REPORT NO. R-8

TERTIARY SUB-SYSTEM MANAGEMENT

PROCEEDINGS Of ONE-DAY WORKSHOP
HELD ON JUNE 18, 1995 IN LAHORE PAKISTAN

ORGANIZED BY

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INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
LAHORE PAKISTAN

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FOREWORD

Since 1989, IIMI Pakistan has ,received support from the Government of The Netherlands for research on mitigating the effects of waterlogging and salinity problems in Pakistan through improved management of the irrigation systems. Under the current phase of the Dutch funding, work is in progress on a project titled "Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan". One sub-component of this project deals with watercourse management. The general objective of the watercourse management sub-component is to

"develop improved irrigation management practices at the watercourse level that will alleviate trends in soil salinity and ground water quality that threaten the sustainability of irrigated agriculture in Pakistan".

In connection with the objectives of the watercourse management sub-component of The Netherlands funded project, IIMI organized a one-day workshop on "Tertiary Sub-System Management" on 18 June, 1995, in Lahore. This document contains the proceedings of the workshop.

Keeping in view the broad objectives of the project, as well as those of the watercourse management sub-component, the workshop participants were asked to address the following issues:

Does previous research reflect a full awareness of issues/problems related to efficiency of water use (below the mogha) ?

Are solutions to some of the perceived problems available ?

What can and should be done to implement those solutions ?

What issues and problems should be'the focus of research efforts over the next five years ?

In the first session, four papers were presented . The authors dealt with issues related to the historical evolution of water management programs; water conveyance and distribution below the mogha; farm level irrigation practices; and economic aspects of tertiary irrigation management.

The presentations were followed by a general discussion in the second session. Later in the session, the participants divided into four smaller groups to deliberate on issues related to: (a) water supply and use at the watercourse level; (b) irrigation methods and practices at the farm level; (c) economics of water transactions; and (d) institutional and social factors affecting water use (below the mogha).

The final session was devoted to a discussion on the results of group deliberations and formulating recommendations. One unique feature of the workshop was the process of drawing up recommendations. Initially, the recommendations were prepared through mutual consultation and circulated among the participants on printed forms. The participants were then asked to rank them in order of priority. The results of this ranking were later tabulated and are included in these proceedings. It is hoped that this exercise not only gave everyone an equal voice, which helped increase participant involvement in formulating recommendations, but it also helped establish the relative importance of different recommendations.

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INTRODUCTION

The Indus Basin irrigation system is one of the largest irrigation system in the world with **16** million hectares of irrigated land. The system has 3 major storage reservoirs (Mangla, Tarbela and Chashma), 19 barrages and **12** link canals, that feed water to 43 canal commands serving about 90,000 tertiary units or watercourses.

Most of the increase in agricultural production that has been recorded in the Indus Basin irrigation system came, initially, from expansion of the irrigated area with construction of new irrigation schemes (Bandaragoda, 1993). However, in the late fifties, the number of sites that could be brought under irrigation **at** reasonable costs had been drastically reduced. At the same time, competition for the allocation of funds became more severe with the construction of barrages and link canals as a results *of* the Indus Basin Treaty in **1960,** and the development of drainage projects to tackle waterlogging and salinity. Thus, the required increase in agricultural production could only ~~to~~ come from higher productivity in the existing irrigated areas.

The major point of attention was the high level of losses within the system, with only 30 to 40 percent of the water delivered at the head of the system reaching the crops. To reduce these losses would have a positive impact on agricultural production, whether directly by increasing irrigation water available at the farm, or indirectly by reducing waterlogging in irrigated areas.

In the seventies, as a result of the recognition of the importance of losses at the watercourse level, a comprehensive research programme was developed for analyzing water management below the mogha, identifying constraints and proposing options for increased water use efficiency and agricultural production. The large amount of information collected[1], the thoroughness of the analysis undertaken and the numerous reports published as part of the Water Management Research Project of the Colorado State University clearly demonstrates the level of efforts undertaken.

This research project looked at technical and institutional issues, under various physical and social conditions. Research results were also operationalized in the context of the various On-Farm Water Management Programs that started with a pilot project phase in 1976. The paper by Prof. Skogerboe summarizes the experience of the Water Management Research Project of the Colorado States University.

