*, Vol.2, pp.241-257.

Gyawali, Dipak, 1993. Tanakpur on the Thames. *Himal*, Himal Association, Lalitpur, Nepal, July/August.

Halcrow, Sir William and Partners, 1984a. Design Guidance Notes, Mahakali Irrigation Project (Stage I), Nepal.

______________, 1984b. Design Manual, Mahakali Irrigation Project (Stage I), Nepal.

Halcrow, Sir William and Partners, 1986. Final Report on Blocks 3 and 4 Redesign, MIP (Stage I), Nepal.

______________, 1988a. Reassessment of Feasibility, Mahakali Irrigation Project (Stage II), Vol.I, Nepal.

______________, 1988b. Operation and Maintenance Manual. Mahakali Irrigation Project (Stage I), Vol.I, Nepal.

______________, 1988c. Operation and Maintenance Manual. Mahakali Irrigation Project (Stage I), Vol. III, Nepal.

______________, 1990a. Implementation of Rotational Water Supply in the Mahakali Irrigation Project: A report on the MIP (Stage II), Nepal.

______________, 1990b. Water Management Consultant's Third Visit Report, Mahakali Irrigation Project (Stage I), Nepal.

______________, 1992. Water Management Consultant's Fourth Visit Report, Mahakali Irrigation Project (Stage I), Nepal.

Hancock, Graham, 1993. *Lords of Poverty*. Macmillan, London. Reprint of the 1989 edition.

Hildreth, G., 1986. Summary Report, Land Resources Mapping Project, HMGN, Nepal (Prepared by Kenting Earth Sciences Ltd., Canada for HMG of Nepal).

Horst, Lucas, 1983. Irrigation Systems - alternative design concepts. ODI, Irrigation Management Network Paper 83/7c, London.

Horst, Lucas, 1984. Irrigation Water Management in Indonesia. *International Journal on Development Technology*, No.2, pp.211-221.

Horst, Lucas, 1987. Choice of Irrigation Structures: The paradox of operational flexibility. *Irrigation Design for Management Proceedings of Asian Regional Symposium*, February 16-18, pp.45-60.

Horst, Lucas, 1990. Interactions Between Technical Infrastructure and Management. ODI/IIMI Irrigation Management Network Paper 90/3b, London.

Hotes, Frederick. L., 1984. World Bank Irrigation Experience. ODI, Irrigation Management Network Paper 9d, London.

Hughes, Thomas P., 1987. The Evolution of Large Technological Systems. In Bijker et al. (ed.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, MIT Press, Cambridge, Massachusetts, pp.51-82.

Hunt, Robert C., 1987. Organizational Control Over Water: the positive identification of a social constraint on farmer participation. Paper read at the conference on Irrigation Design for Management, IIMI, Digana, Sri Lanka, pp.16-18.

Hunt, Robert C., 1988. Size and the Structure of Authority in Canal Irrigation Systems. *Journal of Anthropological Research*, Vol.44, No.4, pp.335-355.

Hunt, Robert C., 1989. Appropriate Social Organization? Water Users' Associations in Bureaucratic Canal Irrigation Systems. *Human Organization*, Vol.48, No.1, pp.79-90.

Huppert, Walter, 1987. Impacts of Irrigation on Land Tenure Conditions. *Quarterly Journal of International Agriculture*, Vol.26, No.4, pp.368-376.

Huppert, Walter, 1989. *Situation Conformity and Service Orientation in Irrigation Management.* Sonderpublikation der GTZ, No.242. GTZ, Eschborn.

Huppert, W. and Hans H. Walker, 1989. *Management of Irrigation Systems: Guiding principles.* Rural Development Series, GTZ, Eschborn.

ISPAN, 1989. Irrigation Management Project, Midterm Evaluation Report, Kathmandu, Nepal, April.

Joshi, Madhav, 1993. "Sanstha Dirghata ko Khojima (In search of sustainable organization)", *Mahakali* weekly. Mahendranagar, Nepal, April 11.

Karki, M.D. and Ujjwal Pradhan, 1993. Beyond Basic Needs and Poverty Alleviation in Nepal: The new challenges in irrigation management. Paper prepared for the presentation at the 15th ICID Congress held at The Hague, The Netherlands.

Keller, Jack, 1990. A holistic Approach to Irrigation Scheme Water Management. In R.K. Sampath et al. (ed.), *Social, Economic and Institutional Issues in Third World Irrigation Management.* Studies in Water Policy and Management, No.15, Westview Press, Boulder, London, pp.31-58.

Khatri C. Durga and Ujjwal Pradhan, 1992. Banganga Irrigation System: An Exercise in Participatory Management. *Proceedings of the National Workshop on Participatory Management in Agency-managed Irrigation Systems in Nepal*, DOI and IIMI/Nepal, Kathmandu, April 29-30, pp.37-52.

Kirkpatrick, William, 1811. *An account of the Kingdom of Nep(a)ul.* William Miller, London.

Korten, David C., 1980. Community Organization and Rural Development: A Learning Process Approach. *Public Administration Review*, September/October, pp.480-511.

Korten, Francis F., and Robert Y. Siy Jr., 1989. *Transforming a Bureaucracy: The Experience of the Philippine National Irrigation Administration.* Kumarian Press Inc., Connecticut.

Kraatz, D.B., and J. K. Mahajan, 1975. Small Hydraulic Structures. FAO Irrigation and Drainage Paper No. 26/1-2, Rome.

Kurmi, B.M., and L.P. Kurmi, 1992. Participatory Management in Banganga Irrigation System: Farmer's Viewpoint. *Proceedings of the National Workshop on Participatory Management in Agency-managed Irrigation Systems in Nepal*, DOI and IIMI/Nepal, Kathmandu, April 29-30, pp.133-141.

Levine, Gilbert, 1977. Management Components in Irrigation System Design and Operation. *Agricultural Adminstration* 4(1), pp.37-48.

Levine, Gilbert, 1980. The Relationship of Design, Operation and Management. In Walter E. Coward Jr. (ed.), *Irrigation and Agricultural Development in Asia: Perspectives from Social Sciences*, Cornell University Press, Ithaca, New York.

Long, Norman, 1989a. Conclusions: Theoretical Reflections on Actor, Structure and Interface. In Norman Long (ed.), *Encounters at the interface: A perspective on Social Discontinuities in Rural Development*, Wageningense Sociologsche Studies 27, Pudoc, Wageningen Agricultural University, Wageningen, pp.221-243.

Long, Norman (ed.), 1989b. *Encounters at the interface: A perspective on Social Discontinuities in Rural Development*, Wageningense Sociologsche Studies 27, Pudoc, Wageningen Agricultural University, Wageningen.

Lowdermilk, M. L., 1985. Improved Irrigation Management: Why Involve Farmers?. ODI, Irrigation Management Network, Network Paper 11c, London.

Mackenzie, D. and J. Wajcman (ed.), 1985. *The Social Shaping of Technology*. Open University Press, Milton Keynes.

Mahat, R. S., 1991. "Inaugural Speech" delivered at *National Workshop on Regenerative Agriculture in Nepal: Issues and Trends*, Community Welfare and Development Society, Kathmandu, October 5-8.

Mahbub, S.I. and N.D. Gulhati, 1951. *Irrigation outlets*. Atma Ram and Sons, Delhi, India.

Malhotra. S.P., 1982. The Warabundi and its Infrastructure. Central Board of Irrigation and Power, Publication No.157, New Delhi, India.

Manzardo, A. and R. Subedi, 1990. Farmer Organization in the Mahakali Irrigation Project: Development of Associations and Field System Management, Mahakali Irrigation Project, Nepal, January.

