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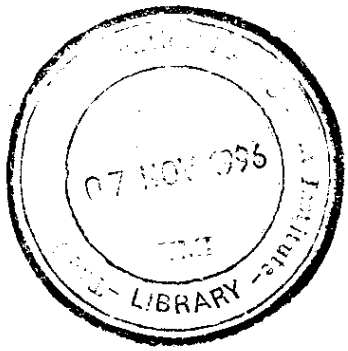
IIMI PAKISTAN

REPORT ON ACTIVITIES

DECEMBER 31, 1989

NATIONAL IRRIGATION MANAGEMENT INSTITUTE
PAKISTAN



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I. INTRODUCTION

In many respects, Pakistan's irrigation environment is different from other countries where IIMI currently employs resources. In contrast to humid tropical Asia, Pakistan is arid or semi-arid. It is located entirely in the subtropical zone and has a long history of irrigated agriculture, particularly wheat production. The irrigated lands are vulnerable to the twin problem of waterlogging and salinity.

Its scale is also different to many other contexts. Pakistan has the largest contiguous irrigation system in the world, extending over a gross area of about 15 million hectares. Approximately 75 percent of Pakistan's total agricultural area is irrigated. The country's primary and secondary canals stretch to 62,000 kilometers (km) with tertiary-level canals estimated to reach another 1.6 million km, while 42 canal commands and 89,000 watercourses serve an estimated 3.6 million irrigated farms. From a total annual river flow of 17.8 million hectare-meters, 12.4 million hectare-meters is diverted for irrigation purposes. Over 250,000 tubewells provide an estimated 2.9 million hectare-meters.

Pakistan's overall irrigation system is also characterized by its complexity. Limited water resources; limited canal capacities; the need to operate the system at not less than 70 percent of full supply level to prevent sedimentation, and not substantially above 100 percent to prevent overtopping; a limited number of regulating structures; combined use of surface and groundwater resources; the threat of waterlogging and salinity; and the large and heterogenous sizes of command areas are all factors that make the operation of irrigation systems in Pakistan a very complex process.

Pakistan's long history of irrigation development has resulted in a system of administrative complexity and a massive physical infrastructure. Most of it has been developed in a physical and socio-economic environment in which land was relatively abundant, water supply was relatively uncontrolled, professional and technical resources were scarce, and the need for equity of water allocation and delivery was high. The result, perhaps more appropriate to an earlier time than the present, was an irrigation system geared more to administration than to active management, and more to stability than adaptability and change.

In keeping with IIMI's mission to enhance national capabilities in the management of irrigation systems, its Division in Pakistan has embarked upon a program of collaborative research activities with national agencies and organizations with responsibilities in irrigated agriculture that addresses key irrigation management issues in the country. The purpose of this document is to summarize IIMI's development in Pakistan and progress made thus far on these activities.

II. BACKGROUND

Memorandum of Agreement with Government of Pakistan

Given the extent and complexity of Pakistan's irrigation system as well as its significance to the country's national economy, IIMI acknowledged the need to establish a major country program in Pakistan. This objective was implemented on 28 September 1986, through the Memorandum of Agreement between IIMI and the Government of Pakistan, signed by the Secretary, Agricultural Research Division, Ministry of Agriculture, representing the Government of Pakistan, and the Director General of IIMI which formally established the Pakistan Division of the International Irrigation Management Institute (IIMI-Pakistan). The MOA recognized IIMI-Pakistan as an integral unit of an autonomous, international, non-profit, research, educational and training organization with its operational base in Lahore. It is headed by an IIMI Director.

Staffing

In 1986, IIMI placed four senior internationally-recruited staff members in Lahore to initiate activities of the Pakistan program. Dr. James Wolf, an agriculture engineer who was the team leader of the IIMI-Pakistan design mission was appointed as its Director. He was joined by two Irrigation Specialists, Dr. Edward J. Vander Velde and Dr. Hammond Murray-Rust, and by Mr. Michael Jones as Director of Administration. Fellowship and local senior staff in the same range of disciplines were added, as were support staff in accounting and administration.

Dr. Murray-Rust left IIMI-Pakistan in late 1987 to assume the position of Head of Country Operations for IIMI in Indonesia. Mr. Michael Jones also departed IIMI-Pakistan in 1987. His position was filled by Mr. Haroon Anwar who was appointed General Manager, Administration. In October, 1988, Ir. F. E.

Schulze was appointed Director, IIMI-Pakistan replacing Dr. Wolf who returned to the United States. The following month, Dr. Jacob W. Kijne joined as Senior Irrigation Specialist. In February, 1989, Mr. D. J. Bandaragoda was appointed Senior Management Specialist.

In 1988 Dr. Akhtar Bhatti joined IIMI Pakistan as nationally recruited Principal Irrigation Engineer with an Agricultural Engineering background. In the same year IIMI Pakistan appointed Mr. M. Badruddin as Senior Principal Irrigation Engineer, followed by a similar appointment of Dr. G.R. Firdousi in 1989.

At the close of 1989, IIMI-Pakistan had a total staff strength of 78 persons, of which 4 were internationally-recruited expatriate specialists.

The national staff of IIMI-Pakistan comprise two broad categories: administrative and logistical support staff, and research staff. Currently, there are 41 administrative and logistical support staff, including the General Manager, Administration and the Accountant. Among the 31 nationally-recruited research staff are 3 senior professionals, 2 mid-level professionals and 10 junior or entry-level professionals. Most of the latter are based at IIMI-Pakistan research sites outside of Lahore where their duties include the collection and initial processing of field data and the supervision of non-professional field assistants performing more routine data collection functions.

Since its establishment in 1986, 14 post doctoral and post-graduate research fellows or scholars and research associates have worked with IIMI-Pakistan. They have made significant contributions to the Institute's overall research program while furthering their own professional development through field research activities over different lengths of time. Included in this group were 8 persons from Pakistan, 2 from United States, 2 from the Netherlands, and 2 from Great Britain.

Facilities

Main Office: IIMI-Pakistan's operations are currently based in rented facilities located at 1-A/B, Danepur Road and 6, College Road, GOR I, Lahore. Permanent office facilities are to be constructed through the Government of Pakistan with financing provided by the World Bank. A five-acre parcel of land at the site of the Punjab Irrigation Department's Niazbeg Canal Rest House is being allocated to IIMI-Pakistan for this

purpose under a separate Memorandum of Understanding. Representatives of IIMI and the GOP have finalized the pre-qualification of architectural services and arranged for pre-qualification of the contractor for construction of these permanent facilities.

Field Research Facilities: A canal rest house located in Farooqabad, Sheikhupura District, Punjab, near the Upper Gugera Branch canal of the Lower Chenab Canal system and about 50 km west of Lahore, was assigned to IIMI-Pakistan in 1987 by the Punjab Irrigation Department. It was subsequently renovated to serve as a research field station. It has office facilities for field staff plus overnight accommodation for four persons. Residential accommodation for Farooqabad-based field staff is provided in two near-by rented bungalows. IIMI-Pakistan also established a field office at Pir Mahal in Toba Tek Singh District, about 260 km south-west of Lahore. The rented house there serves as office-cum-hostel for research activities located in the lower command of the LCC system. Another field office (office-cum-hostel) was opened in Mananwala, about 70 km west-southwest of Lahore on the Lahore-Faisalabad road also in Sheikhupura District. A second field station will soon be operational in Hyderabad, Sindh, which will serve as the primary base for IIMI-Pakistan research activities in that province.

III. *INSTITUTIONAL ARRANGEMENTS*

Consultative Committee

Cooperation and research collaboration with national agencies and organizations is central to the implementation of IIMI's mandate. To facilitate this process, a National Consultative Committee was formed by IIMI in Pakistan with the following objectives:

1. Identify within the limits of IIMI-Pakistan's mandate, program areas that deserve priority attention in Pakistan;

2. Comment on research, professional development, and information exchange programs proposed for implementation;

3. Advise on opportunities and resources available within the country for implementing different components of IIMI-Pakistan's program;

4. Seek active support of appropriate national agencies in implementation activities;

5. Provide guidance to national policy makers on the basis of significant findings arising from IIMI-Pakistan's program;

6. Bring to IIMI-Pakistan's attention local findings and experiences that help sharpen the focus and increase the effectiveness of its research efforts;

7. Promote communication of information on irrigation management at appropriate levels in Pakistan;

8. Assist IIMI-Pakistan in professional development activities.

Membership of the National Consultative Committee includes the Secretaries of both the Irrigation and the Agriculture Departments of the four provinces, as well as representatives from the Federal Ministry of Water and Power, the Federal Ministry of Food, Agriculture and Cooperatives, the Pakistan Agricultural Research Council (PARC), the Water and Power Development Authority (WAPDA), and the private sector.

The Consultative Committee (CC) meets, on average, two times per year. The committee was first chaired by the former Federal Minister of Agriculture, Mr. Sartaj Aziz. In 1989, he was replaced by Dr. Amir Muhammad, Secretary, Agricultural Research Division, Federal Ministry of Food, Agriculture and Cooperatives. The progress of IIMI-Pakistan's research work and its future workplans are extensively discussed at these meetings, and concurrence has been given to specific research proposals. One meeting in 1988 was held at IIMI-Pakistan's Farooqabad Field Station and members participated in an organized field visit to observe the range of field activities IIMI-Pakistan has initiated there in collaboration with Punjab's Irrigation and Agriculture Departments.

The most recent CC meetings have reviewed IIMI-Pakistan's medium-range work program (Lahore, April 1989) and results of research on distributary-level performance, small-scale irrigation in northern Pakistan, watercourse and farm-level irrigation management, and conjunctive management of surface and groundwater (Islamabad, October 1989).

