Report No. R-64

PHYSICAL CHARACTERISTICS AND OPERATIONAL PERFORMANCE OF MIRPURKHAS SUB-DIVISION, JAMRAO CANAL DIVISION, NARA CIRCLE, SINDH PROVINCE, PAKISTAN

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SEPTEMBER 1998
HYDERABAD OFFICE
PAKISTAN NATIONAL PROGRAM
INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
PAKISTAN

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FOREWORD

The International Irrigation Management Institute (IIMI) opened an office at Hyderabad in Sindh Province on 1 September 1995. This was done to undertake a pilot study on Farmer-Managed Irrigated Agriculture under the Left Bank Outfall Drain Stage-I Project. About 16 months earlier, planning had been completed to support this research effort with a program on Decision Support Systems (DSS) under the project, Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan, funded by The Netherlands.

The planning for this DSS program began in early 1996. A few months later, Mr. Abdul Hakeem Khan was transferred from Lahore to Hyderabad. Mirpurkhas Sub-division of Jamrao Canal was selected for the initial effort because:

1. One of our three pilot distributaries was located in this command area;
2. The remodeling of Jamrao Canal had been completed in June 1994; and
3. A telecommunications system was to be installed for Nara Canal, which includes Jamrao Canal.

Several meetings were held with staff of the Department of Irrigation and Power, Province of Sindh. Also, a one-day seminar on DSS was conducted in Hyderabad. The Inception Report was completed during the summer of 1996.

A field team of five people were recruited in August 1996 and trained in Malik Sub-division near Bahawalnagar in Southeastern Punjab during August-September 1996. The Mirpurkhas Field Station (DSS) was opened in September 1996. Then, the field research program was underway.

A previous report on field calibration of the distributary head regulators, plus this report describing the physical system and providing an evaluation of the operational performance of Mirpurkhas Sub-division, represents some of the essential requirements for DSS. This evaluation provides much insight into the present operational situation. Clearly, there is a strong need to improve the hydraulic performance in this sub-division in order to provide more reliable water supplies to farmers. In fact, this is the first requirement for improving agricultural productivity. Unless canal operations can be improved, agriculture will remain stagnant.

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ACKNOWLEDGEMENTS

This report presents the work done by the "Decision Support Systems" team of IIMI Pakistan during the period November 1996 to October 1997. This study includes some basic data regarding the study area from the Irrigation Department, Sindh, field observations by IIMI staff, and the analysis of the observed data.

We would like to thank Mr. Khadim Ali Memon, Superintending Engineer (S.E), Nara Canal, Mr. Ahmad Junaid Memon, Executive Engineer Jamrao Canal, Mr. Iqbal Ali Shah, former S.E. Nara Canal and Mr. Ghulam Mustafa Ujjan, Assistant Executive Engineer Mirpurkhas Sub-division for their kind support in furnishing the required information and visiting our activities from time to time. We also appreciate them for their valuable suggestions during the study.

Thanks are also due to Mr. Saqlain Shah and Mr. Sohrab Shah of the Irrigation Department for their kind help in providing the various data and maps regarding the system from time to time. In fact, these two gentlemen have a very long association (more than thirty years) with the Jamrao Canal and are more informed than anybody else.

At last, we feel very grateful to Dr. Yameen Memon, Dr. Shafqat Ejaz, Mr. Ahsan Ali Qazi and Mr. Ayaz Anwar Solangi for all of their support that was needed in the office or outside the office.

Chapter 1

INTRODUCTION

1.1 BACKGROUND

The development of modern technology to store, divert and regulate surface water resources for bringing more culturable area under irrigation, and for meeting the growing food demands, has resulted in the construction of a huge network of irrigation canals. These canals are considered to be a reliable and dependable source of water for agricultural purposes. Similarly, the exploitation of underground water reservoirs by employing electric and diesel operated machinery was found to be another alternative to artificially irrigate lands. The criteria for water distribution through the irrigation canals varies from place to place depending upon the amount of water available, nature of crops grown, cropping intensity, nature of soil and climate. However, in most of the cases, the distribution of water to the end users has not been equal or according to crop water requirements for various reasons. The cropping intensities, yields and other economic benefits for which the systems have been designed are not being achieved either.

The development of new irrigation areas is declining as water resources are becoming scarce due to the ever growing competition amongst agricultural, industrial and domestic demands, and the excessively expensive investment costs. To meet the ever growing development and food targets, investments in better operation and maintenance of existing irrigation systems becomes imperative. Present performance levels of most of the existing irrigation systems have not been satisfactory. A variety of reasons has been presented to explain these shortfalls, but most of these evaluations lack a reliable information base to quantify irrigation system performance consistently.

In many irrigation departments, low priority is given to system operation and maintenance as compared to design and construction activities. The irrigation agency is responsible for the timely, adequate and equitable delivery of water for irrigation and the maintenance of irrigation and drainage facilities. Several limitations often restrict the proper functioning of the irrigation system. These include lack of interest of the concerned staff, inadequate resource allocation for operation and maintenance, inadequate planning and policies in addressing effectively the structural problems, and lack of an appropriate performance monitoring and evaluation system. Similarly, the absence or lack of clear objectives for the operation and management of many irrigation systems has affected their performance. A lot of data on operation and regulation are collected daily, but are rarely analyzed, which could depict the actual performance level of a canal for a certain time period.

The available technologies to improve canal water control, such as modern regulation structures and electronic communication equipment, have the potential to better match supply and demand and thus reduce operational losses. However, the gradual deterioration (both physically as well as managerially) of the existing irrigation system is contributing to the stagnant and/or declining productivity levels of the agriculture sector. Unreliable and inequitable water distribution, especially at the secondary and tertiary levels, is either causing an abundance of water in the upper reaches or shortages in the tail reach during peak demand periods, or flooding of the tail area when water is not needed.

The role of a communication system for quick and timely information transfer from the field to the manager's office cannot be over-emphasized. The irrigation manager's decisions related to operation of the system are based on information received directly from the control points. A poor feedback information system from control points to the regulating authority for operation and maintenance of a system is also an important factor in the declining performance of the irrigation system. Successful performance is highly dependent upon effective communication between all individuals that play a role in the operation of the irrigation system (Skogerboe and Merkley, 1996).

The absence of discharge ratings for flow control structures also contributes to rotational closures of distributary and minor channels even during the high flow periods, because the manager does not know precisely the supplies coming from upstream or withdrawn by the upstream distribution system.

Lack of a proper monitoring and evaluation process is another important factor contributing to the dismal performance of our irrigation canals. Although water level data are collected daily at all the important control points, but its reliability at some points is highly questionable. Poor maintenance of the staff gauges at control points gives erroneous readings. In some cases, these gauges are not installed at proper places. There are examples where the gauge does not exist in the field, however, office records of water levels or discharges are still recorded and maintained for that point.

An associated problem with the field data collection is the poor maintenance of its records. Most of the time, there is no record available in the field, where it is collected. Similarly, the quick transfer of field information into the manager's office and vice versa, through telephone/telegraph is also faced with serious difficulties. Manual transfer is time consuming and has serious consequences in an emergency.

The collected monitoring data needs to be analyzed for evaluating the performance of an irrigation system. This analysis helps the manager in the smooth functioning of the system under his control. However, this is not done in most of the cases. Because of a lack of evaluation, each off-take is being treated individually, which leads to unequal water distribution in an irrigation system.

The timely communication of the evaluation of monitored data to the concerned operating personnel in the system is also necessary for better functioning of the system and planning future schedules. Here, a question arises; when there is no proper evaluation, what could be communicated to others?

The results of the performance evaluation would help the Irrigation Department authorities to improve the operation of the system in areas where necessary. The results could also help in achieving equitable water distribution at the main system level, which may reduce the frequency of rotational closures during high flow periods. Similarly, the results of the study related to the role of the communication system could also improve the operations of the system.

1.2 BRIEF HISTORY OF IRRIGATION IN SINDH PROVINCE

The Indus River is the main source of water either for drinking or for irrigation for Sindh. Unlike other provinces of the country, especially Punjab and NWFP, Sindh is a parched land getting less than an average of 5 inches of rain per year. Similarly, the groundwater for most of the Sindh is of very poor quality, which can neither be used for irrigation nor for drinking/domestic purposes. Irrigation from natural lakes and hill torrents is negligible and dependent upon rainfall.

Previous to British rule, irrigation in the Indus Basin was dependent upon inundation canals like Nara, Phulleli and Pinyari. Only, the Kalhora Dynasty (1701-1783 AD) can be termed as a canal building period in the history of Sindh. The Kalhoras built the 10 mile long Nurwah, the then inundation canal Begari, two mile long Shah-Ji-Kur, and 20 mile long Date-Ji-Kur which are now absorbed in Warah Canal. They also built Nasrat Wah, Murad Wah and Feroza Branches in central Sindh, which have been absorbed by the present Rohri Canal. Though large tracts of desert were converted into fertile lands, the canals constructed by Kalhoras followed the old courses of the natural rivers and were not quite graded or regulated. They did not have a sound knowledge of hydraulics and engineering, but the irrigation systems were managed more efficiently.

Kalhoras were succeeded by Talpurs. They continued constructing new canals (e.g. Mir Wah in Khairpur), however, lack of interest in agriculture led to the deterioration of existing canals till the British occupied the Sindh in 1843.

The British had visualized the tremendous potential of the Indus River for irrigation. After the success of different canal systems for doabs in Punjab and NWFP, the plains of Sindh were opened for extensive canal irrigation in 1932 with the completion of Sukkur Barrage. The Sukkur Barrage irrigation system is still the largest system of Pakistan by commanding about 7.5 million acres of culturable command area from upper to lower Sindh. Seven canals, three on the right side and four on the left side, are being fed by this system with Rohri Canal being the largest by serving about 2.6 million acres of CCA followed by Nara Canal with 2.2 million acres of CCA.

The remaining two barrages (Guddu and Kotri) were completed after independence in 1947. The Kotri Barrage was completed in 1955 to cover an area of about 2.8 million acres in the lower Sindh. Four canals, one on the right side and three on the left side, are off-shooting from this barrage. Most of the efforts were concentrated to bring new areas under irrigation, while some 40 percent of the command area was formerly irrigated by inundation canals (e.g. Pinyari).

Construction of Guddu Barrage was completed in 1962 to irrigate about 2.2 million acres in Sindh. There are three canal systems offtaking from Guddu Barrage. The Pat-Feeder Canal of this system also serves a large area in Baluchistan. The entire command of this barrage is supposed to be non-perennial and most of it was formerly irrigated by the inundation canals; the construction of this barrage has increased the reliability and availability of water.

The layout and salient features of the Sindh irrigation systems have been given in Figure 1.1 and Table 1.1, respectively.

Table 1.1. Characteristics of major canals in Sindh Province.

Name of Barrage	Name of Canal	No. of Disty/ Minors	No. of outlets	CCA (ac)	Total CCA of Barrage (ac)
Guddu	Desert-Pat Feeder*	45	2,057	380,827	
	Begari Sindh Feeder	11	805	958,857	
	Ghotki Feeder	64	1,643	855,231	2,194,915
Sukkur	North West Canal	127	2,657	940,014	
	Rice	120	2,744	519,660	
	Dadu Canal	90	1,877	550,963	
	Khairpur Feeder West	68	1,316	322,000	
	Rohri Canal	283	5,052	260,1213	
	Khairpur Feeder East	55	1,652	369,596	
	Nara Canal	162	3,387	224,0186	7,543,632
Kotri	Kalri Baghar Feeder	110	2742	603741	
	Pinyari Canal	113	3,392	786,353	
	Phulleli Canal	74	4,018	929358	
	Akram Wah	49	1,558	487,347	2,806,799
Total CCA in Sindh Province					12,545,346

* Desert Pat Feeder also serves some area in Baluchistan, so the value of CCA is for Sindh Province only.

1.3 Brief Description of Jamrao Canal

Jamrao Canal offtakes from the Nara Canal at RD 575 on the right bank to carry 3400 cusecs (1932 design capacity, while the current usual discharge is above 4000 cusecs) to serve an area of about 935,000 acres. This system has been faced with the serious problem of sedimentation since its inception, which has caused raising of the banks from time to time. The bed level has raised by about 8 feet due to sedimentation and some lift channels (e.g. Shahu Branch) have been converted into gravity canals.

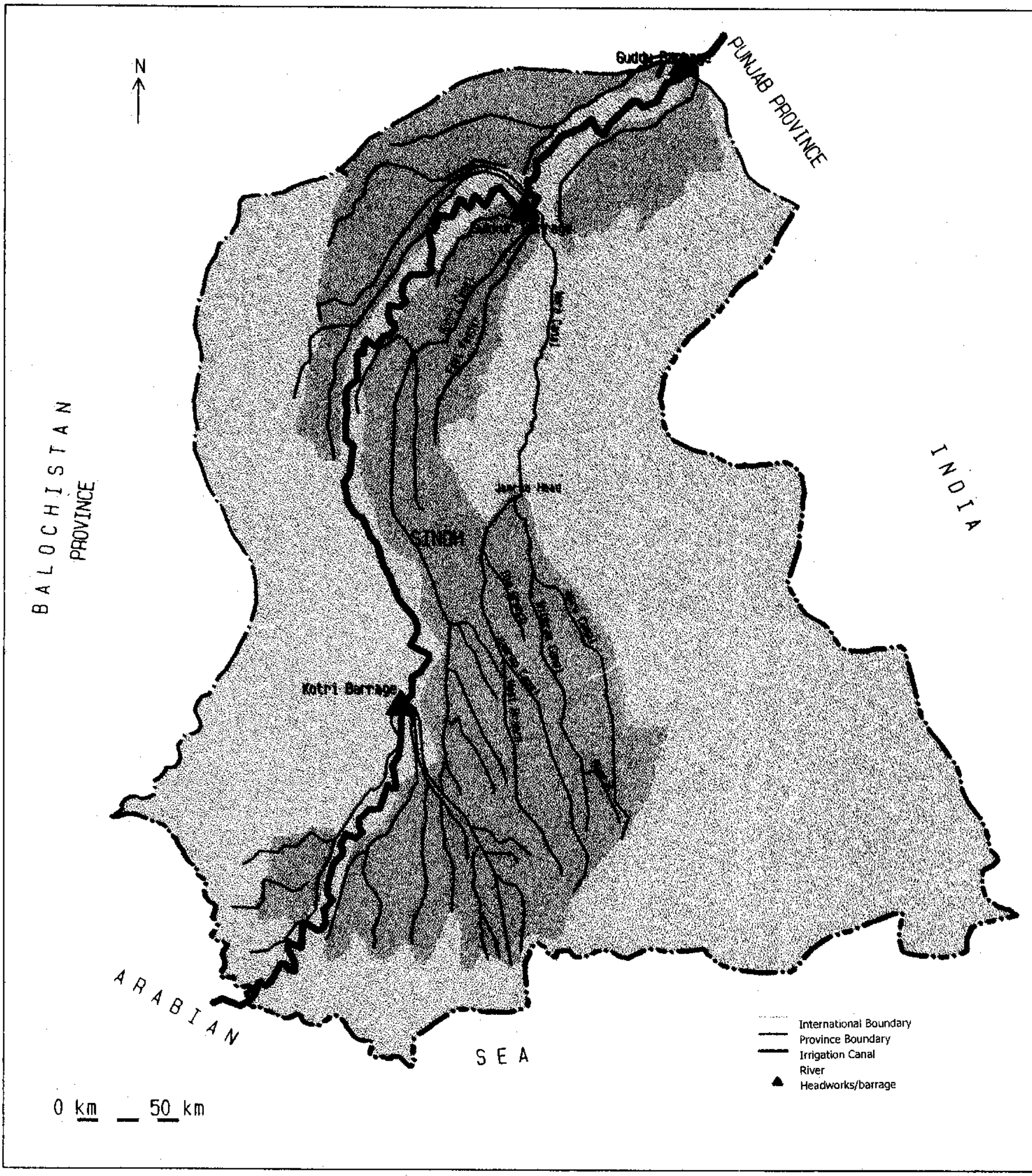

Figure 1.1. Layout of Sindh Irrigation System.

Jamrao Canal is about 124 (canal) miles long, while the network of distributaries and minors is about 426 miles in length. There are three branch canals emanating from the Jamrao Canal. These are Dim Branch, Shahu Branch and West Branch Canals and are offtaking at RDs 87, 163 and 291, respectively. The Dim and Shahu Branch Canals have been remodeled as a part of the Jamrao Canal Remodeling Project completed in 1994, while the West Branch is in the same old condition.

As a part of the Left Bank Outfall Drain Stage 1 Project, the Jamrao Canal has been remodeled in order to accommodate additional flows to be made available after the remodeling of Nara Canal. A parallel channel has been constructed from RD 0 to 240 of Jamrao Canal. Similarly, the cross regulators and head regulators of distributaries and minors located along the main canal from RD 0 to 448 have been newly constructed. Some of the distributaries and minors have also been remodeled by providing new outlet structures and strengthening the banks.

From a management point of view, the Jamrao Canal and its distribution system has been divided into five sub-divisions as shown in Figure 1.2. The culturable command area (CCA) and location of these sub-divisions along the system are given in Table 1.2.

Table 1.2. Major sub-divisions of Jamrao Canal with their location and CCA..

NO.	Name of Sub-division	Location (RD)	CCA (ac)
1	Khadro	0 – 163 of Jamrao Canal	194,874
2	Jhol	163 – 291 of Jamrao Canal	157,523
3	Mirpurkhas	291 – 443 of Jamrao Canal & 0 – 143 of West Branch Canal	236,612
4	Kot Ghulam Muhammd	443 – 620 of Jamrao Canal	131,545
5	Digri	143 – 303 of West Branch Canal	194,669
Total CCA served by Jamrao Canal			915,223

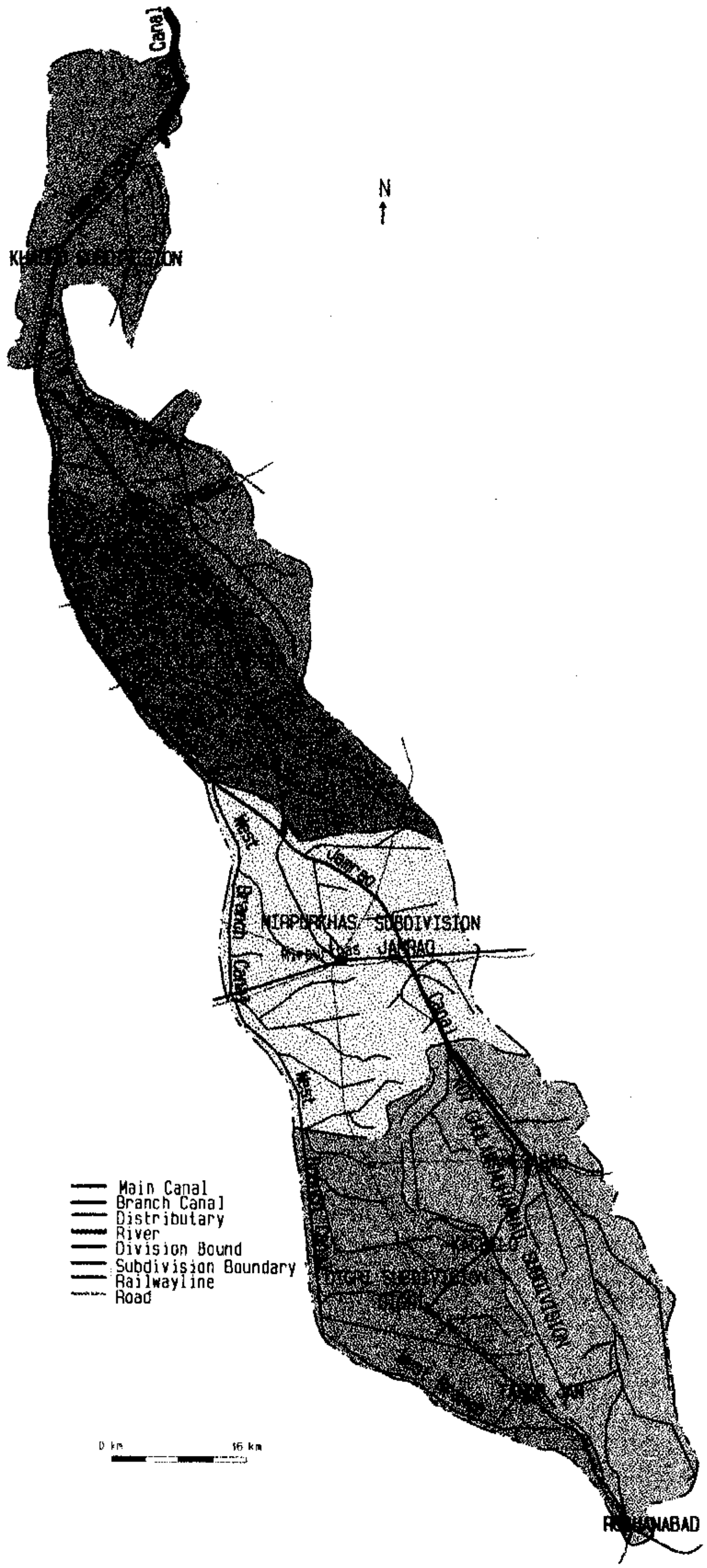

Figure 1.2. Jamrao Canal and its sub-divisions with sub-divisional boundaries.

Chapter 2

DESCRIPTION OF MIRPURKHAS SUB-DIVISION

Mirpurkhas is the third sub-division of Jamrao Canal which is comprised of Jamrao Canal (from RD 291 to 443), West Branch Canal (from RD 0 to 143) and their distribution system in the given reaches.

2.1 JAMRAO CANAL (RD 291 TO 443)

The design discharge of Jamrao Canal below the West Branch Canal Head Regulator at RD 291 is 1250 cusecs. However, sometimes the actual flows are higher than design flows during the peak demand period. The Jamrao Irrigation System has been remodeled, whereby improvements to cross regulator structures, embankments and off-takes have been provided. New staff gauges both upstream and downstream of the cross regulators and head regulators have been mounted. There are three cross regulators in this part of the Mirpurkhas Sub-division, including the upstream turnover regulator. The location of these regulators and the off-taking channels are given below in Table 2.1.

Table 2.1. Cross-regulators on Jamrao Canal in Mirpurkhas Sub-division.

Name of Regulator	Location (RD)	No. of Gates	Gate Width (ft)	Off-taking channels
Mitho Machi Cross Regulator	291	8	10	-
69-mile Cross-reg. (Mira Mori)	343	7	10	Mirpurkhas, Doso Dharoro
78-mile Cross-reg.	408	5	10	Sanro, Bareji

There are two minors which are drawing directly from the main canal. These minors are:

1. Kahu Visro Minor at RD 383 on the right side; and
2. Kahu Minor at RD 385 on the left side.

Every cross regulator or head regulator has been provided with new gauges both upstream and downstream of each flow control structure. Although the gauges are new, most of them have become rusted or obliterated. The Mile 78 Cross-regulator has been provided with a silt ejector below each gate. All of the radial gates for the cross regulators are manually operated with automatic circular scales for gate opening readings. Usually, all of the gates are symmetrically operated by the tyndal (gauge reader/gate keeper). In case that some of the gates have to be closed, then the side gates are closed first.

The old channel below the Mile 78 Cross Regulator has been abandoned and replaced by a new channel constructed between RD 408 and 443 to improve water delivery. Wooden groynes on both sides of the new channel have been built in order to develop strong berms. At some points, trees have been cut and put in the canal to narrow the cross-section to avoid sediment deposition in certain reaches. Direct observations in 1996 have shown that a depth of about 2 to 4 feet of sediment has been carried away by the increased velocities.

During the peak demand period (May to August), the system is operated above the full supply level and most of the offtakes extract more than their design discharge. Since the embankments were raised during remodeling, the system has enough capacity to carry surplus water supplies.

All of the distributaries and minors off-taking from Jamrao Canal have been provided with proper gates at the head regulators, which facilitates proper regulation of the distribution system. During the remodeling of the system, additions have been made to the top of the outlet structures to allow increased flows because of the Nara Canal remodeling. However, no changes have been made in the sizes of these outlets. In all, there are 34 direct outlets (APM) in this part of the Mirpurkhas Sub-division. Because of the tampering that frequently occurs, the design parameters for most of the outlets have been significantly changed.

Before describing the physical condition and characteristics of the distributaries and minors, it would be appropriate to mention about the overall condition (which is common to all) of the outlets emanating from the main canal and the offtaking channels. There are about 470 outlets (direct or indirect) and about 90 percent or so have been tampered by the farmers in order to get extra water . The degree of tampering varies from outlet to outlet. Some have a size more than double of the original, while most of them have got their sill levels lower than the channel bed. The interesting part of this situation is that this exercise is not limited to a certain distributary or minor, or location along the channel, but is universal to the entire system.

2.2 DISTRIBUTARIES AND MINORS OF JAMRAO CANAL SECTION

There are four distributaries, two minors and thirty-four outlets drawing water directly from the Jamrao Canal in this reach (Figure 2.1). Besides, there are four minors which are fed by the distributaries.

2.2.1 Mirpurkhas Distributary

This is the first distributary in the Mirpurkhas Sub-division off-taking from Jamrao Canal at RD 343 upstream of the Mile 69 Cross Regulator. The head regulator consists of three gates, which has been constructed during the remodeling of the main canal. Both the upstream and downstream gauges have been mounted on the head regulator structure, but are difficult to read due to rusting. The embankments and the cross section (in some reaches) of the ten-mile-long distributary have been improved in 1993/94 as a part of the remodeling project. New outlets (having higher sill levels than the old ones) were also constructed, specially in the head reach, to provide for increased flows after the Nara Canal remodeling.

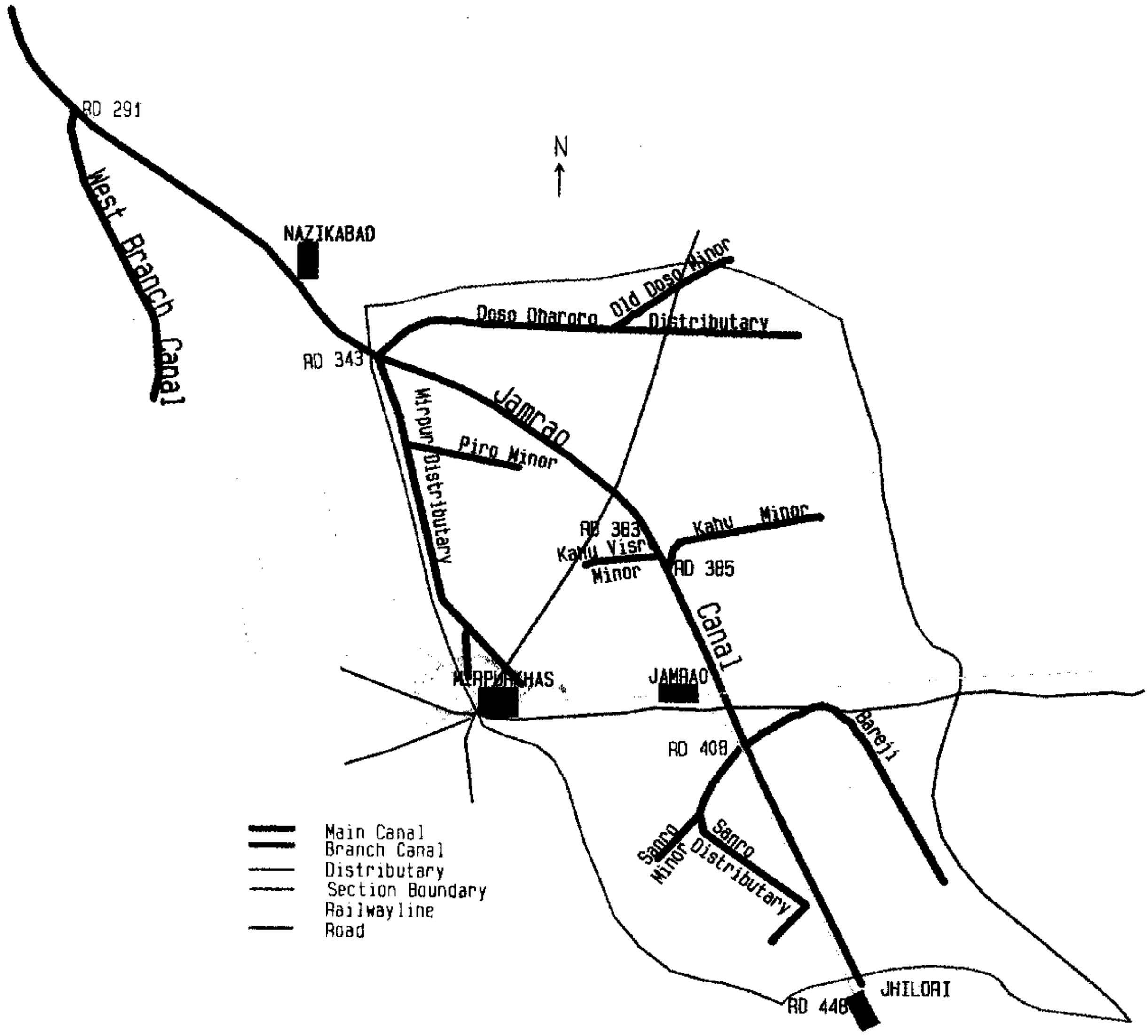

Figure 2.1. Jamrao Canal Section of Mirpurkhas Sub-division with major offtakes.

Table 2.2. Distributaries and minors off-taking from Jamrao Canal.

S.No	Name of Disty/Minor	Parent Channel	Off-take (RD)	Q (cus)	CCA (ac)
1	Mirpur Dy.	Jamrao	343	64	16815
2	Mirpur Mr.	Mirpur Dy.	33	3.5	787
3	Piro Mr.	Mirpur Dy.			
4	Doso Dharoro Dy.	Jamrao	343	66	22743
5	Old Doso Mr.	Doso Dharoro Dy.	30	5	1467
6	Kahu Visro Mr.	Jamrao	383	11.9	3622
7	Kahu Mr.	Jamrao	385	43.5	12018
8	Sanro Dy.	Jamrao	408	53.77	15475
9	Sanro Mr.	Sanro Dy.	10	25	6470
10	Bareji Dy.	Jamrao	408	41.5	14032

These outlets are supposed to replace the old ones; however, their operation seems difficult because the farmers would definitely prefer to have the existing outlets in order to have more water, or they may run both of the outlets simultaneously.

The distributary has almost a straight alignment with two cross regulators at RDs 15 and 33. Both the regulators are in good working condition. They have been provided in order to ensure sufficient water supplies to the two minors Piro and Mirpur. All of the outlets are APM type, except the tail cluster where open flumes have been provided. The tail cluster of four open flumes has recently been constructed, but have been tampered. Similarly, many other outlets have also been tampered or broken.

Mirpurkhas Distributary has sufficient head to draw adequate supplies of water to serve its command area. Normally, the tail is operating. The tail reach frequently experiences sediment deposition, which is periodically removed by the farmers themselves. The total or partial closure of outlets is also practiced whenever needed.

Piro Minor off-takes from Mirpur Distributary on the left side at RD 15 upstream of the first cross regulator. The head regulator structure is broken and water supplies have no hinderance in entering into the minor. There is heavy vegetation all along both sides of this minor, which also has weak embankments. The minor has been poorly maintained and its banks are many times vulnerable to breaches and illegal cuts. All of the outlets are APM except the tail, which are open flume type, and about 90 percent or so have been broken and tampered with by the farmers.

2.2.2 Doso Dharoro Distributary

This distributary also off-takes from the Jamrao Canal at RD 343 on the left side in front of the Mirpurkhas Distributary. The head regulator consists of three vertical gates which were constructed during the remodeling of the main canal in 1993/94 and has been provided with gauges on both the upstream and the downstream sides. These gauges have become obliterated; however, approximate readings are collected daily.

The channel has a good cross-section throughout its length. Chances of overtopping and breaches are almost nil. The Old Doso Minor, which is off-taking on the left side at RD 30 is fed through an open flume to supply 5 cusecs of water for 1467 acres. The condition of this minor is quite bad as compared with the distributary itself. Also, this minor has drawn little attention regarding its maintenance. There is thick vegetative growth on both sides, which makes it difficult to conduct a survey or make any measurements.

Some of the new outlets in the head reach, which are supposed to be operated after increased water supplies are made available through the Twin Jamrao Canal, are running and the old ones have been abandoned. Some of the outlets are tampered. The On-Farm Water Management staff have done a considerable job in this area by lining a majority of the watercourses.

2.2.3 Kahu Visro Minor

This is a small minor off-taking directly from the main canal on the right side at RD 383 to serve an area of 3,622 acres through eight outlets. The one-gated head regulator, channel cross section and embankments have been improved as a part of the remodeling project. The new outlets have replaced the old ones as the bed level has risen due to sediment deposition to such an extent that operating the new outlets is preferred.