Mase, Toru, 1990. A Study of Water Users' Associations for Irrigation in Asia. In *Irrigation Engineering and Rural Planning*, No.18, pp.5-16.

Merry, Douglas J., 1986. Reorganising Irrigation: Local Level Management in the Punjab (Pakistan), IIMI Research Paper No.4, IIMI, Digana, Sri Lanka.

Ministry of Agriculture, HMGN, 1992. Food Statistics of Nepal. Department of Food and Agricultural Marketing Services, Kathmandu, Nepal.

Ministry of Finance, HMGN, 1992. *Economic Survey (1991-92)*, Kathmandu, Nepal.

Ministry of Water Resources, HMGN, 1988. Working Policy on Irrigation Development for the Fulfilment of Basic Needs, Kathmandu, Nepal.

Misra, V. S., 1992. Banganga Irrigation System: Preliminary Results on Main System Management Improvement. *Proceedings of the National Workshop on Participatory Management in Agency-managed Irrigation Systems in Nepal*, DOI and IIMI/Nepal, Kathmandu, April 29-30, pp.81-89.

Morgan, Gareth, 1991. *Images of organization*. Sage Publications. Reprint of the 1986 edition.

Murry-Rust, H. and M. Moore, 1983. Formal and Informal Water Management Systems: Cultivation Meetings and Water Deliveries in Two Sri Lankan Villages, Cornell University, Ithaca, New York.

National Planning Commission, 1957. The First Five-year Development Plan (1957-62), Kathmandu, Nepal.

______________, 1962. The Second Three-year Development Plan (1962-65), Kathmandu, Nepal.

National Planning Commission, 1965. The Third Five-year Development Plan (1965-70), Kathmandu, Nepal.

______________, 1992. The Eighth Five-year Development Plan (1992-97), Unofficial English translation, Kathmandu, Nepal.

National Planning Commission, 1992. Summary of the Eighth Plan (1992-97), Unofficial English translation, Kathmandu, Nepal.

Neupane, Sarita, 1991. *The Nutritional Status of Children in Irrigated and Non-irrigated Villages in Nepal.* PhD Dissertation, Cornell University, Ithaca, New York.

NIACONSULT, Inc. and International Engineering Company Inc., 1984. Project Design Report of the Command Area Development Project, Nepal.

NIACONSULT, Inc. and IECO, Inc., 1987. Operation and Maintenance Manual, Command Area Development Project, Vol.I-III, Nepal.

NIACONSULT, Inc., and IECO, Inc., 1988. An Illustrated Guide of Fieldman's Duties and Responsibilities, Command Area Development Project, Nepal.

NIACONSULT, Inc., and IECO, Inc., 1989. Final Report: Command Area Development Project, Nepal.

Nippon Koei Co. Ltd., 1990. A Report on the Inventory Survey of Existing Farmers-managed Irrigation Schemes in East Rapti, Nepal.

Oad, Ramchand and G. Levine, 1985. Distribution of Water in Indonesian Irrigation Systems. In *The Transactions of the American Society of Agricultural Engineers*, Vol.28, No.4, Michigan, pp.1166-1172.

Ojha, Durga P., 1983. History of Land Settlement in Nepal *Tarai*. In the Contribution to Nepalese Studies, *Journal of the Research Centre for Nepal and Asian Studies*, Vol.II, No.1, Tribhuvan University, Kathmandu, pp.21-44.

Olyphant, Lawrence, 1852. *A Journey to Kathmandu*. D. Appleton and Company, New York.

Ostrom, Elinor, 1992. *Crafting Institutions for Self-governing Irrigation Systems.* San Francisco Institute for Contemporary Studies, New York.

Pant, Niranjan, 1986. Farmers' Organization in Large Irrigation Projects. *Economic and Political Weekly*, Vol.xxi, No.52, Review of Agriculture, pp.A 171-175.

Patil, R.K., 1988. Experiences of Farmer Participation in Irrigation Management: Mula Command Maharastra State, India. *Irrigation and Drainage Systems*. Vol.2, pp.21-41.

Pattersson, Ted. C., 1981. Feasibility Study of the Command Area Development Project, Final Report, Vol.I-III, New Mexico, USA.

Pinch, Trevor J. and Wiebe E. Bijker, 1984. The Social Construction of Facts and Artifacts: or How the Sociology of Science and the Sociology of Technology might benefit each other. *Social Studies of Science*, Vol.14, No.3, August, pp.399-441.

Plusquellec, H., Charles Burt, and Hans W. Wolter, 1994. Modern Water Control in Irrigation: Concepts, Issues, and Applications. Technical Paper 246, World Bank, Washington, D.C.

Poudel, Bholanath, 1965. "Bhaktapurko Rajkulo (The State Irrigation Channel of Bhaktapur)". *Purnima*, No.4, Kathmandu, Nepal, January, pp.44-49.

Poudel, S.N., 1986. *Irrigation Development in Nepal.* Manaslu Press, Kathmandu, Nepal.

Poudel, S.N., 1992. *Irrigation Profile of Nepal.* Research and Training Branch, Department of Irrigation, Nepal.

Poudel, S.N. and C.K. Sharma, 1993. Agriculture Perspective Plan (draft), Technical Paper on Irrigation and Water Control, Vol.I, Kathmandu, Nepal.

Pradhan, Bhubanesh K., 1990. Water Resources Development and Management in Nepal. Paper presented at the first monthly seminar organized by the Department of Roads, Project Directorate, Kathmandu. Nepal.

Pradhan, Prachanda, 1989. Patterns of Irrigation Organization in Nepal: A Comparative Study of 21 Farmer-Managed Irrigation Systems. IIMI Country Paper - Nepal No.1, Sri Lanka.

Rajbhandari, S.P., 1993. Curriculum Development on Social and Institutional Aspects of Irrigation Management. In Shukla et al. (ed.), *Proceedings of the Workshop on Curriculum Development in On-farm Irrigation Management*, Institute of Agriculture and Animal Science, Rampur, Chitawan, Nepal, pp.42-55.

Regmi, Mahesh C., 1978. *Land Tenure and Taxation in Nepal*, Vol.I-IV, H.K. Kuloy (ed.) Bibliotheca Himalaya, Series 1, Vol.26, Ratna Pustak Bhandar, Kathmandu, Nepal.

Reidinger, Richard B., 1980. Water Management by Administrative Procedures in an Indian Irrigation System. In Walter Coward Jr. (ed.), *Irrigation and Agricultural Development in Asia: Perspectives from Social Sciences*, Cornell University Press, Ithaca, New York.

Repetto, R., 1986. *Skimming the Water: Rent-seeking and the Performance of Public Irrigation Systems.* World Resources Institute, Research Report No.4, Washington D.C.

Riccardi, Theodore Jr., 1977. "The Royal Edicts of King Rama Shah of Gorkha". *Kailash: A journal Himalayan of Studies*, Vol.V-1, Kathmandu, Nepal, pp.29-45.

Sagardoy, J.A., A. Bottral, and G.O. Uittenbogaard, 1982. *Organization, Operation and Maintenance of Irrigation Schemes*, FAO, Irrigation and Drainage Paper 40, Rome.

Scoones, Ian and John Thompson, 1994. *Beyond Farmer First: Rural People's Knowledge, Agricultural Research and Extension Practice.* Intermediate Technology Publications, London.

Seckler, David, 1985. The Management of Pad(d)i Irrigation Systems: A Laissez-Faire Supply-Side Theory. ODI, Irrigation Management Network Paper 11b, London.

Seddon, David, 1990. *Nepal, A State of Poverty.* Vikas Publishing House Pvt. Ltd., New Delhi. Reprint of the 1987 edition.