Arrangements for Collaboration

By the end of 1989, IIMI in Pakistan had established both formal arrangements and informal cooperative working relationships with several governmental agencies and institutions, as follows:

Through a formal agreement, the Punjab Irrigation Department (PID) made available one of its canal rest houses to IIMI for use as field research station. The PID also has established a Standing Committee at the Secretariat level to interact with IIMI on matters of mutual research interest. Through a contractual agreement the PID's Irrigation Research Institute conducted systematic pump tests for about 200 public and private tube wells within a distributary command in Farooqabad Sub-Division, Sheikhupura District. IIMI and IRI researchers jointly have used these and other tube well data in research focused upon conjunctive management of surface and groundwater. PID staff have joined IIMI-Pakistan staff in field visit and briefing programs for Nepal government irrigation officials, World Bank staff, and USAID delegations, as well as members of IIMI's Program Committee and its External Review Panel. A Memorandum of Understanding with the PID is currently being finalized to permit the construction of IIMI-Pakistan's permanent offices at Niazbeg.

Field staff of the Punjab Agriculture Department's (PAD's) Directorate of Agriculture Extension joined IIMI scientists in farmer interviews and data collection in several districts in Punjab on a study of irrigation constraints to crop production over a two year period following participation in an IIMI-organized and conducted improved irrigation practices and field observation training program.

IIMI has concluded a formal Memoranda of Agreement with the Center of Excellence in Water Resources Engineering (CEWRE), Lahore and the University of Agriculture (UAF), Faisalabad that encourages and facilitates the development and implementation of collaborative research activities involving scientists and post-graduate students of these organizations.

Formal research linkages are being established with the International Waterlogging and Salinity Research Institute (IWASRI) and the Pakistan Council of Research in Water Resources (PCRWR). In 1989, IWASRI joined IIMI-Pakistan in an expert consultation meeting on IIMI's project "Managing Irrigation Systems to Minimize Waterlogging and Salinity Problems." Representatives and scientists for a wide range

of concerned agencies participated. IIMI also contributed to the two-day seminar on "Waterlogging and Salinity Research in Some Major Problem Countries" jointly organized by IWASRI and UNDP/DTCD.

Also in 1989, IIMI-Pakistan has begun to develop linkages with irrigation related agencies in two additional provinces, Sindh and the North West Frontier. In Sindh, the provincial Departments of Irrigation and Agriculture have assisted IIMI in research site screening and selection. The Drainage and Reclamation Institute of Pakistan (DRIP), the Lower Indus Water Management and Reclamation Research Project (LIM), the Sindh Regional Planning Organization, and the Institute of Irrigation and Drainage of the Mehran University have been invited to be associated with IIMI's planned research on waterlogging and salinity management in the province. In the NWFP, IIMI's proposed research project on crop demand-based irrigation operations has been planned in active association with the Departments of Irrigation and Agriculture, and WAPDA.

IIMI's research on the comparative performance of new and well-established small-scale irrigation systems in northern Pakistan was planned and implemented in close cooperation with the Aga Khan Rural Support Program (AKRSP) in Gilgit. Two AKRSP engineers were attached to IIMI-Pakistan's research team and participated fully in field activities throughout the five month field research phase of this project.

To facilitate inter-agency and federal-provincial dialogue on irrigation management issues, IIMI has organized research seminars that bring together policy makers and senior officers from several federal and provincial irrigation agencies for presentations by visiting international specialists. In a similar context, two-day retreat was held in Saidu Sharif, Swat, NWFP in 1988 for federal and provincial agency officials and IIMI-Pakistan scientists to review options for and constraints to moving from passive irrigation system administration to active irrigation management. IIMI also sponsored the participation of senior Pakistan irrigation officials in IIMI's Strategy Planning workshop in Sri Lanka and the international workshop in the Philippines on farmer participation in irrigation system management, both also in 1988.

IV. RESEARCH ACTIVITIES

Introduction

IIMI's mission is to strengthen national efforts to improve and sustain the performance of irrigation systems in developing countries through the development and dissemination of management innovations. In this context IIMI defines irrigation management as the process in which institutions or individuals set objectives for irrigation systems; establish appropriate conditions; and identify, mobilize, and use resources, so as to attain these objectives; while ensuring that all activities are performed without causing adverse effects.

In developing its strategy, IIMI identified seven main program themes that have a strong bearing on the management and performance of irrigation systems in developing countries. These themes were derived on the basis of IIMI's definition of irrigation management, and cut across all types of irrigation systems - agency and farmer managed, large and small scale, gravity and lift.

These seven main program themes are:

- Institutions for irrigation management,
- Management of water resources for irrigation,
- Management of financial resources for system sustainability,
- Management of irrigation facilities,
- Management of irrigation organizations,
- Management of irrigation support services to farmers,
- Management of change in institutions for irrigation.

Taking into account the problems and priorities of the country, IIMI Pakistan concentrated its efforts in particular on the management of water resources for irrigation.

Opportunities for Irrigation Management Research in Pakistan

The gross area in the command of Pakistan's irrigation system amounts to 15.6 million hectares, or approximately 10 percent of the total irrigated area in developing countries (20 percent excluding China and India). The importance of irrigation in Pakistan is further accentuated by the fact that 75 percent of the total cultivated area is irrigated.

Availability of irrigation supplies, both from surface and groundwater sources is the most important determinant of the performance of irrigated agriculture in Pakistan. So far as surface supplies are concerned, two broad categories of irrigation systems are in existence: perennial systems (8.4 million hectares) which are entitled to year-round irrigation supplies, and non-perennial systems (5.5 million hectares) which receive supplies only for the summer (kharif) cropping season when the river flows are high.

Surface irrigation systems in Pakistan also are characterized by differences in their "water allowance" and "annual intensity", design parameters which fixed for each system at the turnout the amount of water to be supplied in relation to the land to be irrigated, and which in turn determined the capacity of the system. Water allowances for non-perennial systems in Pakistan are typically much larger than those for perennial systems. In Pakistan's perennial systems one also encounters water allowances which range from as low as 1.9 cfs/1000 acres (or 0.13 lps/ha) in older perennial systems, to as high as 19 cfs/1000 acres (1.33 lps/ha) for newly constructed or remodelled perennial systems. Typically, however, the "annual (cropping) intensity" in these latter systems is much higher than in the older canal commands, thereby reducing somewhat the range of expected water availability for agricultural crops.

The surface irrigation system has been supplemented by extensive public and private groundwater development over the past two decades in large areas of the Indus Basin. This has considerably increased the availability of irrigation water while adding a new dimension to the irrigation environment of the country. Approximately 60 percent of the irrigated area in Pakistan is underlain with groundwater with a salinity content of less than 3000 ppm. Therefore, it has been assumed that much of this resource could be utilized for irrigation purposes in combination with surface water of higher quality.

An important distinction in groundwater irrigation in Pakistan is whether its development has been undertaken in the public sector, whereby supplies are essentially available to all farmers within the command of the tube well, or development has been done by the private sector and hence supplies are less readily available to all farmers. Currently, there are approximately 11,000 public tube wells and more than 250,000 private tube wells in Pakistan.

The presence of high water tables, generally brought about by the introduction of irrigation is another component of Pakistan's irrigation environment. Water tables depths over much of the Indus Basin vary considerably during the year. For instance, in irrigated areas having water tables between 0-150 cm, drops have been measured that exceed more than 25% in October to less than 10% in June.

In addition to surface irrigation infrastructure, surface and deep drainage infrastructure has a significant impact upon irrigated agriculture. Extensive, physical infrastructure-intensive efforts have been made to reduce the problems of waterlogging and/or salinity, although the type and degree of density of facilities have varied from one region to another. Nearly one-third of the Indus Basin irrigated area has been covered by one or another of the Salinity Control and Reclamation Projects (SCARP) activities, development of which continues, albeit on a scale reduced from that experienced in the 1960s and 1970s. The Left Bank Outfall Drain (LBOD), currently under construction in Sindh, will provide surface and deep drainage to an estimated 1.3 million acres when completed.

Physical environmental conditions, such as topography, climate, and soils, vary widely from one region in Pakistan to another, although diurnal variations within large areas are frequently greater than between them. For example, the average annual rainfall in Pakistan varies from 100 mm in Sindh, to 750 mm in the northern foothills. To a large extent, these conditions determine the crops that can be grown, cropping calendars, and crop irrigation requirements during different parts of the year.

In the western and northern mountain regions of Pakistan there has been an extensive development of farmer-managed surface irrigation systems. Although in relative terms it may not represent more than 3-4 percent of the total irrigated area of Pakistan, in absolute terms it comprises approximately half a million hectares, an area which is far from negligible when compared to irrigated area in many other countries. This figure does not include the extensive areas (may be in the

order of magnitude of 600,000 hectares) under spate irrigation by diversions from hill torrents encountered in Punjab and Baluchistan (Rod Kohi) and another 500,000 hectares of receding flood irrigation along the major rivers (Sailabe).

The large number of institutions in Pakistan involved in irrigation, drainage and salinity control monitoring and evaluation or research represent a potential wealth of skills, experience and knowledge that could be applied to developing better solutions to the problems of irrigated agriculture in the country. Capitalizing on this knowledge and experience could be highly beneficial for a program of irrigation management research in Pakistan.

The special characteristics of the Pakistan irrigation system and its environment pose some interesting challenges for irrigation management research. The large variety of irrigation conditions prevailing in the country requires different strategies and practices in the supply, delivery and use of irrigation water, and therefore, a different set of physical and management conditions and activities.

A comparative analysis of these requirements can lead to a better understanding of how recent advances in knowledge and practice in management science can be instrumental in improving the management and, consequently, the performance of irrigation systems.