2.2.4 Kahu Minor

This minor is off-taking at RD 385 on the left bank of Jamrao Canal through a head regulator having three vertical gates. The design discharge is 43.5 cusecs to cover a culturable command area of about 12,018 acres. Generally, the physical condition of the channel is good. Sediment clearance was done in July 1996 with the help of a dragline, which has dumped the sediment on the banks and the service road (inspection path) from where it is falling back into the minor. This sediment removal has improved the channel capacity for extra water supplies, as well as allowing water to reach the tail outlets.

A majority of the traditional APM or open flume type outlets are tampered or broken. A couple of them are completely dismantled, where temporary structures have been erected by the farmers according to their needs.

2.2.5 Sanro Distributary

This distributary is off-taking from the right side of Jamrao Canal at RD 408 upstream of the Mile 78 Cross Regulator. The physical condition is not bad; however, at some points it is very poor. Banks and berms are weak; spillovers, leakages and breaches are expected to happen at full supply levels and during heavy rainfall periods. The trespassing and bathing by animals is one of the major causes for the miserable condition of this channel. Poor upkeep associated with the carelessness of farmers has added to the deteriorating performance of the system. The physical condition of the inspection path has also worsened due to jungle, vegetation and the excavated sediment piled on the banks.

New outlets have been provided in the head reach, but are inoperative at present. The outlets are APM, pipe or open flume types, where the majority have been interfered with.

2.2.6 Bareji Distributary

This is the last distributary of Mirpurkhas Sub-division emanating from Jamrao Canal at RD 408 on the left side. The head regulator is comprised of three vertical gates which were constructed during the remodelling of the main canal in 1993/94. The regulator is in good working order and is working without having any problem. In general, the eight mile long distributary has a good channel prism which is free of weeds and has enough freeboard to accommodate extra water supplies. There are a few weak points caused by cattle trespassing, where breaches may take place during high flows or rains. The removal of sediment deposits is carried out, specially in the tail reach, whenever required by the water users.

Water is supplied to the farms through APM or open flume type outlets to cover a culturable command area of 14,032 acres. The tail reach is in cutting where lift irrigation is also practiced. Lift pumps generate considerable fluctuations in the distributary water level, which affects the downstream command area. In many cases, the outlets are tampered or broken in order to extract excess water supplies, which results in inadequate water at the tail during peak periods. However, during slack periods, when the upstream outlets are closed, the tail area is flooded.

The numbers on the gauges at the head regulator can no longer be read, which requires repainting or replacement.

2.3 WEST BRANCH CANAL (RD 0 TO 143)

West Branch Canal is the largest off-take from Jamrao Canal having a design capacity of 900 cusecs, which off-takes from the main canal on the right side at RD 291 to cover a culturable command area of 230,800 acres. Unlike the main Jamrao Canal, no significant improvement is observed in cross-section or any other hydraulic structure of this branch. However, the service road has been improved in some reaches and sediment removal was carried out during 1992.

The head regulator is comprised of three old gates which are most of the times completely open to allow maximum deliveries downstream. The downstream gauge has been fixed in a stilling well, but is in pieces and difficult to understand by a common person. There is only one cross regulator at RD 38 along the 30-mile reach in Mirpurkhas Sub-division, which is called the Jhando Mari Cross Regulator. The upstream gauge at Jhando Mari Cross Regulator is in two pieces of 8 and 2.5 feet, while there is no downstream gauge.

The channel has very thick vegetation on the banks, especially the right bank. An interesting feature of the West Branch Canal is that all of the distributaries and minors in the Mirpurkhas Sub-division jurisdiction are off-taking from the left bank. The command area of

West Branch Canal is seriously waterlogged and saline; therefore, domestic water needs are also dependent on canal water.

2.4 DISTRIBUTARIES AND MINORS OF WEST BRANCH CANAL SECTION

The distribution system of the West Branch Canal consists of two distributaries, three minors and sixty-two outlets drawing water directly from the West Branch in this reach (Figure 2.2). Besides these, there are three minors or sub-minors which are fed by these distributaries and minors. The major information regarding these channels is given in Table 2.3.

Table 2.3. Distributaries and minors off-taking from West Branch Canal.

S.NO.	Name of Disty/Minor	Parent Channel	Off-take (RD)	Q (cusecs)	CCA (acres)
1	Lakhakhi Disty	West Branch	38	64	17,606
2	Bhittaro Minor	West Branch	69	11.6	3,690
3	Sangro Disty	West Branch	88	103.7	30,954
4	Jarwari Minor	Sangro Dy.	10	24	7,178
5	Chahu Minor	Sangro Dy.	29	36	9,948
6	Daulatpur Minor	West Branch	115	49	10,766
7	Bellaro Minor	West Branch	143	54.78	17,124
8	Khumbri Sub-Minor	Bellaro Minor	18	10	2,808
Total Discharge and CCA of West Branch Canal					100,074

There are a total of 62 outlets diverting water directly from the West Branch Canal in the reach from RD 0 to 143. Many of them have been broken or tampered with by the farmers. At a couple of locations in this branch, twin outlets have been constructed below the old ones in order to have more water. They are larger in size and would be able to draw more water because of increased head. The closure of outlets by water users is a common phenomenon on this canal. At several points, sandbags, bushes and bricks have been observed near the outlets, which are used to close them either fully or partially whenever required.

The general physical condition of the channel from the West Branch Canal Head Regulator to the Jhando Mari Cross Regulator (RD 38) is poor. There is vegetation like a jungle on both sides; the service road is very bad at several places; and there are few bridges for crossing over to the other side.

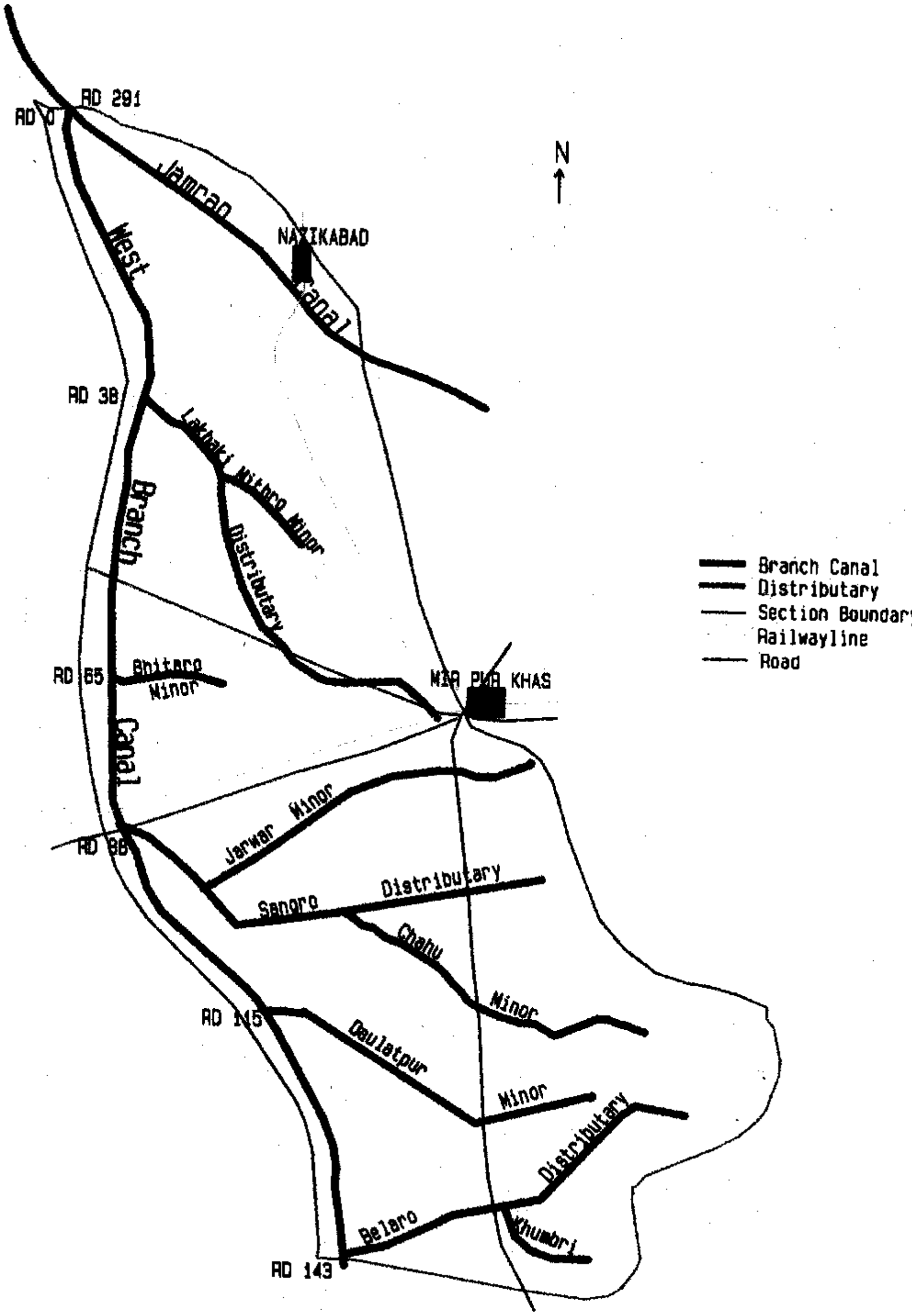

Figure 2.2. West Branch Canal Section of Mirpurkhas Sub-division with major offtakes.

2.4.1 Lakhakhi Distributary

This is the first major off-take from the West Branch Canal which occurs on the left side. The head regulator consists of one gate which is located at RD 38 of West Branch Canal, upstream of Jhando Mari Cross-Regulator. Although the physical condition of the head regulator is poor, it is working properly. Generally, the channel is in extremely bad condition with the exception of a few small reaches. At several locations along the channel, the embankments are very weak, and the berms and the freeboard have also disappeared. Direct irrigation from the distributary without a proper outlet is possible due to weak banks. Heavy jungle has grown on both sides, especially the right side, which could provide protection to illegal cuts by the users. The command area is comparatively heavily populated; therefore, animals trespassing, specially buffaloes, are also contributing to the miserable condition of the channel.

Little attention has been paid to the maintenance of this distributary (maybe due to law and order problems in this area). At some locations, the jungle has encroached upon the service road, while at other places, the culverts have collapsed and there is difficulty traveling along the channel. Similarly, sediment removed from the channel has been deposited on the banks, where it can again be transported into the channel, especially during the monsoon season.

Due to scouring in Nara Canal, the Jamrao Canal and its distribution system receives tons of sediment every year. Lakhakhi Distributary also gets its due share of sediment, which along with other factors, contributes to water shortages in the tail area.

2.4.2 Bhittaro Minor

The four-mile long Bhittaro Minor is fed through a rectangular orifice on the left bank of the West Branch Canal. Excess flows are being diverted because of good working head and a modular flow condition. Similarly, the outlets are also overdrawing and that is why outlet closures by farmers are observed on this minor. The tail is normally operating full, but gets flooded when the upstream outlets are closed. Overall, the channel cross-section is good, with some vegetation near the head and the tail reaches.

Bhittaro Minor serves its command area through 9 outlets, out of which 7 are APM and 2 are open flumes. Extra supplies are available to farmers because most of them have been tampered. There is no gauge at any point from head to tail of this minor for proper regulation of irrigation water.

2.4.3 Sangro Distributary

This is the third major off-take on the West Branch Canal. The supplies are managed through a two-gated head regulator at RD 88 of the West Branch Canal. The head regulator is working satisfactorily and always runs under a submerged orifice flow condition.

The channel all along the length is in good working condition. Sufficient freeboard and berms are available, except near the head, where excess flows will overtop the banks on both sides. Portions of the middle and tail reaches have been desilted recently. Jungle has grown on both sides of the distributary in the middle reach, which disrupts the inspection path at some points. The tail reach is heavily vegetated, which causes sediment deposition that requires frequent clearance. The tail cluster has three open flume type outlets, which have been provided with gates, probably by farmers, a bit downstream of the outlet structure.

Sangro Distributary has two cross regulators, one at RD 10 and another at RD 29 where two minors, Jarwari and Chahu, are off-taking on the left and right banks, respectively. The head regulator of Jarwari Minor is functioning well; however, it is difficult to know the amount of flow being delivered to the minor as no mechanism is available on the spot to observe water levels at this location. Overall, the Jarwari Minor cross-section is good, except for small reaches near dwellings, where animals are trespassing and other uses have damaged the embankments. Some points are vegetated, but the flow is not affected. The tail reach passes through a part of Mirpurkhas town where it supplies water with two outlets for drinking as well as other municipal purposes. The small reach has four outlets located downstream from the water supply schemes, which are usually short of water because water is not allowed to flow downstream as long as it is needed by the municipality.

The head regulator of Chahu Minor is in good working condition. The channel is almost free of vegetation, does not have weak points where breaches or leakages will occur, and has enough freeboard and strong berms.

Like the rest of the Jamrao system, most of the outlets have lost their original size and shape due to farmers interference and lack of management. Similarly, other hydraulic parameters have also been affected due to sedimentation and interventions by water users. The distributary head has a downstream gauge, while there is no gauge at any point all along the distributary and minors.

2.4.4 Daulatpur Minor

The Daulatpur Minor originates from the West Branch Canal at RD 115 having a design flow capacity of 49 cusecs to serve a culturable command area of 10,076 acres. The head regulator consists of two old gates; the left one is working while the right one gets stuck at one point and cannot be moved up or down easily. Sometimes, the trash coming from the main canal gets stuck in the right gate and disrupts the flow.

The physical condition of the channel is good, the cross section is in satisfactory condition, with the exception of some points near an abadi due to cattle trespassing. There is almost no vegetation which could disturb the flow, but sediment deposition takes place in some reaches, which is removed periodically in the tail reach to improve water delivery to the tail outlets. The command area on both sides is saline and waterlogged. Ground water is extremely brackish and the people have to rely on canal water for all of their needs. The outlets are tampered. Usually, the tail is receiving water.

2.4.5 Bellaro Minor

This is the last minor of Mirpurkhas Sub-division off-taking from the West Branch Canal at RD 143. The head regulator is comprised of one gate, which is leaking from the bottom as well as from the sides, even when it is closed. The cross-section of the minor looks good, but there are serious sedimentation problems. Sediment clearance is frequently conducted, but the tail still experiences water shortages. Another reason for tail shortages is the `wider than design' section in this reach, where sediment deposits rapidly accrue due to low flow velocities. The tampering of outlets is a common practice here as well. The inspection path in the middle reach is in extremely bad condition due to jungle on the embankment and a couple of collapsed culverts, while that of the tail reach is quite good.

Chapter 3

CANAL OPERATIONS

3.1 CURRENT OPERATIONAL MODE

As described earlier, the Nara Canal and Jamrao Canal have been remodeled under the Left Bank Outfall Drain Stage-1 Project. One of the objectives of the remodeling was to increase the existing water carrying capacity of these canals so that more area could be brought under cultivation. Similarly, all of the cross regulators and the head regulators in Mirpurkhas Sub-division on Jamrao Canal have also been newly constructed. Although, the control structures in the West Branch Canal Section of the Mirpurkhas Sub-division have not been remodeled, but they have gated regulators in working condition.

All of these facilities provide a good opportunity for an easy and good operation of this system. However, this does not seem to be true all the times. Usually, the Mitho Machi Cross Regulator is adjusted according to the requirements immediately upstream and that of the West Branch Canal. The operation of this cross regulator is quite infrequent as there are no major off-takes except West Branch Canal, which would necessitate its frequent operation. Field observations and measurements suggest that Mitho Machi Cross Regulator is usually running as an open flume. The cross regulator at RD 343 also operates as an open flume and is rarely manipulated. Flow deliveries into Mirpurkhas Distributary and Doso Distributary are regulated through their head regulators. Similar is the case with the cross regulator at RD 408 of Jamrao Canal, where minimum adjustments are made and demands of Bareji Distributary and Sanro Distributary are met through their manipulating head regulators .

Water deliveries into the West Branch Canal are usually regulated through its head regulator only. The old three-gated head regulator adjustments are comparatively changed more frequently than others depending upon the flow levels in the main Jamrao Canal and the requirements of the downstream distribution system. The frequency of operating the Jhando Mari Cross Regulator at RD 38 is low, as there is only one major off-take (i.e, Lakhakhi Distributary) located immediately upstream.

The operation and regulation of the head regulators for the distributaries and minors is guided mainly by the amount of water available in the main canal and influenced by the water users to some extent, as well as the interests of the regulation staff of the concerned agency. Usually, the objective is to run all of the offtakes at full supply levels (FSL) all of the time. Field observations and experience gained so far suggest that the head regulators are manipulated almost daily and, in many cases, even more than once. None of the control structures have been calibrated in the recent past, that would help the manager in operating the system properly. In the Sindh environment, the darogha (equivalent of mate in Punjab and NWFP) is an important field person of the Irrigation Department concerning operation and regulation of the channels. Normally, the darogha and tandyl (gate keeper) adjust the gate settings themselves. Sometimes, they even dare to disobey or delay the orders of their supervisors on the plea that they cannot face the farmers pressure. Generally, daroghas deal with the farmers of their respective areas. The Sub-divisional Officer (SDO) and/or the Executive Engineer (XEN) would strongly intervene only during the peak demand period or under tremendous pressure from influential farmers or politicians.

In September 1997, the superior authorities welded pieces of iron with the gates frames in a bid to restrict water supplies to a certain maximum amount for a few channels of Mirpurkhas Sub-division. However, within a few days, everything was gone; the welded pieces were broken away and the flow deliveries continued as before.

The role (though unauthorized according to existing laws) of water users in the operation and regulation of the distribution system cannot be denied any longer. Field observations have proved that, in some cases, the distributaries and minors are run to possible maximum levels during the periods of irrigation turns by the influential farmers, which may stretch over three to four days. The operation of direct outlets has become mainly the water users responsibility, except for extreme water demand periods, when the ID staff would interfere. The direct outlets are mostly APM type and have been tampered with by the farmers. This tampering, coupled by higher water levels, have tremendously increased the discharges through these outlets. Sandbags, bushes and weeds are used for full or partial closure of these outlets by the farmers during low demand periods.

Rotational closures are implemented throughout the year, even during the slack periods, except for the month of May, when the intensity is low. However, the implementation of a rotational schedule is selective both spatially as well as temporally. Every off-take is supposed to be closed turn-by-turn for seven days, but practically, it varies from zero to ten days. Similarly, there is a lack of uniformity in rotational closure schedules of the Jamrao Canal and West Branch Canal sections. Sometimes, a couple of channels of the Jamrao Canal would be closed, while all the off-takes of West Branch Canal would be running, or vice versa, and sometimes both the canals would have off-take(s) closed simultaneously.

3.2 Data Collection and Transmission System

The primary objective of equitable water distribution to all offtakes can be achieved through constant monitoring and maintaining the flow records at each control point. The existence and the physical condition of the staff gauges at the important hydraulic structures is also of equal importance. As mentioned earlier, the Jamrao Canal has been remodelled, whereby all the cross regulators and the head regulators in the Mirpurkhas Sub-division have also been replaced with new ones. Similarly, new gauges both at the upstream as well as the downstream of these structures were mounted. In contrast, the West Branch Canal has decades old structures and devices.

The Irrigation Department is used to the monitoring of downstream gauges for the operation and regulation of an irrigation system. These downstream gauges are supposed to have their zero level equal to the bed level of the channel. However, the gauges provided on the Jamrao Canal section have been mounted on the downstream wing walls of the head regulators and their zero levels ar quite above the bed levels of the channels. At the same time, markings on these gauges have become obliterated for lack of maintenance and are not readable.

The existence and the physical condition of the downstream gauges at the heads of major off-takes in the Mirpurkhas Sub-division are given in Table 3.1.

Table 3.1. The existence and physical condition of the downstream gauges at the heads of major off-takes in Mirpurkhas Sub-division.

Main Canal	Off-take	Downstream Gauge		Remarks
		Existence Yes/No	Physical Condition	
Jamrao	Mirpurkhas Disty	Yes	Rusted	Markings obliterated, not readable
	Doso Disty	Yes	Rusted	Not readable
	Kahu Visro	Yes	Rusted	Not readable
	Kahu Minor	Yes	Rusted	Not readable
	Bareji Disty	Yes	Rusted	Not readable
	Sanro Disty	Yes	Rusted	Not readable
West Branch	West Branch Head Regulator	Yes	Fair	pieces, only ID staff can understand
	Lakhakhi Disty	No	-	-
	Bhittaro Minor	No	-	-
	Sangro Disty	Yes	Good	Old, reads higher depth than actual
	Daulatpur Minor	Yes	Good	Old, reads higher depth than actual
	Bellaro Minor	No	-	-

All of the daily water levels (correct or erroneous) collected at the control points are supposed to be communicated to the sub-divisional officer's office every day at about 8 or 9 o'clock. However, in actual practice, these are conveyed sometime during the day, or maybe a day or so after. The gate openings are not recorded.

Another important feature of the communication between the office and the field staff is that most of the messages are transmitted verbally.

The upstream gauge readings at the Mitho Machi Cross Regulator and the downstream gauge readings at the West Branch Canal Head Regulator are transferred to Mirpurkhas through a public telephone in the morning. When the telephone line is out of order, then the darogha communicates the information. No record is maintained at site. Water levels at the Mile 69 Cross Regulator and its off-taking channels (Mirpurkhas, Doso Dharoro) are recorded in the morning and sent to Mirpurkhas through a darogha. Gauge readings of the Kahu Visro Minor and Kahu Minor are communicated either by the sub-engineer or darogha. Staff gauge readings at the Mile 78 Cross Regulator and its off-taking channels (Bareji and Sanro) are also communicated through a darogha; although a telephone line has been provided at this structure, it remains inoperative most of the time.

Regulation and operation data at the head regulators of distributaries and minors of the West Branch Canal are also gathered daily and transmitted to Mirpurkhas through a darogha.

At present, the Jamrao Canal lacks the facilities for quick information transfer from the field to headquarters. With the exception of a few of control structures where a telephone facility is available (direct line or through public call office), messages/information are transmitted manually to Mirpurkhas. The telephone/telegraph system of Jamrao Canal was destroyed during the remodeling of the channel and has not been replaced so far. Efforts were underway to build a modern telecommunication system along the Nara Canal irrigation system by the end of 1997, which will link all of the important control points and the sub-divisional headquarters directly.

3.3 Recent Telecommunication System

Irrigation channels are meant to convey water in specified quantities for crop production and are considered a reliable source of water. But the reliability of canal water is dependent on timely transmission of information regarding water levels/discharges from important control points to the mangers and/or water users. The managers need this information for proper operation and regulation of the irrigation system concerned, while the farmers need to know the water levels in the canal so that they could properly plan their water turns and make the best use of the available quantity. Floods and breaches also make it essential that the information is quickly passed on to the managers so that necessary measures are taken to minimize losses and damages.

The telegraph/telephone system along the Jamrao Canal had become inoperative, partly, for lack of maintenance and partly, due to the construction activities of the Jamrao Canal remodeling project in the early 1990s. A big irrigation system serving a command of about 900,000 acres was in miserable condition. Communication of daily water levels to the divisional office would take hours, if not days. The pumping stations in the upper reaches of Nara Canal frequently shut down due to power failures and are causing serious water level perturbations in the downstream system without any information. The two breaches that occurred in the Jamrao Canal near Din Branch Head Regulator (RD 87) and West Branch Canal downstream of Lakhakhi Distributary (RD 38) were reported hours later to the manager's office. In Mirpurkhas Sub-division, most of the communication between the field and the sub-divisional office is manual and is done mainly by the daroghas and gate keepers.

As a part of the Nara/Jamrao Canals remodeling under the LBOD Stage 1 Project, a sub-project for installing a Nara Circle telecommunication system was envisaged in order to provide modern telecommunication facilities after the capacities of this irrigation system are increased. Under the original plan, automatic data loggers were to be installed at strategic points in the Nara Canal Circle, which would be directly linked to the base station in Mirpurkhas. The communication between the base station and the field staff was planned to be through a microwave radio system. However, this project has not been implemented as originally planned and now only the radio system has been installed at the divisional and sub-divisional turnover points in December1997.

In Mirpurkhas Sub-division, this facility has been provided in the form of three base station units at turnover points, plus two mobile units. The base station units have been installed at the following points as shown in Figure 3.1.

1 RD 291, Mitho Machi Cross Regulator, upstream turnover point from Jhol Sub-division.
2 RD 448 of Jamrao Canal, turnover point to the downstream Kot Ghulam Muhammad Sub-division.
3 RD 143 of West Branch Canal, turnover point to Digri Sub-division.

One base station has been established at Mirpurkhas, which serves as a main station both for the Jamrao Canal System as well as the Nara Canal Circle. Other control structures (cross regulators and head regulators of offtakes) in between the turnover points are still without any electronic or mechanical facility for data transmission. They had the telegraph/telephone system in the good old days.

One mobile unit has been provided to the SDO and another one to the Executive Engineer. Hopes are high that this modern telecommunication system would largely contribute to better management of the system.

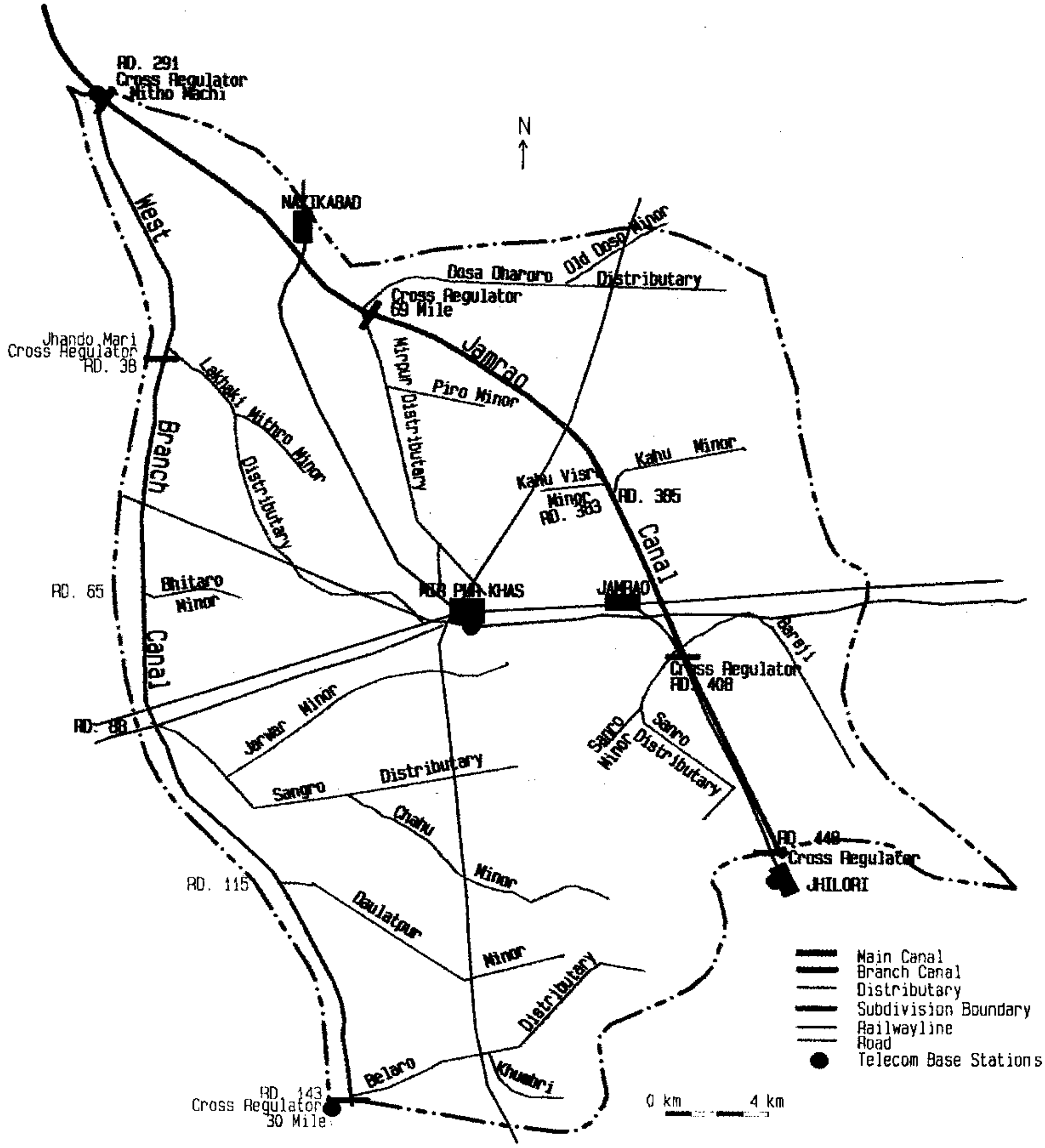

Figure 3.1. Telecommunications base stations in Mirpurkhas Sub-division.

Chapter 4

CALIBRATION OF HEAD REGULATORS

In many developing countries, it is relatively easy to collect from a project agency a series of data on the physical environment (climatic and hydrological data, physical infrastructure) agricultural production, staffing and O&M costs of an irrigation project. These data can be obtained from agencies performing relatively well within a short time. However, the greatest difficulty is found in obtaining and interpreting data on water supply. When these data exist, they are often too unreliable for analytical uses. In most cases, what could be obtained are the volumes delivered to large sections of a project. In these cases, without field research and monitoring there is no possibility to determine the water use efficiency at the conveyance, distribution and field levels (Plusquellec, 1990).

The above statement is also very true in this study's context. All of the actual flow delivery data needed to be collected directly in the field and then analyzed.

4.1. FIELD PROCEDURES

Discharge ratings were established for all the major off-takes of Mirpurkhas Sub-division using the structure formula. The following measurements were made.

4.1.1. Water Depth Measurements

A staff gauge (commonly called a gauge) is the most commonly used device to measure flow depths in irrigation channels. The primary advantage of a gauge is that everybody can read it easily, including farmers. However, the primary disadvantage is that the markings below the water surface become obliterated and need to be repainted once or twice a year (Skogerboe and Merkley 1996). Almost all of the gauges in the Mirpur Sub-division have met the same fate, and are hardly readable. As an alternative, benchmarks were established on all of the flow control structures for measuring flow depths.

These benchmarks were marked with white paint on the walls of the control structures at points where there was a minimum of turbulence in the flow. For free flow control structures, benchmarks were established on the upstream side of the structure, while for submerged flow structures both the upstream and downstream benchmarks were established. In cases where the flow at the downstream side of the submerged control structure was turbulent, the benchmarks were established a bit further downstream.

These benchmarks were marked and referenced to the crest levels of the respective flow control structures, which were rechecked in January 1997 during the annual canal closure to minimize the error that might have occurred in readings taken in flowing water.

Daily flow depths were computed from the tape measurements taken from these benchmarks to the smooth water surface.

Next >>

4.1.2. Gate Openings

One of the most difficult tasks in calibrating a gate structure is obtaining an accurate measurement of gate opening (Skogerboe and Merkley 1996). Obtaining a reasonably accurate measurement of gate opening for a hydraulic control structure is a very difficult and sensitive job. A small error in gate opening has a tremendous effect on developing an accurate and reliable discharge rating. For the eleven channels of Mirpurkhas Sub-division, seven head regulators have covered spindles, one has a fixed orifice and the remaining three have open spindles. Each gate of the gated head regulators has two spindles; one on the right side and another on the left side, except Sangro Distributary Head Regulator, which has one spindle for each gate.

Two benchmarks were marked on the frame of each gate, one on the right side and another on the left side to avoid any error due to faulty functioning of the gate. The elevations of these benchmarks were taken from the top of the gate when the gate was completely closed. Daily tape measurements from the benchmark downward to the top of the gate were subtracted from the benchmark elevation, which are averaged to obtain an average gate opening for each gate. The elevation of the upstream and downstream benchmarks with respect to the crests of the flow control structures for measuring water depth and those for the gate openings are given in Table 4.1.

Table 4.1. Elevations of the benchmarks with respect to the crest at each head regulator of the Mirpurkhas Sub-division.