Shanan, Leslie et al., 1986. Design and Operation Guidelines for Structured Irrigation Networks, South Asia Projects Department, World Bank, Washington, D.C.

Shanan, Leslie, 1992. Planning and Management of Irrigation Systems in Developing Countries. *Agricultural Water Management*, Vol. 22, No. 1 and 2.

Shrestha, J.K. et al., 1992. Pithuwa Irrigation System. *Proceedings of the National Workshop on The Role of NGOs in Irrigation Development in Nepal*, September 29-30; DOI and IIMI/Nepal, Kathmandu.

Sill, M. and J, Kirkby, 1991. *The Atlas of Nepal in the Modern World.* Earthscan Publications Ltd., London.

Silverman, David, 1970. *The Theory of Organization: A Sociological Framework.* Heinemann, London.

Singh, K.K. (ed.)., 1991. *Farmers in the Management of Irrigation Systems.* Sterling Publishers Private Limited. New Delhi.

Singh, Satyanarayan, 1989. Issues in Canal Operations in South India: Past, Present and Future. In *WAMANA*, Vol.IV (3-1:13), Hyderabad, India.

Siriwardena, S.S.A.L., 1989. *From Planned Intervention to Negotiated Development: The struggle of bureaucrats, farmers and traders in the Mahaweli irrigation scheme in Sri Lanka*, PhD Dissertation, Department of Rural Sociology, Wageningen Agricultural University, Wageningen.

Sivamohan, M.V.K. and Christopher A. Scott, 1992. The Command Area Development Programme in India: A Policy Perspective. ODI, Irrigation Management Network Paper 20. London.

Small, Leslie E., and Mark Svendsen, 1990. A Framework for Assessing Irrigation Performance. In *Irrigation and Drainage Systems* 4:283-312.

Subedi, R., 1989. Four Months of Farmer Organization Development Process in the Mahakali Irrigation Project, Nepal, June.

Subedi, R., 1990. Farmers' Response to On-farm Water Management Program, The Mahakali Irrigation Project, Nepal.

Subedi, R., and U. Gautam, 1992. Formation of Water Users' Organization in Nepal: A case of Mahakali Irrigation Project. In *Proceedings of the National Workshop on Participatory Management in Agency-managed Irrigation Systems in Nepal*, DOI and IIMI/Nepal, April 29-30, pp.15-23.

Stone, Ian, 1984. *Canal irrigation in British India: Perspectives on Technological Change in a Peasant Economy.* Cambridge South Asian Studies, Cambridge University Press.

Swantz, M.L., 1989. Transfer of Technology as an Intercultural Process. Helsinki.

Tamaki, A., 1977. The Development Theory of Irrigation Agriculture, Special Paper No.7, Institute of Development Economics, Tokyo.

Ubels, Jan, 1989. Irrigation Systems as Social Interfaces: towards an understanding of irrigation development as an interactive process. In Norman Long (ed.), *Encounters at the Interface: a perspective on social discontinuities in rural development*, Wageningense Sociologische Studies 27, Pudoc, Wageningen Agricultural University, Wageningen, pp.183-203.

Uphoff, Norman, 1986. *Improving International Irrigation Management with Farmer Participation: Getting the Process Right*. Studies in Water Policy and Management, No.11, Westview Press, London.

Varshney, R.S., S.C. Gupta, and R.L. Gupta, 1983. *Theory and Design of Irrigation Structures*, Vol.I. Nemchand and Brothers, Roorkee, India.

Vincent, Linden, 1995. *Hill Irrigation*. Oversees Development Association, Intermediate Technology Publications, London.

Wade, Robert, 1982. The Systems of Administrative and Political Corruption: Canal Irrigation in South India. *Journal of Development Studies*, Vol.18, No.3, pp.287-327.

Walker, W. and Walter E. Coward Jr., 1984. Small-scale Irrigation Development, Water Management Synthesis Project Report 30. Utah State University, Department of Agricultural and Irrigation Engineering, Logan, Utah.

Water and Energy Commission/IBRD, 1982. Performance Review of Public Sector Intensive Irrigation Based Agricultural Development Projects, Report No.3/2/140782/1/3, Nepal.

Water and Energy Commission/IBRD, 1984. Consultancy Study on Institutional and Management Aspects of Large-scale Public Sector Irrigation, Report Nos.3/1/210384/1/2 and 3/1/210384/2/2, Nepal.

Wensley, C. J. and M.F. Walter, 1985. Small-scale Irrigation: Design Issues in Government-assisted Systems. Water Management Synthesis Project Report 39, Cornell University, Ithaca, New York.

Whiting, Peter et al., 1986. Economics Report, Land Resource Mapping Project, Nepal (Prepared by Kenting Earth Sciences Ltd., Canada for HMG of Nepal).

Winner, Langdon, 1993. Upon Opening the Black Box and Finding it Empty: Social Constructivism and the Philosophy of Technology. *Science, Technology, and Human Values*, Vol.18, No.3, Summer 1993, pp.362-378.

Wittfogel, Karl A., 1963. *Oriental Despotism, a comparative study of total power*. Yale University Press. Reprint of the 1957 edition.

World Bank, 1980. Staff Appraisal Report, Mahakali Irrigation Project (Stage I), Nepal. Washington D.C.

Wyatt-Smith, J., 1982. The Agricultural System in the Hills of Nepal. APROSC, Kathmandu, Nepal.

Yoder, Robert D., 1986. *The Performance of Farmer-managed Irrigation Systems in the Hills of Nepal*. PhD Dissertation, Cornell University, Ithaca, New york.

Zaag, P. van der, 1992. *Chicanery at the canal: changing practice in irrigation management in Western Mexico*. CEDLA, Amsterdam, PhD Dissertation, Wageningen Agricultural University, Wageningen.

Zaag, P. van der, 1992. Users, Operators and Hydraulic Structures: A Case of Irrigation Management in Western Mexico. ODI/IMN Paper No.19, October.

Appendix 1

Arrangements for irrigation in the *tarai* Region

I) Revenue regulations promulgated for the district of the *tarai* region on *Baisakh* 13, 1992 (April 25, 1935) made the *Mal Adda* (Revenue Office) of each district responsible for the construction and maintenance of irrigation facilities. The chief of that office was required to prepare a detailed plan for the development of such facilities in the district in consultation with the local *jimidars* and other landowners.

The regulations added:

"In case irrigation channels are damaged, or fields are damaged by floods or washouts, the local cultivators or tenants shall undertake necessary repairs themselves or through collective efforts... In case a new irrigation channel must be constructed in any *mauja*, or a damaged one must be repaired, a levy shall be collected from each *jimidar*, *birta* owner, or other landowner whose lands will be irrigated through such channel, and labour too shall be impressed for that purpose. In case any landowner is unwilling to provide such labour, their obligation shall be commuted to a cash payment at certain wage-rates.

"In case local *jimidars* and landowners are unable to construct irrigation channels through collective efforts as mentioned above, an amount sufficient to meet the estimated cost of the construction or repair project shall be raised through a levy *jirayat*, *birta*, and other lands, and placed under the custody of the local *jimidar* or other responsible person. The project shall then be executed through wage labour under the supervision of the *jimidar*, as well as the *qumasta* and the *jethraiti* of that *mauja*. The surplus amount if any, shall be kept in reserve with the *jimidar* to finance necessary repairs from time to time.

"No new irrigation dam shall be constructed within a radius of 100 chain-lengths from an existing dam on a perennial stream, or in such a way that the supply of water through the existing dam is affected. A dam may be constructed on the upper reaches of a stream if the existing dam, built on the lower reaches, cannot supply sufficient water.