A program of irrigation management research, based on the unique opportunities offered by the Pakistan irrigation environment, would not only benefit Pakistan, it would also benefit irrigation development in Third World Countries in general.

The development of an irrigation management research program in Pakistan, however, encounters some constraints. Prominent among them is the general attitude that problems and issues of irrigation systems performance are seen as those essentially of a technical nature and as a consequence of system inflexibility.

It is against this general background that IIMI Pakistan has tried to meet its challenge by engaging itself in irrigation management research in Pakistan.

It has done so by adhering as much as possible to three basic principles that underly an effective approach to improved irrigation management:

First, taking the whole system as the initial unit of analysis. Quite often there is overconcentration on one component of an irrigation system without prior attention to the whole. The whole system here includes all water and non-water related activities, functions, tasks or missions and their operational and institutional dimensions needed to achieve systems objectives. Appraisal of the whole system is a necessary stage while interventions often have to apply initially only to parts of the system.

Second, multidisciplinarity. Narrow disciplinary perspectives, and the omission of the concerns of any major discipline or group of disciplines (especially engineering, hydrology, soil science, agronomy, agricultural economics, sociology and management) can generate misleading diagnosis and ineffective prescriptions. Some aspects of irrigation can also be left unilluminated as gaps between disciplines.

Third, a field (action) orientation. Analysis and activities to improve irrigation management must be rooted in field realities. Diagnostic analysis, planning, design and operation must all be practical, field tested and implementable given the constraints of the real world.

These three principles are not often implemented together. Whole systems are analyzed, but by one or two disciplines only. Multidisciplinary field-based diagnosis are undertaken, but mainly below the outlet. These partial analysis leave gaps in diagnosis, prescription and understanding.

With the objective of improving and sustaining the performance of irrigation systems through management innovations, IIMI Pakistan therefore follows an approach of multi-disciplinary collaborative field research involving representative portions of existing irrigation systems where the full range of physical, agricultural, social and economic factors inter-play.

IIMI's collaborative research program in Pakistan therefore is based on the selection of "representative areas". These areas act as "field laboratories" for addressing a number of problems encountered in the operation, maintenance and management of irrigation systems in Pakistan in a holistic way in different irrigation environments.

Progress of Research Activities

IIMI Pakistan's research activities include two broad categories:

- Component specific, or irrigation management issues related to certain specific components or functions of the irrigation system.

- Environment specific, or irrigation management issues that relate to a specific irrigation environment.

In the category of component specific research, three projects were initiated during the period: main system irrigation management, management of distributary systems, and farm-level irrigation management. Work on the first item was interrupted when the irrigation specialist left IIMI-Pakistan, and was revived later but only to be continued on a low key, pending the appointment of an Irrigation Engineer.

In terms of environment specific research, three projects were carried out during this period: conjunctive management of surface and groundwater in fresh groundwater areas, farmer-managed irrigation systems in the mountain region of northern Pakistan, and irrigation management in waterlogging and salinity hazardous environments.

The progress of these activities as at the end of year 1989 is given below.

IV.1 ***COMPONENT SPECIFIC RESEARCH ACTIVITIES***

1. *Main System Irrigation Management*

In the Indus system, the relatively few control points from which irrigation operations can be managed are mostly located upstream. Operational changes at these points can dramatically affect water distribution in branch and distributary channels and the vast areas they serve. Further, there is little opportunity downstream to compensate for changes made upstream.

IIMI addressed how large canals can be managed given few control points and limited connection between water supply and demand. Initial work focussed on the Upper Gugera system in the vicinity of Farooqabad. Main channel gauges and the head gauges of several distributaries were observed on a daily basis. Rating curves were derived from this data. Collecting similar data on water flow was also started two hundred kilometers downstream in the Lower Gugera system, so that changes in the upper portion of the main system could be related to changes lower down in the same system.

Analysis of several years of PID data shows that equity of water distribution between distributaries is rarely achieved. In the case of some distributaries, it is impossible to predict distributary discharges from the main channel data. There is a seasonal relationship between variability in the main channel and variability in the distributaries. Data suggest that differences in management inputs at distributary head gates directly affect equity of water delivery between distributaries.

Field observations have shown that during periods of restricted discharges (following the canal closures and during floods), the deliveries of water to the distributaries in the head and tail reaches is greatly upset. However, when main channel discharges are above 95% of their design level, the head distributaries take at least their design discharges but the distributaries at the tail do not get their appropriate share. At the tail of the main channel (Bhagat Sub-Division), most of the time there is rotation between the different distributaries, due to a shortage of water.

After analysis of data collected from Farooqabad and Bhagat, it will be possible to explain the variations at the main system level, and to suggest management interventions to improve canal operations.

2. *Management of Distributary Systems: Variability and Equity in Secondary Canals*

A distributary, as the name implies, is the most important link in the canal network for distribution of supplies to the farmers through the outlets. An outlet is a masonry structure through which water is delivered from a distributary into a watercourse serving an area in the order of 150 - 250 hectares. The distributary is the last link which is managed by the government whereas the watercourse is managed by the farmers. Thus it is the border where the state management ends and farmer's management starts. All distribution of water is done at distributary level. Generally no outlets are provided in the main canal and the branches.

There is usually no control on the distribution of supplies in the distributaries. Once a proper supply of water enters the head of a distributary, it is distributed to each outlet automatically according to its design capacity (based on the area served) as the outlets are not provided with any control device. The

late Mr. R. G. Kennedy, an eminent irrigation engineer of Punjab Irrigation Department, remarked about the automatic working of a distributary without a manual control, "that it be so designed and worked that at all times and at each point it will just carry as its full supply a discharge sufficient to supply to all outlets below that point so that when the proper quantity enters the head, all the watercourses should run their calculated allowance with no surplus at the tail of the distributary".

This gave rise to the concept of "equitable distribution of supplies". Distributional equity remains a performance objective central to the irrigation system in Pakistan. The efficiency of the Department for distribution of supplies to achieve equity mainly depends upon the efficient operation and management of supplies in the distributary canals.

Most of the efforts of the department are directed and concentrated at the distributary level. The general problems faced by the irrigation engineers in the field also concern the distributaries. The main problems regarding distribution of supplies at distributary level are:

- to allow correct discharge into the distributary at head with minimum variation in discharge;
- siltation of the distributary especially the small distributaries;
- unauthorized interventions by water users to draw more water illegally.

IIMI's research on distributary systems includes research on variability and equity of water distribution (the subject of this chapter) and on impact of lining (the subject of the next chapter).

Research on variability and equity focused on analyzing and documenting three aspects of this problem: adequacy of system operations, the relation between current conditions and design norms, and the extent and forms of management currently practiced in representative canal systems.

Data Collection and Analysis

Research activities started in the Lagar Command Area and expanded to other distributaries within the Lower Chenab Canal (LCC) system. In addition to regular observations of several distributary head gates in Upper Gugera, regular field observations were extended to distributaries at the tail of Lower Gugera where the water supply conditions were quite different.

The measurement program of outlet discharges under different distributary head conditions within Lagar command, began in mid-1987. It was continued until sufficient data were available to establish rating curves and discharges throughout the command area.

Beginning in late 1987, IIMI Pakistan began measuring water deliveries to selected sets of watercourses on Pir Mahal Distributary, Bhagat Sub-Division, expanding to additional watercourses on Mananwala Distributary, Farooqabad Sub-Division, in early 1988. Staff also began monthly sample surveys of irrigated cropping patterns within the commands of a more limited number of watercourses along these distributaries. Khikhi Distributary, Bhagat Sub-Division, also was included in this water measurement program, primarily to monitor performance changes in the distributary as the lining program there was progressing. There were several reasons for this expansion in field data collection activities.

First, it would permit the validation of preliminary research findings concerning distributary channel performance in terms of equity and variability for a relatively small distributary, Lagar, by results from larger distributaries. Pir Mahal, Mananwala and Khikhi Distributaries are larger (165-300 cusecs), physically more complex channels--each having several minors or sub-minors, that serve much larger command areas.

The second reason was to test the feasibility of more practical methods to assess secondary system performance which would be more rapid, efficient and cost-effective.

Thirdly, there was a need to expand the scope of research to encompass distributary conditions within a greater range of hydrologic environments and conditions. Fresh groundwater suitable for irrigation is assumed to be prevalent throughout most of Mananwala command. In Pir Mahal command, groundwater is considered to be more

saline. Hence fewer opportunities exist to use tube wells to moderate the impact of inequity and variability in surface water supplies. Also in Pir Mahal, rotational deliveries between minors are commonly implemented.

Two sampling procedures were followed in selecting sample outlets and watercourse commands for daily monitoring of water deliveries, water measurements and calibration, and cropping pattern surveys. In selecting sample sites, one method employed was the common procedure of selecting head, middle and tail watercourses with respect to absolute distance measures. A second employed the concept of Equivalent Distance, a measure which combines hydraulic factors with absolute distance along a channel. Equivalent distance is a new concept with potential utility not only as a survey research tool in irrigation research, but also as a management tool. ("Equivalent Distance: Relating Distance to Hydrology," IIMI Review, vol. 2, no. 1 [April, 1988], pp. 17-18)

Examination of partial data sets for the additional distributaries under study in the LCC system confirm earlier findings that the distribution of surface water is substantially inequitable when original design parameters no longer prevail. However, data for Khikhi Distributary indicate that when design parameters are re-established, the equity objective is largely met.

Data indicate that, first, as long as discharge is kept above 70 percent of design, tail end effects are not proportionally different than at full discharge -- tail outlets draw about 40 percent of design discharge whereas head outlets draw in the range of 125 - 150 percent. Second, when distributary discharge drops below 70 percent of design, this relationship is disrupted, and when discharge falls to about 50 percent of design discharge, tail outlets draw no water at all.