Channel	U/S BM	D/S BM	Gate 1 BMs		Gate 2 BMs		Gate 3 BMs		Flow Condition	Remark
			Left	Right	Left	Right	Left	Right		
Mirpur Disty	5.05	3.02	3.47	3.45	3.49	3.48	3.74	3.72	S.O.F.	
Doso Disty	6.88	4.49	3.95	3.95	3.78	3.79	3.74	3.75	S.O.F.	
Kahu Visro Minor	5.76	0.17	3.19	3.17	3.17				F.O.F.	
Kahu Minor	6.77	1.89	2.45	2.46	2.54	2.52	2.56	2.53	F.O.F.	
Bareji Disty	5.75	2.49	2.38		2.53		2.32		F.O.F./S.O.F.	
Sanro Disty	4.30	0.12	2.81		2.85				F.O.F.	
Lakhakhi Disty	7.48	4.66	1.87	1.92					S.O.F.	
Bhittaro Minor	6.66	3.32	Fixed orifice						F.O.F.	
Sangro Disty	7.49	4.07	2.90	2.90	2.96	2.93			S.O.F.	
Daulatpur Minor	8.06	4.48	2.68	3.01	2.65	3.09			S.O.F.	
Bellaro Minor	7.48		2.36	2.39					F.O.F.	

Note: S.O.F. is submerged orifice flow through the gates (s).
F.O.F. is free orifice flow through the gate (s).
All the measurements are in feet.

4.1.3 Discharge Measurements

The head regulators for all of the eleven distributaries and minors in the Mirpurkhas Sub-division have been calibrated. Discharge ratings were developed after a series of discharge measurements taken at different gate openings.

The area-velocity method was used for discharge measurements. The vertical axis type current meter, Price Type A, was used for velocity measurements in the channels. The two-points (0.2 and 0.8) method was used for measuring velocity in a vertical. The average of the two measurements has been taken as the mean velocity in the vertical.

The cross-sections for measuring velocities were selected downstream of the channel head regulator. These locations were about 150-300 feet downstream of the control structures depending upon the alignment of the channel reach, vegetation, bed formation and flow turbulence. Cross-sections having stagnant water near the bank(s) or having shallow flow depths (less than 0.50 ft.) were avoided.

Each cross-section was subdivided into twenty or more verticals, depending upon the width of the cross-section. However, the verticals were not spaced closer than one foot (Corbett and others 1943). The width of the verticals near the banks was usually less than in the middle because of the changing depth near the banks.

4.2. DISCHARGE CALIBRATION OF GATE STRUCTURES

Several discharge measurements over a normal operating range of gate openings were taken for developing discharge ratings for the respective control structures. The following equations were used to compute the discharge coefficient, C_d, from the measured data in the field. For free-orifice flow head regulators:

For submerged orifice flow head regulators

$$Q_f = C_d G_o W \sqrt{2gh_u} \quad \text{......(4.1)}$$

$$Q_s = C_d G_o W \sqrt{2g(h_u - h_d)} \quad \text{......(4.2)}$$

Where,

Q_f	=	discharge in cusecs for a free flow condition
Q_s	=	discharge in cusecs for a submerged flow condition
G_o	=	average gate opening in feet
W	=	Width of the head regulator gate opening in feet
h_u	=	upstream head in feet
h_d	=	downstream head in feet
C_d	=	discharge coefficient

The computed C_d values were plotted along the X-axis and the gate opening along the Y-axis to plot a curve for each flow control structure. The C_d value decreases as the G_o increases as shown in Figure 4.1.

Obtaining an accurate gate opening, G_o, measurement is a difficult job. Errors may be introduced if the gate is not completely horizontal or the gate lip does not seat at the same elevation as the gate sill and/or there is leakage from the bottom and sides of the gate even when the gate is totally seated. This implies that the datum for measuring the gate opening is below the gate sill.

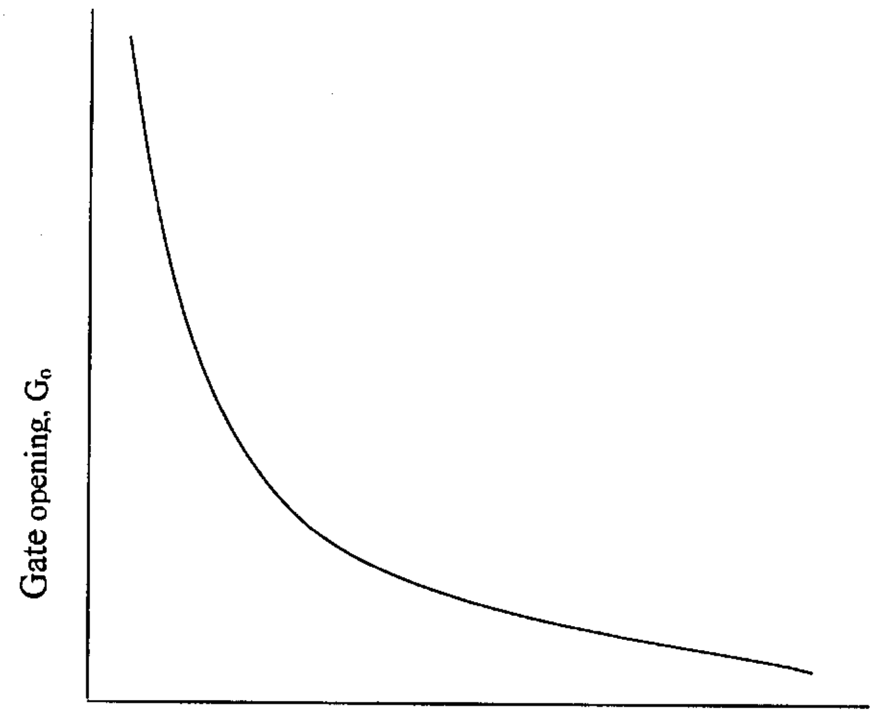

Figure 4.1. Schematic showing typical variation of discharge coefficient , C_d, with gate opening, G_o.

In order to determine a constant value of C_d, a gate opening correction factor ΔG_o was introduced into Equations (4.1) and (4.2) and rewritten as

$$Q_f = C_d(G_o - \Delta G_o)W\sqrt{2g(h_u)_{\Delta G_o}} \qquad (4.3)$$

for free flow orifice , where $(h_u)_{\Delta Go} = h_u - \Delta G_o$.
Also,

$$Q_s = C_d(G_o - \Delta G_o)W\sqrt{2g(h_u - h_d)} \qquad (4.4)$$

for submerged flow orifice, where ΔG_o is a measure of the zero datum level below the gate sill.

In order to determine an appropriate value of ΔG_o, the trial-and-error method was employed. The resulting values of C_d for different values of ΔGo were computed from Equations (4.3) and (4.4). These C_d values were plotted against G_o-ΔG_o, which would typically look like Figure 4.2.

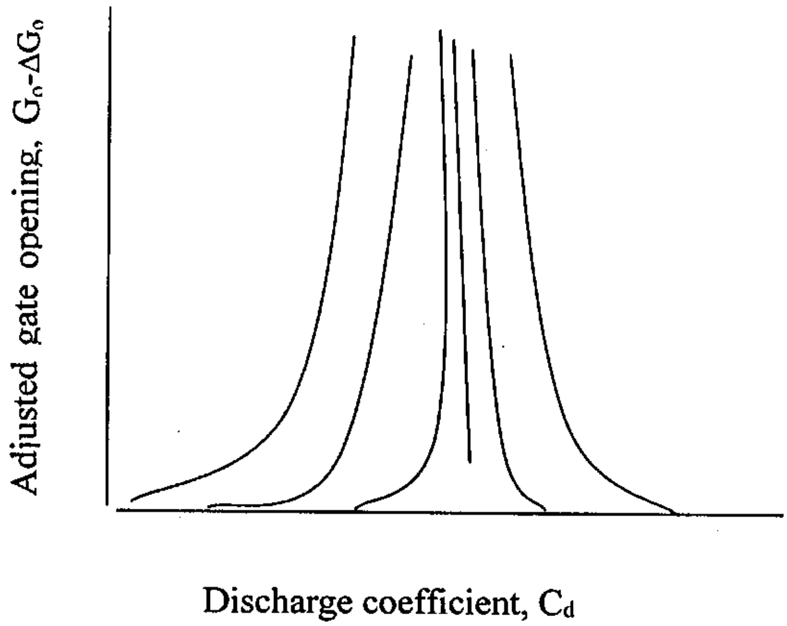

Figure 4.2. Schematic showing typical variation of discharge coefficient, C_d, with adjusted gate opening, G_o - ΔG_o.

For the values of ΔG_o for which the C_d values had a minimum of difference (represented by a vertical line in Figure 4.2) was taken as an appropriate value of C_d for the respective control structure.

The daily water levels, gate openings and flow conditions data were collected and then converted into discharges for each offtaking channel with the help of the discharge ratings developed for the head regulator of each channel. The values of ΔC_d and ΔG_o for major control structures in Mirpurkhas Sub-division are given in Table 4.2.

There are two distributaries (Mirpurkhas and Doso Dharoro) of the Jamrao Canal which are running as submerged orifice flow and the remaining four channels are running as free orifice flow. On the contrary, there are two minors (Bhittaro and Bellaro) of the West Branch Canal which are running as free orifice flow and the remaining three are running as submerged orifice flow.

Table 4.2. Established values of C_d and ΔG_o for the head regulators of Mirpurkhas Sub-division offtaking channels.

Parent Channel	Offtake	C_d	ΔG_o (ft)	Flow Condition	Number of gates	Each gate width (ft)
Jamrao Canal	Mirpurkhas Distributary	0.600	-0.04	S.O.F.	3	5
	Doso Dharoro Distributary	0.684	-0.04	S.O.F.	3	5
	Kahu Visro Minor	0.528	-0.05	F.O.F.	1	5
	Kahu Minor	0.432	-0.12	F.O.F.	3 (only two are operated)	5
	Bareji Distributary	0.63	-0.02	F.O.F.	3	5
		0.527	-0.02	F.O.F		
	Sanro Distributary	0.518	-0.09	F.O.F.	2	5
West Branch Canal	Lakhakhi Distributary	0.674	-0.10	S.O.F.	1	10
	Bhittaro Minor	0.62	-	F.O.F.	Fixed orifice	
	Sangro Distributary	0.710	-0.03	S.O.F.	2	6
	Daulatpur Minor	0.540	-0.04	S.O.F.	2	6
	Bellaro Minor	0.490	-0.06	F.O.F.	1	6

Chapter 5

HYDRAULIC CHARACTERISTICS OF MIRPURKHAS SUB-DIVISION

5.1 GENERAL

Mirpurkhas is the largest sub-division of Jamrao Canal, but has been marred by characteristically poor management, like the rest of the system. The offtakes are run at full supply levels even encroaching on the freeboard, as far as possible, irrespective of the command area and crop water requirements. Field observations have proved that water users are tempted to close their outlets, especially after sunset, to flood the tail reaches, with little or sometimes no adjustments in water supplies at the head of the channels. Although better regulation facilities (e.g. gated head regulators and cross regulators) have been provided throughout the Mirpurkhas Sub-division, but flow regulation is mostly implemented by daroghas and gate keepers in collusion with the farmers, resulting in large variations in flow deliveries among the offtaking channels. The following characteristics will be discussed in this chapter:

1. Variations in daily discharge;
2. Number of operations performed at the offtake head regulators;
3. Canal closure;
4. Upstream water level fluctuations;
5. Lift irrigation; and
6. Other uses of water in Mirpurkhas Sub-division.

5.2. VARIATIONS IN DAILY DISCHARGE

The daily water levels, gate openings and flow conditions were collected and then converted into discharges for each offtaking channel with the help of the discharge ratings developed for the head regulator of each channel. The values of C_d and $^{\Delta}G_o$ for major control structures in Mirpurkhas Sub-division were given in Table 4.2.

5.2.1 Jamrao Canal Section

The daily discharge of each offtake has been compared with the average seasonal discharge of the respective channel for two seasons (Rabi 1996-97 and Kharif 1997). The daily monitoring of flow supplies started in mid-November 1996 and continued till October 31, 1997. The variation in daily discharge with respect to the average seasonal discharge has been shown in Figures A.1 through A.12 as given in Annexure A.

The discharge of every offtaking channel is changing almost daily irrespective of its location along the main canal. Even two channels (e.g. Mirpurkhas and Doso Dharoro or Bareji and Sanro Distributaries) offtaking at the same location, but from the opposite sides of the main canal, have a lot of variation in daily water deliveries. They have no link with each others operation. The flexibility of operation provided by the gated head regulators has been abused and the water distribution pattern varies from one point to another. There is difficulty in saying that a distributary or minor had a stable water supply for a certain week or month during the study period.

Kahu Minor has performed relatively better during December 1996 (Figure A.7) and May 1997 (Figure A.8) with small ups and downs. Similarly, Kahu Visro Minor has been better during May and September 1997 (Figure A.6). Discharge fluctuations in Bareji Distributary during December 1996 (Figure A.9) are also less than the rest of the months.

5.2.2 West Branch Canal Section

The offtakes of the West Branch Canal have two distinctive features: (1) all of the five channels are offtaking from the left bank; and (2) every downstream channel is about five (canal) miles away from its immediate upstream channel. Also, the Bhittaro Minor has a fixed orifice of 1.25 x 1.25 feet.

The daily flow monitoring started in November-December 1996 and continued till October 1997. The daily water supplies vary from day to day and channel to channel. The daily fluctuations in water deliveries at each offtake of the West Branch Canal with respect to the respective average seasonal discharge have been shown in Figures A.13 through A.22 as given in Annexure A.

The Lakhakhi Distributary has received highly fluctuating supplies during the study period with the exception of September 1997 (Figure A.13), where the flow delivery pattern is better than the rest of the period. Also, this distributary has been running at 15 to 20 cusecs below the seasonal average discharge for most of March 1997 (Figure A.14). Similarly, July 1997 has been the worst month, where Lakhakhi Distributary remained closed for about 17 days (54 per cent of the month's period).

Discharge variations for the rest of the four channels (Bhittaro, Sangro, Daulatpur and Bhittaro) are comparatively low. Variations in water supplies to Bhittaro Minor are caused mostly by water level fluctuations in the main canal as it has a fixed orifice. Figures A.15 and A.16 show the relatively smooth flows into this minor. Deliveries into the Sangro Distributary have been below the seasonal average in February and March 1997 and have been relatively smooth in August and September 1997 (Figures A.17 and A.18).

Although both the Jamrao Canal Section (RD 291 to RD 443) and the West Branch Canal Section (RD 0 to RD 143) are parts of the Mirpurkhas Sub-division, however, a close look to the average seasonal discharge for the offtakes of both the sections reveal that they are different and independent systems. Normally, the average seasonal discharge for rabi is lower than the kharif average discharge and gives a considerable difference, which is true to a greater extent for the Jamrao Canal system. But, the situation in the West Branch Canal system is quite different (Table 5.2). For the West Branch Canal offtakes, the seasonal discharge for both of the seasons gives a mixed situation. For three channels, the rabi discharge is higher than kharif discharge (e.g Sangro Distributary, Daulatpur Minor and Bellaro Minor). One of the reasons that could be attributed to this situation is that some of the West Branch Canal offtakes have experienced longer rotational closures (discussed later in this chapter) than the Jamrao Canal system. The maximum and minimum discharge drawn by each offtake in both of the seasons is also given in Table 5.2.

Table 5.2. The seasonal average, along with the maximum and minimum discharges, of major offtakes of Mirpurkhas Sub-division .

Parent Channel	Offtake	Average Q (cfs)		Maximum Q (cfs)		Minimum Q (cfs)	
		Rabi 96-97	Kharif 1997	Rabi 96-97	Kharif 1997	Rabi 96-97	Kharif 1997
Jamrao Canal	Mirpurkhas Disty	69.26	70.96	99.21	99.61	25.70	23.32
	Doso Dharoro Disty	50.26	77.03	98.99	121.33	12.12	20.73
	Kahu Visro Minor	16.37	19.38	29.20	31.28	6.23	5.35
	Kahu Minor	42.41	49.67	65.79	75.94	23.0	4.43
	Bareji Disty	63.10	61.01	80.879	86.324	39.932	48.146
	Sanro Disty	51.13	52.49	83.525	102.05	11.04	37.016
West Branch Canal	Lakhakhi Disty	57.99	67.77	97.49	134.13	21.40	32.22
	Bhittaro Minor	16.99	16.04	18.51	19.06	13.10	14.37
	Sangro Disty	131.39	123.64	184.90	163.37	92.77	76.48
	Daulatpur Minor	38.93	36.30	57.94	57.81	20.73	31.74
	Bellaro Minor	59.39	51.29	70.980	75.24	45.21	48.21

5.3 NUMBER OF OPERATIONS AT OFF-TAKING HEAD REGULATORS

The purpose of an irrigation system is to deliver water of an appropriate quality in a specified quantity and at the specified time and place for optimizing agricultural production in a given area. Therefore, "considerable emphasis must be placed on measurement and control of the water in transit through the system" (Operation and Maintenance Manual Volume-II, Sindh Irrigation and Power Department, April 1993).

However, the actual field conditions are entirely different from the above statement. The operation of the head regulators and cross regulators for regulating flows into the distribution system has become mainly the domain of the field staff (daroghas and gate keepers), who operate the control structures as they deem fit. The gate operations in Mirpurkhas Sub-division were monitored an average of 318 days between November 1996 and October 1997, excluding the annual closure period during January-February 1997. Usually, the daily gate opening of the channel head regulators were measured in the morning. Field observations and experience has shown that gates are manipulated even for a couple of millimeters at the request of the water users. However, a difference of more than 0.01 foor in gate openings between two successive days has been assumed a change in the gate opening and the results are given in Table 5.3.

Kahu Minor of Jamrao Canal and Bellaro Minor (both minors have one gate each) of West Branch Canal have experienced the minimum manipulations, while Doso Dharoro Distributary has received the maximum number of manipulations (e.g. more than two-thirds of the study period). Kahu

Table 5.3. Operation of Mirpurkhas Sub-division 's major off-taking head regulators.

Channel	Monitored Days	Change Days	NO Change Days	Frequency (%) of change
Mirpurkhas Disty	316	181	135	57.28
Doso Dharoro Disty	319	217	102	68.03
Kahu Visro Minor	316	119	197	39.12
Kahu Minor	316	136	180	43.04
Bareji Disty	313	202	111	64.54
Sanro Disty	311	207	104	66.56
Lakhakhi Disty	297	139	158	46.80
Sangro Disty	331	214	117	64.65
Daulatpur Minor	330	148	182	44.85
Bellaro Minor	330	125	205	37.88
Average				53.27

Visro is a small minor (CCA 3622 acres) near Mirpurkhas town, where some of the tail has been converted to dwellings. Bellaro Minor has a political influential, where supplies are more stable than others.The Doso Dharoro Distributary is confronted with serious siltation problems as compared to others and requires more frequent discharge adjustments than others. On average, the gate settings are changed almost every other day. Figure 5.1 shows the number of days, in percent, when the gate settings of the off-taking channels have been changed.

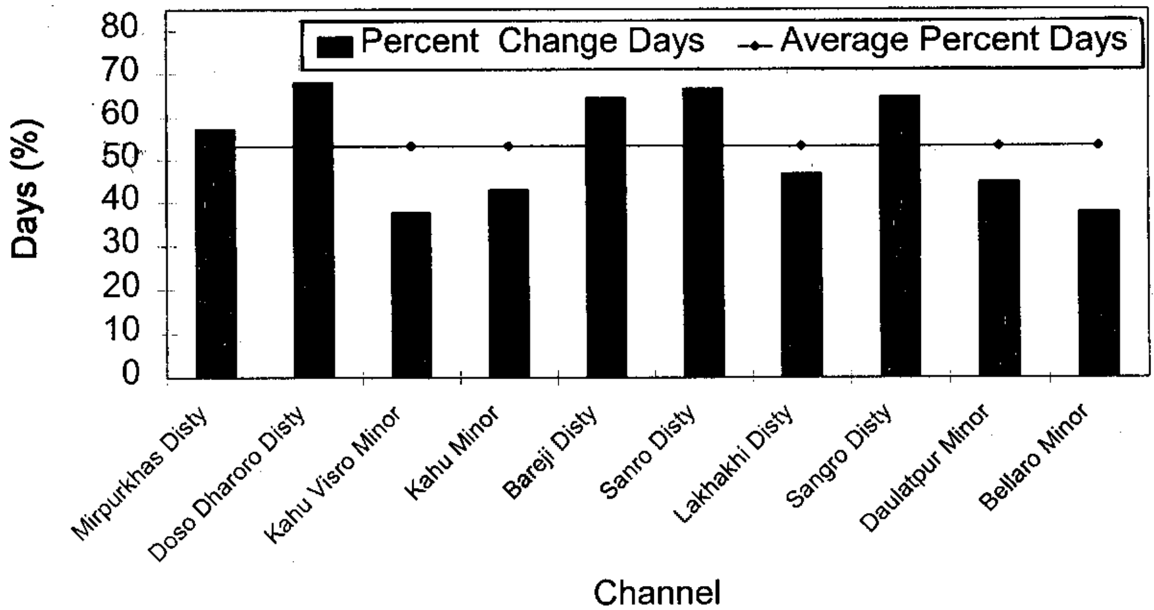

Figure 5.1. Operations (percent of total days) performed at head regulators in Mirpurkhas Sub-division.

5.4 CANAL CLOSURE IN MIRPURKHAS SUB-DIVISION

There are two types of closures that have been studied: (i) annual closure; and (ii) rotational closure .

5.4.1 Annual Closure

An interesting observation was that the annual closure period of 1997 differs for the two different sections of Mirpurkhas Sub-division . The Jamrao Canal Section experienced a longer closure than the West Branch Canal Section. The Jamrao Canal Head Regulator was closed in the first week of January 1997, which affected the Mirpurkhas Sub-division on January 10, 1997. The Jamrao Canal off-takes remained closed for 32-33 days, which is 44 percent higher than the last three off-takes of the West Branch Canal (Table 5.4). Lakhakhi Distributary and Bhittaro Minor remained closed for 27 and 22 days, respectively.

The difference in the duration of the closure for the two sections is because of the low supplies in the main canal after the closure period, which were diverted to the West Branch Canal, where the downstream channels were opened earlier than the upstream channels.

Table 5.4. Number of days for annual closure in1997 of the major off-takes of Mirpurkhas Sub-division.

Parent Channel	Off-take	No. of days closed
Jamrao Canal	Mirpurkhas Distributary	32
	Doso Dharoro Distributary	32
	Kahu Visro Minor	32
	Kahu Minor	32
	Bareji Distributary	33
	Sanro Distributary	33
West Branch Canal	Lakhakhi Distributary	27
	Bhittaro Minor	22
	Sangro Distributary	18
	Daulatpur Minor	18
	Bellaro Minor	18

5.4.2 Rotational Closure

The purpose of implementing the rotation schedules is to avoid running the irrigation channels below 70 to 75 percent of the full supply level, which causes siltation. This option is supposed to be exercised during the water-short periods, but in this study area, this practice is more selective than subjective. Rotational closures are implemented irrespective of the amount of water available and the season, but the frequency and intensity is less during rabi than in kharif. Similarly, the announced monthly schedules are also highly violated by the implementing agency, both spatially as well as temporally. Supposedly, each channel should be closed for a maximum of seven days in a turn, which has been rarely practiced in the Mirpurkhas Sub-division during the study period as given in Table 5.5a for Jamrao Canal Section and Table 5.5b for West Branch Canal Section.

A close look at Tables 5.5a and 5.5b also reveals the some channels have received preferential and selective treatment from the implementing agency at the rotation schedule preparation stage. For example, Kahu Visro Minor was planned to be closed for 21 days, while Bareji and Sanro Distributaries were planned for 35 days during the kharif season. However, Bareji and Sanro received preference as compared with Kahu Visro at the implementation stage. Kahu Visro Minor was closed for 20 days (against 21), while Bareji and Sanro were closed for 15 days each (against 35) due to rotation.

Each channel has been treated individually. Tables 5.5a and 5.5b show the official and the actual rotational closure of the eleven channels from November 1996 to October 1997. The planned schedules for the months of November-December 1996 and January-February 1997 were not available: however, all of the channels were running without any break in November and December, except Doso Dharoro Distributary. Overall, for the study period, Mirpurkhas Distributary, Lakhakhi Distributary and Daulatpur Minor are the worst hit (Figure 5.2). While the favorites have been the Bareji Distributary, Sanro Distributary, Sangro Distributary and Bhittaro Minor.

Table 5.5a. Rotational closure in days for Jamrao Canal Section, November 1996 to October 1997.

Month	Mirpur Disty		Doso Dharoro Disty		Kahu Visro Minor		Kahu Minor		Sanro Disty		Bareji Disty	
	Plan	Act	Plan	Act.	Plan	Act	Plan	Act.	Plan	Act.	Plan	Act.
November 96		0		1		0		0		0		0
December 96		0		0		0		0		0		0
January 97												
February 97		6								0		
March 97	0	0	7	13	7	4	7	4	7	4	7	3
April 97	7	3	0	5	7	5	7	7	7	0	7	0
Rabi Total Days	7	9	7	19	14	9	14	11	14	4	14	3
May 97	0	0	0	3	0	0	7	0	7	0	0	3
June 97	7	5	7	5	7	5	0	4	0	3	7	0
July 97	7	7	0	3	0	9	0	7	7	8	7	6$
August 97	7	11	7	6	7	6	7	0	7	4	7	5
September 97	7	4	7	3	7	0	7	4	7	0	7	6
October 97	0	0	7	0	0	0	7	0	7	0	7	0
Kharif Total Days	28	27	28	20	21	20	28	15	35	15	35	20
Total Closed Days	35	36	35	39	35	29	42	26	49	19	49	23

Table 5.5b. Rotational closure in days for the West Branch Canal Section, November 1996 to October 97.

Month	Lakhakhi Disty		Bhittaro Minor		Sangro Disty		Daulatpur Minor		Bellaro Minor	
	Plan	Act.	Plan	Act.	Plan	Act.	Plan	Act.	Plan	Act.
November 96						0		0		0
December 96		0		0		0		0		0
January 97										
February 97		0		0		0		8		4
March 97	0	0	0	0	7	4	7	0	0	0
April 97	7	10	0	0	7	0	7	8	7	0
Rabi Total Days	7	10	0	0	14	4	14	16	7	4
May 97	0	2	0	0	7	0	0	0	0	6
June 97	7	5	0	2	0	0	7	6	7	1
July 97	7	17	7	9	7	6*	7	6	7	18#
August 97	7	8	7	2	7	8	7	5	0	8
September 97	0	2	0	6	0	2	7	9	0	0
October 97	7	0	0	0	7	3	7	5	7	0
Kharif Total Days	28	34	14	19	28	19	35	31	21	23
Total Closed Days	35	44	14	19	42	23	49	47	28	27
Note:	* 2 days (breach), 4 days (rotation)									
	# 6 days (breach), 12 days (rotation)									

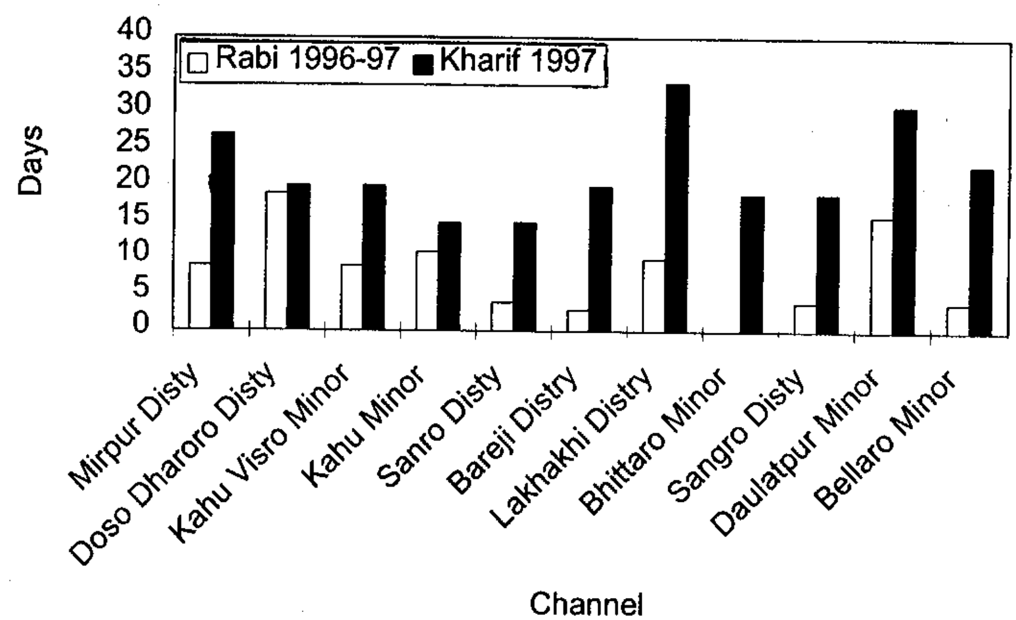

Figure 5.2. Roatational closure in Mirpurkhas Sub-division offtakes.

A big variation has been found in the rotation implementation during Rabi 1996-97. This variation is from zero days for Bhittaro Minor to nineteen days for Doso Dharoro Distributary (Tables 5.6). Lakhakhi Distributary farmers have suffered much more than others followed by Daulatpur Minor during kharif.

Certain channels could not draw water in the first week of July 1997, when water supplies were decreased at the head of the main canal due to a breach in the head reaches. The number of days for which these channels could not get water have been marked in Tables 5.5a and 5.5b.

Table 5.6. Rotational closure of the distributaries and minors during Rabi1996-97 and Kharif 97 in Mirpurkhas Sub-division.

Channel	Rabi1996-97	Kharif 1997
Mirpurkhas Disty	9	27
Doso Dharoro Disty	19	20
Kahu Visro Minor	9	20
Kahu Minor	11	15
Sanro Disty	4	15
Bareji Disty	3	20
Lakhakhi Disty	10	34
Bhittaro Minor	0	19
Sangro Disty	4	19
Daulatpur Minor	16	31
Bellaro Disty	4	23

5.5 WATER ALLOCATION

The irrigation systems of the sub-continent were designed and constructed to be drawing a specified amount of water throughout the year for different cropping intensities during the rabi and kharif seasons. The water allocations were based on the amounts of water available for most parts of the year. The construction of water storage reservoirs has not only ensured a more reliable supply of water, but has also increased the supply. This is why water duty (cusecs per thousand acres of CCA) has been used as a measure to study water allocation.

There is always a serious problem with different values of CCA for each offtaking channel in different records of the Provincial Irrigation Department. There have been adjustments in the allocated culturable command areas from time to time, but the records have not been updated. The figures used for this study have been computed from the CCA of the outlets of the respective channels and verified by the Executive Engineer of the Jamrao Canal. The actual water duty varies from time to time and channel to channel. The monthly water duties have been given in Table 5.7.

Seasonal water duties computed from the observed discharges have been shown in Figure 5.3. As is evident from this figure, there is little consistency in water allocation; however, the tendency is towards higher water supplies to the Jamrao Canal offtakes (Mirpur to Bareji Distributaries). Although water deliveries are increased in the kharif season, but the difference in water duties is not significant (with the exception of Doso Dharoro Distributary, Kahu Visro Minor and Kahu Minor) because of the frequent rotational closures during this season.

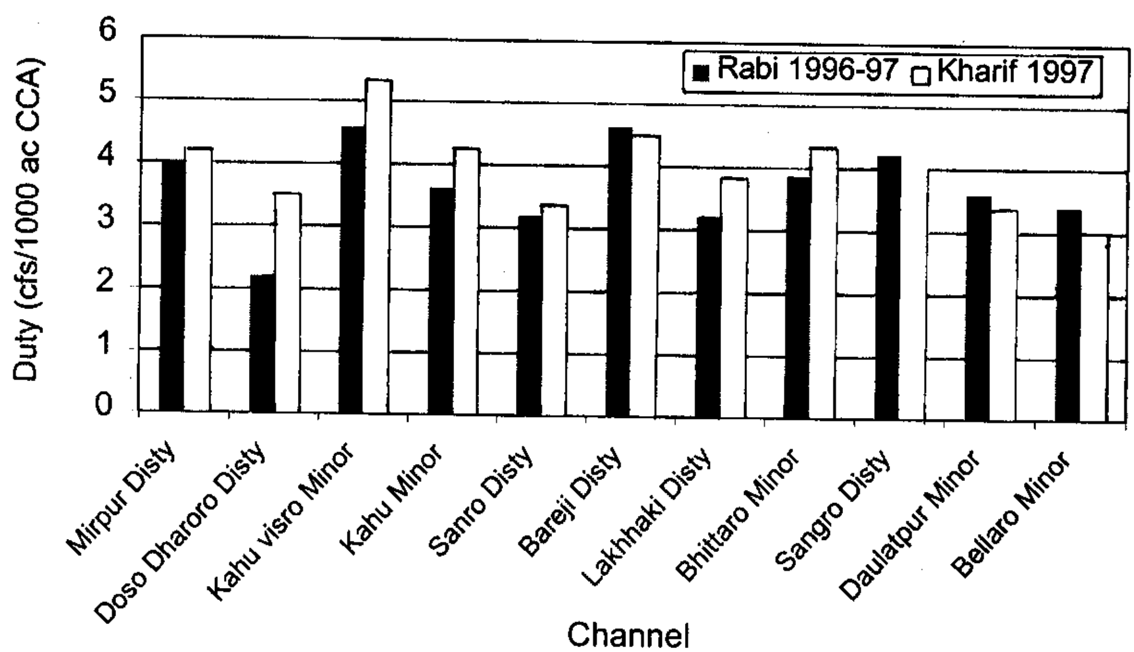

Figure 5.3. Seasonal water duty of Mirpurkhas Sub-division offtakes.