"If the chief of the Revenue Office finds that the *jimidar* and landowners of any *mauja* are not capable of collecting funds in advance and mobilizing labour in the manner mentioned above, and that both the government and the people will suffer if no dam is constructed there, he shall report the matter to the District (*Goswara*) Office. Arrangements may then be made to supply interest free loans for the construction of the dam under the liability of local *jimidars*. Such loans are recovered after the crops are harvested.

"Plans for the construction and repair of the dams and irrigation channels must be finalized before the last day of month of *Magh* (February 11) and implemented before the last day of the month of *Jestha* (June 14) each year.

"Local *jimidars* shall be ordered to repair immediately any damage to dams and irrigation channels resulting from floods and submit reports accordingly... As soon as the month of *Aswin* (September 17) commences, officials of the District Office and the Revenue Office shall be deputed to each *mauja* to arrange for the repair of damaged dams and irrigation channels.

"The Revenue Office shall exercise supervision to ensure that *jimidars* use available irrigation facilities properly. Priority in such case shall be given to those landowners who have contributed money and labour for construction of such facilities. Those land owners who have made no such contributions shall be allowed to use the irrigation facilities thereafter on payment of a proportionate share of the cost, and additional fee of one rupee for each *bigha*.

"Since dams will be more durable if reinforced with beams, permits may be obtained from the local *Kathmahal* office for the necessary quantities of non-commercial timber, which shall be cut and transported through the labour of the local people.

"In case the Revenue Office needs additional staff to discharge the function mentioned above, it shall procure such staff from the local District Office,

"Crops cannot be cultivated without water, and dams and irrigation channels cannot be constructed in all *maujas*. At some places, water cannot be brought from streams and rivers, so that it is necessary to use run-off water for irrigation. Accordingly, in districts where there are no canals and permanent dams, it is necessary to construct dams and irrigation channels during the appropriate season for utilizing such run-off water. Otherwise irrigation facilities will not be available when needed. South of Chure range, the *tarai* region slopes toward the south. North-south irrigation channels must, therefore, be constructed on both sides, east and west, of each *mauja*, from the northernmost point (Siraha) to the southernmost (Bhatha), so that all lands under the jurisdiction of the Revenue Office are irrigated."

II) The following regulation was enforced on *Magh* 2, 1988 (January 15, 1942):

"In case dams and irrigation channels cannot be constructed through the efforts and contributions of *jimidars* and landowners alone, so that the governmental assistance is essential, the local *Bada Hakim* is empowered to provide interest-free loans subject to the limits mentioned below. Such loans shall be recovered after the new crop is harvested. The District Office shall be held liable for arrears, if any.

District	Amount
1. Jhapa	Rs 5,000
2. Biratnagar	Rs 7,500
....	
....	
22. Surkhet	Rs 500

"The Chief of the Revenue Office shall check personally or through a trusted employee, whether or not dams and irrigation channels are in proper condition, and whether or not dams and irrigation channels have been made available to landowners according to the regulations. In case any damage is detected, he shall make immediate arrangements for repairs. In case any landowner submits a complaint, the Chief of the Revenue Office shall make water available to him according to the regulations. In case he neglects his duties, and the landowners submits a complaint accordingly, he shall be held to have failed to make necessary arrangements regarding irrigation facilities, and be punished accordingly."

Source: Government of Nepal, Madhesh Malko Sawal (Revenue regulation for the *tarai* region), Kathmandu: Gorkhapatra Press, n.d., secs. 94-105, and 107, pp.42-48. Reproduced in Regmi Research Series (RSS), Year 14, 1982, pp.181-184.

Appendix 2

Administrative arrangements for the *tarai* Region (1849 A.D.)

The following regulations were promulgated in the name of General Krishna Bahadur Kunwar Rana, who was appointed as the chief administrator of several districts in the tarai:

1) Do not create any disturbances on the borders from your side, nor shall any government official or *ryot* be allowed to do so. Anyone who creates such disturbances shall be arrested and a statement shall be recorded from him confessing his guilt. The case shall then be reported to us, and action shall be taken as ordered.

....

....

7) Construct dams and irrigation channels in different districts through wage labour and arrange for the reclamation of uncultivated lands after stipulating tax-exemption for a specified period in the beginning. Exempt the newly-settled villages from the obligation to supply food and fodder to state owned elephants on a compulsory basis. Send particulars of newly-settled *maujas* on virgin (*kalabanjar*) lands. Arrange for the supply of irrigation facilities according to customary shares to *Mal*, *jagir*, *birta*, *guthi*, *sadavarta*, *bekh*, *marwat*, and other lands in the different *parganas*. Let no complaint come from anyone in this regard.

Source: Adapted from Regmi Research Series (1979), pp.181-186.

Appendix 3

Table 1 Irrigation development by the government in each plan period

	Plan period	Target area (ha)	Achievement (ha)		Remarks
			Total	Per year	
1	Before First Plan	-	6,228	-	Chandra Canal
2	First Plan (1957-62)	20,785	5,200	1,040	Five years
3	Second Plan (1962-65)	32,544	1,035	345	Three Years
4	Third Plan (1965-70)	50,654	52,860	10,572	Five years
5	Fourth Plan (1970-75)	253,711	37,733	7,547	Five Years
6	Fifth Plan (1975-80)	230,220	95,425	19,085	Five Years
7	Sixth Plan (1980-85)	233,482	172,918	34,583	Five Years
8	Seventh Plan(1985-90)	235,000	179,337	35,867	Five Years
9	Fiscal Year (1990-91)	41,158	20,810	20,810	No Plan
10	Fiscal Year (1991-92)	38,000	27,527	27,527	No Plan
11	Eighth Plan (1992-97)	293,895	-	-	Five Years
	Total	1,429,413	599,073	-	

Sources: CIWEC, Master Plan for Irrigation Development (1990); National Planning Commission (1992); and DOI documents (1992-93).

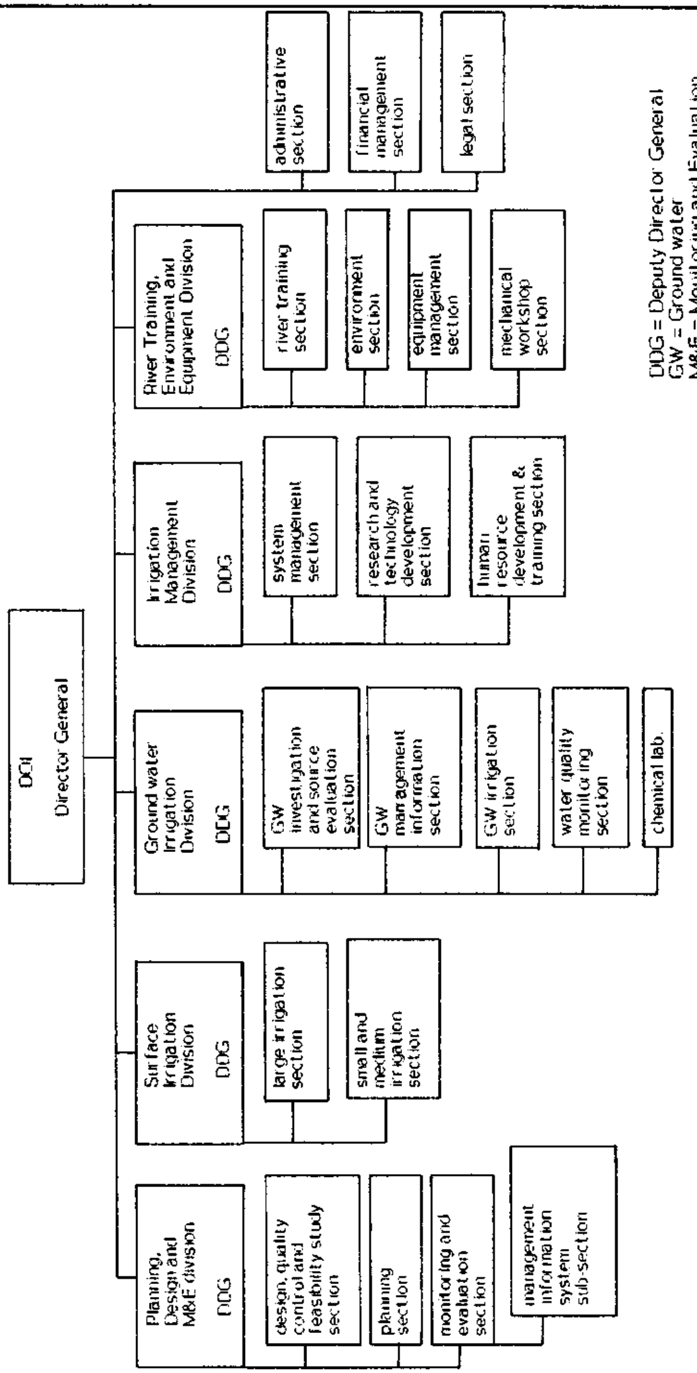
Table 2 Government-built large canal irrigation systems in the *tarai* until 1992. (CCA > 5,000 hectares)