These findings verify Irrigation Department operational criteria. They also have serious implications for management. Without considerable design changes, operating long distributary channels without gated structures above or below a discharge range of 70 - 100 percent will have a devastating effect on equity and variability of outlet discharges to watercourses. Thus, in situations where irrigation demand varies outside this range, and maintenance of distributional equity remains an operational objective, there must be a major change in both system design and management.

Research completed on Lagar Distributary in 1987 identified watercourse improvement as an additional cause of inequity in surface water distribution. This as a result of a tendency to concentrate watercourse improvement measures as lining on the head reaches of distributaries. Watercourse lining usually results in the reestablishment of modular discharge conditions at the outlet where non-modular flows previously prevailed, as it should do. When this occurs, distributary head-end outlets frequently deliver discharges greater than sanctioned because of the synergistic interaction with poor distributary maintenance. This necessarily reduces water supplies available to more distant outlets.

During 1989, IIMI augmented its continuing field measurement and data collection activities related to the performance of distributaries in two sub-divisions of the Lower Chenab Canal system by action research to assist the PID in improving equity conditions and reducing variability in water distribution in a distributary command. Following the approval by the Chief Engineer, Faisalabad Zone, of IIMI's proposal to target annual closure maintenance on Lagar Distributary based upon field data and performance profiles, resources were allocated to the Executive Engineer, Upper Gugera Division, to implement the proposed activity.

Re-sectioning and desilting of Lagar Distributary as close to design conditions as practical were targeted for two reaches, as were bund restoration activities for specific points of erosion. IIMI completed longitudinal and cross-sectional surveys of the targeted reaches in order to benchmark and subsequently monitor the effects of this annual maintenance which was completed during the annual canal closure of Farooqabad Sub-Division canals from late January through February.

Analysis of data collected for Lagar Distributary operations in the first two months following the targeted maintenance activity revealed a marked improvement in water distribution to outlets in the lower half of the distributary. Whereas water supplies to the third quartile of Lagar Distributary outlets had averaged below 50% of sanctioned discharge for eleven of the twelve previous months, they averaged more than 90% of sanctioned discharge for March and April, 1989. Perhaps even more dramatic was the increase in average discharge to the fourth or tail quartile of Lagar outlets. Here

water supplies which had exceeded 25% of design in merely one month but had been below an average of 10% of design in eight of the previous twelve months averaged 40% of sanctioned discharge throughout March and April.

Overall, the distributary operated with the most equitable distribution of water for any two month period that IIMI has measured since performance monitoring began on Lagar two years ago. Numerous tail farmers claimed that surface water supplies to their outlets were greater than they could remember for any period in the past 10 years.

Continued monitoring of Lagar Distributary performance through June and July revealed, however, that this improvement in water distribution equity was not sustained. Field measurement and observational data permit at least a preliminary identification of two crucial reasons for this development that have significant implications for similar management interventions designed to improve secondary canal performance. These are (1)targeted maintenance was not implemented and carried out as completely as planned, and (2) improved water supply conditions led directly to additional interventions by farmers and ID field staff to appropriate supplies at points of locational advantage on the channel.

The first condition points to the need for a more effective oversight and management capability of contracted maintenance activities at both sub-divisional and divisional levels. The second situation highlights the necessity for institutional strengthening to halt the drift toward anarchy in irrigation operations.

What is needed is a functional institutional structure wherein agency officers and farmers can cooperate to support the restoration and maintenance of the integrity of the physical system and ensure adherence to and enforcement of established rules and laws in system operations. This is a major irrigation management challenge in Pakistan.

A second IIMI proposal for an action activity aimed to reduce the impact of variations in branch channel flows upon discharges into Lagar Distributary; it has not been implemented as yet. Here the objective is a more careful management of distributary head gate operations.

A hydraulic model has been developed and calibrated for Punjab applications by using empirical data collected at the distributary level. This model has been used to successfully predict actual water supplies at all outlet heads on a daily and monthly basis by using only daily head, bifurcation and tail gauge readings. In addition, the model is being tested for its suitability for wider use as a management decision support tool.

In Farooqabad Sub-Division, an available canal management option is rotational operations at distributary level. This practice was simulated for Lagar Distributary and compared with actual operational practices. Initial results indicate that while there was a modest decrease in discharges of offtakes in the upper two-thirds of the distributary, most continued to draw at or above their sanctioned amounts. More importantly, there was a substantial increase--two to three times--in supplies to offtakes in the lower one-third of the channel. Insofar as distributary hydraulic conditions vary little, if at all, among Farooqabad Sub-Division channels, the preliminary conclusion is that equity in surface water distribution could be significantly improved by introducing rotations at distributary heads in the sub-division, especially during low discharge periods in the branch channel.

In Bhagat Sub-Division, flood-disrupted performance monitoring of Pir Mahal Distributary continued following the completion of repairs to the extensively damaged lower one-half of the channel. Here, simultaneous intra- and inter-distributary rotational operations are being carefully monitored in order to evaluate their impact on water distribution throughout the distributary and its minors. For this purpose, benchmarking of Junejwala Minor, Pir Mahal's principal offtake where intra-distributary rotational operations are implemented and a distributary that closely parallels Lagar Distributary in its physical conditions, was completed and three clusters of outlets here were added to the overall Pir Mahal monitoring program.

3. *Management of Distributary Systems: Impact of Lining Secondary Channels and Rehabilitation Strategies*

The main objectives of IIMI Pakistan's research on rehabilitation strategies, involving the lining of distributary channels, are: 1) to assess the impact of rehabilitation activities upon water deliveries to the

turnouts; 2) to identify more cost-effective approaches to distribution system rehabilitation by analyzing current rehabilitation programs in the field.

In late 1986, the Punjab Irrigation Department requested IIMI scientists to evaluate the impact of tail-reach lining of two distributaries, Ghordour and Lagar, upon water delivery to tail-end outlets. The study utilized existing Irrigation Department records and secondary data. Unfortunately, baseline data on pre-project water deliveries to outlets had not been compiled, and other gaps and inconsistencies were also present in the secondary data made available to IIMI.

Completed in early 1987, the study revealed some apparent improvement in the reliability of post-lining water deliveries. However, it was impossible to distinguish whether changes in water supplies to outlets resulted from increased channel inflows or were due to the lining. More conclusively, the study recommended that before a large scale program of lining minor and distributary canals was initiated, there should be a substantial evaluation of the relative benefits of channel lining compared to upgraded maintenance. ("The Impact of Lining of Lagar and Ghordour Distributaries," by D. Hammond Murray-Rust, IIMI Review, no. 1, [1987], pp. 7-10.)

In mid-1987, the PID requested IIMI Pakistan to undertake further studies of distributary rehabilitation, and offered to allow IIMI to conduct baseline studies before implementation of a lining project on Khikhi Distributary In Bhagat Sub-Division, LCC. Originally, the PID had planned to line nearly all 28 miles of the distributary over a two-year period. Beginning its work in October 1987. Before the initiation of the first phase lining of Khikhi below RD 108, IIMI Pakistan staff completed baseline distributary and outlet waterflow measurements under different head conditions. Pre-lining, benchmark profile and cross-sectional surveys of Khikhi Distributary were also completed during the annual closure period. Following initiation of the project, field researchers observed and documented the lining process itself.

Parallel baseline and benchmark surveys were also carried out on the neighboring Pir Mahal Distributary in preparation for monitoring and evaluation of a major desilting program for rehabilitation planned for the 1988 annual closure period, later rescheduled for 1989. IIMI's objective was to make a cost-benefit comparison

between lining and major desilting as rehabilitation strategies in comparable hydrologic environments. Such a study would have provided the Irrigation Department with an improved basis for determining its rehabilitation and maintenance strategies for secondary channels. Unfortunately the PID again postponed desilting Pir Mahal Distributary at least to 1991.

Field data measurement and observational activities were carried out on Khikhi Distributary during rabi 1988-89 to monitor post-lining performance changes in the reach below RD 108. These activities were halted after the close of rabi season because distributary conditions and operations were substantially disrupted when the Phase II lining work was initiated between RD 70 and RD 108. IIMI resumed post-lining performance monitoring following the completion of Phase II lining in late 1989.

During the 1988 annual canal closure, a major maintenance activity was implemented along Lagar Distributary. IIMI Pakistan completed both profile and cross-sectional surveys of Lagar prior to the initiation of maintenance works, and again after maintenance was completed. This information, combined with pre- and post- maintenance water measurement data for several distributary reaches and all watercourse outlets, permitted the comparison of distributary performance in water distribution before and after the annual closure maintenance activity. Analysis of data showed that the impact of maintenance was substantial, and actually increased inequity in water supplies between different channel reaches.

There was a significant increase in water supplies at Jhinda Minor (Lagar subsidiary channel) bifurcation after this maintenance. Concomitantly, there were increased difficulties in maintaining adequate water deliveries to outlets below the bifurcation in the lower half of Lagar Distributary. The management implication was obvious: annual maintenance programs need to be better planned and carefully implemented so that maintenance in one part of the system does not have adverse effects upon water supplies to users in other parts of the system. This work led directly to IIMI's proposal to the ID to target annual maintenance in the Lagar in 1989 as reported in the previous chapter.

4. *Farm-Level Irrigation Management*

Availability of irrigation supplies, both from surface and groundwater sources is the most important determinant of the performance of irrigation systems in Pakistan.