Table 5.7. Monthly water duty of the major off-takes of Mirpurkhas Sub-division.

Month	Mirpur Dy.	Doso Dy.	K.Visro Minor	Kahu Minor	Sanro Dy.	Bareji Dy.	Lakhaki Dy.	Bhitao Minor	Sangro Dy.	Daulatpur Minor	Belaro Minor
Nov. 96	4.69	2.4	5.46	3.44	3.27	4.62			4.79	4.52	3.77
Dec. 96	4.52	2.72	4.64	3.47	3.44	4.65	4.61	4.93	5.05	4.74	3.76
Jan. 97	3.72	2.19	4.77	4.11	3.51	4.9	4.28	4.71	4.54	4.42	3.44
Feb. 97	2.83	2.17	3.91	4.39	1.89	4.32	3.85	4.45	3.9	2.5	2.96
Mar. 97	4.46	1.22	4.3	3.34	3.57	4.63	2.35	4.44	3.41	3.79	3.42
Apr. 97	3.94	2.63	4.48	3.11	3.64	4.75	2.7	4.66	4.19	2.55	3.56
May. 97	5.05	2.78	5.97	4.27	3.49	4.43	4.16	4.9	4.19	4.17	2.73
Jun 97	4.33	2.92	5.15	3.97	2.91	4.84	3.8	4.51	4.5	2.97	3.51
Jul 97	3.58	3.45	3.83	3.12	2.73	4.29	2.26	3.28	3.37	3.48	1.62
Aug 97	3.29	3.48	5.05	4.7	3.81	4.91	3.98	4.48	3.44	3.39	2.87
Sep 97	4.4	3.61	6.34	4.75	3.58	3.72	4.41	3.84	4.26	2.88	3.68
Oct 97	4.6	4.07	5.78	4.66	3.78	4.82	4.51	5.06	4.17	3.35	3.59

5.6 UPSTREAM WATER LEVEL FLUCTUATIONS

The unilateral or unplanned gate manipulations cause disturbances in the downstream irrigation system. As discussed earlier in this chapter, water supplies into individual channels are regulated independent of each other. Lack of systematic operations responsive to the amount of water available and the crop water requirements causes dishcarge fluctuations. There is difficulty in quantifying the temporal variations in water levels over a certain period of time for lack of concrete data; however, field observations suggest that water levels go down in the morning and rise up again in the evening.

Because of the improper, illegal or merely malicious gate operations by the field staff of the operating agency and/ or the farmers, water level fluctuations occur all along the irrigation system. For this study, water depth variations have been studied at two points: (1) RD 343 of Jamrao Canal where the Mirpurkhas and Doso Dharoro Distributaries offtake, which are the first major offtakes of Mirpurkhas Sub-division in the Jamrao Canal Section; and (2) RD 38 of the West Branch Canal where Lakhakhi Distributary offtakes and is the first major channel in the West Branch Canal Section.

Figures 5.4 shows the daily water level variations in Jamrao Canal at RD 343, both for Rabi 1996-97 as well as for Kharif 1997. The water levels are changing almost daily. There is no particular trend of rise or fall in this variation; however, the fluctuations are usually in the range of 0.10 to 0.20 foot. Other important information revealed by Figure 5.4 is that water levels both for rabi and kharif are also almost the same, except in October 1997, when these levels have increased for about a two-week period. One of the reasons could be that the cross regulator at RD 292 is usually not operated and the discharge increases in the main canal are diverted to the West Branch Canal during kharif.

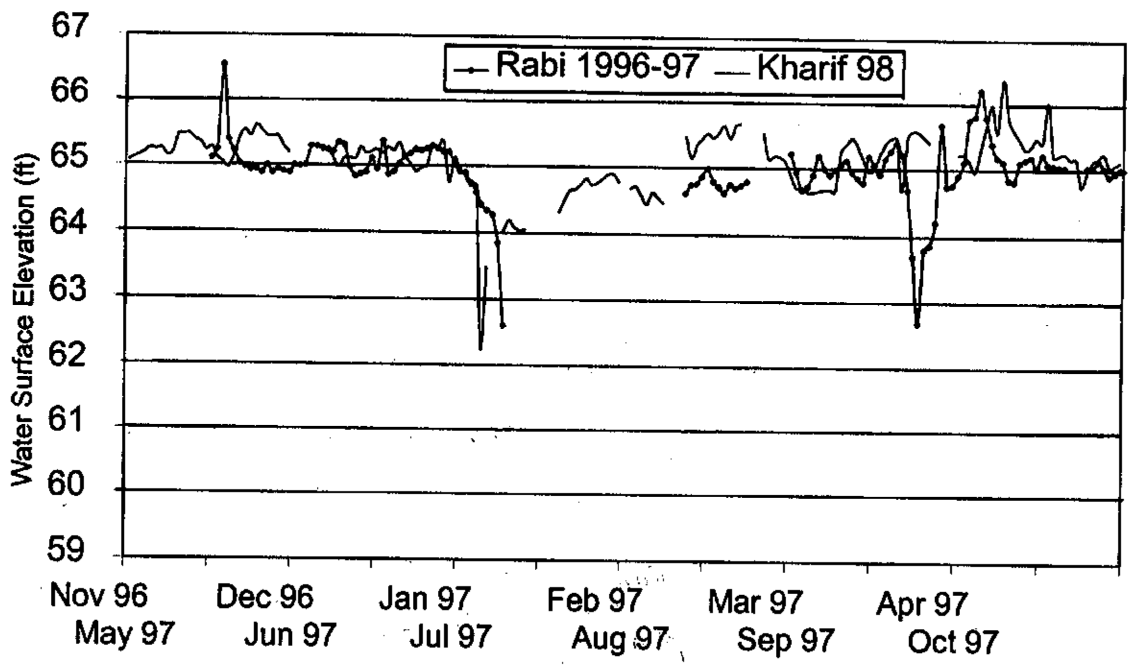

Figure 5.4. Water level fluctuations in Jamrao Canal at RD 343.

Figure 5.5 shows the daily water level fluctuations in the West Branch Canal at RD 38. The water depth has been changing nearly every day during both of the seasons, except for some parts of February and March 1997. There is a drop of about one foot in the water level during the last two weeks of March, when wheat is ripe in this part of Sindh and water is not much needed. The water level has increased by about one foot during kharif, however, the fluctuations are also higher than Rabi 1996-97.

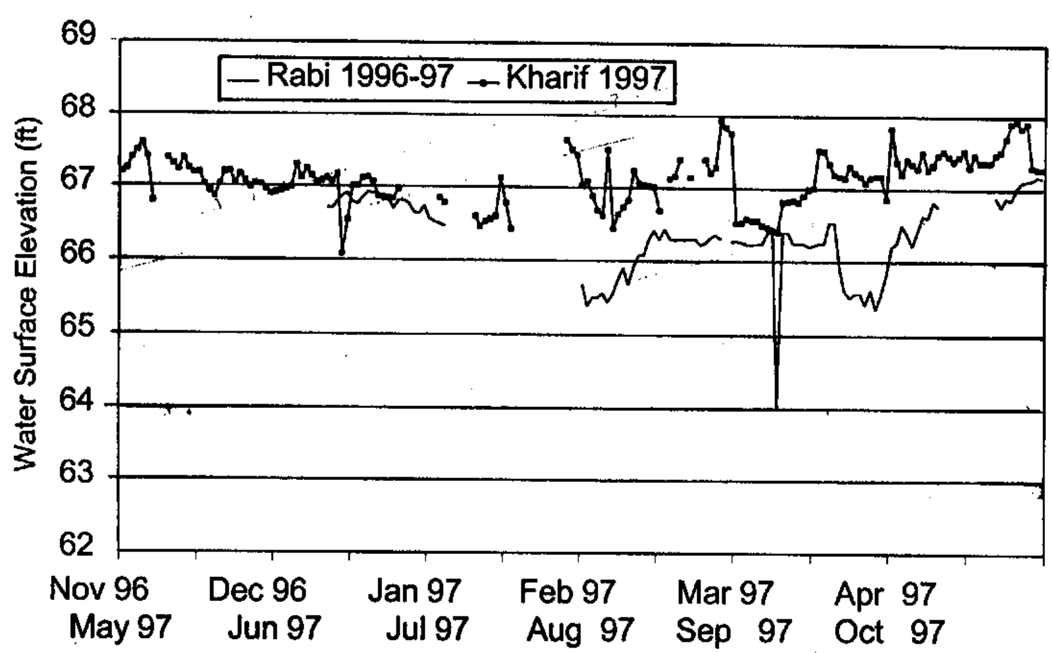

Figure 5.5. Water level fluctuations in West Branch Canal at RD 38.

The discontinuity of the plots for both of the channels shows that readings could not be taken for these days for one reason or another. However, there was water running except for the annual closure period (January-February 1997).

5.7 LIFT IRRIGATION IN MIRPURKHAS SUB-DIVISION

The command area of both the Jamrao Canal, as well as the West Branch Canal, is highly saline with a high water table. Tile drains have been laid in a part of this area under the Left Bank Outfall Drain (LBOD) Stage-I Project. The ground water is of very poor quality and cannot be used for irrigation. There are some areas, especially in the tail reaches of some channels where canal water can not be conveyed by gravity. Water is pumped from the distributaries or minor channels and even watercourses for irrigating these areas.

A survey conducted in this area revealed that there are about 80 to 100 pumping machines used for lifting water for irrigation. This number may be higher as there are some engines installed inside the houses. The details of the surveyed lift machines are given in Annexture B.

5.8 OTHER USES OF WATER

As discussed in the preceding section, ground water quality is very poor and cannot be used even for irrigation. There are few locations near the main canals where shallow groundwater is used for drinking and other household purposes; otherwise, the dependence is mainly on canal water.

Water requirements for drinking and other purposes of the municipal committee of Mirpurkhas Town are met mostly form the West Branch Canal and its off-takes, with special outlets sanctioned for this purpose. All of the industrial units in this area have access to and dependence on canal water supplies. Similarly, water is also provided to Mirpurkhas Railway Station through an outlet form Mirpurkhas Distributary. The details of these water supply schemes are given in Table 5.8. The actual discharge of these outlets may be higher than shown in this table.

Table 5.8. Details of non-irrigation uses of canal water in Mirpurkhas Sub-division.

S.No.	Name of Agency	Location	Discharge (cfs)
1	Railway Station, Mirpurkhas	W/C No. 120/1, Ex: Mirpur Dstry	1.5
2	Thar Mineral Processing Plant	W/C No. 5L, Ex: Jarwar Minor	0.75
3	S. L. D. Cotton Factory	W/C No. 120/1, Ex: Mirpur Distry	3.25
4	Municipal Committee Mirpurkhas Phase III	W/C No. 104/1BL, Ex: West Branch	10.00
5	Municipal Committee Mirpurkhas Phase I	Pipe, Ex: Jarwar Minor	4.00
6	Hindu Mari at Khan	W/C No. 93/2, Ex: Lakhakhi Disty	1.47
7	Darul Qamat Hostel Church	W/C No. 109/3L, Ex: Lakhakhi	1.13
8	Kak Bunglow	Pipe, Ex: Jarwar Minor	0.10
9	Mirpurkhas Sugar Mills	D/O No. 120/6R, Ex: Jamrao Canal	3.00

Source: Irrigation Department, Jamrao Division, Mirpurkhas, 1998.

Chapter 6

WATER DISTRIBUTION

6.1 GENERAL

Most of the studies and evaluation reports on irrigation system performance note a substantial gap between actual and expected performance levels. However, the level of performance assessment may be different for different systems, which can be from a tertiary level to the secondary and upward onto the national level. Similarly, operational performance could be assessed by different parameters, ranging from yield or cropping intensity at the farm level to a specific input target such as discharge, water level or timing of irrigation deliveries.

For comparative purposes between systems, the performance can be expressed as a dimensionless ratio or percentage. But the comparison between different systems may not make much sense because of a host of site-specific influences. At any given location, a time series analysis of real values may be the most useful measure of performance, but dimensionless ratios are more effective in comparing performance at different locations during the same time period (Murray-Rust, D.H. and Snellen, W.B., 1993).

As described in Chapter 5, the parameters to be evaluated for assessing the operational performance of Mirpurkhas Sub-division are equity in water distribution, variability in water distribution, reliability of water supply, frequency of gate operations and upstream water level fluctuations, with the help of different performance indicators.

6.2 EQUITY IN WATER DISTRIBUTION

The layout of the Mirpurkhas Sub-division irrigation system (Figures 2.1 & 2.2) shows that the Jamrao Canal Section comprises six distributaries/minors and the West Branch Canal Section comprises five offtakes.

The delivery performance ratio (DPR), which is the ratio of the offtakes duty to the system duty has been used as a measure to assess equity in water distribution along the Jamrao Canal and the West Branch Canal. The average of the seasonal water duty of the respective channels of Jamrao and West Branch Canals has been taken as the duty of the system. Inequity could be associated with different factors like lack of maintenance of the irrigation system, lack of interest of the operating agency, theft of water by the water users, lack or non-existence of objective oriented operations, and rent-seeking. This inequity is neither site-specific nor time-specific and could be observed anytime at any point along the system. Monthly DPR computed from the daily values, for all of the offtakes, is given in Table 6.1.

Table 6.1. Monthly DPR of the Mirpurkhas Sub-division offtakes.

Month	Mirpur Disty	Doso Dharoro	Kahu Visro Mr.	Kahu Minor	Sanro Disty	Bareji Disty	Lakhakhi Dy.	Bhittaro Mr.	Sangro Disty	Daulatpur Minor	Bellaro Minor
Nov96	1.26	0.64	1.47	0.92	0.88	1.24			1.30	1.23	1.02
Dec96	1.21	0.73	1.25	0.93	0.92	1.25	1.25	1.34	1.37	1.28	1.02
Jan97	1.00	0.59	1.28	1.10	0.94	1.32	1.16	1.28	1.23	1.20	0.93
Feb97	0.76	0.58	1.05	1.18	0.51	1.16	1.04	1.21	1.06	0.68	0.80
Mar97	1.2	0.33	1.15	0.90	0.96	1.24	0.64	1.20	0.92	1.03	0.93
Apr97	1.06	0.71	1.20	0.84	0.98	1.27	0.73	1.26	1.14	0.69	0.97
Average	1.08	0.60	1.23	0.98	0.86	1.25	0.96	1.26	1.17	1.02	0.94
May97	1.21	0.66	1.43	1.02	0.84	1.06	1.12	1.32	1.13	1.12	0.74
Jun97	1.04	0.70	1.23	0.95	0.70	1.16	1.02	1.21	1.21	0.80	0.95
Jul97	0.86	0.83	0.92	0.75	0.65	1.03	0.61	0.88	0.91	0.94	0.44
Aug97	0.79	0.83	1.21	1.12	0.91	1.17	1.07	1.21	0.93	0.91	0.77
Sep97	1.05	0.86	1.52	1.14	0.86	0.89	1.19	1.03	1.15	0.78	0.99
Oct97	1.10	0.97	1.38	1.11	0.91	1.15	1.21	1.36	1.12	0.90	0.97
Average	1.01	0.81	1.28	1.02	0.81	1.08	1.04	1.17	1.07	0.91	0.81

The Mirpurkhas and Doso Dharoro Distributaries both are offtaking at RD 343 of the Jamrao Canal, but in opposite directions. The difference in their withdrawals is on average about 50 percent for the rabi season (Figure 6.1). Similarly, Bareji and Sanro Distributaries are offtaking at RD 408 of the Jamrao Canal, but are having a big difference in water deliveries. Kahu Visro and Kahu Minors are also offtaking close to each other (2000 feet apart), but Kahu Minor is drawing about 25 percent less than Kahu Visro. Monthly variation in DPR of each offtake can also be observed from Figure 6.1.

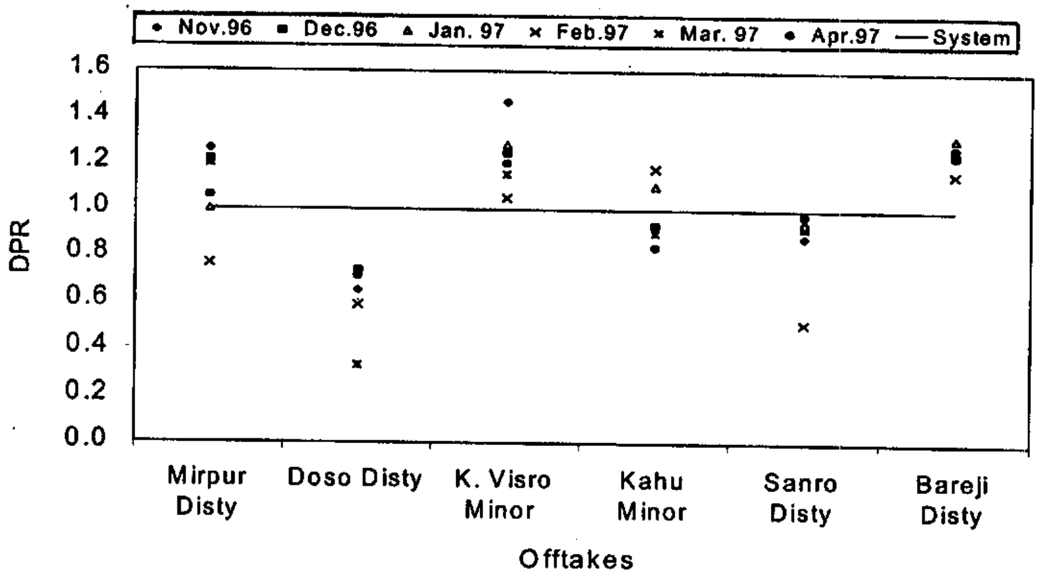

Figure 6.1. Equity in water distribution along Jamrao Canal, Rabi 1996-97.

The water distribution in the West Branch Canal Section in Rabi 1996-97 is shown in Figure 6.2. Each offtake of this section is located, on average, about five miles downstream of its upstream offtake, with Lakhakhi Distributary being the first one. However, being located in a head reach does not mean much in this system. Lakhakhi Distributary has been receiving much less than the rest of the channels during March and April. Bhittaro Minor looks to be a privileged channel followed by Sangro Distributary.

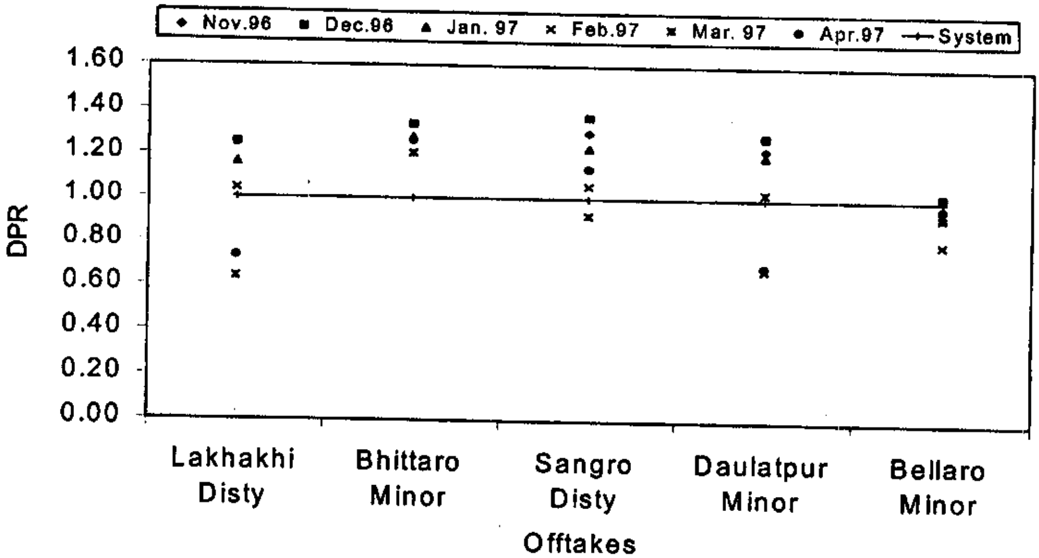

Figure 6.2. Equity in water distribution along West Branch Canal, Rabi 1996-97.

The kharif season is not very different from rabi. In rabi, February or March were a bit harder months, while in kharif mostly July has been the harder one regarding water supplies. In the Jamrao Canal Section, Doso Dharoro and Sanro Distributaries have received about 20 percent less than many other channels during kharif (Figure 6.3). Kahu Visro Minor has been supplied with 52 percent more than expected during September 1997.

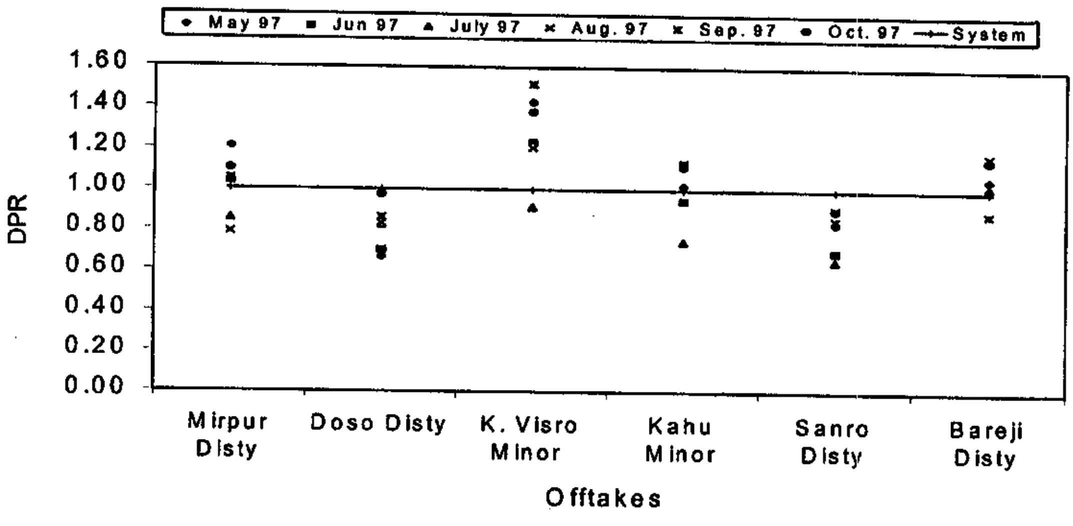

Figure 6.3. Equity in water distribution along Jamrao Canal, Kharif 1997.

During kharif, Bhittaro Minor has again received much higher supplies than the other channels. The DPR of Bellaro Minor is the least of all of the West Branch Canal Section offtakes followed by Daulatpur Minor (Figure 6.4). While, field observations show (as discussed in Chapter 5) that the discharge of Bellaro Minor has been more than the full supply levels most of the times; however, the problem seems to be with the figure of CCA provided by the Irrigation Department, where most likely the actual CCA is less than officially recorded. The higher value of CCA results in smaller values of duty and, hence, lower DPR values.

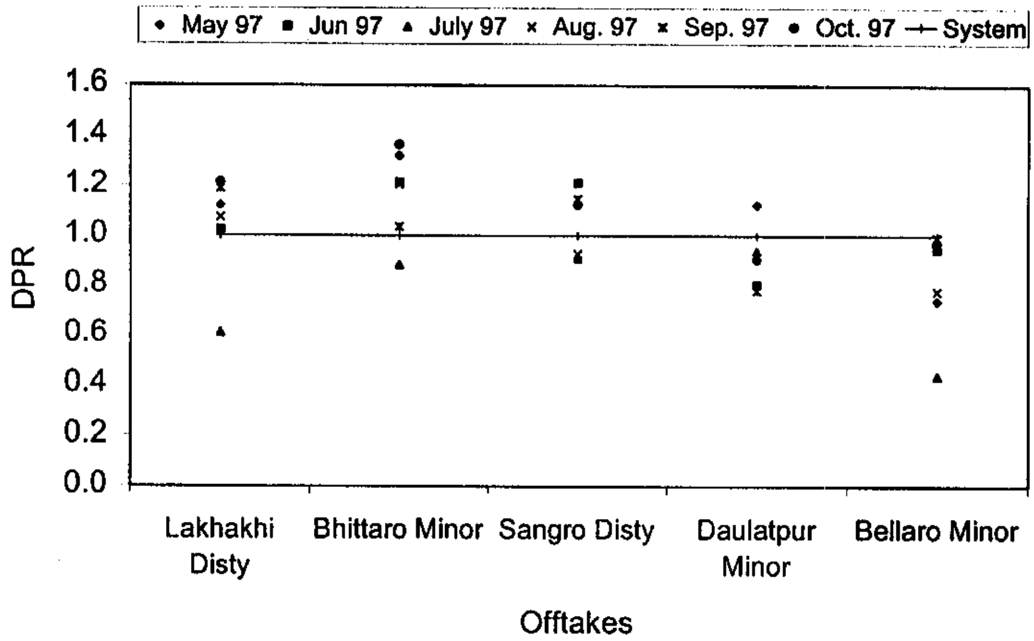

Figure 6.4. Equity in water distribution along West Branch Canal, Kharif 1997.

Interestingly, the seasonal DPR values for most of the offtakes have little difference between rabi and kharif seasons for both of the canal sections. As has been discussed in Chapter 5, water levels at RD 343 of the Jamrao Canal do not vary much between rabi and kharif seasons, while those of the West Branch Canal (RD 38) had a variation of about one foot. However, the DPR of Sangro Distributary, Daulatpur Minor and Bellaro Minor for rabi is higher than kharif (Figure 6.5). Six channels out of eleven have either reached or surpassed the expected level of performance, while the remaining five have performed below the expected levels.

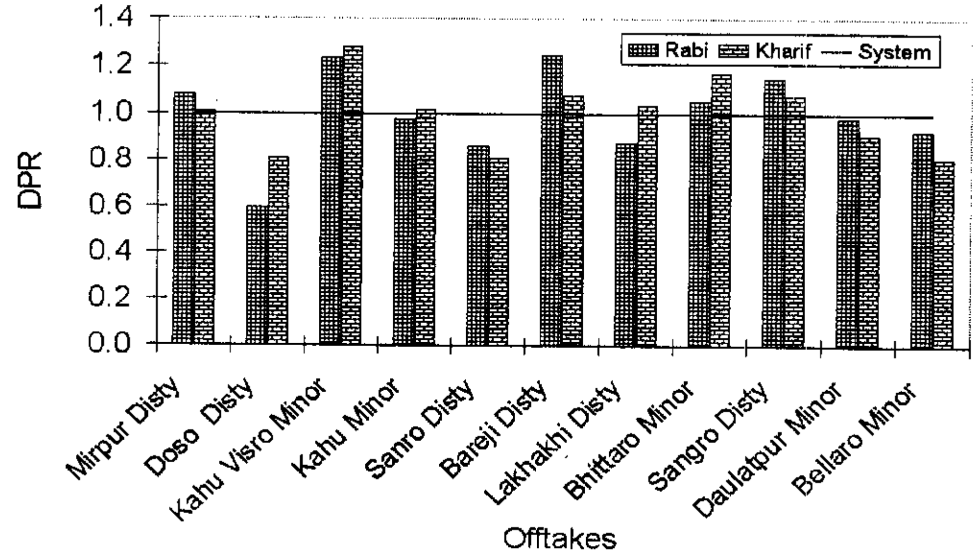

Figure 6.5. Seasonal DPR of Mirpurkhas Sub-division offtakes.

6.3 VARIABILITY IN WATER DISTRIBUTION

Irrigation flow deliveries are consistently fluctuating all of the time, mainly because of deliberate human interventions. These interventions are more prominent during the high demand periods and are predominantly caused by the " more water" desire of the water users in collusion with the operating agency. Any manipulations at an upstream control structure can be witnessed downstream as well in the form of water level fluctuations.

Two scenarios have been studied while analyzing the data for variability:

1. Variability in flow deliveries by taking into account the rotational closures; and
2. Variability in flow without considering the rotational closures (i.e. analyzing the data only for the period when the channel was open).

6.3.1 Variability in Flow With Rotation

Rotation schedules are supposed to be implemented when water supplies are below 70 to 75 percent of the expected levels, which is not really the case in the study area. Similarly, upstream water level fluctuations and unplanned gate operations have their own contribution to flow variability. The Jamrao Canal and the West Branch Canal Sections have been studied separately for two seasons. The first three months (November 1996 to January 1997) of Rabi1996-97 have comparatively the minimum variability in flow deliveries in the Jamrao Canal Section, which was caused by gate adjustments and upstream water levels as there had been no rotational closures (Figure 6.6). Mirpurkhas Distributary was closed for six days during February 1997 when variability reached 73 percent. With the start of rotational closures in March, the variability increased to as high as 95 percent for Doso Dharoro Distributary, which was closed for 13 days against the official schedule of 7 days. Overall, Bareji Distributary has performed much better than others during rabi.. The months of November and December 1996 have less than 10 percent variability for all the offtakes of West Branch Canal except Lakhakhi Distributary (Figure 6.7). Daulatpur Minor was closed for 8 days each in February and April 1997, while flow variability in Lakhakhi increases continuously from January onward to April (75 percent) when it was closed for 10 days. Bhittaro Minor has been the best: (1) for having no rotational closures; and (2) being a fixed orifice, there were no gate manipulations

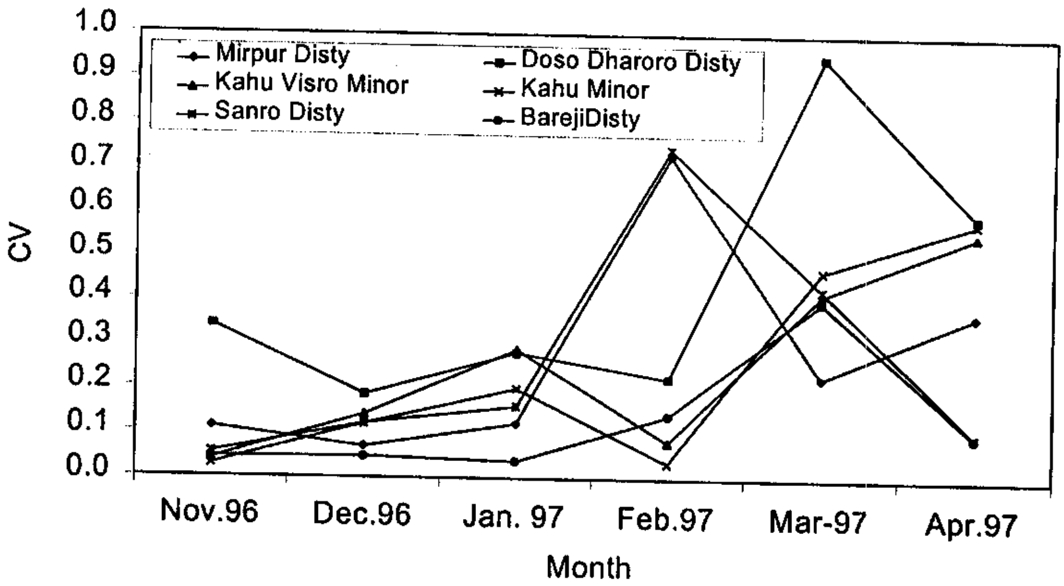

Figure 6.6. Variability in water distribution along Jamrao Canal, Rabi 1996-97.

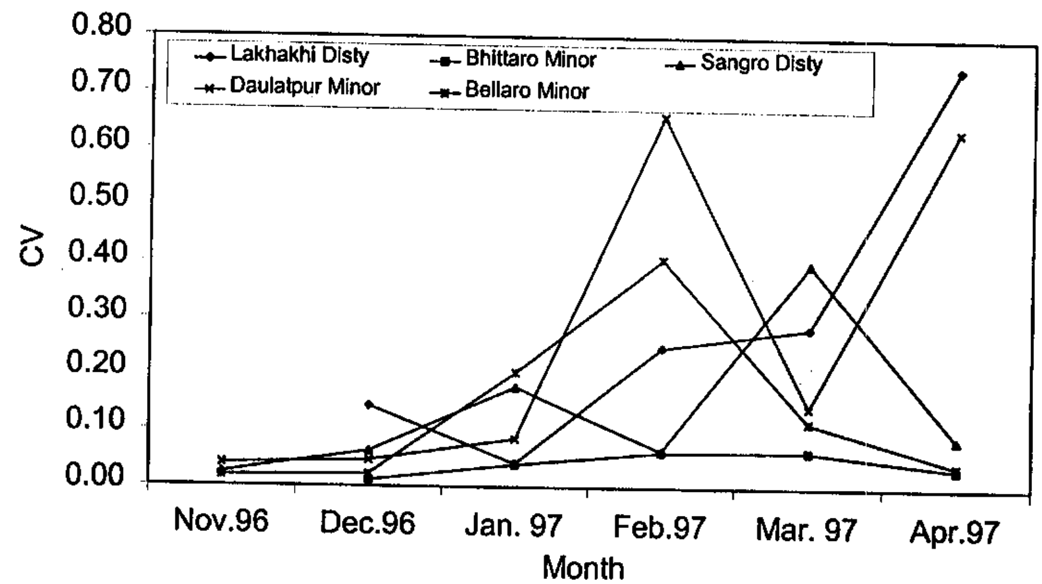

Figure 6.7. Variability in water distribution along West Branch Canal, Rabi 1996-97.