	Canal system	Construction period	External financing	CCA (ha)	Monsoon irrigation (ha)
1	Kankai (I and II)	1972-90	ADB	7,000	6,000
2	Sunsari-Morang (I and II)	1965- ongoing	IBRD	66,000	30,000
3	Chandra Canal	1920-28	ICM	10,000	6,000
4	West Kosi (including pump irrg.)	1977-90	ICM	21,000	14,000
5	Kamala	1975-85	-	25,000	10,000
6	Manusmara	1976-87	ICM, ADB	5,800	5,000
7	Bagmati	1980- ongoing	SAUDI	36,000	-
8	Narayani (I, II, and III)	1967- ongoing	IBRD	34,400	22,600
9	Chitawan (Lift Irrigation)	1973-88	ADB	10,400	4,600
10	West Gandak	1969-87	ICM, ADB	13,400	10,000
11	Marchawar	1985- ongoing	UNCDF	5,600	2,800
12	Banganga	1970-87	ADB	6,000	5,000
13	Babai	1982- ongoing	-	13,500	-
14	Mahakali (I)	1971-88	IDA	5,000	4,000
	Total area covered	-		208,600	120,00
	" " (%)			(100)	(57.53)

Sources: CIWEC, Master Plan for Irrigation Development (1990); and DOI documents (1992-93).

Appendix 4

Organization of
Department of Irrigation (DOI), Central Office (1993)



Source: Department of Irrigation (1993).

Appendix 5

Irrigation Development Plan (1992-97)

Objectives

The basic objectives will be to:

1. increase agricultural production through the application of irrigation technologies appropriate to diverse climatic and soil conditions and with minimum detrimental effects to the environment.

2. enhance the credibility of irrigation systems through improvements in the management of existing irrigation systems.

3. provide irrigation facilities for maximum area of land by implementing economically, technically and environmentally sustainable projects with the participation of farmers.

Policies

1. During the Eighth Plan period, the government agencies will be more actively involved in the implementation of multipurpose, large and medium-scale projects.

2. Small irrigation projects will be implemented with the participation of users' groups and the construction cost of such projects will be jointly shared by the government and the users' groups, in keeping with provisions made in the Irrigation Policy 1992. The semi-government, non-government and private sectors will be encouraged to implement projects with people's participation.

3. Arrangements will be made to jointly manage and where appropriate turn over the government constructed irrigation projects to users' groups. The repair and maintenance and implementation of smaller projects will be gradually transferred to users' groups.

4. Users' groups will be involved in every stage, from appraisal to implementation of irrigation projects. As for large projects, users' groups will be involved, where necessary.

5. Users' groups will be involved in the collection of water charges in projects jointly managed by the government and users' groups. Water charges in government run projects will be imposed only if services are available.

6. The dependency of lift irrigation projects on imported fuel will be reduced; substantial expansion will be made to sprinkler method of irrigation in hilly areas while other appropriate technologies will also be disseminated.

7. Completed project feasibility study reports will be forwarded to District Irrigation Offices for execution. A list of reports will be provided to District Development Committees and users' groups.

8. Projects under construction over long periods, involving high per hectare cost, will be reappraised. Additional investment in such projects will be made on the basis of reappraisal.

Targets and Programmes

Irrigation facilities will be provided to an additional 293,895 hectares of land by completing ongoing projects and implementing new projects. It is estimated that a total of 892,699 hectares of land will have access to irrigation by the terminal year of Eighth Plan.

Large scale projects will provide irrigation to 108,482 hectares of land, while small and medium scale schemes under ISP/ILC will irrigate 52,650 hectares of land. Small scale irrigations projects executed by the Agricultural Development Bank will provide irrigation facilities to 119,700 hectares. Irrigation facilities will be provided to 13,063 hectares through the non-government and private sectors with the implementation of small scale projects.

During the Plan period, feasibility studies for the Bheri/Babai and other large scale projects will be completed and these will be advanced to the implementation stage. People's participation will be encouraged in river control programmes to control the loss of agricultural land. Irrigation management training programmes will be launches for the sustainable and reliable management of irrigation projects.

Implementation

During the Eighth Plan period, the government, semi-government and private sectors will be involved in the implementation of the irrigation programmes. Of the total 293,895 hectares targeted to receive irrigation facilities, the Department of Irrigation, the Agricultural Development Bank and the non government and private sectors will contribute 54.83, 40.73 and 4.44 percent respectively.

Management expenses will be provided to the semi-government, NGO and private sectors to cover execution overhead cost as fixed.

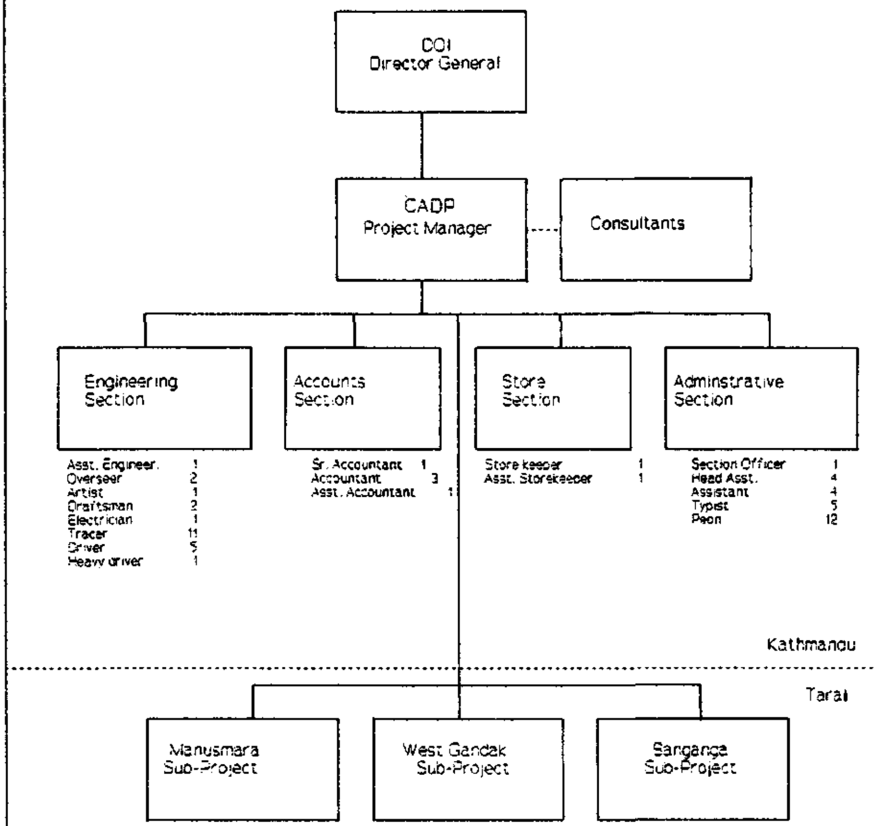
Financial provisions

Rs. 11,996 million has been allocated for the development and expansion of irrigation facilities during the Plan period.