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[1] **The information collected for 3 watercourses for the analysis of the operation of watercourse systems and presented in Ali et al. (1978) is a good example** of **the intensity of some of the data collection activities undertaken as part of Water Management Research Project of the Colorado State University. Since then, no similar research has been undertaken in Pakistan.**

Twenty years later, there is a need to assess what has been done as much on the operational side than on the research side. With the large amount of funds that have been allocated to the On-Farm Water Management Programs, did we resolve the main issues that were identified in the 70ies? Do we still need research at the watercourse level? And towards which direction? With increasing budgetary constraints and the need to develop well targeted research programmes, what are the priorities for irrigation management research below the mogha?

Whether the issues identified in the 70ies have been resolved is indirectly tackled in the papers presented at the workshop and included in the present proceedings. The first paper, Prof. Skogerboe summarizes some of the lessons learned from the implementation of the On-Farm Water Management Projects. The paper highlights that only the lining component of the projects have been really successful. In fact, the institutional component of the projects did not lead to the development of sustainable water users associations as initially planned.

The importance of socio-economic issues is also emphasized in the papers of **A.** Hai and M.S. Shafique at the watercourse level and at the farm level, respectively. M.S. Shafique broadens the discussion by using examples from other countries (Egypt, Soudan) and putting watercourse management research in the context of the management of the irrigation system as a whole.

The paper by Ali and Chaudhry underscores the need to clearly assess irrigation performance below the mogha and to identify options that would improve performance. Some of these options may be related to changes in the physical system such as lining of watercourses as implemented in the context of the On-Farm Water Management Programs. However, the authors emphazise the need to analyze management activities undertaken by farmers and related institutions such as the century old *warabandi* system that allocates water turns to farmers according to their land holding size but does not consider seepage losses along the watercourse.

There is a general agreement (although not always clearly specified) among the authors that have presented papers at the workshop about the need to move forward and to continue research on irrigation management below the mogha and test new options that would tackle agricultural productivity and sustainability. Several reasons explain the need for further research efforts:

(i) the lack of success of components of the On-Farm Water Management Programs: as said before, institutional aspects require more attention and new approaches; and there is a need to put extra effort in the development and dissemination of improved irrigation practices at the farm and field level;

(ii) changes in the physical and socio-economic environment: increasing use of groundwater via private tubewells that makes conjunctive use (in terms of quantity and quality of irrigation water) a major issues; increases in cropping intensity that leads to a higher pressure on water resources; mining **of** the aquifer in some areas with good groundwater quality; etc;

(iii) changes **in** the policy focus: with recent options such as decentralization and water market development that have been proposed for improving the management of the irrigation sector, more focus is required to analyze institutions such as warabandi, government agencies, water rights, water markets, etc.

The main objectives of the workshop was to investigate the irrigation management below the mogha in the context of these new developments, using the experience of researchers and line agency staff that have been involved in watercourse level activities during the last decade. One objective of the workshop was to answer the other questions listed above such as the identification of research issues and priorities in research and development programs.

1. PRESENTATIONS

PAPER I: PHYSICAL VERSUS INSTITUTIONAL DEVELOPMENT IN THE EVOLUTION OF WATERCOURSE IMPROVEMENT IN PAKISTAN

by

Gaylord V. Skogerboe[2]

RESEARCH AND DEVELOPMENT

Backaround

The United States Agency for International Development (USAID) provided funding to Colorado State University (CSUF) from 1968-80 under the Water Management Research Project. CSU Faculty were present in Pakistan during the 1970s. The research at the watercourse level began in 1972.

Much of the research on watercourse improvement was undertaken by the research staff of the Mona Reclamation Experimental Project (MREP) near Balwal in the Punjab Province. MREP is a research unit under the federal Water and Power Development Authority (WAPDA).

The primary focus of this research was on renovation of earthen watercourses. The earliest trials used steel gates for water control, but these were replaced by a concrete collar with a concrete lid, called pucca nakka, which took about 18 months to develop at a private workshop in Sargodha. At the same time, trials were underway to informally organize farmers served by a watercourse.