Upstream water levels at RD 343 of the Jamrao Canal do not differ much between rabi and kharif, but flow variability in the offtaking channels continuously runs high for almost all of the offtakes from May to July 1997 (Figure 6.8). The month of maximum discharge variability in the Jamrao Canal offtakes, with no exceptions to any channel, was July. These variations are decreasing with ups and downs to a minimum of 10-20 percent for five out of six channels in October, when even planned closure schedules were not implemented. October is a low water requirement month and farmers would not mind if a channel were closed for a few days.

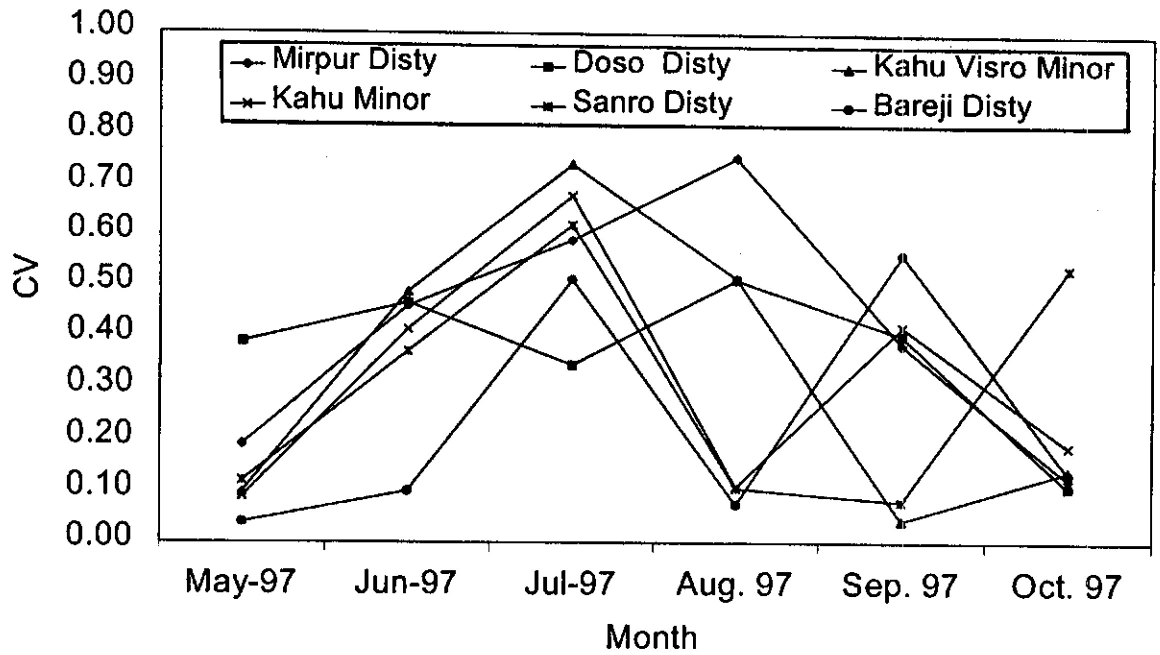

Figure 6.8. Variability in water distribution along Jamrao Canal, Kharif 1997.

A similar trend has been observed in the West Branch Canal offtakes, but with some higher variability than in Jamrao Canal. Lakhakhi Distributary and Bellaro Minor, the first and the last offtakes of Mirpurkhas Sub-division on West Branch Canal, respectively, were supplied variable deliveries even above 100 percent in July, even though both of them were closed for more than 50 percent (17 and 18 days, respectively) of the month against 7 days according to the official schedule. Daulatpur Minor was operated between 20 and 60 percent variability (Figure 6.9).

A comparative analysis of the coefficient of variation (CV) for rabi and kharif for all the offtakes of Jamrao Canal, as well as West Branch Canal, is shown in Figure 6.10. The CV for kharif is higher than rabi in all cases, but with very significant variations in the West Branch Canal offtakes. Figure 6.10 also reveals that Bareji Distributary was the least affected, which may be most probably because of the existence of an active Water Users Federation (WUF) created under a pilot study for farmer-managed irrigated agriculture conducted by the International Irrigation Management Institute (IIMI). The second least affected is Bhittaro Minor.

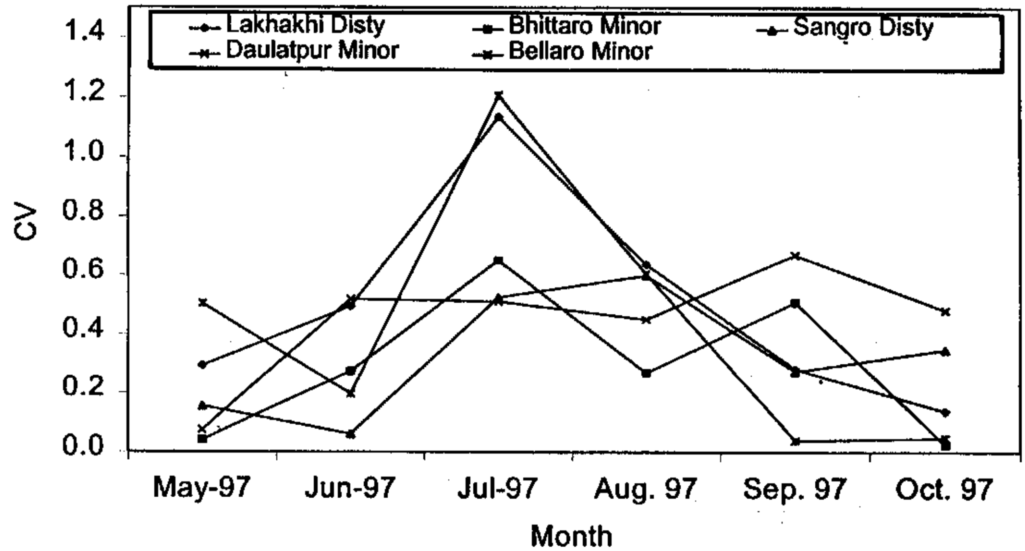

Figure 6.9. Variability in water distribution along West Branch Canal, Kharif 1997.

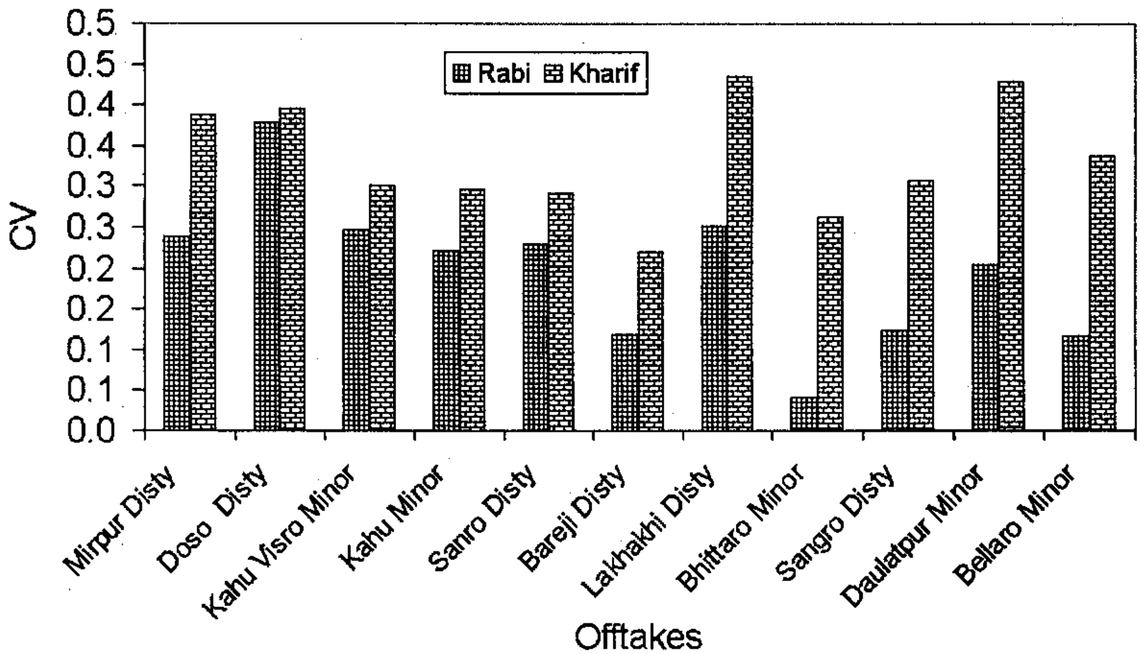

Figure 6.10. Seasonal variability of water distribution in Mirpurkhas Sub-division.

6.3.2. Variability in Flow Without Rotation

The purpose of this analysis was to evaluate the extent to which the rotation implementation contributed to variability in flow deliveries in the distribution system. The unwarranted and, sometimes, the prolonged rotations have an adverse effect, not only on crops, but also on rational economy. Also, canal water is a source of drinking water in the study area, where groundwater is of very poor quality.

Figures 6.11 to 6.14 show the variability in water supplies into the distributaries and minors of Mirpurkhas Sub-division without taking into account the closed days due to rotation. Figure 6.11 shows flow variability in the Jamrao Canal Section, where the maximum variability was found to be 30 percent for Doso Dharoro Distributary in March 1997, while the value for the same month and channel was 95 percent in the "with rotation" case. Flow variability in all of the West Branch Canal offtakes increases from November 1996 to April 1997, but still remains below 20 percent, with the exception of Lakhakhi Distributary (Figure 6.12). The highest variability for this distributary is about 30 percent in March, which was 73 percent during the same month for the "with rotation" case. (Please note that the scale of plots is the same in both cases for the respective canals.)

A tremendous difference can be observed in flow variability between kharif plots "with rotation" and "without rotation" (Figure 6.14). Variations are below 20 percent throughout the season for all of the offtakes in the "without rotation" case even in July, which was reaching about 120 percent in the "with rotation" case for Bellaro Minor.

A comparison of the seasonal values of the coefficient of variation for both rabi and kharif for all of the offtakes, and for both cases, is given in Figure 6.15, where the difference could be easily observed.

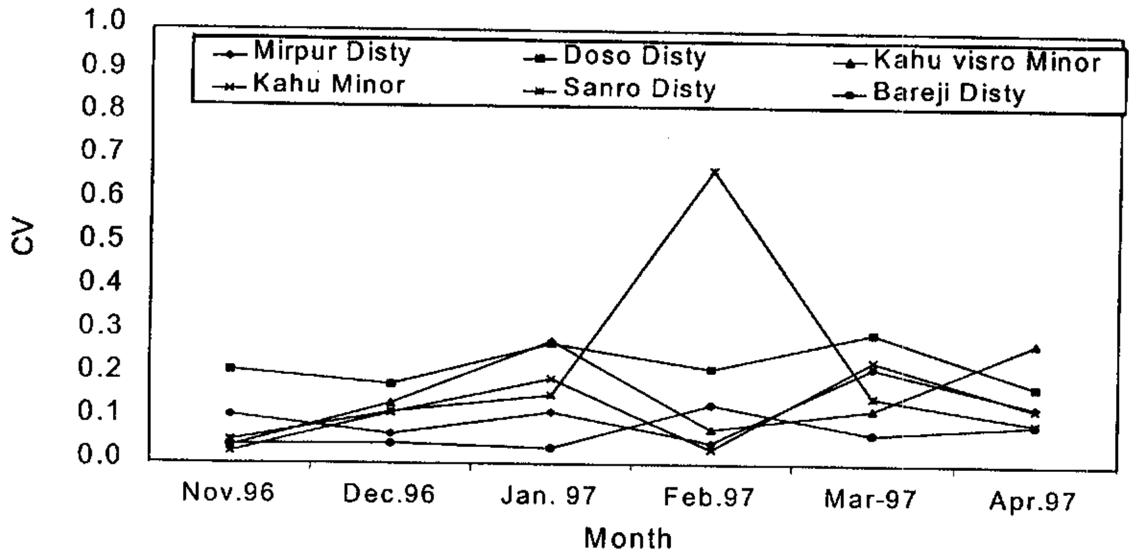

Figure 6.11. Variability in water distribution, without rotation, along Jamrao Canal, Rabi 1996-97.

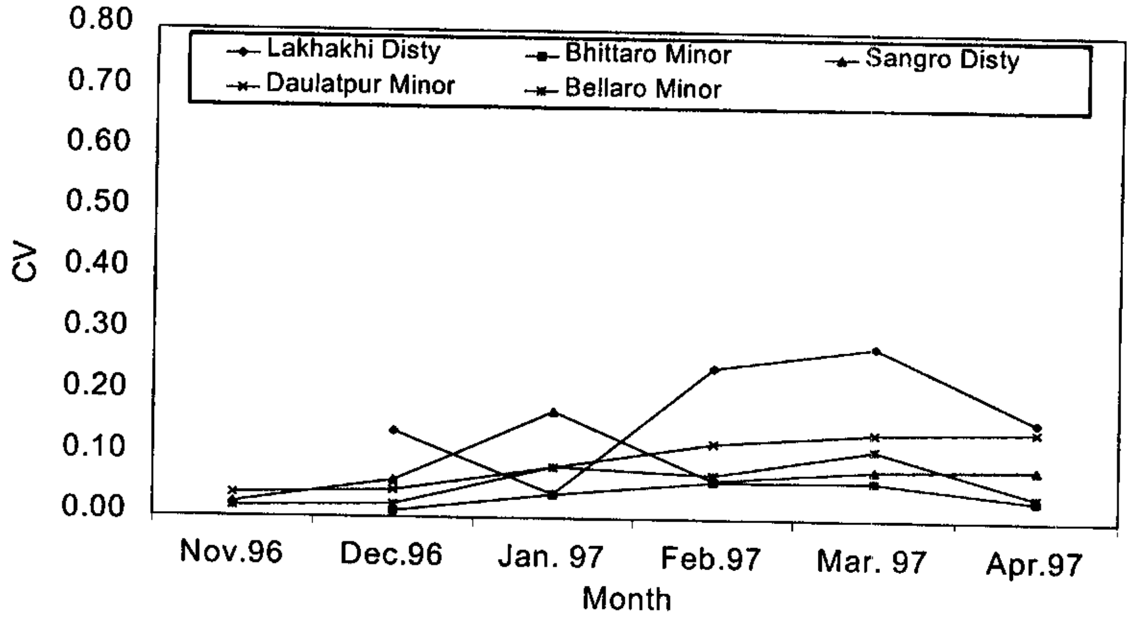

Figure 6.12. Variability in water distribution, without rotation, along West Branch Canal, Rabi 1996-97.

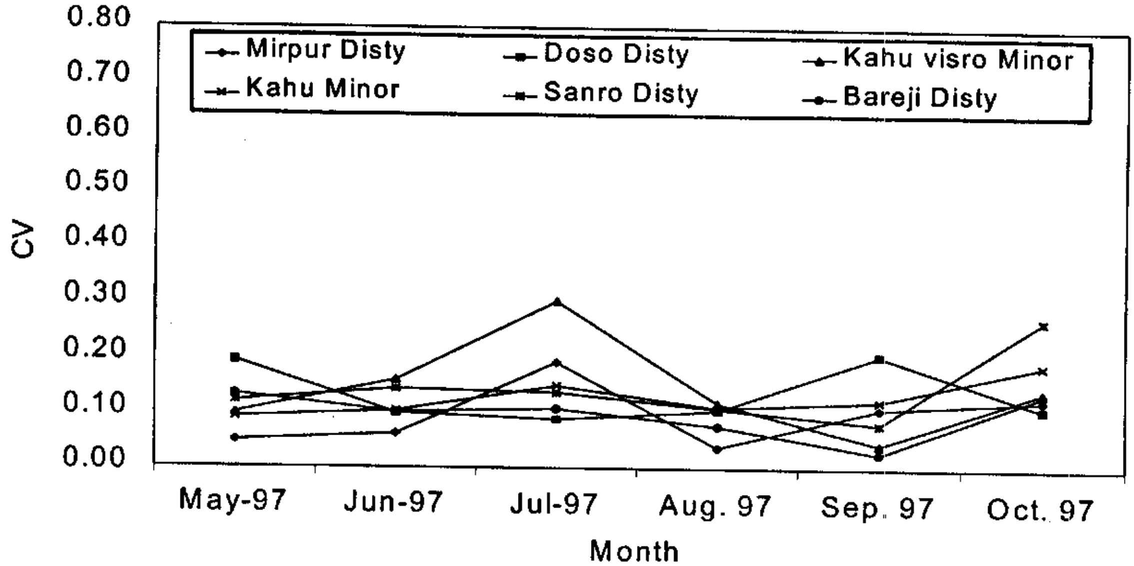

Figure 6.13. Variability in water distribution, without rotation, along Jamrao Canal, Kharif 1997.

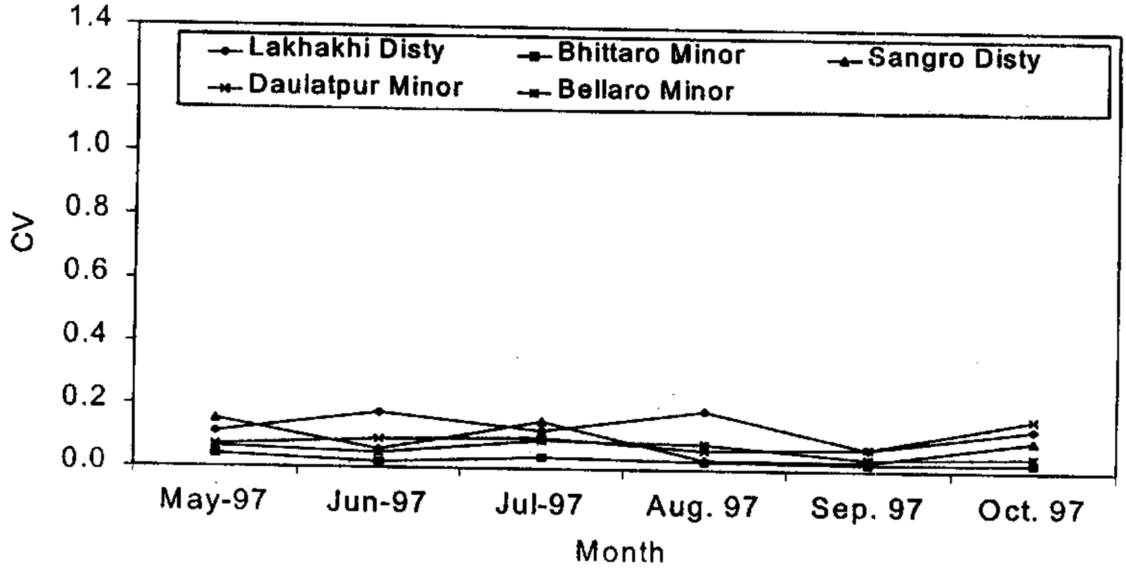

Figure 6.14. Variability in water distribution, without rotation, along West Branch Canal, Kharif 1997.

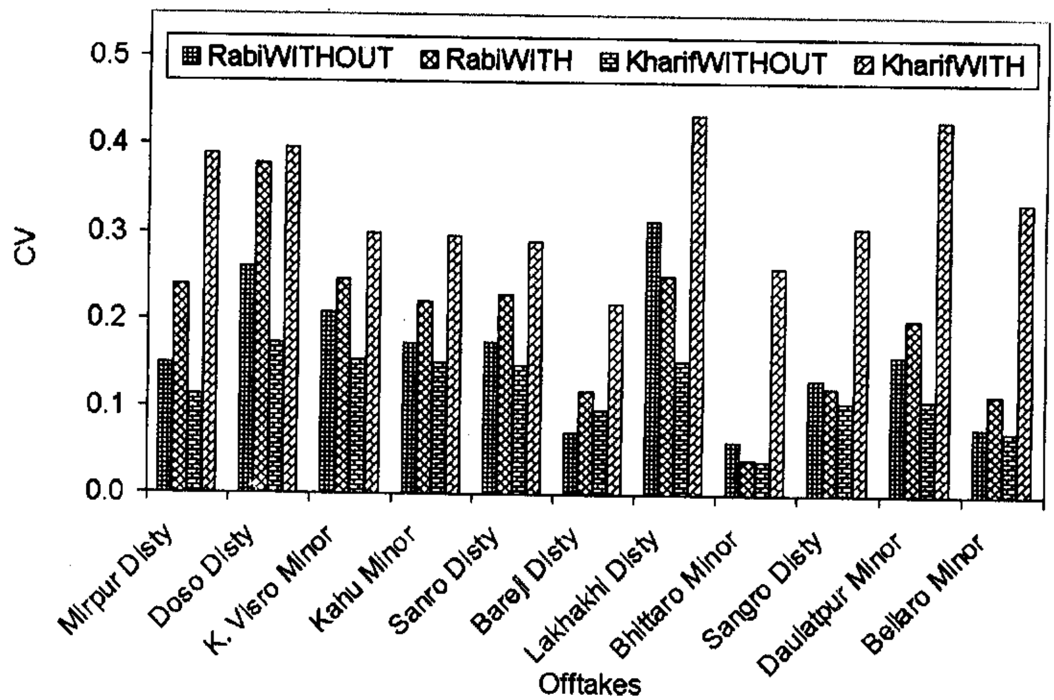

Figure 6.15. Seasonal variability in water distribution with and without rotation in Mirpurkhas Sub-division.

6.4 Reliability Of Water Supply

This section studies the degree of reliability or dependability of water supplies in the study area. The water delivery schedules prepared by the implementing authority have been analyzed with the actual field conditions to see whether these were implemented as planned, or there were deviations, and to what extent. Similarly, the uniformity in the planning and implementation of the schedules has also been studied.

Table 6.2 shows the ratio of the actual duration to the planned duration of the offtakes closure for the study period (November 1996 to October 1997). The annual closure was planned for two weeks only (January 1997) and water was released in the main canal after two weeks, but the offtakes could only draw water later. The last three offtakes of West Brach Canal were able to draw three days later when water had reached this section and the total closure period was 1.2 times the planned period.

Table 6.2. Annual canal closure in Mirpurkhas Sub-division.

Parent Channel	Off-take	No. of closed days		
		Official	Actual	Ratio
Jamrao Canal	Mirpurkhas Distributary	15	32	2.13
	Doso Dharoro Distributary	15	32	2.13
	Kahu Visro Minor	15	32	2.13
	Kahu Minor	15	32	2.13
	Bareji Distributary	15	33	2.20
	Sanro Distributary	15	33	2.20
West Branch Canal	Lakhakhi Distributary	15	27	1.80
	Bhittaro Minor	15	22	1.46
	Sangro Distributary	15	18	1.20
	Daulatpur Minor	15	18	1.20
	Bellaro Minor	15	18	1.20

The first four offtakes of the Jamrao Canal were closed for 32 days each, which is 2.13 times the planned duration. Bareji and Sanro Distributaries each were opened after 33 days, which is 2.2 times of what was officially planned. There is a considerable deviation from the official schedule of the annual closure, in general, and for the Jamrao Canal Section in particular; however, there is considerable uniformity in its actual implementation, except Lakhakhi Distributary and Bhittaro Minor.

Official records of the rotation schedules (for November 1996 to February 1997) could not be obtained from the Irrigation Department, because these were probably not prepared. Also, there were actually few closures from November 1996 to February 1997.

The ratios of the actual closure duration to the planned closure duration are given in Table 6.3 for rabi, kharif and the overall study period of one year. From Table 6.3, it is evident that the planned schedules have not been implemented for all of the channels. Mirpurkhas and Doso Dharoro Distributaries are the only channels in Jamrao Canal Section, which were closed for more than the planned period in Rabi 1996-97. Doso Distributary remained closed almost three times more than was originally scheduled. Bareji and Sanro Distributaries were the most advantageous of all both during rabi as well as kharif, where the closure schedules were implemented for less than half of the planned period.

Table 6.3a. Ratio of the actual closed duration to the planned duration of rotation in Mirpurkhas Sub-division for Jamrao Canal Section.

Period	Mirpur Disty	Doso Dharoro Disty	Kahu Visro Minor	Kahu Minor	Bareji Disty	Sanro Disty
Rabi	1.28	2.71	0.64	0.78	0.28	0.21
Kharif	0.96	0.71	0.95	0.53	0.42	0.57
Year	1.02	1.11	0.82	0.61	0.38	0.46

Table 6.3b. Ratio of the actual closed duration to the planned duration of rotation in Mirpurkhas Sub-division for West Branch Canal Section.

Period	Lakhakhi Disty	Bhittaro Minor	Sangro Disty	Daulatpur Minor	Bellaro Minor
Rabi	1.42	-	0.28	1.14	0.57
Kharif	1.21	1.35	0.67	0.88	1.09
Year	1.25	1.35	0.54	0.95	0.96

In the West Branch Canal Section, Lakhakhi was closed for more than the planned duration both in rabi and kharif, while Bhittaro Minor was closed for 1.35 times of the scheduled duration in Kharif only. Sangro Distributary was denied supplies for 28 and 67 percent of the seasonal schedule.

In one sense, it can be concluded from the above analysis that irrigation water supplies have been very reliable in most of the cases throughout the year because most of the channels have received water for more than the originally planned period. However, a big question is, can it be called reliable when the officially planned rotational closure schedule is erratic and biased?

Chapter 7

ABIANA ASSESSMENT AND COLLECTION

7.1 INTRODUCTION

Revenue is the total annual income of the state (Province/Country) which comes in the form of taxes. The government income from agricultural land (which in Pakistan goes to the provincial exchequer) includes abiana as well. The abiana is the service charges of water delivery for different crops under cultivation at different rates varying from canal to canal or barrage to barrage. These charges are being paid by the land owners to the Revenue Department.

There are wide diversities of agricultural conditions in most of the districts. These include soil, rainfall, water table depth, climate, to which may be added the construction of irrigation canals, which produces notable variation in the agriculture of different tracts and thus affect revenue.

7.2 DATA COLLECTION METHOD

Generally, the data for the cropped area under a canal command are collected by the Departments of Irrigation and Revenue. The Irrigation Department deputes "Abdar" and the Revenue Department deputes "Tapedar". The data are normally collected by physically measuring all the areas under different crops. Abdar always follows the command area map of the canal and surveys block to block or survey number to survey number. All of the information are recorded in the survey sheet, which are compiled and recorded in the assessment book. On the basis of cropped area, the revenues are estimated according to the prevailing rates for different crops.

Mirpurkhas Sub-division is the largest sub-division of Jamrao Canal and is being fed by the Jamrao Canal and West Branch Canal. The crops which had been cultivated since 1987 in Mirpurkhas Sub-division are given below.

To know the situation regarding the cropping intensity, cropping pattern and the revenue assessment, the data for about 10 years (1987-96) have been collected from the Irrigation Department, Jamrao Canal Division. The collected data have been analyzed and evaluated. The area under major crops such as cotton, sugarcane, rice, gardens, wheat, oil-seeds and fodder have been analyzed and explained in detail, while minor crops like jowar, bajra, maize, hurries, etc. are mentioned as miscellaneous and used in determination of cropping intensity and cropping pattern.

7.3 KHARIF CROPS (SUMMER CROPS)

The crops which are generally being cultivated since 1987 in kharif season are; cotton, sugarcane, rice, gardens, banana, vegetables, pulses, jowar, bajra, maize, fodder, chilies, oilseed and hurries.

7.4 RABI CROPS (WINTER CROPS)

The crops which are being cultivated in rabi season since 1986/87 are; wheat, garden, banana, vegetables, oilseed, fodder, pulses and hurries.

Crops cultivated from 1987 to 1996 and their intensity are discussed in the following subsections.

7.5 CROP CULTIVATION IN KHARIF SEASON

Cotton is one of the major crops of the Mirpurkhas Sub-division. The ten years of data are presented in Figure C.1., which shows that during 1987 and 1988 an average of about 23,000 acres were being cultivated. From 1989 to 1994, it has declined on an average of about 31 percent; while, it has increased significantly to about 100 percent and 70 percent more in 1995 and 1996 respectively, as compared to the previous six years (1989 to 1994).

Sugarcane cultivation figures for the 10-year period show that the trend of cultivation from 1987 to 1989 was almost the same Figure C.2 . The average cultivation was 13,000 acres for the three-year period; while, from 1990 to 1993 the cultivation was constantly decreasing from about 11,000 to 9,000 acres. Again, it has increased from about 12,500 acres to 16,000 acres during 1994 and 1995. However, it has gone down to about 10,000 acres, in 1996.

Rice was cultivated during the period under study (1987-1996). The annual cropped area has been given in Figure C.3, which shows that the rice cultivation varies from about 1,700 acres to 4,800 acres. Generally, rice cultivation is not much as compared to cotton and sugarcane. During ten years, the rice was cultivated more during 1994 and 1996.

Garden is considered as a one year/ two seasons crop. The cultivation of garden has slightly decreased from 1987 to 1993. After 1993, it has increased again as shown in Figure C.4 .

Miscellaneous crops like banana, vegetable, pulses, jowar, bajra, maize, chilies and hurries were cultivated from 1983 to 1996, which on an average was about 5000 acres for the ten-year period.

Next >>

7.6 CROP CULTIVATION IN RABI SEASON

Wheat is one of the major crops of the rabi season. From the collected data, it is observed that the cultivation of wheat was almost the same from 1987-88 to 1990-91, which was on an average of about 45,000 acres in each year. While from 1992-93 to 1996-97, it decreased from 45,000 acres to about 35,000 acres. Thus, for a 5-year period, the wheat cultivation decreased by about 10,000 acres. The results are presented in Figure C.5 .

Oil seed cultivation data for 10 years was gathered and is shown in Figure C.6. The data show that oil seed cultivation during the period 1987-88 to 1993-94 was very small, ranging from about 17 acres to 220 acres, whereas, in 1994-95 and 1996-97 the cultivation has increased to about 430 acres and 758 acres respectively .

Fodder cultivation data from 1987-88 to 1994-95 show that the cultivation varied from about 7,500 acres to about 10,000 acres. This shows that the cultivation of the fodder crop was not significantly changed. However, in 1996-97, it was almost nil as shown in Figure C.7.

Miscellaneous crops such as banana, vegetable and hurries were cultivated during the ten-year period. The average for ten years of data show that each year the cultivation was about 2500 acres.

7.7 CROPPING INTENSITY FOR KHARIF SEASON

Using the collected data on crop cultivation during the kharif season, the cropping intensity has been determined, and is presented in Figure 7.1, which shows that the cropping intensity for the year 1987-89 was about 33 percent. From 1990 to 1993 it has decreased to about 30 percent. But again it has increased to an average of about 35 percent in the last three years (i.e from 1994 to 1996).

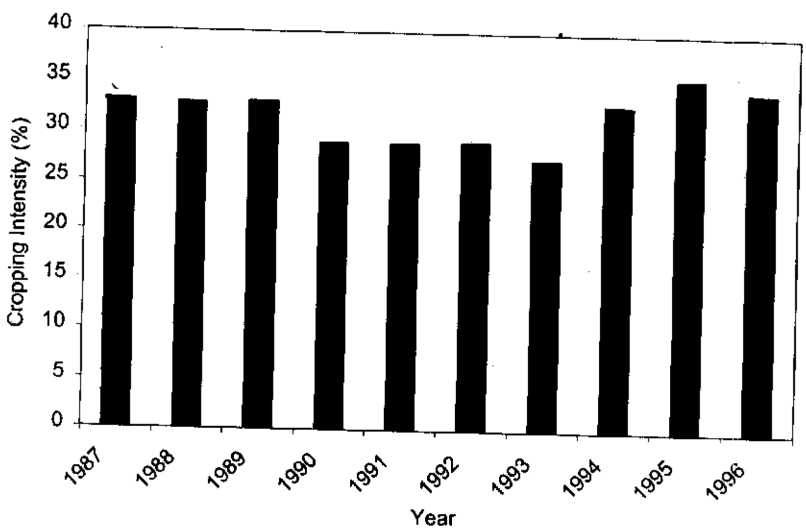

Figure 7.1. Cropping Intensity for Kharif in Mirpurkhas Sub-division from 1987 to 1996.