Source: National Planning Commission (1992), Summary of the Eighth Plan (1992-97).

Appendix 6

Command Area Development Project
Organization and Staffing



Appendix 7

Functions of different levels of water users' organization in a joint-managed irrigation system (adopted from Rajbhandari 1993: 43-46)

A) The functions of the general assembly are:

- to prepare and enact rules and regulations required for the construction, operation, and maintenance of the irrigation system,
- to elect the executive officers of the main committee of the water users' organization (WUO),
- to approve the audit report of the WUO,
- to discuss and approve the annual programmes, budgets and expenditures prepared by the main committee,
- to monitor the performance of the main committee, and
- to ratify the WUO constitution and to amend it if necessary.

B) The functions of the main committee are:

- to establish linkage between individual farmers and government agencies and discuss field problems with them,
- to prepare the programmes and budgets for the operation and maintenance (O and M) of the irrigation system,
- to make arrangements for the repair and maintenance of the main canal,
- to mobilize local resources,
- to distribute and control water on equitable basis,
- to collect membership fees, contributions, penalties and other fees,
- to resolve the disputes that appear during the maintenance of the system and distribution of water, and
- to coordinate branch committees and sometimes *tolis* and *upa-tolis* also.

C) The functions of the branch committee are:

- to co-ordinate *tolis* and sometimes *upa-tolis* also,
- to mobilize local resources,
- to make arrangements for the repair and maintenance of the branch canals,
- to distribute and control water equitably,
- to prepare annual programmes and budget for the O and M of branch canals, and
- to resolve disputes.

D) The functions of the *toli* are:

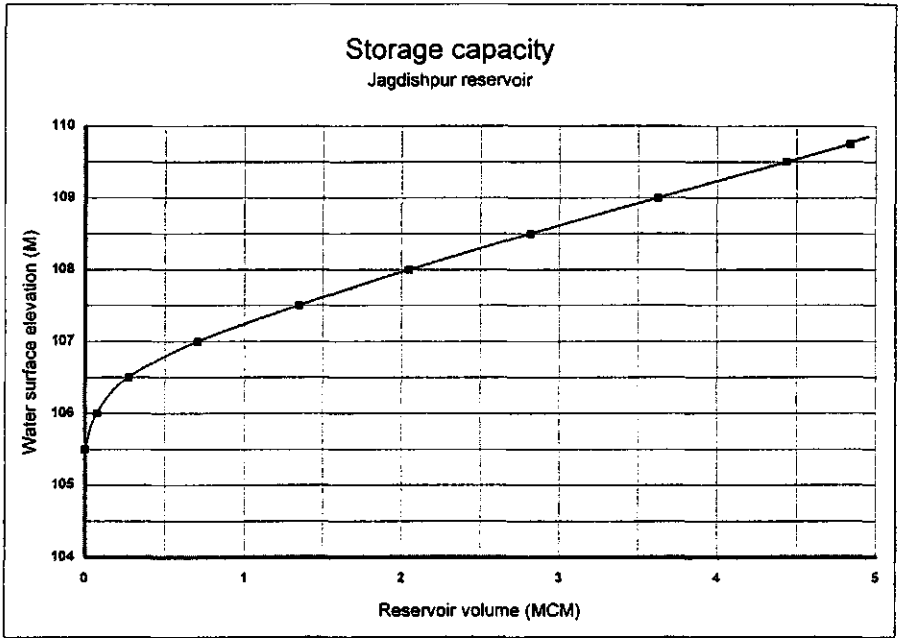
- to coordinate *upa-tolis*,
- to prepare programmes and budgets for the O and M of tertiary and minor canals,
- to repair and maintain the tertiary canals by mobilizing local resources,
- to distribute and control water equitably, and
- to resolve disputes.

E) The functions of the *upa-toli* are:

- to prepare programmes and budget,
- to repair and maintain field channels,
- to mobilize local resources,
- to prepare irrigation scheduling and to distribute and control water on an equitable basis,
- to resolve disputes,
- to assist the main committee in collecting fees, contributions and penalties, and
- to assist the main committee, branch committees and *tolis* by mobilizing local resources for cleaning the canals.

Appendix 8

Storage capacity of the *Jagadishpur* reservoir with respect to the water level (Source: NIACONSULT and IECO 1984.)



Water surface elevation (m)	Surface area (ha)	Incremental volume (MCM)	Reservoir volume (MCM)
105.50	0.00	0.000	0.000
106.00	30.00	0.075	0.075
106.50	48.00	0.195	0.270
107.00	125.00	0.433	0.703
107.50	132.00	0.643	1.346
108.00	146.00	0.700	2.046
108.50	160.00	0.770	2.816
109.00	162.00	0.805	3.621
109.50	162.50	0.801	4.432
109.75	163.00	0.408	4.840

Appendix 9

Varieties of paddy, oilseeds, wheat and maize cultivated in Pithuwa (1992-93)

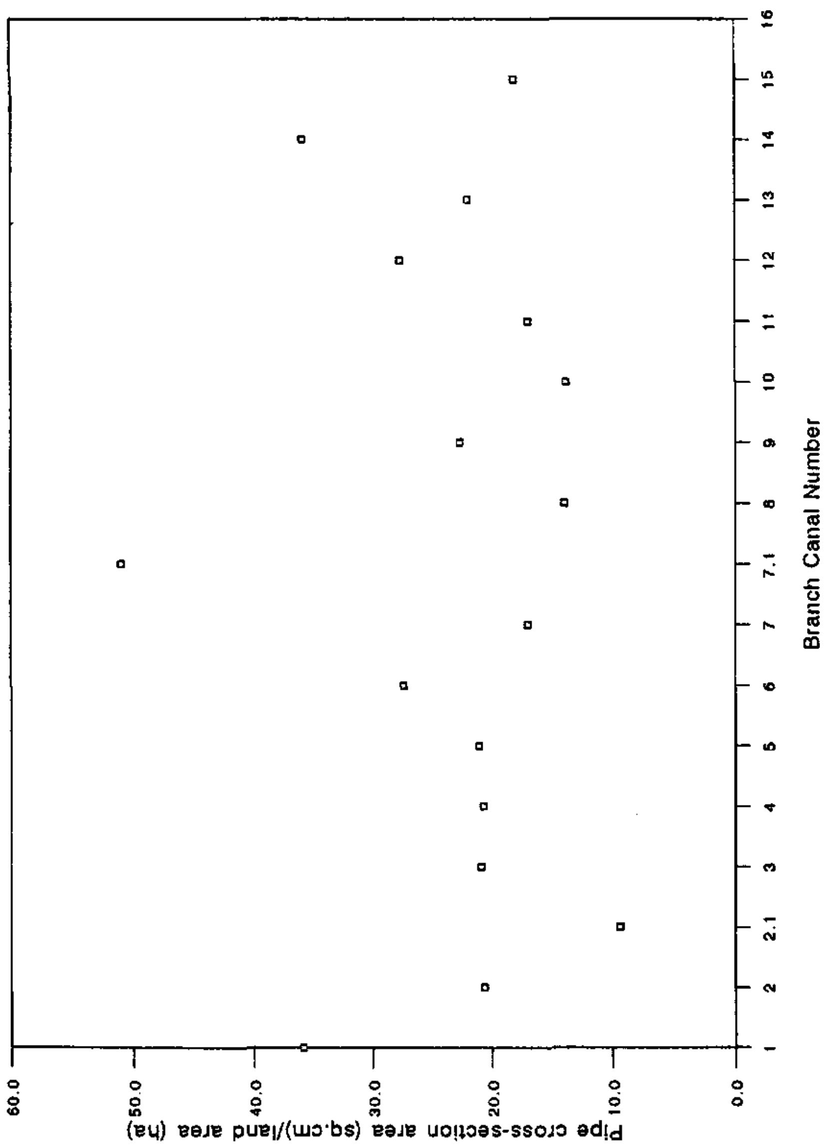
Crop	Name of the variety	Variety
Paddy	Anadi	Local
	Bam Morcha[@]	Improved
	Bindeswari	Improved
	BG-90	Improved
	Haridwar	Improved
	IR-20	Improved
	IR-22	Improved
	BG-1271	Improved
	IR-84	Improved
	IR-85	Improved
	Jogini	Local
	Juwa	Improved
	Mansuli	Improved
	Pakha (Japani) Mansuli	Improved
	Pithuwa-85	Improved
	Radha-6	Improved
	Radha-9	Improved
	Sabitri	Improved
	1008	Improved
Oilseeds	Gol Tori	Local
Wheat	Local	
	RR-21 (red wheat)	Improved
	UP-262 (white wheat)	Improved
Maize	Local	
	Arun-2	Early maturing
	Khumal-yellow	Improved
	Rampur-yellow	Improved