Social Experiment

A very interesting experimental program was undertaken in 1974. A social survey was completed for a number of villages within MREP (110,000 acres) regarding community activities requiring cooperation, such as the construction and upkeep of a village mosque, or communal construction of a school. Particular value was placed on previous informal cooperation on water management issues, such as solving water disputes and cleaning the watercourse (Early, et al, 1976). Other questions pertained to caste or biraderi dominance, as well as village leadership.

Based on this survey, villages were ranked from high to low in terms of cooperative activities. The village having the highest rating was approached and the farmers agreed to undertake earthen renovation of their watercourse, which required the efforts of more than 40 laborers for a period of 35-45 days.

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[2] Director, International Irrigation Management Institute, Pakistan.

Finally, after a number of watercourses had undergone earthen improvement, along with the installation of pucça nakkas, a village was approached that had three contentious biraderis that precluded having a village leader. This village had a long history of murders, with the most recent being three years earlier. When all three biraderis agreed to organize for the khacha (earthen) improvement of their watercourse, then it was known that any village in the area could be organized for renovating their watercourse(s).

Watercourse Survev

Since the research studies on watercourse improvement had been done at MREP, there was a major concern about the representativeness of the findings for other areas in Pakistan. So, before embarking upon a USAID-funded pilot project, additional watercourses were investigated. The results, some of which are listed below, were reported in six volumes (Lowdermilk, Freeman and Early, 1978).

Data were collected during 1975 and the winter-spring months of 1976 on a sample of 387 farmers located in 16 villages and 40 watercourses stratified by head, middle and tail location. The research sites were selected so as to represent the major agro-climatic zones of the Punjab and Sindh provinces, but because of USAID's emphasis on the small farmer, a disproportionately large sample of villages are characterized by small farmer owner-operator majorities.

Losses of irrigation water in conveyance (bothseepage and leakage) from the mogha to the field nakkas averaged about 47 percent over the sample of 40 watercourse. Losses ranged from 65 to 33 percent. In general, the more water available on a watercourse command, the lower the watercourse conveyance ‘efficiency. Sample SCARP public tubewell augmented watercourses, for example, had a weighted mean efficiency of 47 percent as compared to a value of 54 percent for sample watercourses without public tubewells. Private tubewell commands, however, in the sample had a weighted mean efficiency of 58 percent as compared to 51 percent for commands with neither public nor private tubewells.

Wherever and whenever ample water supplies are available, farmers tend to overirrigate. Farmers on watercourses served by public tubewells, or numerous private tubewells, tend to overirrigate more than those without such sources of supply. Field application efficiency refers to the proportion of water entering the field basin which is stored in the crop root zone. Mean field application efficiency was about 50 percent for the sample farmers. Those located at tail reaches of watercourse commands, where water was less available, had higher mean and median field application efficiencies than those at the head of watercourse commands.

Although no difference were found in field application efficiencies by farmer tenure class, larger farmers (25 acres or more) had lower mean application efficiencies (64 percent) than did smaller farmers (80 percent). Larger farmers tend to secure greater tubewell supplies.

Water supply significantly affects cropping intensity. Tubewells not only make higher intensities possible, they provide greater control over timing of irrigation deliveries--a condition often more important than water quantity. Given substantial losses of water in conveyance, tail farmers have lower intensities than do farmers located toward the head of watercourses.

Stipulations of the Canal and Drainage Act (1873), which could be employed to support watercourse improvement, are evaded with high frequency. Many other stipulations must be evaded for the farmer to secure a minimum of control over his water supplies--e.g. water trading, water purchasing, and unauthorized modifications in moghas are widespread and probably essential to sustain existing production levels. A thorough review of the uses and limits of the Canal and Drainage Act is justified by the evidence (Lowdermilk, Freeman and Early, 1978).

PROPOSED FRAMEWORK

Sufficient data had been collected and analyzed by the end of 1975 to define some of the major irrigation water management problems within the watercourse command areas. At that time, the components of a water management program considered to be most important were: (a) watercourse rehabilitation; (b) precision land levelling; (c) small tubewells; (d) effective agricultural and water management technical assistance and extension; and (e) development of local institutions to insure the effectiveness and sustainability of the program (Early, et al, 1976). The remaining material in this section has been taken from this reference.