7.8 CROPPING INTENSITY FOR RABI SEASON

From the cultivated data for rabi season for ten years, the cropping intensity has been determined, as shown in Figure 7.2, where from 1987 –88 to 1991-92 the cropping intensity is almost constant, which is about 30 percent. From 1992-93 to 1996-97 it has continuously decreased and has reached about 20 percent in 1996-97. It is also clear from this data that the cropping intensity of each year is much lower than the designed cropping intensity, which is 53 percent.

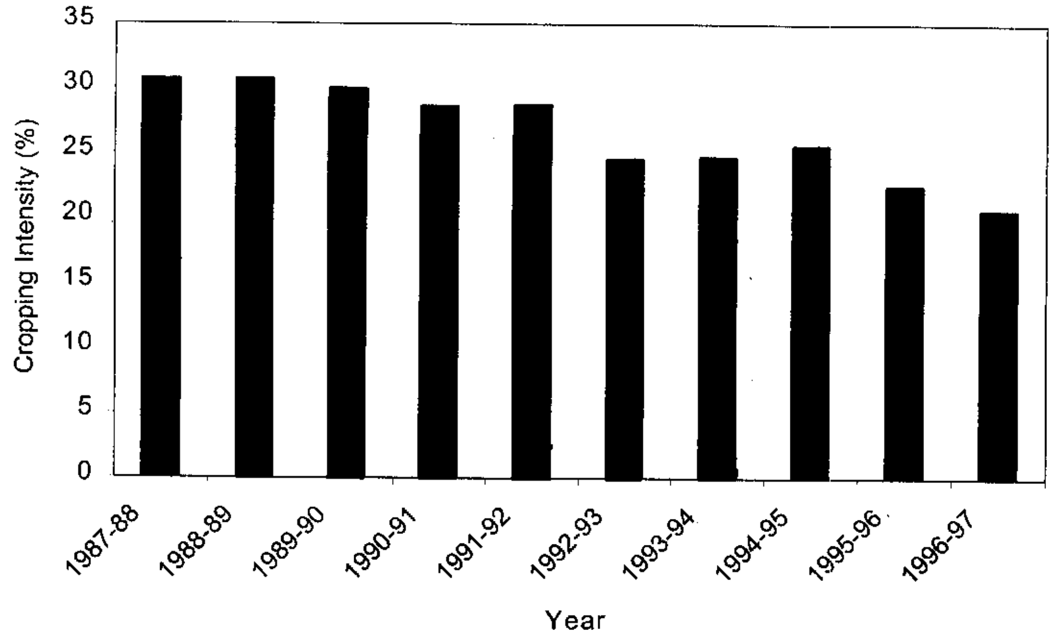

Figure 7.2. Cropping Intensity for rabi in Mirpurkhas Sub-division from 87-88 to 96-97.

7.9 CROPPING PATTERN FOR KHARIF SEASON

The collected data on crops cultivated in the command area of Mirpurkhas Sub-division have been analyzed and the cropping pattern, in percent, has been determined. The year-wise and crop-wise cropping pattern is presented . The average of ten years data for each crop has been plotted and is shown in Figure 7.3, where the fodder and cotton are cultivated more than others at about 9 percent, while the garden and sugarcane are the third and fourth ranked crops (i.e. about 6 and 5 percent, respectively). The rice has the least cultivation of all and is about 1.4 percent. Other miscellaneous crops are a very small percent that are shown in Figure 7.3.

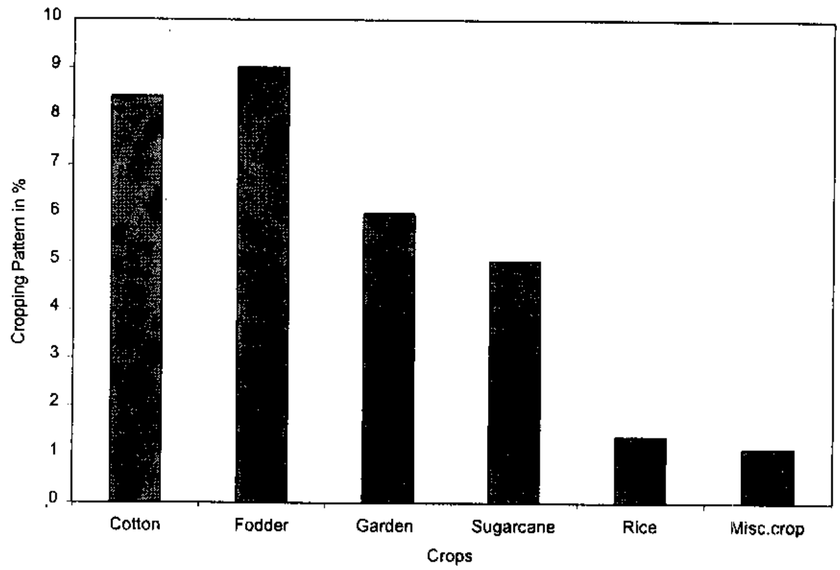

Figure 7.3. Cropping Pattern for Kharif in Mirpurkhas Sub-division from 87 to 96.

7.10 CROPPING PATTERN FOR RABI SEASON

Similarly, like the kharif season , the cropping pattern for rabi season has been determined from the collected data on crop cultivated. The average of ten years data for each crop has been plotted and shown in Figure 7.4, where the wheat is the most significant crop being cultivated during this period at about 16 percent. The second highest crop of this season is garden (garden is for both seasons) that is about 6 percent. The fodder ranks third at 3.3 percent. The miscellaneous crops including vegetables are about 0.7 percent while the oilseeds are a very small percent that are shown in Figure 7.4 as well.

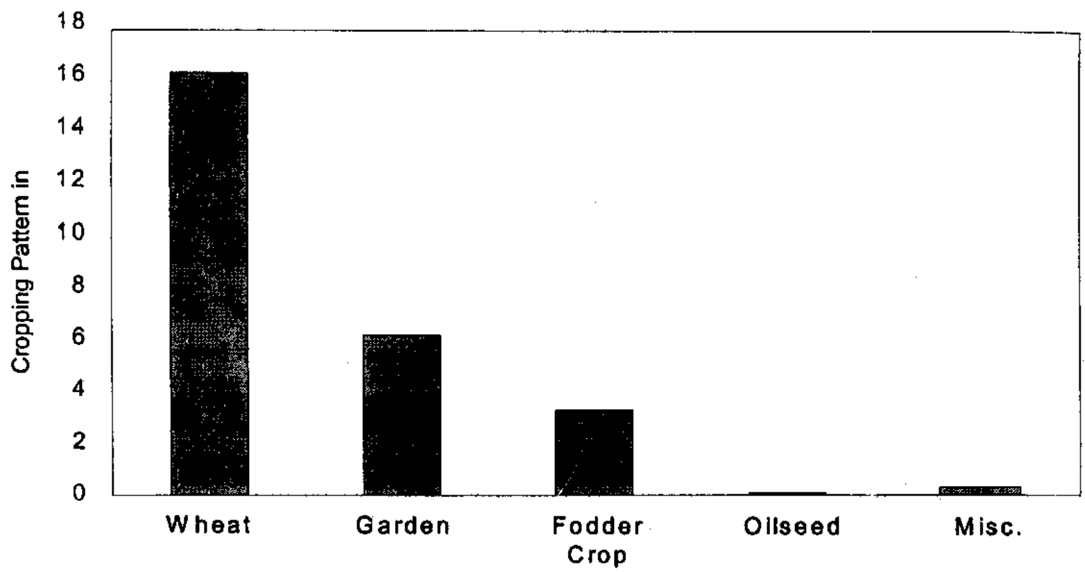

Figure 7.4. Cropping Pattern for Rabi in Mirpurkhas Sub-division from 1987-88 to 1995-96.

7.11 WATER RATES

Water rates for different crops for kharif and rabi seasons from 1987-88 to 1996-97 have been collected and presented in Tables C.1 and C.2, respectively. The tables show that the water rates were the same from 1987 to 1992, but after 1992, every year the rates were increased for all crops ranging from 10 percent to 20 percent.

7.12 ABIANA ASSESSMENT FOR RABI

On the basis of crops cultivated and their water charges, the abiana has been assessed for the ten-year period from 1987-88 to 1996-97. These assessments are shown in Figure 7.5, where the assessment from 1987-88 to 1991-92 was almost the same, which is an average about Rs. 1.8 million. During this period, the cropping intensity and water charges are almost the same. Figure 7.5 also shows that from 1993-94 to 1996-97, the assessment has constantly increased, though the cropping intensity has decreased during this period. The reason for more assessment is that the water rates from the year 1993-94 has continually increased .

7.13 ABIANA ASSESSMENT FOR KHARIF SEASON

Similarly, like the rabi season , the assessment for the kharif season for the ten-year period from 1987 to 1996 has been made and shown in Figure7.6, where the first three years are almost the same at about Rs. 3.1 million. Looking into the cropping intensity and water charges, these two variables have remained almost the same for this three -year period. Whereas, from 1990 to1992, the assessment has decreased. This has been confirmed from the cropping intensity that has also decreased, and water rates had remained the same. This figure further shows that the assessment from 1993 to 1996 has continuously increases significantly. The reasons for abrupt increased in assessment are that the cropping intensity and water rates for this period are continuously increasing.

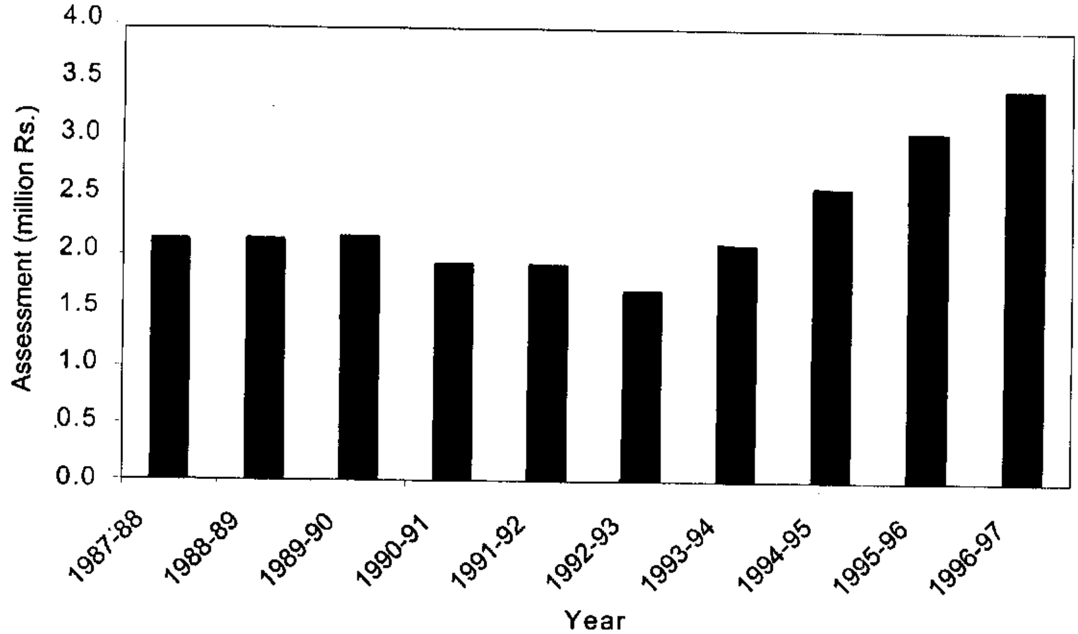

Figure 7.5. Assessment in Million Rs. for rabi from 1987-1996 in Mirpurkhas Sub-division.

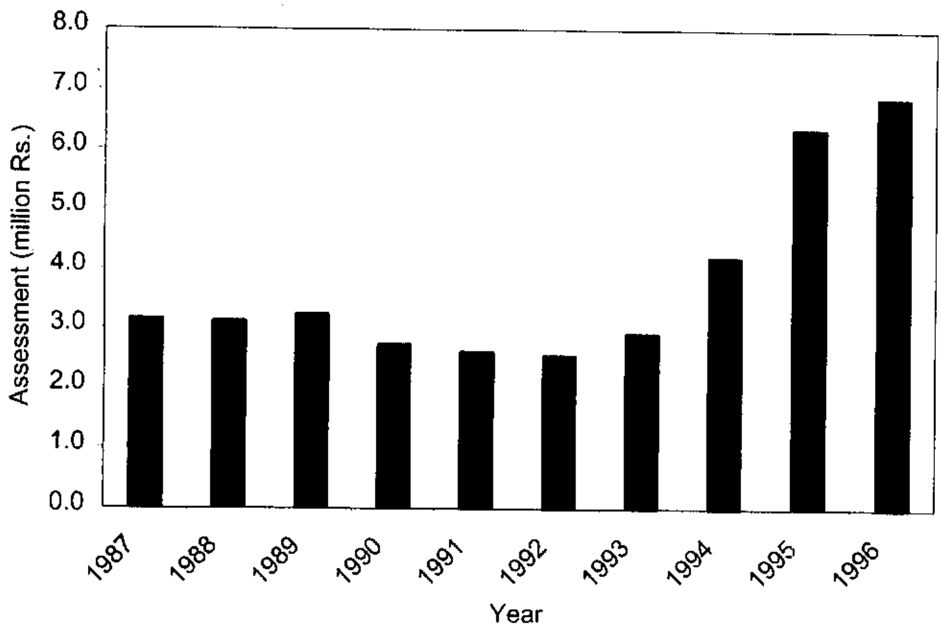

Figure 7.6. Assessment in million Rs. for kharif from 1987-1996 in Mirpurkhas Sub-division.

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APPENDICES

ANNEXURE: A VARIATIONS IN DAILY DISCHARGE AT THE HEAD REGULATORS IN MIRPURKHAS SUB-DIVISION

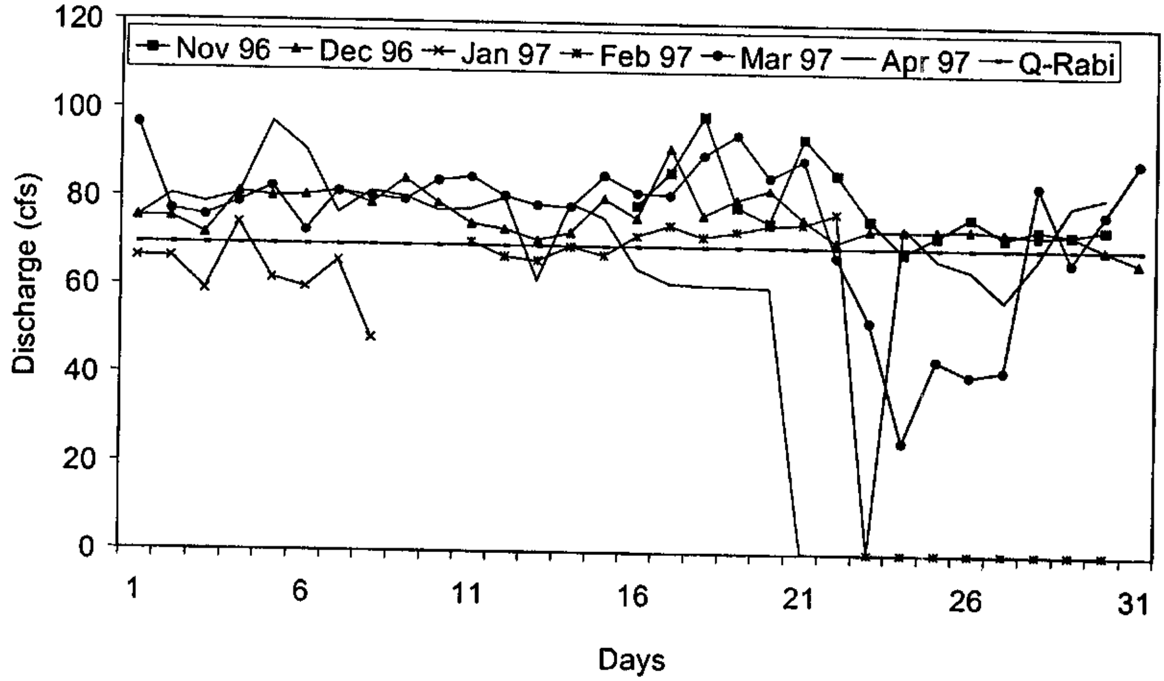

Figure A.1. Daily discharge variations at Mirpur Disty head, Rabi 1996-97.

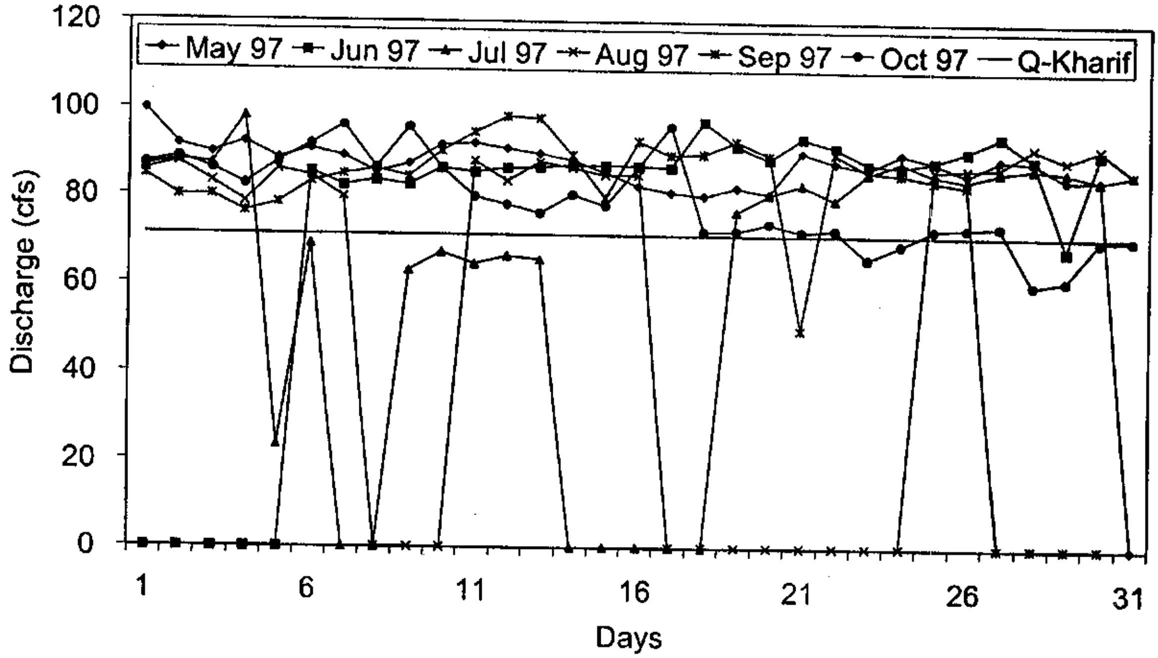

Figure A.2. Daily discharge variations at Mirpur Disty head, Kharif 1997.

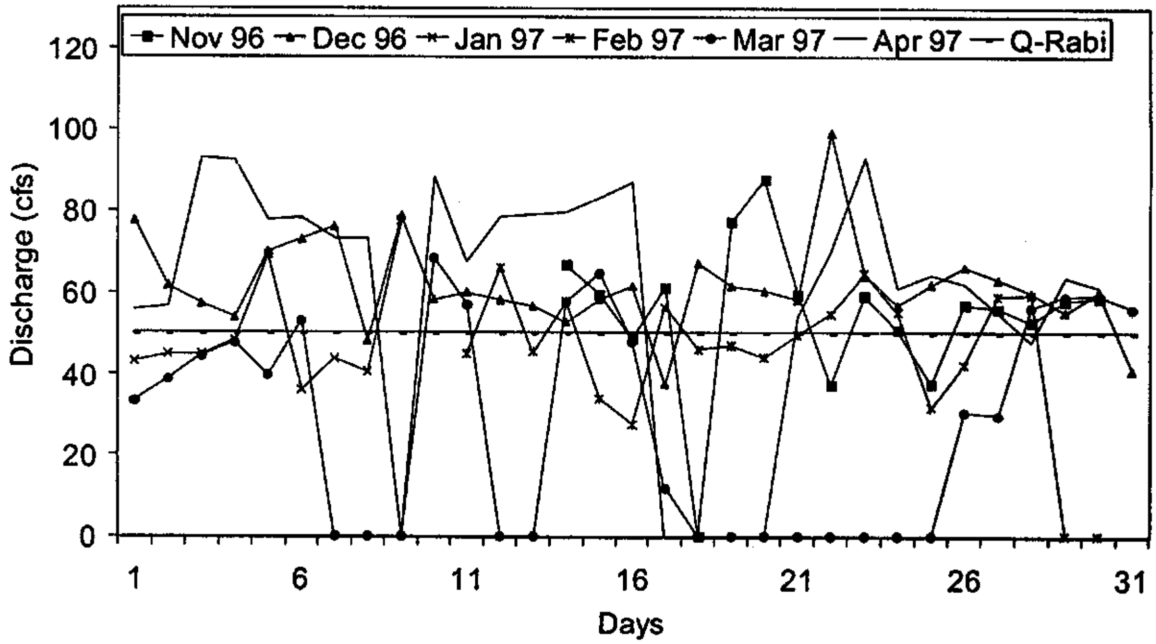

Figure A.3. Daily discharge variations at Doso Disty head, Rabi 1996-97.

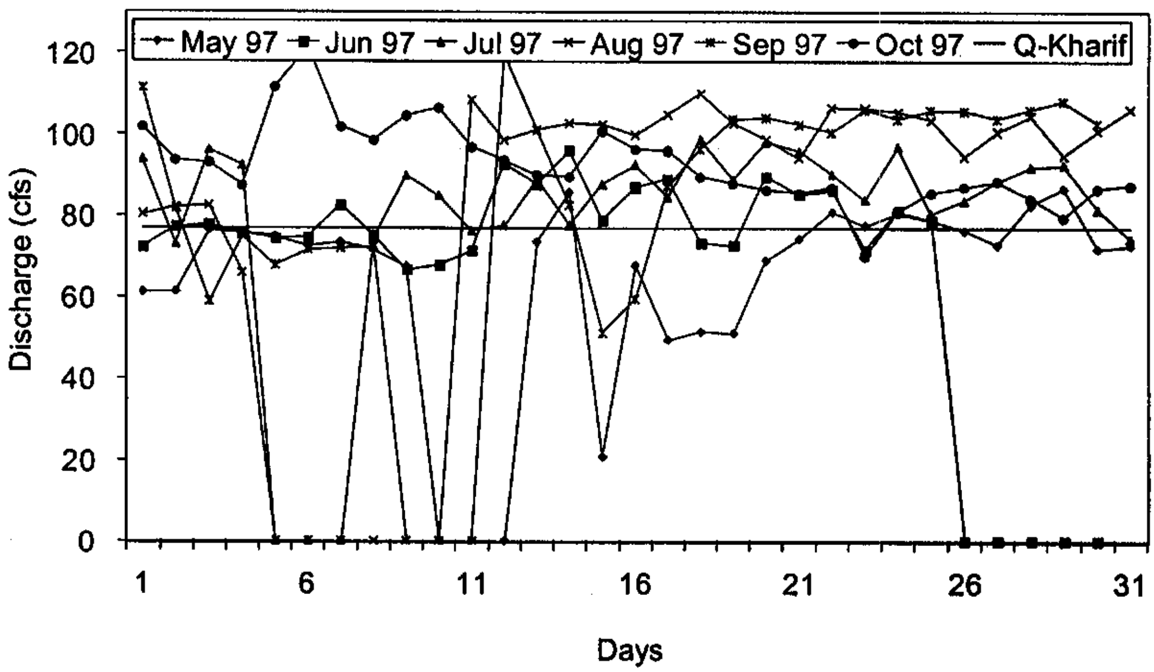

Figure A.4. Daily discharge variations at Doso Disty head, Kharif 1997.

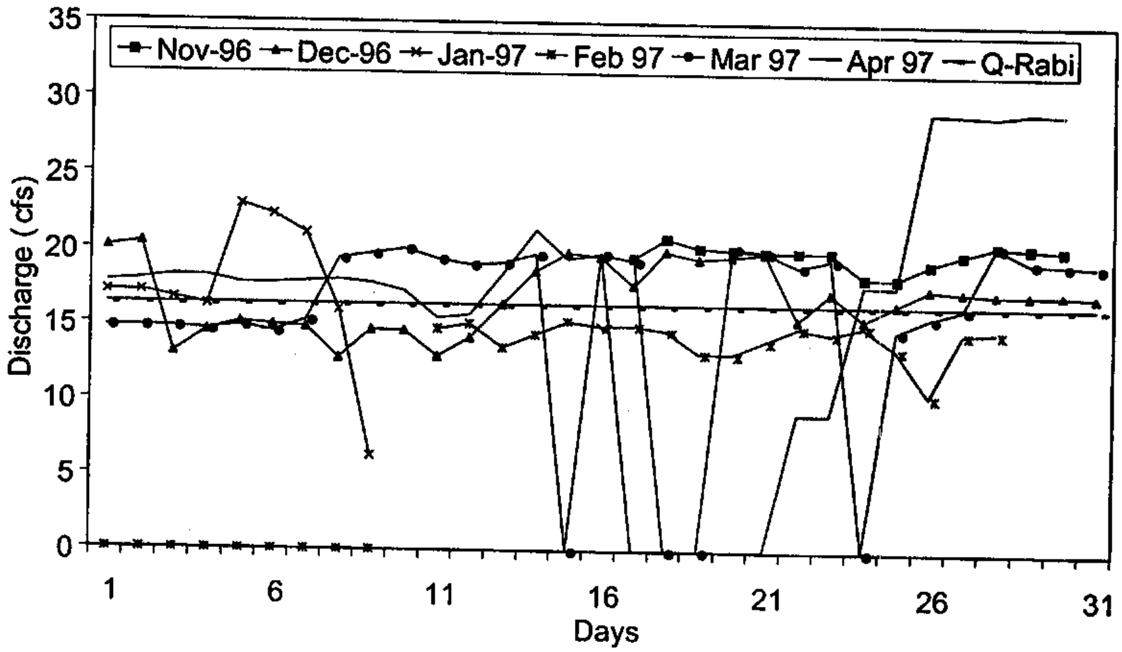

Figure A.5. Daily discharge variations at Kahu Visro Minor head, Rabi 1996-97.

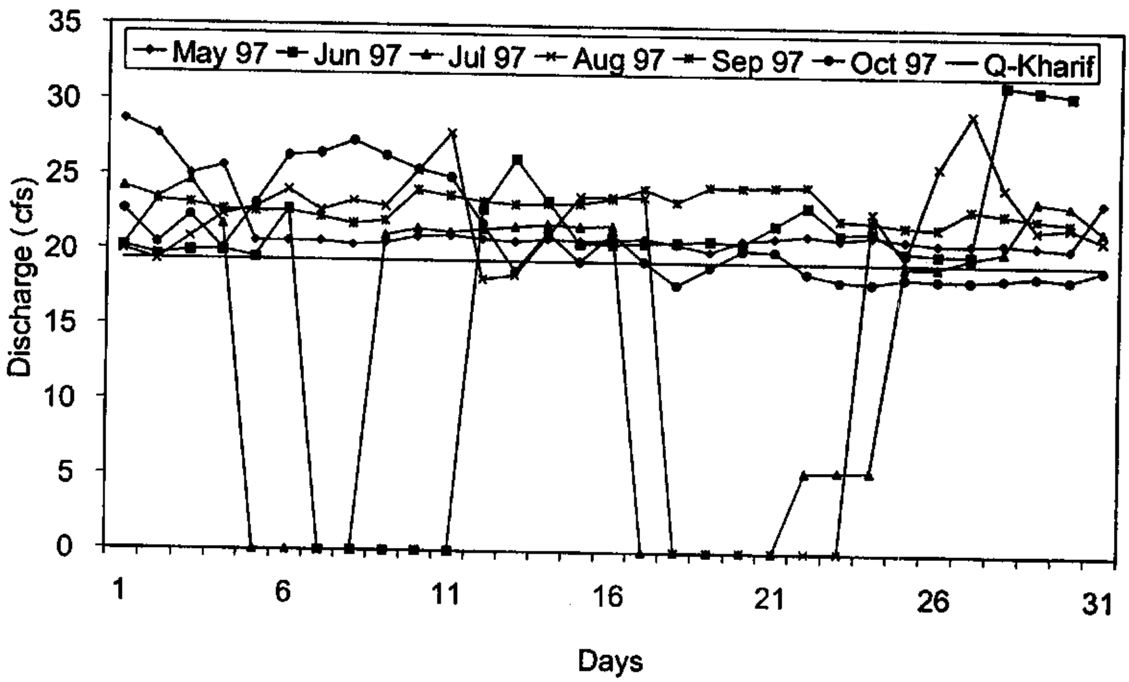

Figure A.6. Daily discharge variations at Kahu Visro Minor head, Kharif 1997.

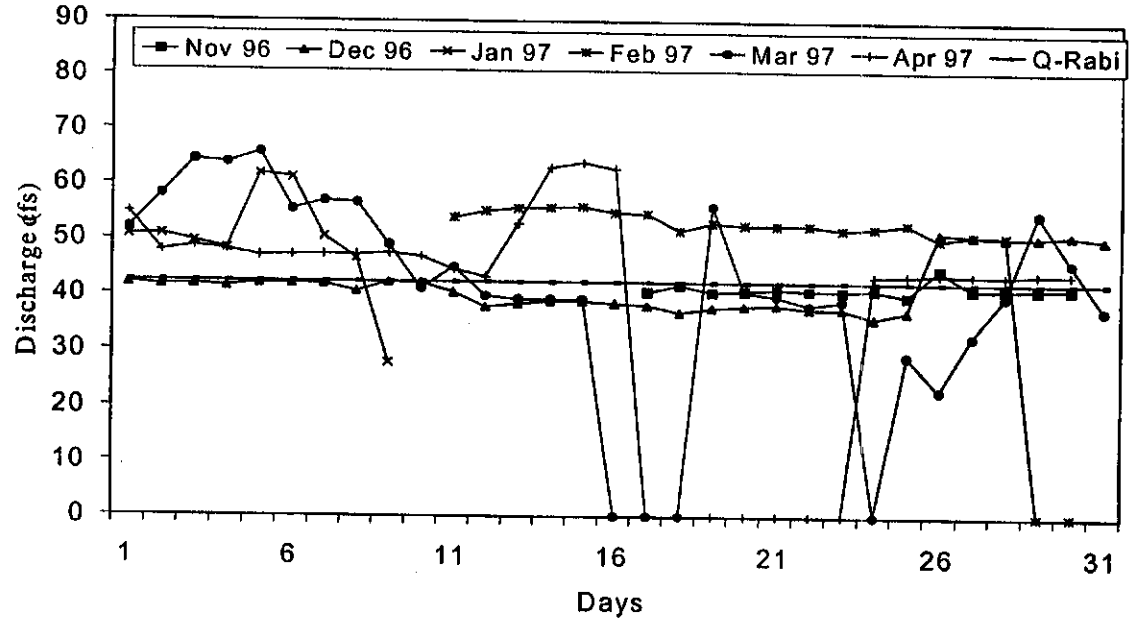

Figure A.7. Daily discharge variations at Kahu Minor head, Rabi 1996-97.

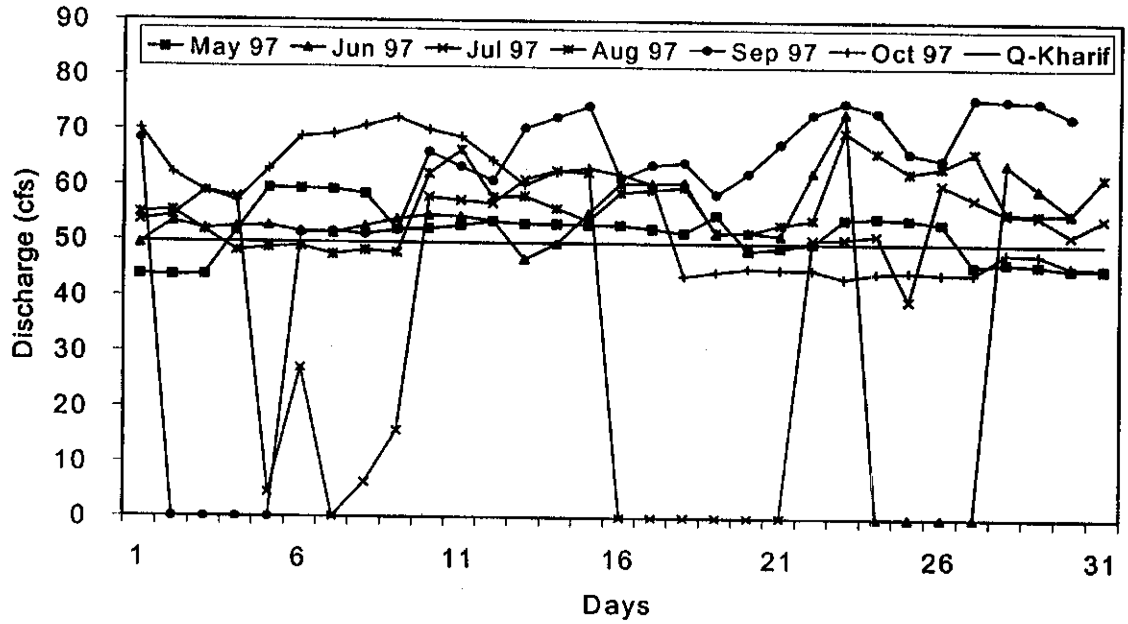

Figure A.8. Daily discharge variations at Kahu Minor head, Kharif 1997.