[@] This is the local name given by farmers to an improved variety. Likewise, some improved varieties also have local names.

Source: Field observation (1992-93).

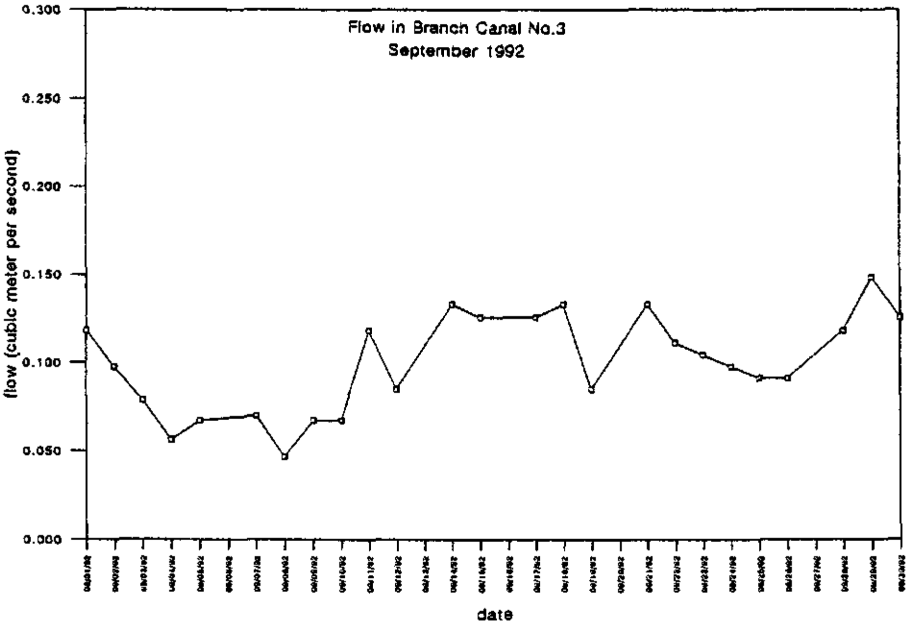
Appendix 10

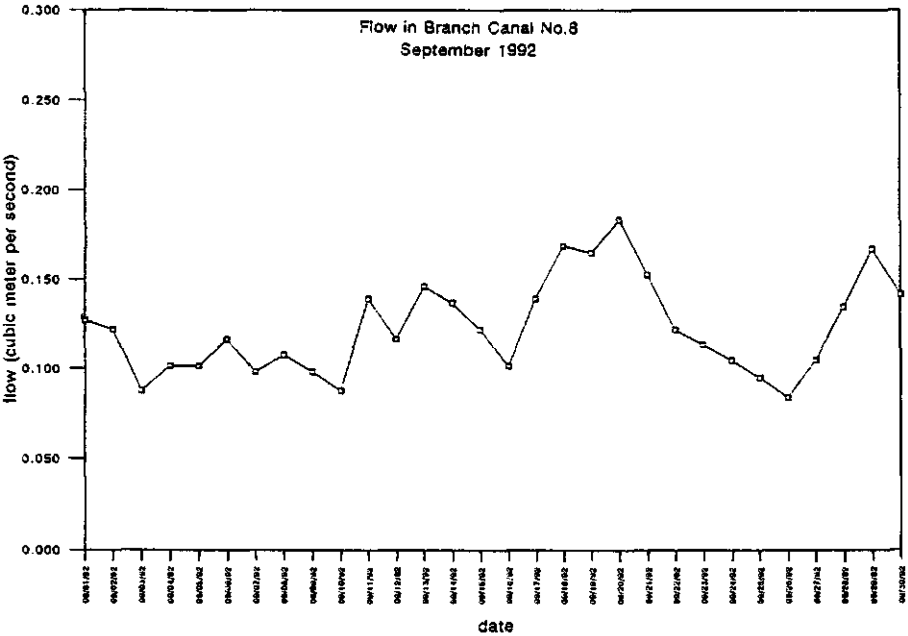
Cross-section area of pipe outlets per unit area of land for each branch canal in Pithuwa (1992-93)