Physical Component

The necessary physical program was seen as a set of watercourses in which the three physical components of watercourse improvement, land levelling and tubewells would be integrated with irrigation extension. Some institutional mechanism (whether foreign assistance, Government assistance, or private initiative) was deemed advisable so that small discharge tubewells could be included as need. The field program was expected to have a capability for incorporating all appropriate technological and institutional components in a water management improvement plan for each watercourse.

Watercourse improvement and land levelling were seen as synergistic in most watercourses. Saving water in delivery is a much more profitable investment if levelled fields permit efficient application to fields. Neither physical modification can achieve maximum potential food production if farmers remain ignorant of modern water handling and irrigated cropping techniques. Hence, irrigation extension was considered critical for the success of improvements in water delivery or field levelness.

Finally, village organization for the purpose of better maintaining earthen watercourses was proposed throughout the country, whether or not the watercourses were involved in the primary water management program. In fact, the water management program was not intended to be restricted to those watercourses qualifying for the full program. Instead, Pakistan was considered to have sufficient resources for implementing several programs simultaneously, thereby achieving a broader and more rapid impact on conserving the nation's water resources. indeed, the magnitude of water losses throughout the country mandated as widespread a program as possible.

In addition to the primary water management program, the Government of Pakistan was encouraged to implement the following general water management program thrusts:

1. Induce as many watercourses (or villages) as possible to organize and implement a permanent program of routine maintenance. This program should probably be implemented by the existing Irrigation Department itself, supported by national emphasis through several media and an appropriate incentive. The program is very inexpensive, the benefits very large, and without it millions of acre-feet are being lost needlessly.

2. In sweet groundwater areas, a program of support should be mounted for installation of community tubewells pumping directly into the watercourse, as in SCARP areas. In general, these tubewells should be the small size (100 to 150 feet deep and 0.2 to 1.2 cusecs capacity) which are efficiently dug by local drilling contractors using rural labor, and generally produce water with lower salt content than deeper wells. These tubewells would be situated where they can most effectively meet the water and drainage needs of the area. Benefit cost ratios were estimated to exceed 8:1. This program could be implemented mainly by selective credit programs. Either a water users association could own and operate tubewells, or a group of farmers could own and operate a tubewell (s) on an informal and cooperative basis.

Institutional Component

The second major component in the water management program consisted of the institutional framework that would be necessary to implement the technological propositions and to carry out the necessary training and extension functions designed to ensure a long term success in achieving the project objectives. Pakistan already had a structured institutional framework upon which to build in terms of the existing legislation in the field of water law, land regulations, revenue, etc., and with respect of implementing government entities such as Irrigation and Power Departments, the Agriculture Departments and the Revenue Departments in the various provinces, WAPDA, Agricultural Universities and the several governmental research institutions. The philosophy behind the recommendations contained in the institutional component was to utilize all existing institutions to the extent possible. But, where constraints or impediments to implementation of improved water management practices exist, it was proposed that institutions be restructured or redeveloped consistent with the goals and objectives of the program.

There were three levels to the institutional component which require attention, modification or adoption. These three levels are:

1. The agricultural sector level. Primary focus was upon the creation of a system of water user associations at the watercourse or village with the potential to develop a hierarchy as the associations matured into effective organs for improving on-farm water management. This hierarchy would consist of a federation of associations and an executive council that would pursue the interests of the water users associations in a dynamic spatial and temporal effort.

2. The government related and support organizations level. Primary emphasis would be placed upon the Irrigation Department, Agriculture Department, and such entities as WAPDA, Agricultural Universities, and agricultural research institutes. The thrust at this level was to identify and discuss the role of these agencies to on-farm water management and their participation in the implementation of this program.

3. The laws and regulations level. Key features included formation of water use policies, authorization for creation of water users associations, possibility of expanding the powers and functions under the Soil Reclamation Act, and the need to develop ground water legislation which would include management of the conjunctive use of the ground and surface waters and integration of water quantity and quality.