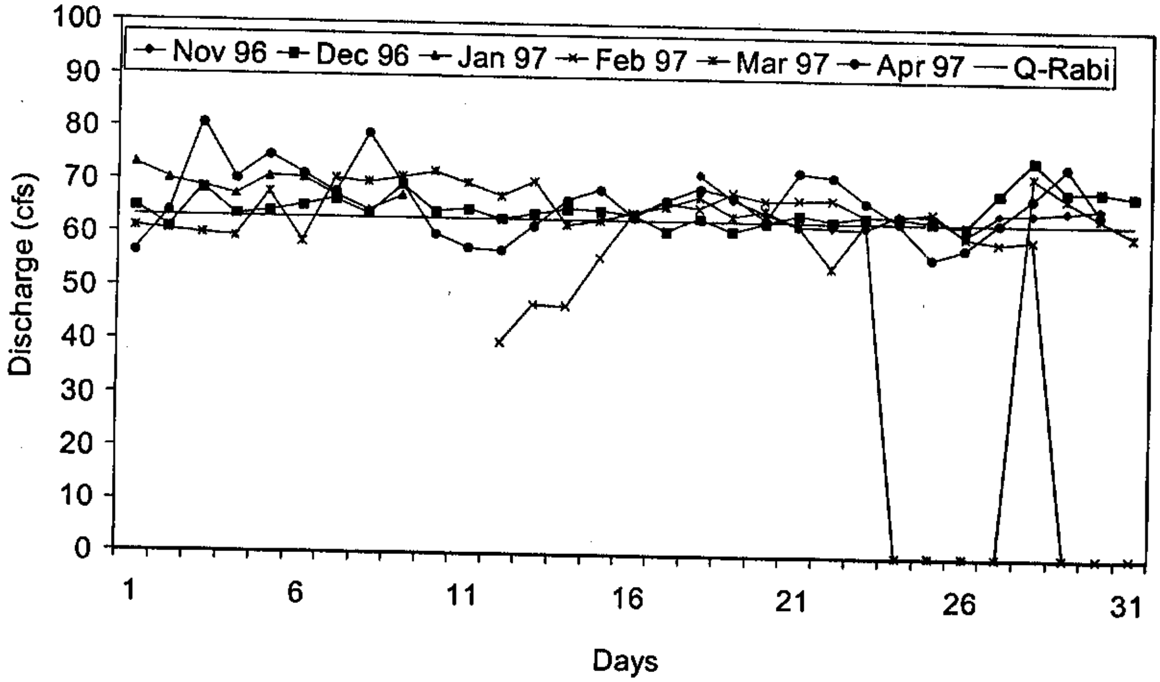

Figure A.9. Daily discharge variation at Bareji Disty head, Rabi 1996-97.

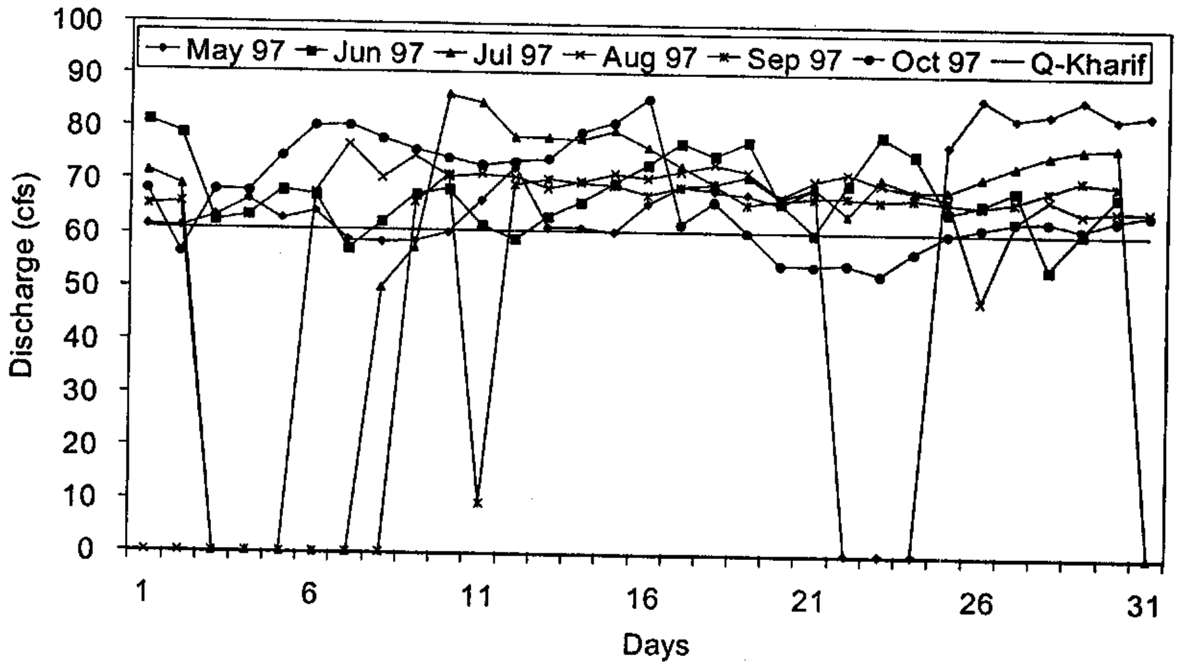

Figure A.10. Daily discharge variations at Bareji Disty head, Kharif 1997.

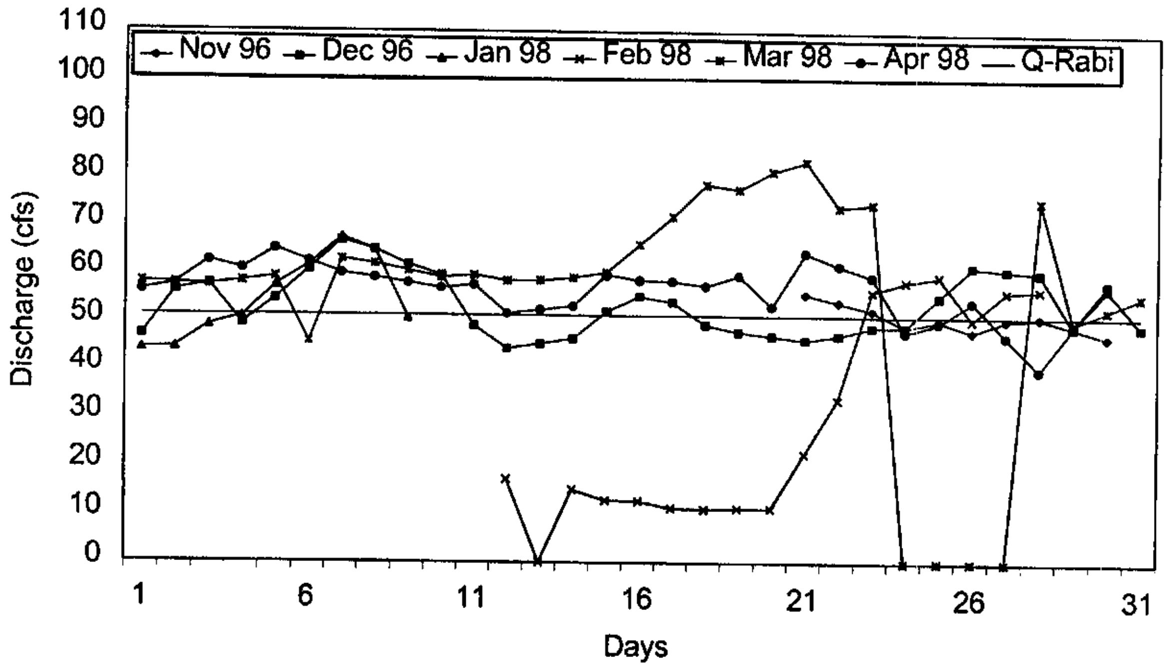

Figure A.11. Daily discharge variation at Sanro Distributary head, Rabi 1996-97.

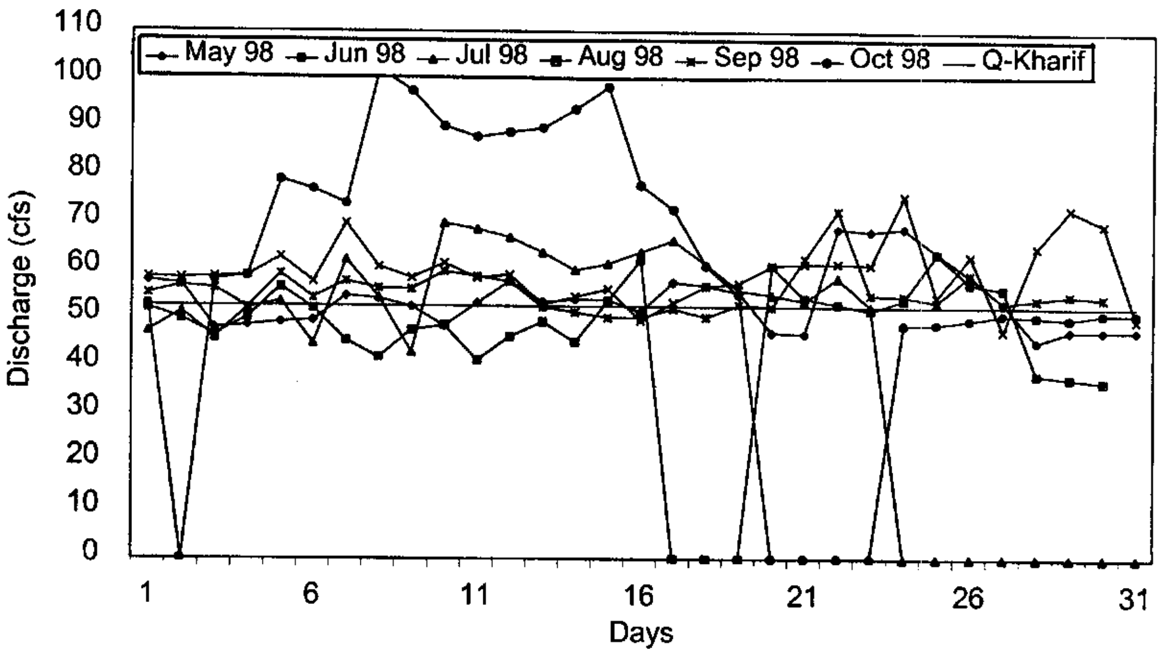

Figure A.12. Daily discharge variation at Sanro Distributary head, Kharif 1997.

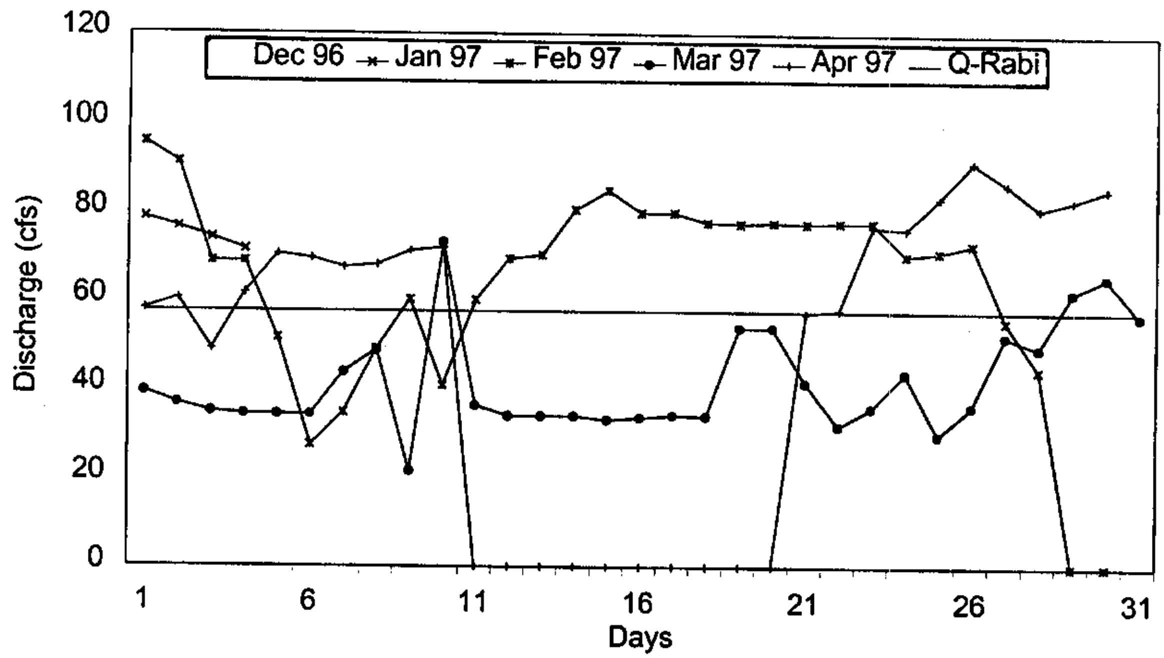

Figure A.13. Daily discharge variation t Lakhakhi Distributary head, Rabi 1996-97.

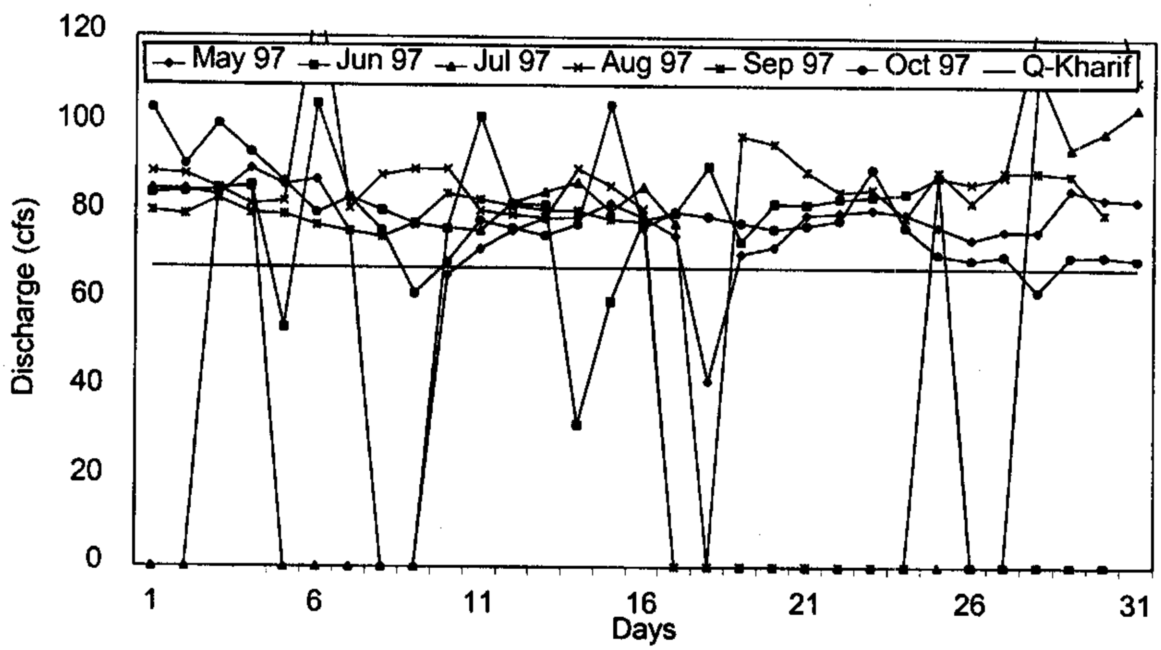

Figure A.14. Daily discharge variation at Lakhakhi Distributary head, Kharif 1997.

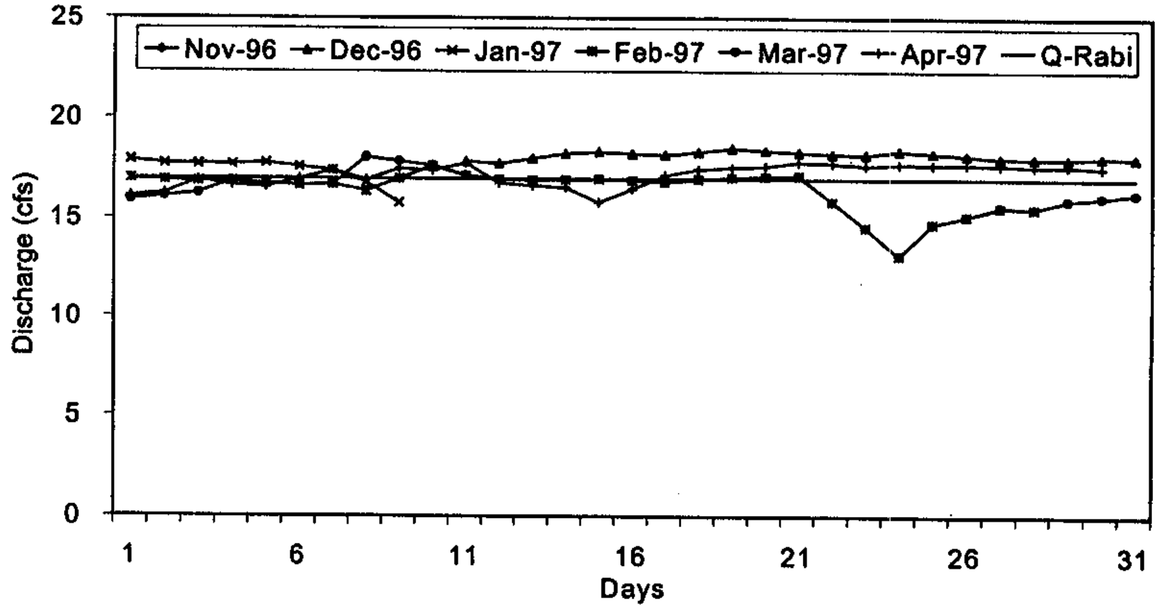

Figure A.15. Daily discharge variation at Bhittaro Minor head, Rabi 1996-97.

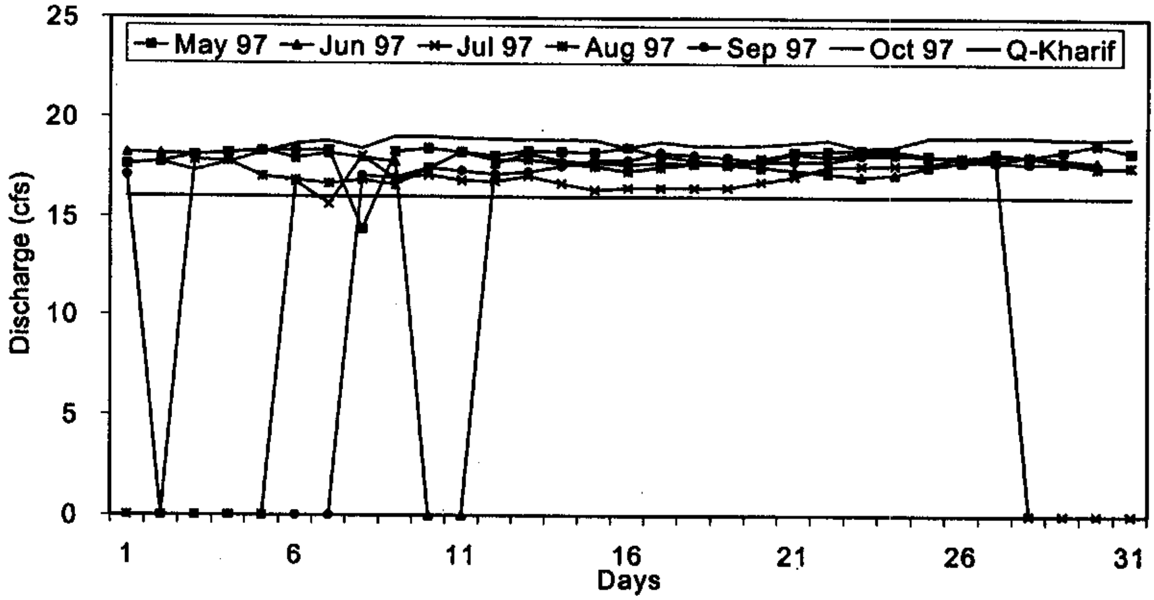

Figure A.16. Daily discharge variation at Bhittaro Minor head, Kharif 1997.

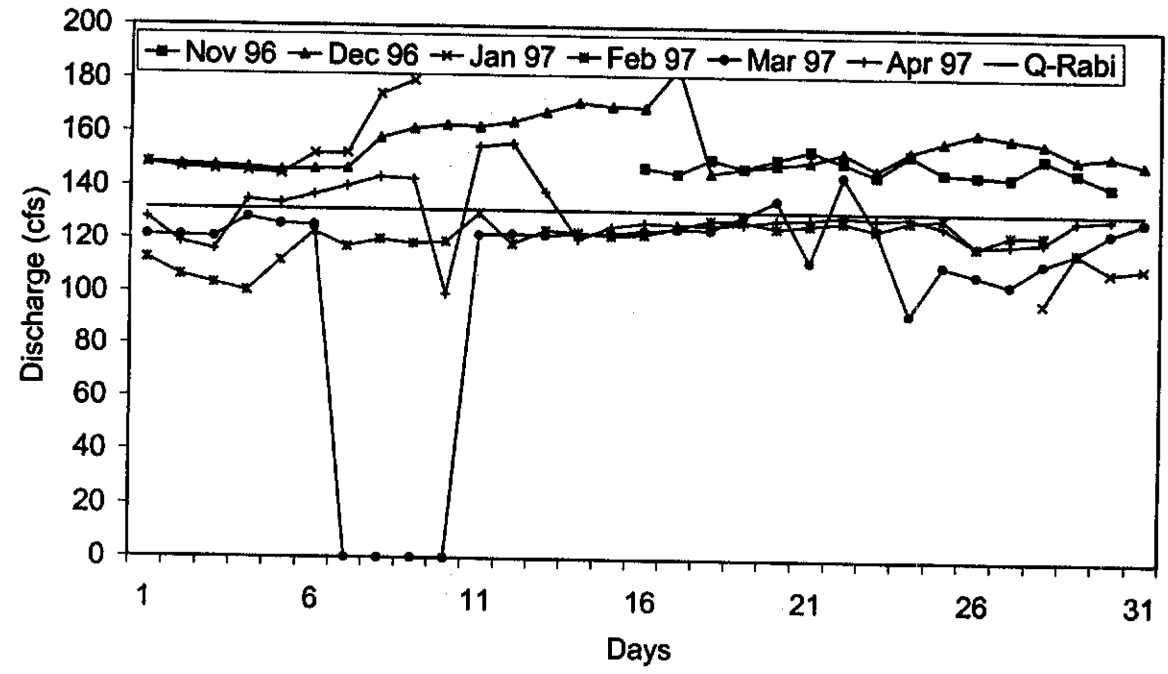

Figure A.17. Daily discharge variation at Sangro Distributary head, Rabi 1996-97.

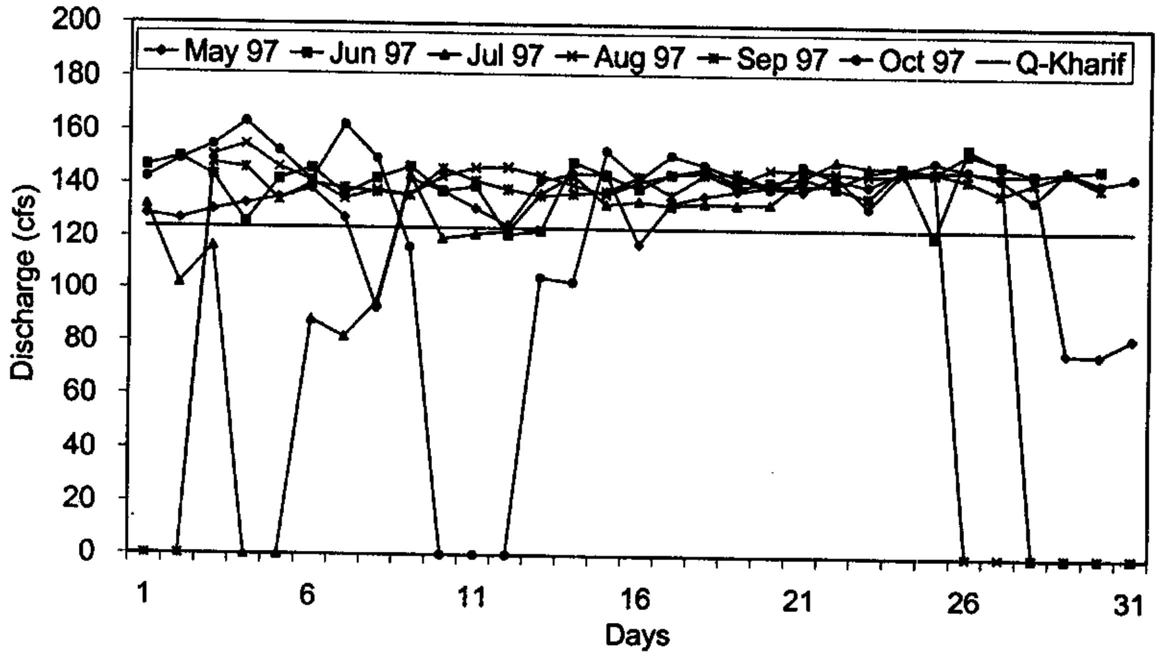

Figure A.18. Daily discharge variation at Sangro Distributary head, Kharif 1997.

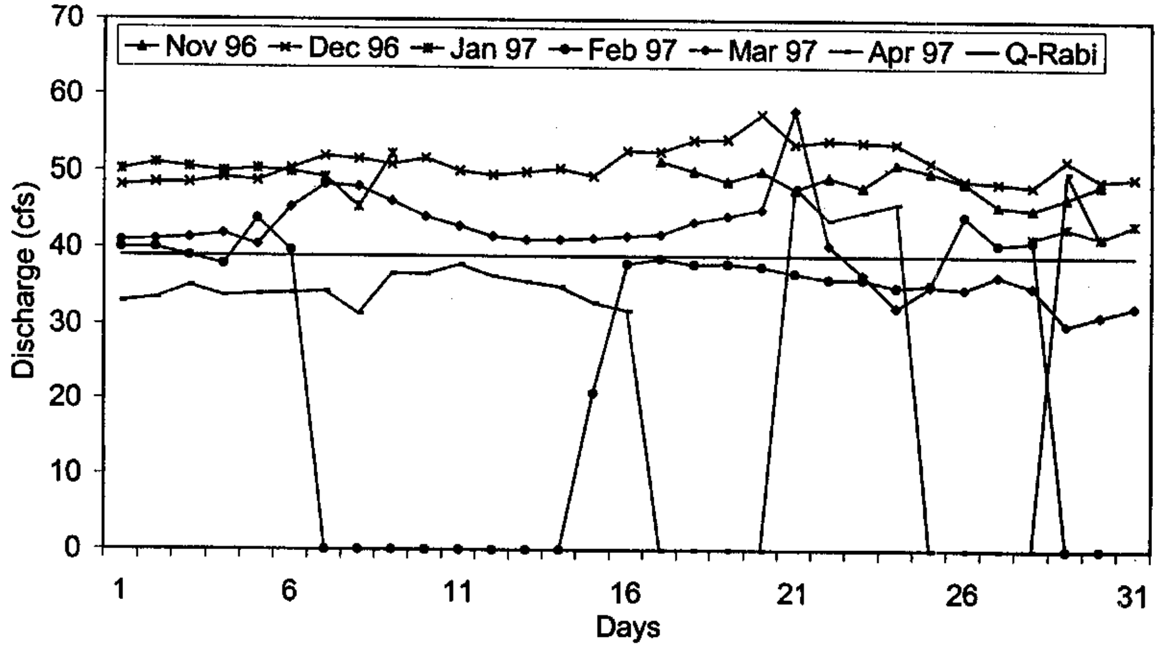

Figure A.19. Daily discharge variation at Daulatpur Minor head, Rabi 1996-97.

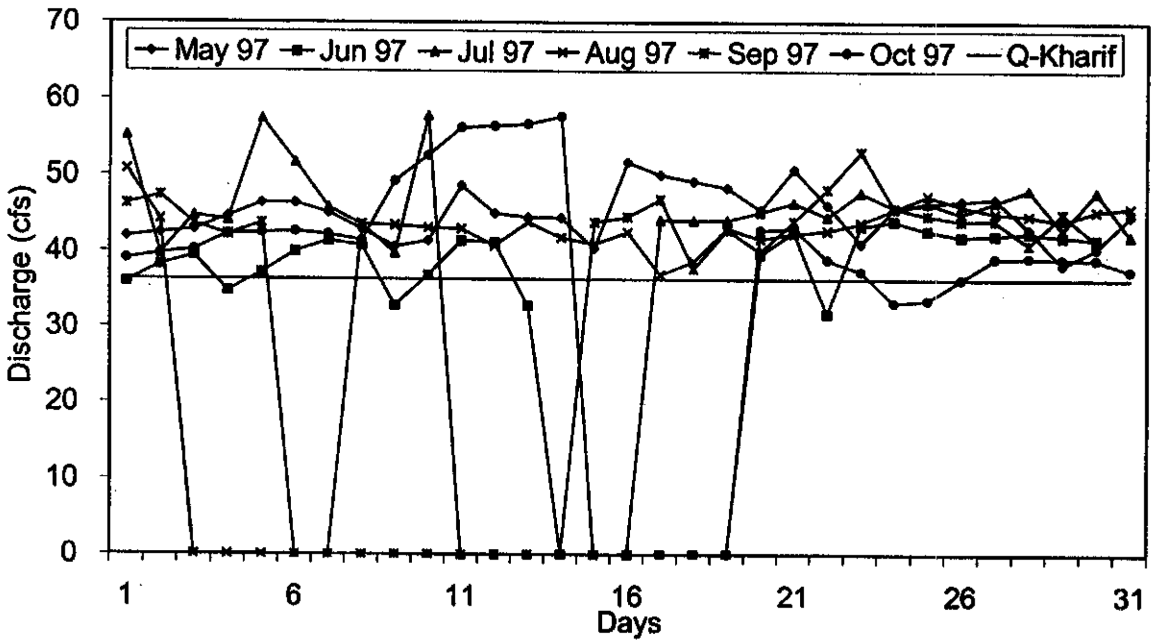

Figure A.20. Daily discharge variation at Daulatpur Minor head, Kharif 1997.

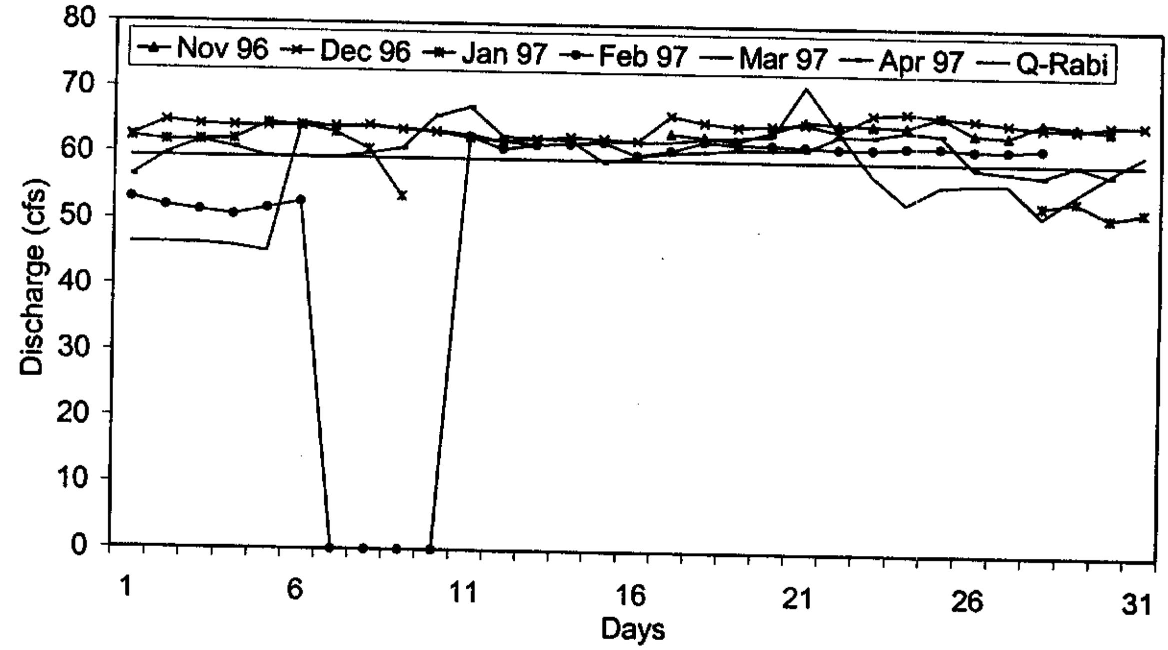

Figure A.21. Daily discharge variation at Bellaro Minor head, Rabi 1996-97.