Pakistan's irrigation system has been designed as a "protective" system, giving every one an equal share of the limited resources available. This resulted in water allowances as low as 1.5 - 2.4 mm/day for the traditional perennial systems and 2.4 - 3.6 mm/day for the non-perennial non-rice systems. Non-perennial rice based systems have considerably higher water allowances, exceeding 6.0 mm/day.

In addition Pakistan's irrigation system is considered highly inflexible. Here flexibility means the possibility of adjusting in time, both supply and demand to a certain extent, without increasing the total amount of available resources.

Pakistan irrigation systems are considered highly inflexible because of limited canal capacities (see above) and lack of sufficient control structures. In addition there are limited possibilities for surface storage within the irrigation system; therefore, opportunities for a more flexible surface water supply are relatively modest, except in the modernized perennial systems. Conjunctive use of ground and surface water offers an opportunity to increase the flexibility of the system. This, however, generally goes hand in hand with an increase in the total volume of water consumed per unit of area. The question is what can the farmer do with a given supply of water, and what could he do if a certain amount of flexibility could be introduced, either at the farm or systems level.

If little can be done in terms of flexibility in supply, the emphasis should be on adjusting demand to supply. Adjustment of cropping patterns with an appropriate mix of drought or salt tolerant and sensitive crops could be an option, provided it does not conflict with aspects of profitability and sustainability.

The most important decision the farmer has to make is what and how large an area to plant. In water short environments this decision is taken, realizing that there is insufficient water for unconstrained crop water requirements for the entire farm area. Partial irrigation or deficit irrigation, in terms of purposely

under-irrigating crops to reduce yields per unit of area and increase yields per unit of water, is one option the farmer could consider. Partial irrigation is, however, a much more complex process in terms of irrigation management, than irrigation for optimizing crop production per unit of area.

Against this general background farm-level irrigation management research performed by IIMI Pakistan has as its broad objectives: (1) to capture farmer perceptions to irrigation problems and new opportunities, for example, inadequate or variable supply, additional water supplies, or waterlogging. This will lead to an understanding of how farmers cope with such problems or respond to such opportunities; (2) to better understand main system - farm-level interactions; (3) to suggest irrigation - related farm -level management solutions that can be successfully employed.

Collaborative Arrangements

Soon after its establishment in September, 1986, IIMI Pakistan started looking for management opportunities which offer improvement potential and where national agencies particularly Provincial Irrigation and Agriculture Departments could be jointly involved to improve performance of irrigated agriculture in the country. One of such opportunity was to assist the Punjab Agriculture Department (PAD) especially its extension wing in carrying out research activities leading towards improved efficient and productive use of available irrigation supplies.

The Extension Directorate General, the agency responsible for advising farmers on improved production practices, is primarily engaged in crop related extension activities. Most of its field staff, therefore, is not well trained for irrigation extension activities. Therefore, IIMI organized several training courses to train Agricultural Officers (AOs) and Field Assistants (FAs) on irrigation water management. These courses were held in collaboration with Water & Power Development Authority (WAPDA) and On-Farm Water Management Directorate. About 15 AOs and 60 FAs of PAD were trained during the past three years.

Also three staff members of On-Farm Water Management Directorate undertook their MSc thesis research on various aspects related with these collaborative activities under the guidance of IIMI staff. A special training session was held to train On-Farm Water Management staff on use of tensiometers.

Data Collection and Analysis

IIMI Pakistan's collaborative activities with the Punjab Agriculture Department focussed in particular on irrigation constraints to wheat production.

Wheat is indeed one of the most important commodities in agricultural production in Pakistan. It covers an area of approximately 7.5 million hectares; average yields are 1.8 tonnes / hectare; and wheat imports are in the order of 1-2 million metric tonnes / year.

Several irrigation related constraints for wheat production based largely on analysis of existing records and supported by few field observations were discussed with the PAD. These included: inadequate and variable water supply; period of canal closure; early termination of irrigation; waterlogging and salinity. Initial research focussed on two subjects in particular: canal closure and early termination of irrigation.

The study was initiated during the Rabi season of 1987-88 in four districts of Punjab, namely: Kasur, Lahore, Sheikhupura and Gujranwala. For the year 1984-85, wheat represented 56.5, 41.4, 47.4 and 53.1 percent of the total cultivated area (year round) in these districts, respectively (Punjab Agriculture Statistics, 1986). One hundred and ninety four (194) farmers, cultivating irrigated wheat as the major Rabi crop, were selected from 50 villages. They represented a range of good, average and poor farming conditions and irrigation practices. Employees of the Provincial Agriculture Department selected farmers for the sample survey.

Data collection included information on crop rotation, land preparation, date and method of sowing, wheat variety, seed rate, plant population, fertilizer application, amount and timing of each irrigation. Canal closure and early termination of irrigations were broken using supplementary water supply from tubewells while keeping all other variables constant. The work initiated

in Rabi 1987-88 was continued during Rabi 1988-89. Most of the field work was carried out by employees of the PAD, with supervision provided by IIMI Pakistan. The results are summarized as follows.

- The timing of first irrigation, is most critical. In cases when first irrigation was applied in time, an average increase of 20% over the average wheat yields was obtained.

- The impact of late irrigation at the soft dough stage showed an increase in yield of 6 percent. This yield increase, though small, was statistically significant. Unusually heavy rains in the area in March in both Rabi seasons possibly reduced the difference in yields which otherwise might have resulted from the late irrigation of wheat.

- Wheat production per unit of irrigation water was higher where the farmers had access to private groundwater supplies, implying that reliability of supplies has a dominant impact on water use efficiency.

A final report covering the entire study period and summarizing finding and recommendations is to be published by the middle of 1990.

These findings have to be placed in the background of irrigation management practices carried out on wheat production by farmers in Central Punjab and who deviate from recommended practices in three significant ways:

- Seasonally, less water is applied by farmers who tend to over plant and under irrigate, hoping that abundant rains will close the gap between irrigation supplies and evapotranspirative demands.

- The first irrigation is often applied too late, because canal closure for maintenance and sowing dates are insufficiently coordinated. The delay in first irrigation has a double negative impact because a side-dressing of nitrogen is commonly applied with that irrigation, and consequently, a delay in irrigation affects uptake and utilization of nitrogen in addition to crop water status.

- Farmers terminate their irrigations in early to mid-March, when the crop is at the grain filling stage, when temperatures rise abruptly, and therefore when the crop needs water the most.

Analysis were also carried out on wheat yields in relation to source of irrigation water. Wheat yields were compared for three different water sources or combinations thereof: public canal water, public tubewell water or private tubewell water.

The general conclusions from these studies are two-fold:

- Comparing yields per unit of area the general conclusion is that there is relatively little difference associated with different water sources, alone or in combination. In addition, when efficiency of water use is measured in these terms, private tubewells are not better than canal sources.

- Comparing yields per unit of irrigation water suggests a different interpretation. Here the highest yields are obtained from fields having simultaneous access to all three sources of water. Fields that rely on public water sources only (canal water, or canal water and public tubewell water) show the lowest yield per unit of water, though these improve when coupled with private tubewells.

This illustrates the importance of using appropriate performance measures. Yields per unit of water is likely to be the most appropriate measure for evaluating the technical efficiency of this scarce resource. Technical efficiency, however, not necessarily needs to be the only system's objective. Net income per unit of irrigated area for instance is an important indicator for the financial utility of the system, and has implications for the ability of farmers to pay water and other service fees.

A more complete understanding of farmer irrigation and agricultural rationales is therefore necessary to determine appropriate irrigation policies.

IV.2 ***ENVIRONMENT SPECIFIC RESEARCH ACTIVITIES***

1. *Conjunctive Management of Surface and Groundwater*

The relative importance of the role of groundwater in irrigated agriculture in Pakistan is illustrated by the following figures:

From a total annual river flow of 17.8 million hectare-meters, 12.4 million hectare-meters or 70% is diverted for irrigation purposes.

Mangla and Tarbels storage reservoirs provide together an annual storage of 1.9 million hectare-meters.

On an all lPakistan basis the total contribution from groundwater pumpage to irrigation supplies is estimated to be 2.9 million hectare-meters per year or 23.4% of the surface supplies. For the Punjab, the province with the largest number of tube wells (approximately 10,000 public and 240,000 private) contribution from groundwater pumpage is as high as 39.0%.

The average increase of private tube wells in Punjab at present is 8,000 to 10,000 tube wells per year. The private tube wells are contributing about 73% of the total pumpage.

This clearly illustrates the importance of tubewells in sustaining agriculture production in Pakistan.

IIMI-Pakistan, therefore, initiated an irrigation management oriented research program an conjunctive management of surface and groundwater in Punjab. The main objectives of the research program are:

- To define the ways private and public tube well operations correlate with canal system operations in de facto conjunctive use irrigated agriculture environments.

- To evaluate the options for conjunctive management of surface and groundwater irrigation systems under different conditions of ownership of private pumps and public tube wells.

- To initiate development of a reliable, current, empirically-based information database on private tube well location, service area, discharge, operations and water quality organized on the basis of surface irrigation units.

Collaborative Arrangements

IIMI's field research focusing on de facto management of surface and groundwater supplies for irrigation is an effort that involves the Punjab Irrigation Department's

Irrigation Research Institute (IRI), WAPDA's SCARP Monitoring Organization (SMO), the Economic Analysis Network (EAN), ENERCON, and Cornell University, the latter through ISPAN support. The IRI continues to collaborate with basic field research; EAN has made economic expertise available to IIMI; ENERCON and IIMI have cooperated with energy efficiency appraisals for selected private wells within one distributary command area; the SMO has provided access to historical water quality information for some areas in which IIMI is working; and Cornell has provided technical research staff and support. All groundwater research activities are coordinated with IIMI's canal operations research at different locations in the Lower Chenab Canal system, as well as with below the outlet research on irrigated agriculture.