ORGANIZATIONAL PROPOSAL

The question was frequently raised **as** to what agency or agencies would be appropriate implementing bodies for the water management program. Several of the existing branches of government had been suggested, as well as a newly created agency. In favor of creating a new agency was that: (a) the organizational structure could be developed specifically around the objectives of the program; (b) the new agency could be the communication link between the water users and the government; (c) established bureaucracies with their rigid modus operandi would not restrict the program; and (d) the agency could begin with a simple structure and mature into a sophisticated entity as the program developed.

Against creating a new agency was that: (a) considerable duplication of responsibilities, staff and efforts would result; (b) the strong probability that a new agency would be staffed by people drawn from existing agencies by deputation or seconding with the result that the new agency would start out staffed by less productive people with split allegiances; (c) another potential level of influence and corruption would be created; and (d) considerable time lag is necessary before a new agency matures sufficiently to implement a major program.

Also, water is a provincial subject; so in keeping with this mandate, theoretically, only provincial organizations would be acceptable to the provincial government as an implementing agency. The exception to this case may be with WAPDA.

In view *of* these considerations, it was recommended that the program be implemented within existing departments.' Some reorganization was recommended in many cases to adequately encompass the necessary functions and responsibilities. Where these new duties would require a new conceptual framework, or new administrative procedures, ample training was recommended *so* that the personnel in existing agencies could adequately implement the program.

Several departments demonstrated skills and resources which could be brought to bear on this program. The Irrigation Department had the experience *of* water collection, delivery and allocation. They have responsibility for construction and maintenance of water delivery structures and the administration of most of the water regulations affecting individual farmers. **Also,** the Irrigation Department has the engineering skills for water channel design, construction and modification. One conceptual change was necessary; the Irrigation Department must accept certain additional engineering responsibilities below the mogha, on the watercourse.

The Agriculture Department had the extension function nationwide, with an existing field staff located throughout rural areas. These people lacked training in water related subjects, a deficit which needed to be remedied. Also, in the

Agriculture Department was the Directorate of Agricultural Engineering, whose responsibilities included implementation of the governmental supported land levelling program. While skills were there, the techniques and equipment being used were unsuitable for <u>precision</u> land levelling. Again, a training program was suggested.

The Water and Power Development Authority (WAPDA) had concentrated within its staff much of Pakistan's expertise in managing the implementation of water development projects. In addition to administrative competence for water developmental projects, internal WAPDA offices handled research and evaluation functions. Furthermore, internal reorganizations had resulted in a major subdivision dealing directly with on-farm water management.

The primary advantage of the proposed administrative structure (Figure 1) was that all of the major government agencies in Pakistan concerned with "water" were involved, thereby maximizing the national involvement in on-farm water management. Such arrangements, if successful, would also result in the maximum development *of* "institutional capability"; however, it was recognized that this feature would add to the complexity of the water management loan program.

There was room for considerable debate as to whether this proposed organizational arrangement would be superior to organizing a new government agency for on-farm water management, or whether an "On-Farm Water Management Directorate" should be established within one of the existing governmental agencies such as WAPDA, the Agriculture Department, or the Irrigation Department.

PROGRAM IMPLEMENTATION

The organizational approach selected for implementing the water management program was to establish an On-Farm Water Management Directorate within each provincial agriculture department (PAD). This became the logical choice when the provincial irrigation departments (PIDs) showed no interest. In addition, a Federal Water Management Cell was created in Islamabad to coordinate the provincial programs. The responsibility for monitoring and evaluation was assigned to WAPDA, which in turn established the Watercourse Monitoring and Evaluation Directorate (WMED).

USAID funded an On-Farm Water Management Pilot Project from July 1976 to June **1981.** The major target was the improvement of 1,500 watercourses scattered throughout Pakistan. The major emphasis was upon earthen improvements by the farmers, followed by brick-and-mortar lining of 10 percent of the watercourse length. The lining could be located anywhere along the watercourse, which was expected to be through the village (for health and social reasons) or at the head of the watercourse. Almost universally the lining was done at the head in order to gain support from the farmers located in this area, whb otherwise would not have benefitted. Prior to watercourse improvement, the water losses were measured and this information was shared with the' farmers. In addition, considerable effort wasexpended in developing training courses for OFWM staff. Eventually, there were also research activities associated with the program.