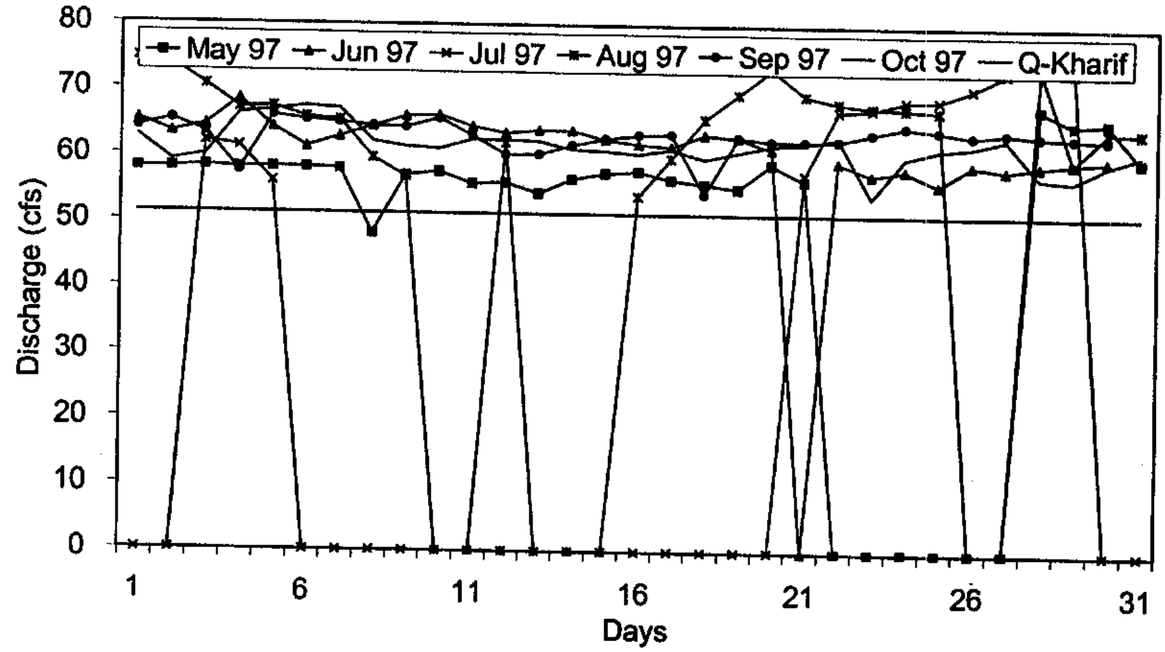

Figure A.22. Daily discharge variation at Bellaro Minor head, Kharif 1997.

ANNEXURE B: DETAILS OF THE LIFT MACHINES IN MIRPURKHAS SUB-DIVISION COMMAND AREA

Table B.1. Details of the lift machines in Mirpurkhas Sub-division command area.

S.#	W/C #	No. of Machines at W/C.	Disty/ Minor.	Model of Machine	Type of Engine	Rated Power (hp)	Rated Speed (RPM)	Dia of Suction Pipe (in)	Dia of Delievery Pipe (in)	Location/Remarks
1	-	1	Sanro	SD-1100	Diesel	16	-	7.88	7.5	Near Vil. Mehmood Malkani
2	-	2	Sanro	SD-1100	Diesel	20	2200	9.5	10	Near Vil. Ali Mohd Malkani
3			Sanro	-	Diesel	-	-	9.5	10	Near Vil. Ali Mohd Malkani
4	-	1	Sanro	-	Diesel	-	-	-	8	Near Vil. Kolhi
5	-	3	Sanro	SD-1115	Diesel	18	2200	-	7.88	Near Vil. Dhani Bux Malkani
6			Sanro	SD-1115	Diesel	18	2200	-	7.88	Near Vil. Dhani Bux Malkani
7			Sanro	-	-	-	-	-	6.375	Engine was closed
8	1-R	2	Doso	HF-450	Diesel	26	450	-	10	Near Vil. Mohd Umar Narejo
9			Doso	-	Electric	25	-	-	8	Near Vil. Mohd Umar Narejo
10	Tail O/L	7	Doso	LD-195	Diesel	12	2200	-	5.87	Tail of the Distry
11			Doso	LD-195	Diesel	12	2200	-	6.125	Tail of the Distry
12			Doso	SD-1100	Diesel	16	2200	-	8	Tail of the Distry
13			Doso	SD-1100	Diesel	16	2200	-	8.31	Tail of the Distry
14			Doso	SD-1100	Diesel	16	2200	-	8.31	Tail of the Distry
15			Doso	SD-1100	Diesel	16	2200	-	8	Tail of the Distry
16			Doso	SD-1100	Diesel	16	2200	-	8.31	Tail of the Distry
17	383/1A	3	Daulatpur	H-113	Diesel	12	2200	5	5	Used when no electricity
18			Dualatpur	-	Electric	10	980	-	-	Having Wings
19			Daulatpur	-	Electric	10	980	-	-	Having Wings
20	379	1	Daulatpur	-	Electric	15	-	-	-	Having Wings
21	379/4Rt	1	Daulatpur	-	Electric	7.5	-	-	-	Having Wings
22	380/1	3	Daulatpur	-	Diesel	12	-	-	-	Having Wings
23			Daulatpur	-	Diesel	12	-	-	-	Having Wings
24			Daulatpur	-	Diesel	16	-	-	-	Having Wings
25	-	2	Daulatpur	-	Electric	7	-	-	4	Vil. Jageerdar
26			Daulatpur	SD-1100	Diesel	16	2200	-	6	Vil. Jageerdar
27	-	2	Daulatpur	-	Diesel	12	2000	-	-	Vil. Ghous Malkani

Table B.1 (Continued)

S.#	W/C #	No. of Machines at W/C.	Disty/ Minor.	Model of Machine	Type of Engine	Rated Power (hp)	Rated Speed (RPM)	Dia of Suction Pipe (in)	Dia of Delievery Pipe (in)	Location/Remarks
28			Daulatpur	195	Diesel	12	2000	-	-	Vil. Ghous Malkani
29	-	1	Daulatpur	-	Diesel	16	2200	-	-	Vil. Saleem Khan
30	-	1	Daulatpur	-	Electric	15	-	-	-	Vil. Jawaid Anwer
31	-	2	Daulatpur	-	Diesel	12	2000	-	-	Rana Tahi (Owner)
32			Daulatpur	-	Diesel	12	2000	-	-	Kashi (Owner)
33	Tail	2	Daulatpur	-	Diesel	-	-	-	-	Vil Babu
34	-		Daulatpur	-	Diesel	-	-	-	-	Vil Babu
35	-	2	Bellaro	-	Diesel	-	-	-	8	Vil. Ali Quatub Shah
36	-		Bellaro	-	Electric	-	-	-	-	Vil. Ali Quatub Shah
37	-	1	Bellaro	-	Diesel	16	2200	-	6.5	Vil. Kishan Kolhi
38	-	1	Bellaro	-	Diesel	7.5		-	4	Vil. Ramzan Kumbhar
39	6-R	1	Sangro	-	Electric	-	-	-	6 & 6.5	Sample Outlet
40	-	1	Sangro	-	Electric	20		-	8	On left side after Sample O/L
41	-	1	Sangro	-	Electric	-	-	-	8	Vil. Khadim Ali Shah
42	-	1	Sangro	-	Electric	-	-	-	8.5	Closed(Rt side) Vill:Kh:Ali
43	7-CR	3	Sangro	-	Electric	25	-	-	8	Sample Outlet
44			Sangro	-	Electric	20	-	-	6	Sample Outlet, Stopped
45			Sangro	-	Electric	15	-	8	8	Sample Outlet, Stopped
46	7-L	2	Sangro	-	Electric	20	1460	8	8	Sample Outlet
47			Sangro	-				8	8	Sample Outlet
48			Sangro	195	Diesel	12	2000	-	-	Used when no electricity
49	7-Culve	1	Sangro	-	Electric	20	1460	-	-	Stopped
50		1	Sanro	-	-	-	-	-	-	No any information
51	11-L		Bareji			16.5				
52	12-L		Bareji			16				
53	8-L		Bareji			16.5				
54	10-L		Bareji			18				
55	10-L		Bareji			12				
56	10-L		Bareji			16				
57	9-R		Bareji			12				
58	9-R		Bareji			12				

Table B.1 (Complete)

S.#	W/C #	No. of Machines at W/C.	Disty/ Minor.	Model of Machine	Type of Engine	Rated Power (hp)	Rated Speed (RPM)	Dia of Suction Pipe (in)	Dia of Delievery Pipe (in)	Location/Remarks
59	9-R		Bareji			12				
60	9-R		Bareji			12				
61	10-R		Bareji			12				
62	10-R		Bareji			16				
63	9-L		Bareji			22				
64	9-L		Bareji			12				
65	7-L		Bareji			12				
66	7-L		Bareji			-				

ANNEXURE C: CROP CULTIVATION IN MIRPURKHAS SUB-DIVISION COMMAND AREA 1987 TO 1996

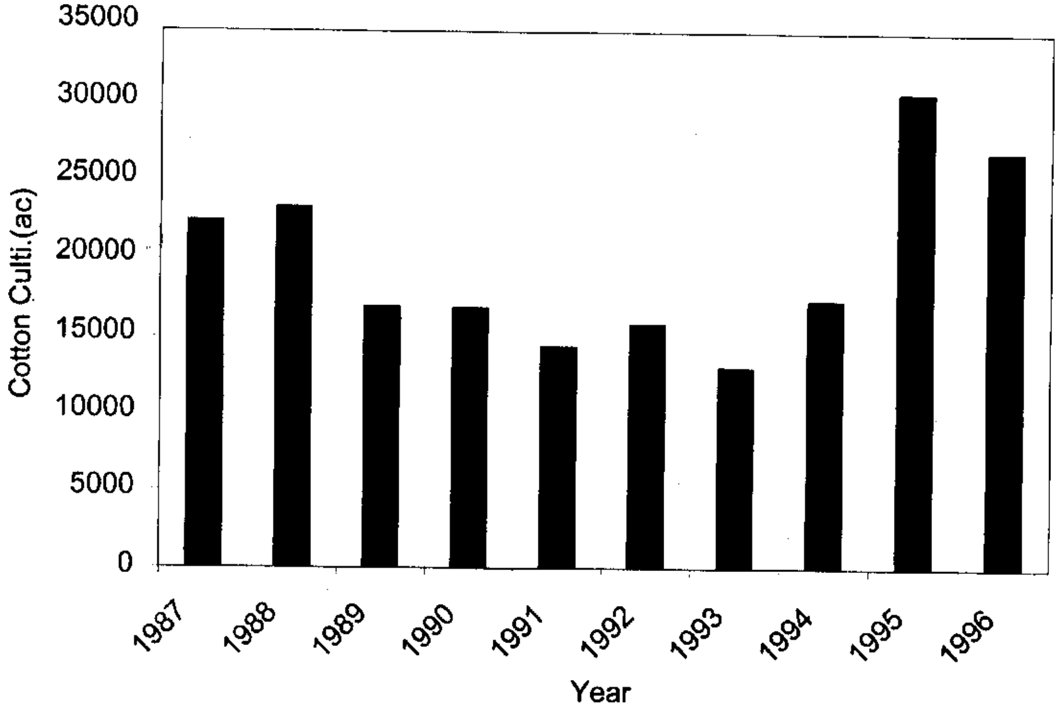

Figure C.1. Cultivation of Cotton in Mirpurkhas Sub-division from 1987 to 96.

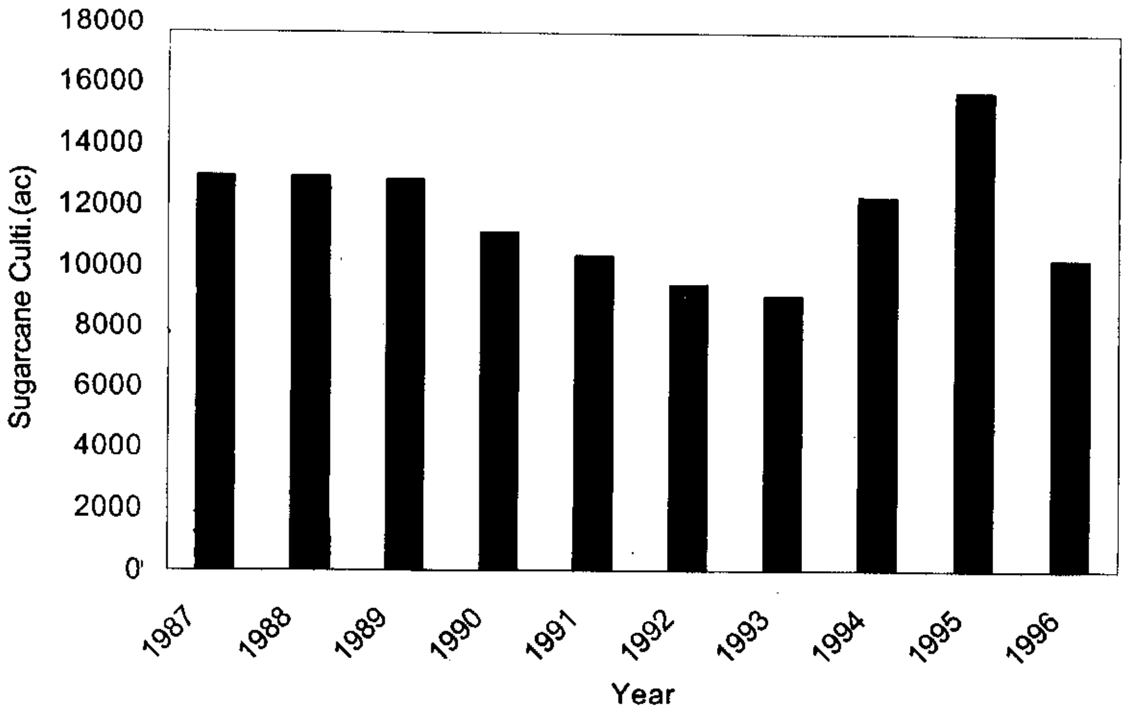

Figure C.2. Cultivation of Sugarcane in Mirpurkhas Sub-division from 1987 to 96.

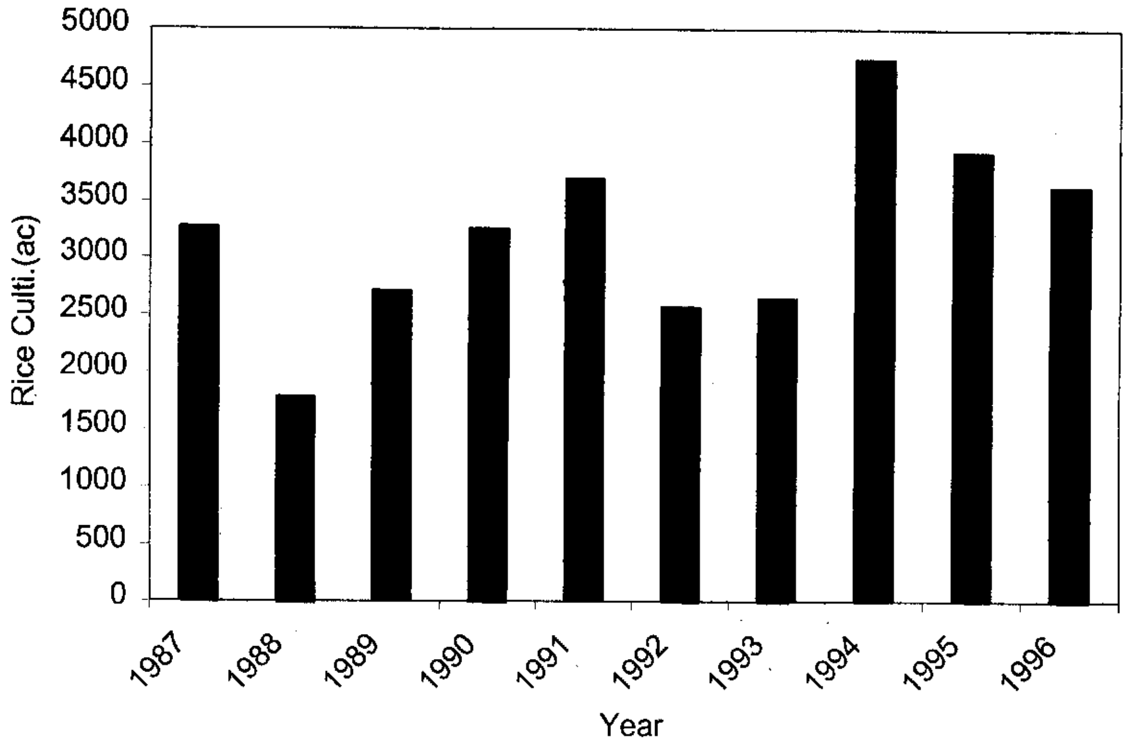

Figure C.3. Cultivation of Rice in Mirpurkhas Sub-division from 1987 to 96.

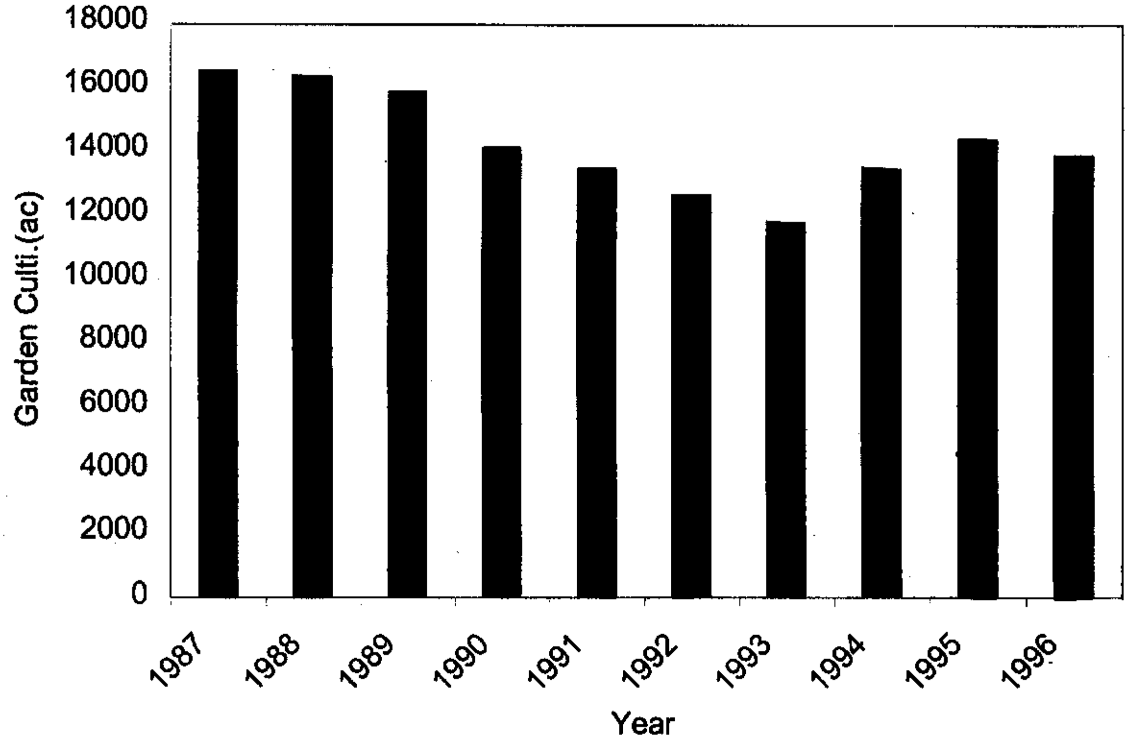

Figure C.4. Cultivation of Garden in Mirpurkhas Sub-division from 1987 to 96.

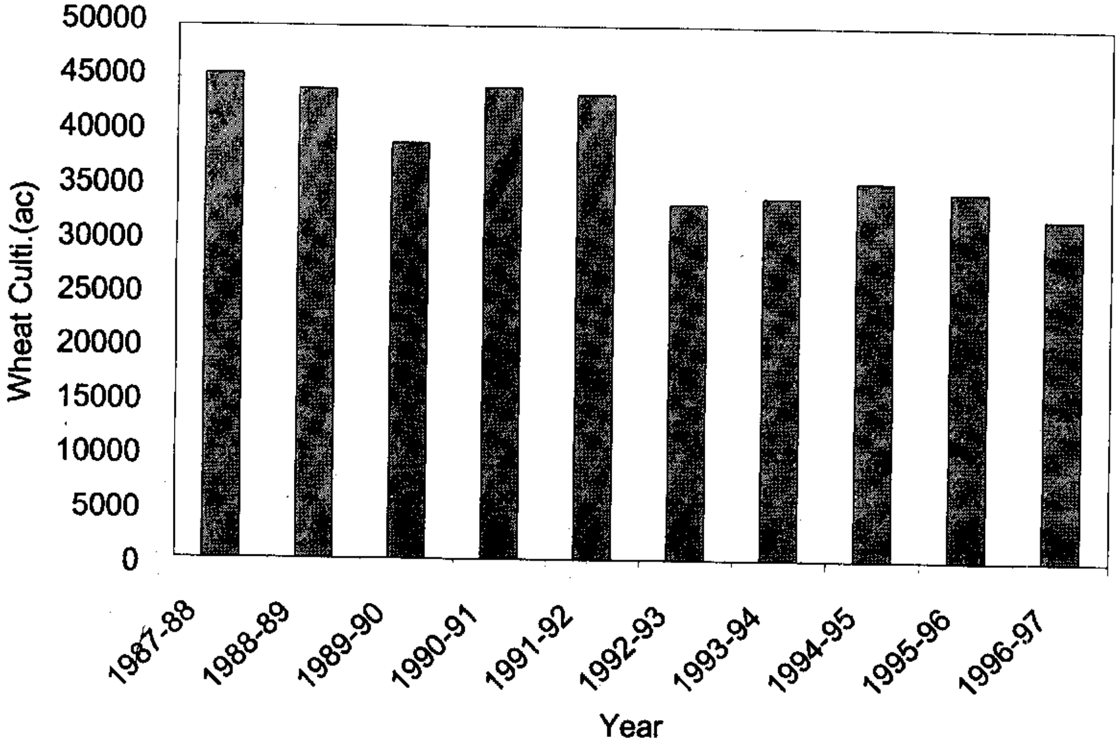

Figure C.5. Cultivation of Wheat in Mirpurkhas Sub-division from 87-88 to 96-97.

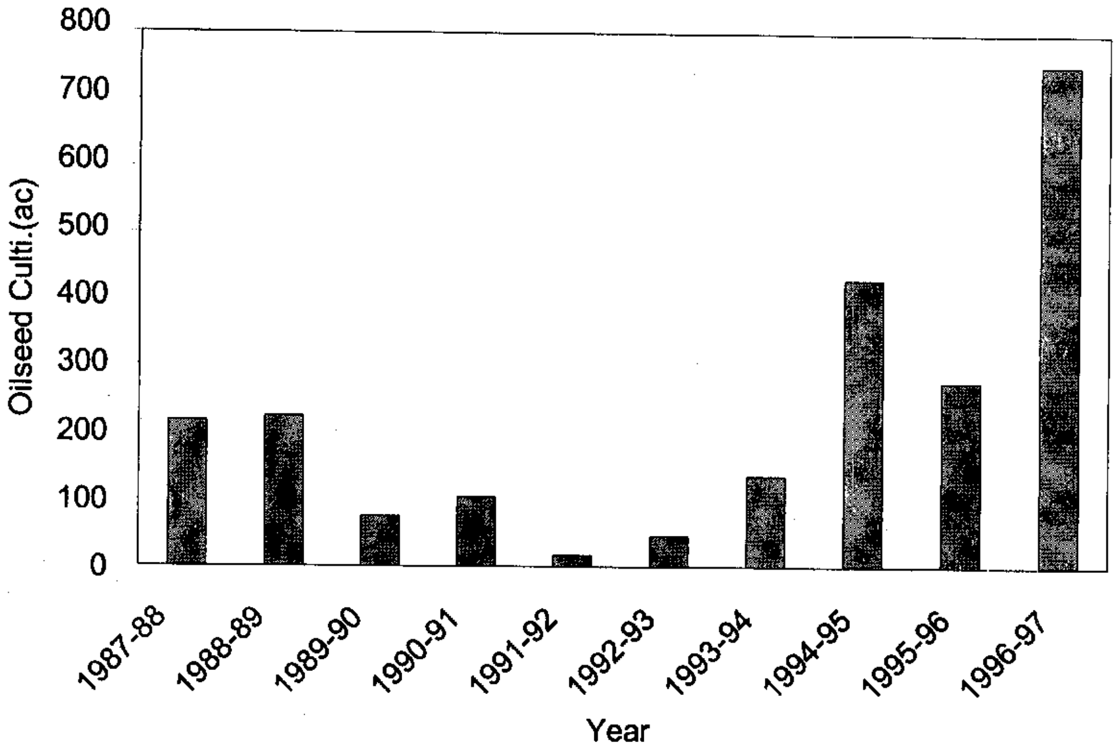

Figure C.6. Cultivation of Oilseed in Mirpurkhas Sub-division from 87-88 to 96-97.

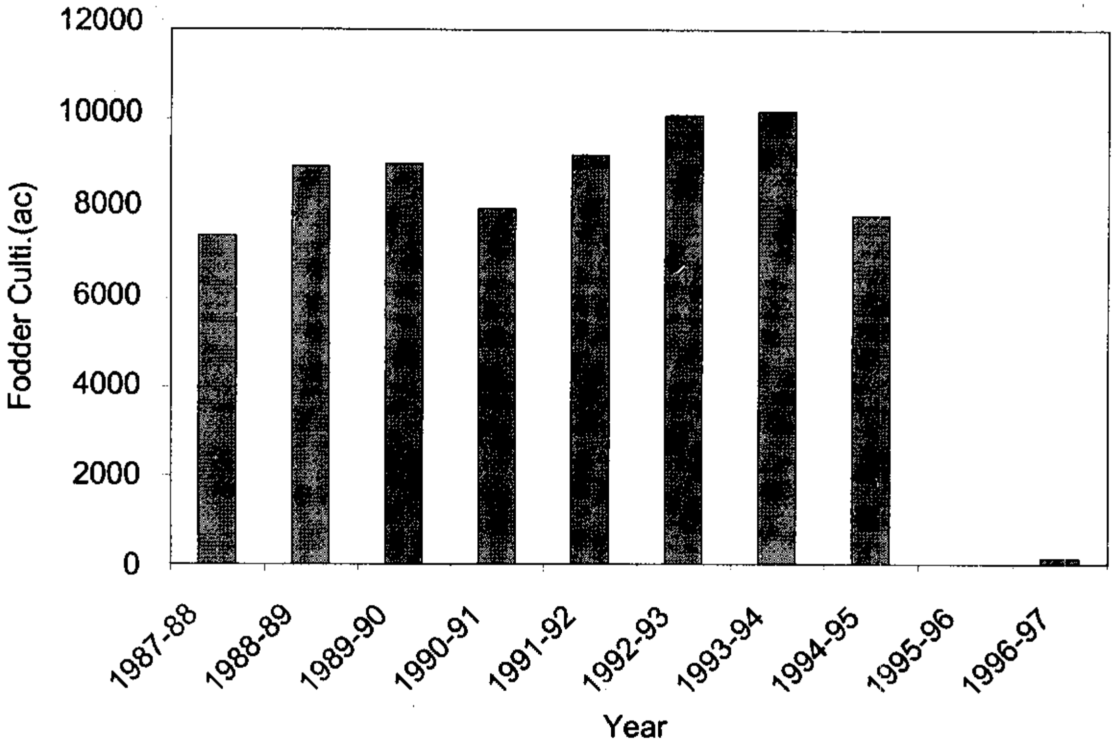

Figure C.7. Cultivation of Fodder in Mirpurkhas Sub-division from 87-88 to 96-97.

Table C.1. Water Rates for Kharif Crops from 1987 to 1996, in Mirpurkhas Sub-Division of Jamrao Canal.

Crops	Water Rates (Rupees per acre)									
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Rice	34.4	34.4	34.4	34.4	34.4	34.4	43.0	49.4	61.8	77.2
Cotton	36.0	36.0	36.0	36.0	36.0	36.0	45.0	51.8	64.8	81.0
Sugarcane	70.4	70.4	70.4	70.4	70.4	70.4	88.0	101.2	126.5	158.2
Garden	55.0	55.0	55.0	55.0	55.0	55.0	68.8	79.1	98.9	123.6
Banana	55.0	55.0	55.0	55.0	55.0	55.0	68.8	79.1	98.9	123.6
Vegetables	55.0	55.0	55.0	55.0	55.0	55.0	68.8	79.1	98.9	123.6
Pulses	15.4	15.4	15.4	15.4	15.4	15.4	19.3	22.1	27.7	34.7
Jowar	15.4	15.4	15.4	15.4	15.4	15.4	19.3	22.1	27.7	34.7
Bajra	15.4	15.4	15.4	15.4	15.4	15.4	19.3	22.1	27.7	34.7
Maize	15.4	15.4	15.4	15.4	15.4	15.4	19.3	22.1	27.7	34.7
Fodder	15.4	15.4	15.4	15.4	15.4	15.4	19.3	22.1	27.7	34.7
Chilies	29.2	29.2	29.2	29.2	29.2	29.2	36.4	41.9	52.4	65.5
Hurries	10.5	10.5	10.5	10.5	10.5	10.5	29.9	15.0	43.0	54.0

Table C.2. Water Rates for Rabi Crops from 1987-88 to 1996-97 in Mirpurkhas Sub-Division of Jamrao Canal.

Crops	Water Rates (Rupees per acre)									
	87-8	88-9	89-90	90-1	91-2	92-3	93-4	94-5	95-6	96-7
Wheat	20.6	20.6	20.6	20.6	20.6	20.6	25.8	29.7	37.1	46.4
Garden	55.0	55.0	55.0	55.0	55.0	55.0	68.8	79.1	98.9	123.6
Banana	55.0	55.0	55.0	55.0	55.0	55.0	68.8	79.1	98.9	123.6
Vegetable	55.0	55.0	55.0	55.0	55.0	55.0	68.8	79.1	98.9	123.6
Oilseeds	20.6	20.6	20.6	20.6	20.6	20.6	25.8	29.7	37.1	46.4
Fodder	20.6	20.6	20.6	20.6	20.6	20.6	25.8	29.7	37.1	46.4
Pulses	20.6	20.6	20.6	20.6	20.6	20.6	25.8	29.7	37.1	46.4
Hurries	10.5	10.5	10.5	10.5	10.5	10.5	13.0	15.0	43.0	53.8

IIMI-PAKISTAN PUBLICATIONS
RESEARCH REPORTS

Report No.	Title	Author	Year
R-1	**Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan** Volume I: Synthesis of Findings and Recommendations	Carlos Garces-R D.J. Bandaragoda Pierre Strosser	June 1994
	Volume II: Research Approach and Interpretation	Carlos Garces-R Ms. Zaigham Habib Pierre Strosser Tissa Bandaragoda Rana M. Afaq Saeed ur Rehman Abdul Hakim Khan	June 1994
	Volume III: Data Collection Procedures and Data Sets	Rana M. Afaq Pierre Strosser Saeed ur Rehman Abdul Hakim Khan Carlos Garces-R	June 1994
R-2	Salinity and Sodicity Research in Pakistan - Proceedings of a one-day Workshop	J.W. Kijne Marcel Kuper Muhammad Aslam	Mar 1995
R-3	Farmers' Perceptions on Salinity and Sodicity: A case study into farmers' knowledge of salinity and sodicity, and their strategies and practices to deal with salinity and sodicity in their farming systems	Neeltje Kielen	May 1996
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