Data Collection and Analysis

Although IIMI's groundwater and tube well-related research is currently underway in three distributary commands within the Lower Chenab Canal system, to date, detailed studies have been concentrated in the command area of Lagar Distributary, building upon the tube well census work previously completed there. IIMI's attention has focused primarily on two issues related to de facto conjunctive use: shallow groundwater quality and tube well utilization.

Joint field work conducted by IRI and IIMI within Lagar's command area produced some rather startling results regarding the quality of groundwater farmers use for irrigation purposes. In particular, IIMI and IRI found that the majority of private wells pumped water that was unfit or very marginal for irrigation purposes, based on water quality standards used by the Punjab Irrigation Department's Directorate for Land Reclamation. Furthermore, groundwater quality tends to deteriorate dramatically between the head reach of Lagar Distributary and its tail areas. Finally and importantly, private tube wells on average were found to pump water of poorer quality than adjacent public tube wells. Insofar as Lagar's command area falls entirely within SCARP-1, and the upper quarter of the command is included within Scarp Transition Pilot Project (STPP) Khanwah Dogran area, these findings may have significant implications for the public tube well divestment strategy currently embodied by the STPP concept.

To verify these findings in Lagar's command area, to further explore the physical water quality situation for the Punjab both spatially and temporally, and to investigate the implications of these findings for agricultural production, IIMI initiated several new groundwater research activities. First, IIMI researchers completed a literature review of the groundwater quality publications available within Pakistan to determine the current state of knowledge about the shallow groundwaters tapped by private farmers for irrigation purposes.

Second, historical data has been obtained from WAPDA's SMO on water quality changes for deep public wells within the SCARP-1 area since its inception in the early 60s. The SMO also has supplied test bore data for Rechna Doab that includes information on vertical variations in groundwater quality for over 200 test bores sunk there in the late '50s and early 60s. Third, IIMI and IRI jointly cooperated in a resampling of private wells within Sheikhupura District for which IRI collected water quality information in the mid-1970s.

Fourth, IIMI resampled private and public wells within Lagar command to determine whether there are seasonal variations in water quality. As part of this project, hand pump bores are also being sampled for water quality to determine whether water quality further deteriorates as one approaches the water table. Finally, IIMI staff interviewed private tube well owners in order to link measured water quality parameters with farmer-reported agricultural production problems.

Several interesting results already have begun to emerge. Analysis of test bore data for Rechna Doab revealed that as early as 1960, the majority of test bores sunk within the Doab showed the quality of shallow groundwater (usually tapped by the typical private wells) to be worse than the quality of deep groundwater (usually tapped by public wells). Tube well owners within Lagar's command report that in some cases cropping patterns must be changed (i.e. crops with a high water requirement are replaced by crops that need less water) to adjust to poor or deteriorating tube well water quality. Finally, almost without exception distributaries within the SCARP-1 area show the same marked difference between groundwater quality in their head reaches and their tail reaches as was found in Lagar's command area.

By the end of October, 1989, IIMI had collected tube well utilization data for some 200 private and public wells within Lagar's command area, and more than 60 wells from selected watercourses on Mananwala Distributary covering a one year period (rabi 1988-89 and kharif 1989). This data is now being thoroughly analyzed, but preliminary work again has revealed some important initial findings.

Based on data collected between July, 1988, and December, 1988, the average private well utilization rate was 12%, while for public wells it was 57%. In the case of private wells, however, the utilization rate for electric wells was 27%, but for diesel wells and tractor off-take bores, it was 8% and less than 3%, respectively. One obvious conclusion is that private electric wells are used more than 3 times as much as diesel wells, and more than 10 times as much as tractor off-take bores. More importantly, based on the surveyed installed capacities for private and public wells within Lagar's command, these utilization rates imply that private and public wells pump approximately the same amount of water from the aquifer underlying the canal command, and that the two combined provide more than two thirds of the total water supply used by farmers to irrigate crops.

This highlights both the extremely important role groundwater currently plays in the irrigated agricultural system in Lagar command, as well as, the significance of pumpage by electrically driven tube wells (all public tube wells and a substantial fraction of private tube wells). Clearly, any improvements in the current pattern of de facto conjunctive use or movement to an active program of conjunctive use management of groundwater and surface water will require both more reliable electric power supplies and much better institutional linkages between WAPDA power distribution, farmers and the Irrigation Department than now exists.

Detailed water budgets were maintained for 45 tube well owners to identify and quantify the determinants of private tube well utilization. Special attention is being given to the remarkably different pattern in utilization rates for electric and non-electric private wells. How much of the additional pumpage by electric wells is attributable to the fact that electric wells seem to have more owners per well, on average, than non-electric wells? How much is due to the possibility that electric well owners own more land, on average, than their non-electric well owner counterparts? How much is due to the extra selling of water electric well owners

do to tube well non-owners? How much might be due to differences in cropping patterns between electric well and non-electric well owners? The answers to these questions will have special meaning for electricity tariff policies and the SCARP Transition Pilot Project, which has chosen to emphasize electric private tube wells development over non-electric tube wells.

In several watercourse command areas of Lagar Distributary, IIMI is looking more closely at the availability of private groundwater resources for those farmers who do not own wells. IIMI is also monitoring the progress and effects of the SCARP Transition Pilot Project for the three Lagar watercourses that it directly affects. Finally, work is currently underway to combine the knowledge IIMI has gained about the operation of several distributaries within the Lower Chenab Canal system and their tube wells to gain a more complete understanding of how surface and groundwater supplies are directly and indirectly linked.

2. *Irrigation Efficiencies in Farmer-Managed Irrigation Systems in Hunza-Gojal*

In the difficult and marginal environments of Northern Pakistan, irrigation development programs directly confront the problems of increasing and sustaining agricultural production, food security and income equity for small farmers. The dry continental climate of the region is characterized by low annual rainfall (100-150 mm) and a marked seasonal temperature range at elevations in the inter-montane river valleys where settlement is concentrated. This means that agriculture is dependent upon irrigation water tapped from snow and glacial melt or the occasional spring. Irrigation systems here are small-scale, traditionally farmer-designed, constructed and managed using indigenous technology and techniques. Since 1982 in the Northern Areas, the Aga Khan Rural Support Program / AKRSP has been mobilizing rural people to undertake development work on a permanent, locally-sustainable basis through village organizations.

Having created a successful intervention strategy for developing farmer-managed irrigation systems (FMIS) AKRSP was asked by a World Bank interim evaluation report to address several interrelated downstream operation and maintenance issues. The Bank report recommended that attention be given to distributing the available water efficiently throughout these new systems and to minimizing water losses as well as system maintenance.

In this context IIMI, in collaboration with AKRSP, undertook research to determine current system performance in several AKRSP-assisted as well as older, established FMIS in Hunza Gojal and to identify what improvements, if any, can be made in the design, development and management of irrigation systems currently followed by farmers. Proposed research included the following components:

- A comparative assessment of irrigation system goals and efficiencies in new, AKRSP - assisted and previously existing Gojal FMIS;

- A diagnosis of major facators -- physical and operational --that govern irrigation efficiencies in Gojal FMIS;

- Recommendations of ways to improve irrigation efficiencies in Gojal FMIS, where justified, desirable and feasible.

Data Collection and Analysis:

An IIMI-AKRSP field research team established their "base camp" in Gulmit, Gilgit District, during the third week of March, 1989. Three older, well-established FMIS in Passu, Khaiber and Soust and three new, AKRSP-assisted systems in the same villages were identified for study in consultation with the senior management of AKRSP. Detailed field reconnaissance was immediately initiated on the 6 FMIS selected for study, although actual irrigation operations in these systems did not get underway until early April because of an unusually late spring in Gojal.

Preliminary data collection included longitudinal profile and cross-sectional surveys of each FMIS, schematic mapping of the systems and their command areas, identification of all farmer irrigation outlets, and basic soil characteristics and infiltration rates. These activities were essentially completed by late April and were the basis for subsequent selection of measuring points in each system to determine irrigation efficiencies in main and distribution channels, and of sample farmers and sample fields to determine field-level application efficiencies.

Primary data collection for system performance parameters--measurements of actual system flows at different locations, systematic observations and measurements of field irrigation applications and techniques, detailed interviews of irrigation practices--was carried out on all 6 Gojal systems. AKRSP team-members participated fully in these activities in order to gain intensive, direct experience in water measurement and data collection techniques suitable to determine system performance and to identify existing or potential operational problems. Field research was completed by August, 1989.

Data relating to system conveyance efficiencies indicate that at the main and distribution channel level, new FMIS are performing very nearly as well as older, well-established FMIS. Glacial silt deposited in the channel beds of new systems greatly reduces channel water losses and improves conveyance efficiency. Silt from irrigation deliveries is also an important component in the soil building process in new system command areas. Gojal farmers are well aware of this fact and rather systematically "use" silt deposition to both "harden" new irrigation channels and to reduce infiltration rates at the field level.

Detailed field application measurements on 24 separate grain (wheat, barley) and potato fields in the 6 systems, supplemented by systematic observations of irrigation applications on neighboring plots demonstrated that there is a significant degree of variation in irrigation techniques and subsequent differences in field application efficiencies achieved by farmers, notably in the command areas of new systems. Not incidently, women are actual irrigators of Gojal farm fields far more often than less systematic field observations have suggested, and their irrigation techniques frequently are quite different than those of men. However, insufficient data are available to evaluate the marginal costs and returns and assess the range of options for improving field application efficiencies.