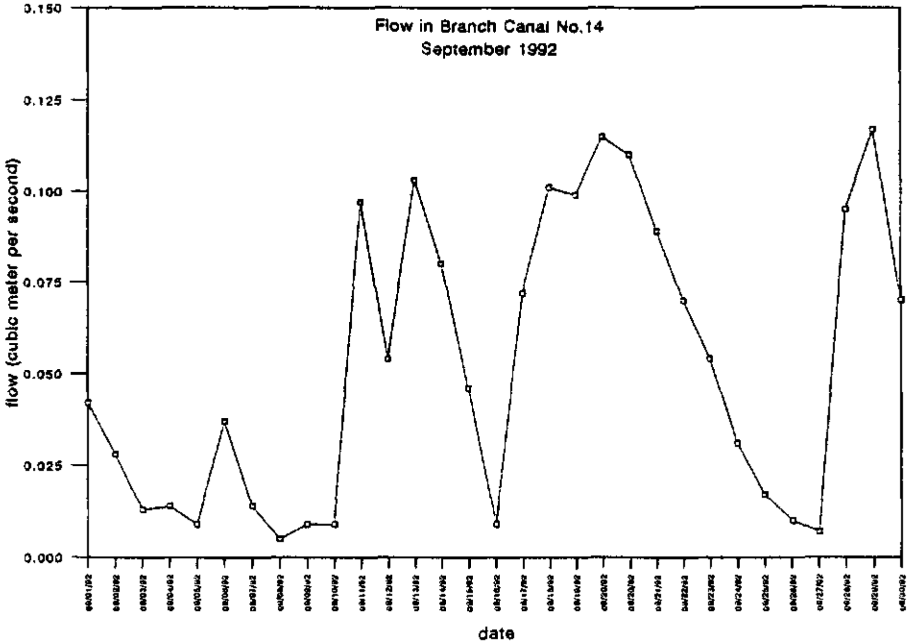


Appendix 11

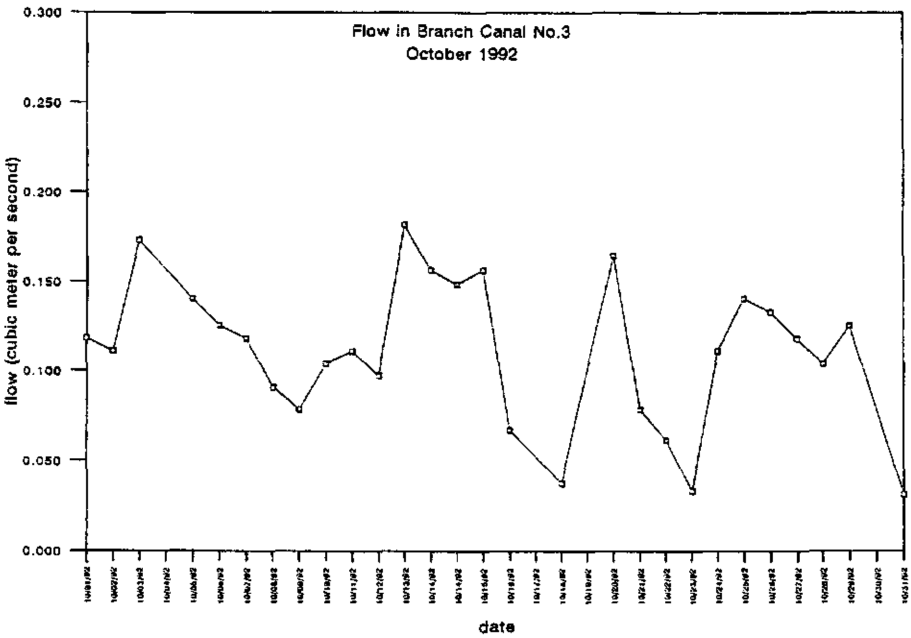
Variation of flow in Branch Canals Nos. 3, 8 and 14 in Pithuwa
(September-October 1992)



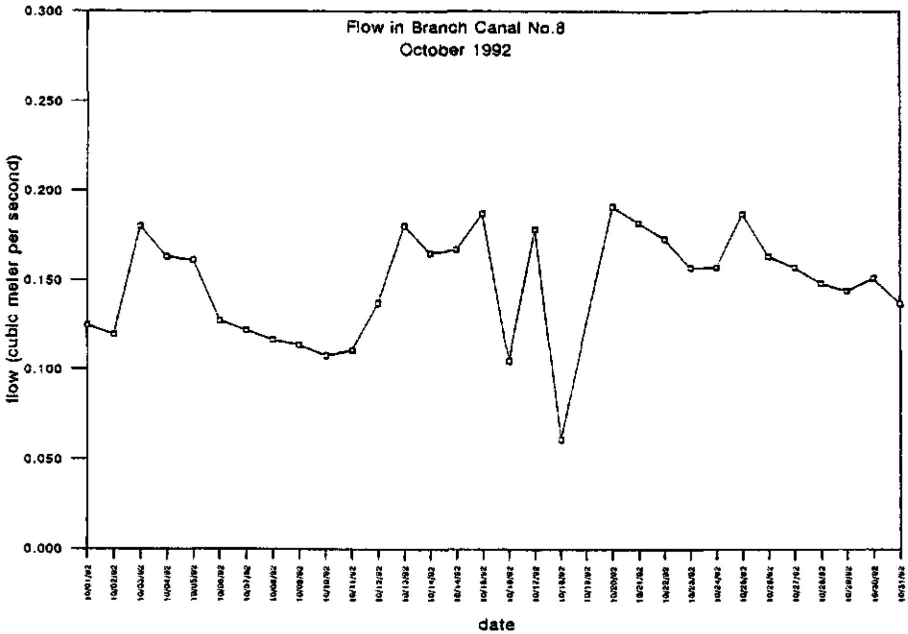


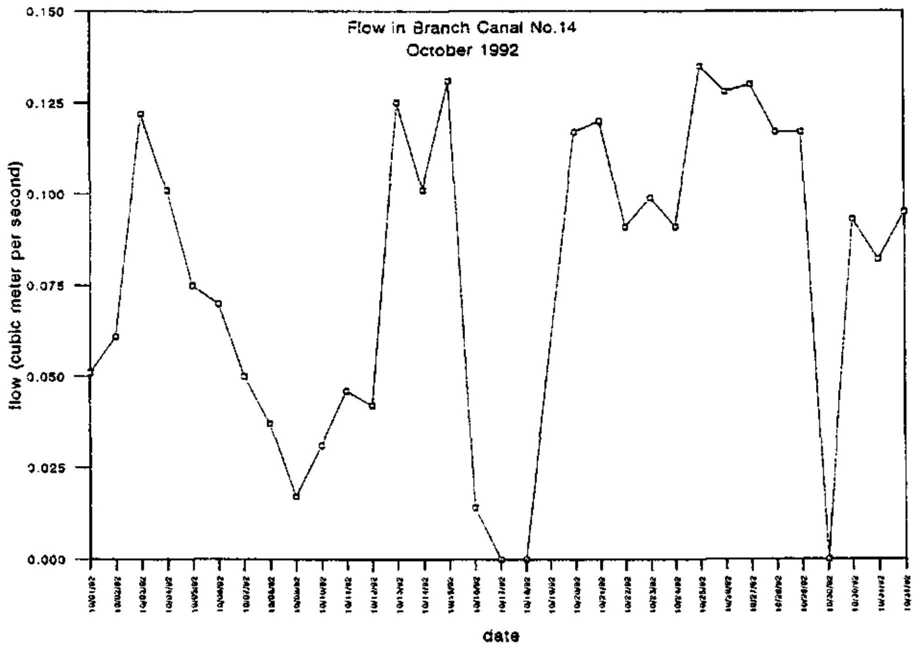


Flow in Branch Canal No.14
September 1992
flow (cubic meter per second)
date



Flow in Branch Canal No.3
October 1992
flow (cubic meter per second)
date


Flow in Branch Canal No.8
October 1992
flow (cubic meter per second)
0.300
0.250
0.200
0.150
0.100
0.050
0.000
date


Flow in Branch Canal No.14
October 1992
flow (cubic meter per second)
0.150
0.125
0.100
0.075
0.050
0.025
0.000
date

Appendix 12

Nepali months and corresponding Gregorian months

Nepali Months	Gregorian Months
Baisakh	April-May
Jestha	May-June
Asar	June-July
Srawan	July-August
Bhadra	August-September
Aswin	September-October
Kartik	October-November
Mansir	November-December
Push	December-January
Magh	January-February
Falgun	February-March
Chaitra	March- April

Biographical sketch

Trilokya Man Singha Pradhan was born in Kathmandu in Nepal on February 22, 1954. In October 1974, he received a Bachelor's degree in civil engineering from the Bhopal University in Madhya Pradesh, India. Back in Nepal, he joined the National Construction Company Nepal (Ltd) as a civil engineer in November 1974. He worked with the company until 1981, supervising construction works of different kinds.

In 1982, he joined the Ministry of Local Development. In August 1985, after working for three years with the ministry, he entered a Master's degree programme at Wageningen Agricultural University (WAU) in irrigation water management. After the completion of the Master's programme in June 1987, he returned to his home country and resumed his work in the Ministry of Local Development. From 1988 to 1990, he was with the Department of Irrigation in Nepal, working in the Irrigation Management Project.

In March 1991, he began his PhD study at Wageningen. In August 1991, he returned to Nepal again for field research, which was carried out until June 1993. He returned to Wageningen in July 1993 to complete his PhD study.