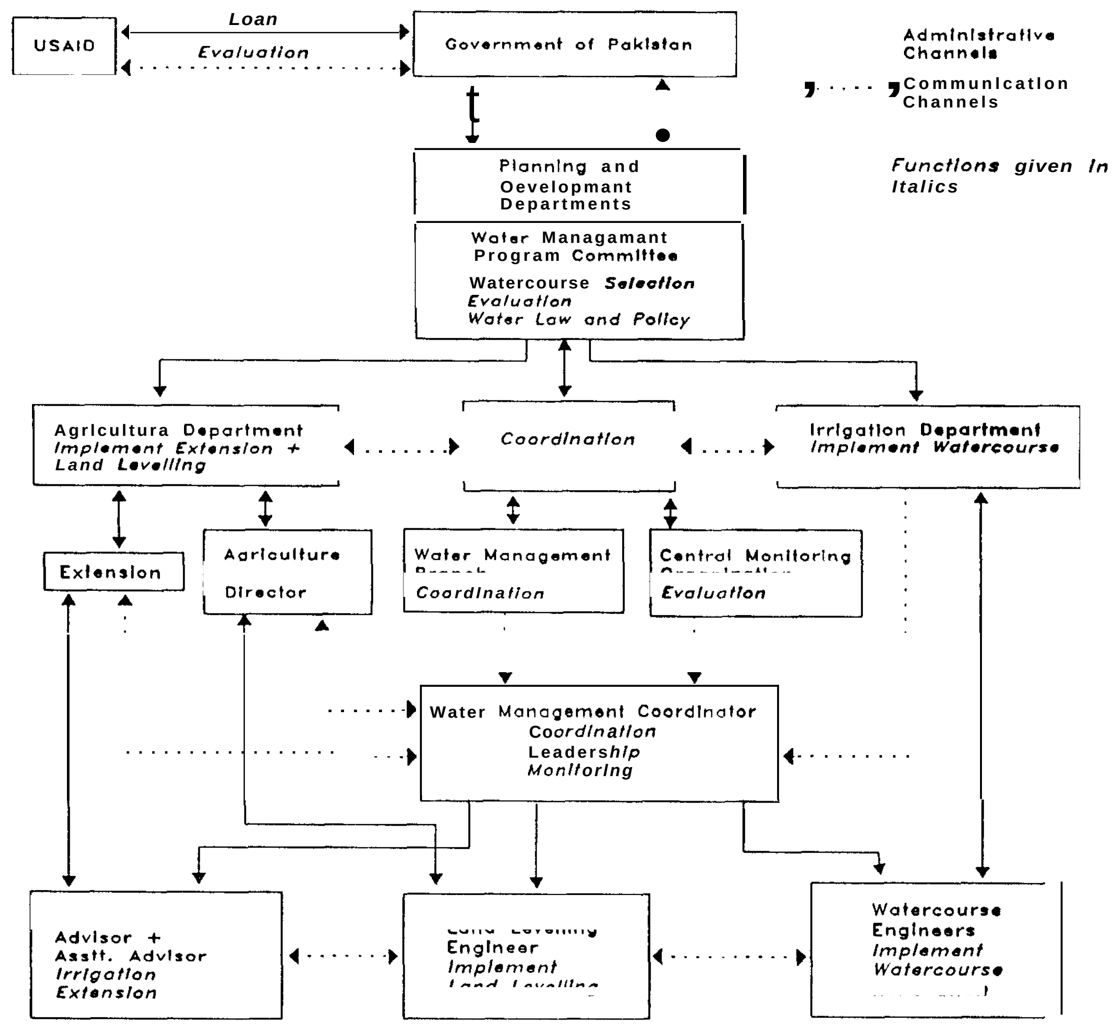

Figure 1. Proposed administrative structure for implementing an On-Farm Water Management Program in Pakistan.

The Water Management Research Project staff (4-7 faculty) of Colorado State University (CSU) were in Pakistan from June 1970 to November 1979, when they had to depart because *of* the Pressler Amendment. At their time **of** departure, the highest priority research activity was to sustain and strengthen water users associations so that they would maintain their improved watercourse. A part of this effort was to provide a legal basis by having each 'provincial assembly enact a Water Users Association Act. This finally occurred during the period 1980-82.