Overall, data and information collected tend to confirm that for Gojal FMIS, land and labor (including labor to create more land) are much more scarce than is water throughout much of the agricultural year. Whenever water scarcity is a factor, farmers in Gojal have well-developed and appropriate institutional arrangements to ensure a high degree of equity in its distribution.

Finally, data suggest that Gojal farmers are clearly aware of environmentally appropriate techniques to operate and maintain FMIS--new and old--efficiently and effectively.

3. *Irrigation Management to Minimize Waterlogging and Salinity Problems*

Pakistan is accurately identified as a country where the adverse effects of irrigation are manifested in widespread waterlogging and salinity problems. Waterlogging at depths less than 1.5 meters typically affects more than 2.2 million hectares before the monsoon season and over 4.5 million hectares following the end of the monsoon rains. Salinity or sodicity affects an estimated 2.8 million hectares.

Since 1978, there appears to have been no statistically significant change in the overall area affected by waterlogging or salinity in the Indus Basin. Data collected by WAPDA indicate that although the extent of waterlogging and salinity is declining in areas where drainage is provided, in non-drained areas, particularly in those overlying saline groundwater, the problems are becoming worse.

Pakistan has invested heavily in physical solutions to its waterlogging and salinity problems (e.g. SCARPS, Left Bank Outfall Drain, tile drainage schemes). It has focused far less attention upon potential management solutions, designed to mitigate these problems or to diminish the probability of their occurrence.

This is not to suggest that management solutions alone could solve the problems of waterlogging and salinity. Rather a combination of physical works and changed system management practices, plus their effective integration, will offer the greatest likelihood of success in addressing the range of existing and potential waterlogging and salinity problems in the Indus Basin. Moreover, insofar as physical solutions to these problems are increasingly costly to implement, managing irrigation systems to minimize irrigation's contribution to waterlogging and salinity merits examination as a highly cost-effective strategy in the long run.

In early 1989, IIMI therefore initiated a research program to address irrigation management issues that could minimize waterlogging and salinity problems. The specific objectives of the program are to:

- Define system management practices which impact upon waterlogging and salinity.

- Define the array of possible physical and management solutions which have potential for minimizing irrigation's contribution to waterlogging.

- Identify irrigation system operational strategies for Kharif and Rabi seasons at various levels in the system -- main, branch, distributary, watercourse, that have promise of minimizing irrigation's contribution to waterlogging and salinity.

- Develop specific analytical methods to assess irrigation's contribution waterlogging and salinity, vis-a-vis other sources of the problems.

- Identify farmer mechanisms for coping with excess water, e.g. changing crops, modifying cropping calendars, providing on-farm drainage works.

- Evaluate under field conditions the environmental and agricultural productivity impacts of irrigation system management strategies with potentials to reduce waterlogging and salinity.

The program covers a period of five years and is implemented by utilizing irrigation systems in both Punjab and Sind.

The program started with a series of field visits and visits to potential collaborating agencies and universities, including the provincial irrigation departments of Punjab and Sind and WAPDA.

The information obtained during these visits, combined with a review of available literature, has led to a review of management issues related with waterlogging and salinity. This was submitted as IIMI's contribution to the Program Advisory Panel Meeting, held at Lahore, May 29-31, 1989, organized by the International Waterlogging and Salinity Research Institute, IWASRI,

with support from UNDP/DTCD. The meeting was held to draw up the national research agenda on waterlogging and salinity. IIMI's contribution was entitled "Irrigation Management in Relation to Waterlogging and Salinity".

A review of the project document was assigned to two eminent local experts, Mr. A. Wahab Sheikh, former Secretary, Ministry of Water and Power, and Ch. Altaf Hussain, former Chief Engineer Advisor, Government of Pakistan. These consultants were asked to comment on the research project and to suggest modifications which would make the project outcomes most relevant to the needs of the country. In particular the consultants were asked for recommendations with respect to strengthening of the national efforts to improve and sustain the performance of the irrigation systems. Their reports were discussed during an Expert Consultation organized by IWASRI on May 17, 1989.

During the Expert Consultation valuable contacts were made between the project management and representatives of institutes with whom the project plans to enter into collaboration agreements.

Collaborative Arrangements

- *With IWASRI:*

Following negotiations with its Director General, it was decided that IWASRI would undertake a review of existing information and methods used in Pakistan to combat waterlogging and salinity problems

- *With DRIP:*

At the Expert Consultation in May, 1989 it was suggested that the Drainage and Reclamation Institute of Pakistan (DRIP) would be the proper institute to address the ecological context in which waterlogging and salinity problems occur in Pakistan which would than lead to a more systematic characterization of these problems.

- *With CEWRE:*

The Center of Excellence in Water Resources Engineering (CEWRE) at Lahore is another institute which has the capability and interest in the subject of waterlogging and salinity. Possibilities of associating the

professors and post-graduate students from the Center with the program were discussed with its Director and subject areas for collaborative research identified.

- *With SSOP:*

Contacts are established with the Soil Survey of Pakistan (SSOP) having its headquarters in Lahore. SSOP will collaborate with IIMI Pakistan in carrying out detailed soil and salinity surveys (including physical and chemical analysis of soils and waters) in those areas that are selected by IIMI Pakistan for irrigation management research in relation to waterlogging and salinity problems.

- *With IWASRI / NRAP:*

NRAP stands for Netherlands Research Assistance Project. Collaboration with NRAP resulted in a publication under joint authorship of Dr. Hendrickx (NRAP) and Dr. Kijne (IIMI Pakistan) entitled "Soil Physical Managements for Drainage Design in Arid Regions". Staff of both institutions also worked together on the assessment of available flumes for discharge measurements in lined canals.

Data Collection and Analysis

Four types of data need to be collected : hydrological, institutional and managerial, agricultural and socio-economic. A start has been made with the collection of the hydrological data in two ways: firstly, through data collection on canal operation, discharge data, and water table depths from existing records with the Provincial Irrigation Departments and WAPDA, and secondly, through field measurements by IIMI field teams. With respect to the first type of data, from the existing records, it is realized that the data were not collected for research purposes, but are often recorded on a routine basis without any clear indication of their possible use. That limits the accuracy and reliability of the data recorded and is likely to restrict its use for research purposes.

The data on pre-monsoon and post-monsoon depths to water table of all 42 canal commands in the Indus basin for the last 8 years, as compiled by WAPDA, were analyzed to characterize the water table behavior and to see if there

were any persistent trends. This has helped in identifying a limited number of behavior patterns which were used to select local areas for detailed hydrologic investigations.

The information on water table behavior was also combined with the dominant characteristics of all canal systems (water allowances, availability of useable groundwater, precipitation, soil salinity, drainage, cropping patterns) to develop a matrix, which is intended to be used as a general guide for activities under various IIMI-Pakistan projects.

In the 1989 Kharif season two British civil engineers from the Institute of Irrigation Studies, University of Southampton, with IIMI supporting staff, collected data on the water balance during the monsoon in an irrigated area in the command of the Mananwala Distributary of the Upper Gugera Branch. It is not known with any degree of precision how the water table fluctuates as a result of recharge from irrigated rice fields and monsoon rains in an area where tubewells provide part of the irrigation water. Through a network of observation wells and determination of transmissibility characteristics of the soil profile, including infiltration rates and hydraulic conductivity, it is intended to quantify the sources of recharge to the water table. As part of other measuring programmes of IIMI in the command area, the use of tubewell water and of canal water is being monitored. Together these data will give some insight in the management of excess water as occurs during the monsoon season.

Agricultural data are collected from sources in the Department of Agriculture and through IIMI's field operations. Data collection in the two other areas, institutional and socio-economic, have not yet started. It is intended that these data should be collected through collaborative efforts with local institutes or university departments. Such efforts could be supported by IIMI-consultants and initial contacts to establish collaborative efforts in this direction and to attract consultants have been made.

V. Professional Development

In keeping with its policy of promoting professional development, IIMI-Pakistan provided opportunities for selected post-graduates to conduct field research on irrigation management problems related

to its research program. These research fellows and scholars worked on specific research topics developed in consultation with IIMI scientists who provided supervision and guidance for their field work.

The following persons were included in the program:

- *Dr. M. Akhtar Bhatti*, conducted post-doctoral research concerning Irrigation Constraints to Crop Production in Central Punjab. He also lead the research work on relative water supply;

- *Mr. Andrew Stone*, associated with the Kennedy School of Government, Harvard University, was engaged in research for his doctoral dissertation on Public Institutional Management: Interagency Coordination;

- *Mr. Muhammad Nawaz Bhutta*, Research Fellow, a PhD candidate in the CEWRE who did his research on The Effect of Varying Discharges on the Equity of Water Distribution in Irrigation Systems;

- *Mr. Robert Johnson*, Research Associate, a PhD candidate at Cornell University. His field research was on Latent Groundwater Demand for Private Tubewells;

- *Mr. Eric-Jan Huyskes* of the Faculty of Civil Engineering, Delft Technical University, and *Mr. Piet Klopp* of the Agricultural University, Wageningen, the Netherlands, were Junior Research Associates who carried out field work in IIMI's research project "Irrigation Efficiencies in Farmer-Managed Irrigation Systems in Hunza-Gojal" in Gilgit District, the Northern Areas;

- *Mr. Brian John Warnes* and *Mr. Adrian John Mills*, Research Scholars from the Institute of Irrigation Studies, University of Southampton, UK, conducted field research on water balance changes during monsoon season in Mananwala Distributary command as part of IIMI's research activities related to waterlogging and salinity;

- *Mr. Mehtab Ali*, from the University of Agriculture in Faisalabad did his thesis work with IIMI Pakistan on the subject of Farmer Allocation and Uses of Irrigation Water Under Relatively Adequate and Inadequate Supply Conditions.

Five Pakistani nationals studying at the Asian Institute of Technology (AIT) in Bangkok joined IIMI Pakistan as Research Scholars for their thesis work. They include:

- *Mr. Nazir Hussain Javeid*, Subject: Comparison of Irrigation Practices at Improved and Unimproved Watercourses on Wheat Crop in Punjab, Pakistan.

- *Mr. Mohammad Azhar*, Subject: Simulation of Irrigation Schedules for improving Wheat Yields.

- *Mr. Mohammad Akram*, Subject: Critical Evaluation of Irrigation Schedules in Canal Command Areas of Punjab, Pakistan.

- *Mr. Zahoor Ahmad*, Subject: Rainfall Probabilities in Upper Gugera Canal Command.

- *Mr. Muhammad Saeed*, Subject: Salinity Profile Under Deficit Irrigation.

ATTACHMENT 1

PUBLICATIONS

PUBLICATIONS

1. BHATTI, M.A; WOLF, J.M. and THORNE, M.D (1988). Impact of Late Irrigation on Wheat Production in the Central Punjab of Pakistan.

   Paper No. 88-2581. Presented at the International Winter Meeting of the American Society of Agricultural Engineers (ASAE) held at Hyatt Regency Chicago in Illinois Center U.S.A. on December 13-16, 1988.

2. BHATTI, M.A.; WOLF, J.M. AND THORNE, M.D (1989). Farmer's Irrigation Practices for Wheat Production in the Central Punjab of Pakistan.

   Paper No. 892093. Presented at the ASAE/CSAE Summer Meeting held at Quebec Municipal, Convention Center Quebec, Canada on June 25-28, 1989.

3. JOHNSON, R (1989). Private Tubewell Development in Pakistan's Punjab: Review of Past Public Programs/Policies and Relevant Research. IIMI Country Paper - Pakistan No. 1.

4. KIJNE, J.W (1989). Irrigation Management in Relation to Waterlogging and Salinity. IIMI Country Paper - Pakistan No. 2.

5. KIJNE, J.W (1989). A comparative Study of Farmer Managed Irrigation Systems in Northern Pakistan. IIMI, Internal Program Review, 20-23 November, 1989.

6. MURRAY-RUST, D.H.; VANDER VELDE, E.J. AND VERMILLION, D.J (1989). Design - Management Intervention and Their Effeects on Canal Performance: Comparative Results from IIMI's Work in Indonesia and Pakistan. IIMI, Internal Program Review, 20-23 November, 1989.

7. SCHULZE, F.E (1989). The Role of Soil Physics in Relation to Irrigation Management. International Symposium on Applied Soil Physics in Stress Environments. Islamabad, 22-26 February, 1989.

8. TARIQ HUSSAIN AND VANDER VELDE, E.J (1988). Intervention and Innovation in Farmer - Managed Irrigation Systems in Northern Pakistan. Seventh World Congress for Rural Sociology. Bologna, 26 June - 2 July, 1988.

9. VANDER VELDE, E.J (1989). Irrigation Management in Pakistan Mountain Environments. IIMI Country Paper - Pakistan Number 3.

10. VANDER VELDE, E.J. AND BHUTTA, M.N (1989). Performance of Secondary Canals in Pakistan Punjab. Research on Equity and Variability at the Distributary Level. IIMI, Internal Program Review, 20-23 November, 1989.

11. VANDER VELDE, E.J. AND JOHNSON, R (1989). Issues in Conjunctive Management of Groundwater and Surface Irrigation Systems in Punjab, Pakistan: An Initial Assessment. IIMI, Internal Program Review, 20-23 November, 1989.

ATTACHMENT 2

S T A F F I N G

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE PAKISTAN
LIST OF INTERNATIONAL STAFF AS OF DECEMBER 31, 1989

S.No.	Name of Employee	Designation	Work Location
1	Ir. F.E. Schulze	Director	Lahore
2	Dr. J.W. Kijne	Senior Irrigation Specialist	Lahore
3	Mr. D.J. Bandaragoda	Senior Management Specialist	Lahore
4	Dr. E.J. Vander Velde	Irrigation Specialist	Lahore

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE PAKISTAN
LIST OF NATIONALLY-RECRUITED PROFESSIONAL RESEARCH
STAFF AS OF DECEMBER 31, 1989

S.No.	Name of Employee	Designation	Work Locat
		Senior Technical	
1	Mr. M. Badruddin	Sr. Principal Irrigation Engineer	Lahore
2	Dr. G.R. Firdousi	Sr. Principal Irrigation Engineer	Lahore
3	Dr. M. Akhtar Bhatti	Principal Irrigation Engineer	Lahore
		Senior Research Professionals	
1	Zaigham Habib	Systems Analyst	Lahore
2	Rana Mohammad Afaq	Irrigation Engineer	Lahore
		Research Professionals	
1	Mohammad Anees	Senior Field Research Hydrologist	Lahore
2	Faiz Hanif Sendhu	Senior Field Research Hydrologist	Pir Maha
3	Saeed-ur-Rehman	Senior Field Research Economist	Lahore
4	Mohammad Saleem	Field Research Social Scientist	Farooqab
5	Khurshid A. Babar	Field Research Engineer	Pir Maha
6	Waheed-uz-Zaman	Field Research Engineer	Farooqab
7	Ahmed Saleem Safdar	Field Research Engineer	Farooqab
8	Hakim Khan	Field Research Engineer	Mananwa
9	Asad Sarwar Qureshi	Field Research Engineer	Pir Maha
10	Tariq Shahzad	Field Research Engineer	Farooqab

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE PAKISTAN
LIST OF NATIONALLY-RECRUITED NON-PROFESSIONAL RESEARCH
STAFF BASED IN FIELD AS OF DECEMBER 31, 1989

S.No.	Name of Employee	Designation	Work Location
1	M. Rafiq Khan	Senior Field Assistant	Farooqabad
2	Abdul Hamid	Field Assistant	Farooqabad
3	Abdul Rehman	Field Assistant	Farooqabad
4	Anwar Iqbal	Field Assistant	Farooqabad
5	Asghar Hussain	Field Assistant	Farooqabad
6	Aziz Ahmad	Field Assistant	Farooqabad
7	Khalid Mahmood	Field Assistant	Farooqabad
8	Tahir Iqbal	Field Assistant	Farooqabad
1	Atiq-ur-Rehman	Senior Field Assistant	Mananwala
2	Mohammad Ayub Tahir	Field Assistant	Mananwala
3	Nasarullah Abid	Field Assistant	Mananwala
4	Talha Awan	Field Assistant	Mananwala
5	Mohammad Saleem	Field Assistant	Mananwala
1	Javed Iqbal	Senior Field Assistant	Pir Mahal
2	Mohammad Ishaque	Field Assistant	Pir Mahal
3	Said Amir	Field Assistant	Pir Mahal
1	M. Riaz-ud-Din	Data Entry Specialist	Lahore
2	Sameeullah	Field Assistant	Lahore

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE PAKISTAN
LIST OF NATIONALLY-RECRUITED SUPPORT STAFF
AS OF DECEMBER 31, 1989

S.No.	Name of Employee	Designation	Work Location
1	Haroon Anwar	General Manager Administration	Lahore
2	Abdul Majeed	Personnel/Admn. Supervisor	Lahore
3	Noor Hassan	Field Station Manager	Farooqabad
4	Hoshi Irani	Accountant	Lahore
5	Haroon Zafar Maggo	Accounts Assistant	Lahore
6	Sheikh Tahir Khalil	Supplies & Stores Officer	Lahore
7	Azam Muneer	Supplies & Stores Assistant	Lahore
8	Kenneth R. Shams	Secretary/Admin. Assistant	Lahore
9	Aftab I. Gillani	Secretary/Admin. Assistant	Lahore
10	Maureen Johnson	Secretary/Admin. Assistant	Lahore
11	Eric Suhail Benjamin	Receptionist	Lahore
12	Mazhar Ali	Office Assistant (Xeroxer)	Lahore
13	Munawar A. Sheikh	Transport Supervisor	Lahore
14	Zaheer Anwar	Driver	Lahore
15	Harry Nathaniel	Driver	Lahore
16	Bashir Ahmed	Driver	Lahore
17	Pervaiz Ramzan	Driver	Lahore
18	Shakeel Rehman	Driver	Lahore
19	Yousef Amin	Driver	Lahore
20	Sabir Hussain Shah	Driver	Lahore
21	Imtiaz Khan	Driver	Lahore
22	Mohsin H. Dar	Maintenance Supervisor	Lahore
23	Mohammad Iqbal Khan	Security Guard	Lahore
24	Khalid Mahmood	Security Guard	Lahore
25	Mohammad Hafeez Khan	Security Guard	Lahore
26	Riaz Wicky	Security Guard	Lahore
27	Mohammad Aslam	Security Guard	Lahore
28	Asghar Ali	Security Guard	Lahore
29	Faryad Ali	Security Guard	Pir Mahal
30	Maqsood Ahmed	Security Guard	Mananwala
31	Mohammad Tariq	Security Guard	Farooqabad
32	Habib Ullah	Laborer	Farooqabad
33	Mohammad Asghar	Laborer	Farooqabad
34	Sajid Abbas	Laborer	Mananwala
35	Abdul Ghaffar	Laborer	Pir Mahal
36	Mohammad Shabbir	Bearer	Lahore
37	Mohammad Jehangir	Bearer/Cleaner	Lahore
38	Yaqoob Masih	Laborer	Lahore
39	Sharif Masih	Gardener	Farooqabad
40	Mohammad Hussain	Gardener	Farooqabad
41	Mohammad Arshad	Cook	Farooqabad