Surprisingly, the target of improving 1,500 watercourses was achieved by June **1981.** Then, the World Bank provided loan funds for OFWM-I in July **1981.** this was followed by OFWM-II and presently OFWM-III. In addition, the Asian Development Bank has also been providing loan funds for very similar projects. **Also,** Canada and Japan have been supporting OFWM projects.

The OFWM prograrn has been very popular with farmers. They have been clamoring for this prograrn. Certainly, this has been one of the most popular development activities in Pakistan. Unfortunately, this highly successful program has been steadily degenerating through the years.

Presently, watercourse losses are not measured by the OFWM staff. Also, farmers no longer rebuild their earthen watercourse. Instead, the focus is almost entirely upon watercourse lining. This emphasis is also recognizable by the almost total lack of sustainable WUAs. A common statement is that WUAs have nothing to do after watercourse lining is completed. This is true because the only purpose in organizing the farmers was to get the lining underway. There was very little concern about creating sustainable WUAs that would maintain their improved watercourse, along with making more effective use of any water savings through improved water management (including agronomic) practices. From the very start, the major emphasis was focused upon the targets for improved.watercourses. In the end, the emphasis was largely confined to watercourse lining.

LESSONS LEARNED

The most important lesson to be learned is that when the emphasis is upon civil works, then the institutional component is relegated to such a low priority that it is unlikely to be successful. In future development projects, the institutional component needs to lead the way with the physical cornporieiit following in a manner that supports the institutional component.

On-Farm Water Management became a misnomer as the program steadily degenerated into a Watercourse Lining Project. There is still a tremendous need to reach the farms in Pakistan. They have been ignored for too long. In fact, an integrated approach is needed, starting with the operation and maintenance of the canals and branch canals, overcoming the enormous inequities that occur along distributaries, improving the management of watercourses, and assisting farmers with improved irrigation and agronomic practices. All of these activities, and more, are needed to overcome the present situation of a stagnant agriculture.

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PAPER II: WATER CONVEYANCE AND DISTRIBUTION AT WATERCOURSE LEVEL

by

***Arshad Ali and Muhammad Rafiq Chaudhry*[3]**

Watercourses are the important link that carries water from the mogha to the farmers fields. Although watercourses constitute the arteries for our agriculture, yet over time these have not been maintained properly and thus have become inefficient and badly deteriorated.

FUNCTIONS OF A WATERCOURSE

A properly designed watercourse should carry the designed flow with a free board of at least 15 cm and not resulting in excessive deposition or erosion of sediments within the watercourse. The water is to be delivered at the field with sufficient head to adequately irrigate the field, usually of 20 cm to 30 cm. The operation of a watercourse should allow delivery of the water without excessive **loss,** whether at the head or the tail. Reliability of the delivery is also essential during operation as if the flow fluctuates it is impossible to apply a given amount of water to a field. Proper operation of the watercourse requires provision for either stopping the flow at the mogha, delivering un-needed water into the drainage system, or storing the excess water at the watercourse command. During certain times of the year, excess water does result and disposal of the water must not be on the farmers fields.

Watercourse maintenance is necessary for proper system operation. Farmers must reach an agreement on the operation of the system and an agreement is also necessary for proper maintenance which is required to retain the proper cross-section and grade, and in order to prevent the excessive growth of grass, weeds, trees and other obstruction, as well as to prevent the deterioration of diversions, nakkas and sides of the watercourses over time. Without maintenance, a properly designed and constructed watercourse can rapidly deteriorate into an inefficient delivery system.

EXISTING OPERATIONAL EFFICIENCY OF WATERCOURSE SYSTEM

The watercourse system operation has not been found very efficient due to certain physical constraints. The same are discussed below:

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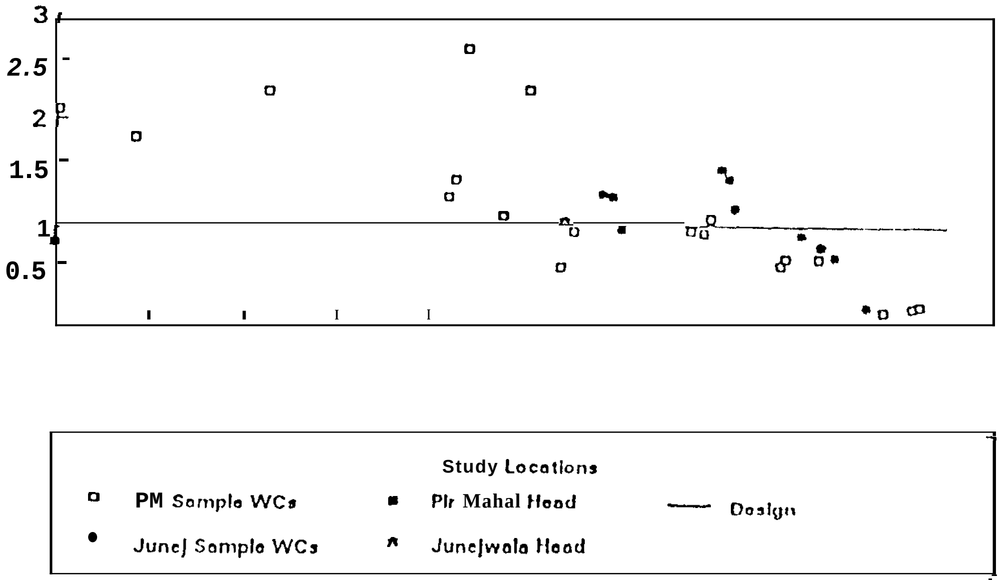
A) INEQUITY IN WATER DISTRIBUTION

The long standing system performance objective of equity in water distribution is rarely achieved and almost never sustained. When distributaries are operating at or near to full supply levels, outlets in the tail reaches seldom obtain more than a fraction of their authorized discharge at the watercourse head, in contrast to outlets in the upper reaches which commonly receive much more than their design discharge. It is due to the poor state of cleaning and maintenance of the distributaries which results ultimately into a deteriorated physical condition (e.g. extensive silt accumulation, severe embankment erosion etc.). The situation of flow in the tail reach outlets further worsens when the discharge at the distributary head falls below 70% of design.

Figure 1
Pir Mahal & Junejwala Mnr Distributaries
Equity of Water Distribution



Bhagat Sub-Division, 1990

The phenomenon of inequity of water distribution is illustrated for Pir Mahal distributary and its large subsidiary minor Junejwala in Figure 1 (Vander velde and Kijne, 1992). Delivery performance ratio has been used to describe water distribution equity among or between outlets along the distributary. Delivery Performance Ratio (DPR) is the ratio of actual discharge received at the outlet to its designed or sanctioned discharge. The data on DPR of the Pir Mahal distributary and its minor Junejwala indicate that farmers in the command areas of tail watercourses, on an average, receive less than one fifth of that received by farmers in the head reach of the distributary. When the canal system, particularly in the lower reaches of the distributaries, has been unable to deliver useable amounts of water to many watercourse heads for most of the time of the year, alternatively the farmer have resorted to ground water development to meet the water requirements of their crops by installing shallow tubewells. Undoubtedly, the increased availability of irrigation water from private tubewells has helped either to increase irrigation cropping intensities or sustain the existing intensities of less drought-tolerant crops.

Unluckily, the tubewell water at most of the watercourse commands in the.tail reaches is saline and its use is producing secondary soil salinity, which is affecting the crop yield adversely as additional good quality water is not available with the farmers of these command areas.

Similarly, inequity also exists within a watercourse command due to seepage losses in the system. Farmers at the tail reaches receive less water within the fixed per acre warabandi time. Thus, as determined by Vander Velde and Kijne (1992), the salinity problem is relatively more in the tail reaches as compared to the head and middle reaches of watercourses (Table I).

The question is what can be done to mitigate this salinity problem. This is only possible if additional canal water supplies are made available for these areas for leaching purposes.·One of the means to solve the twin problem of water scarcity and salinity is the reallocation of canal water supplies.

Reallocation of canal water supplies can be done within a watercourse command, on a distributary command, as well as within different distributary commands. The following strategies can be suggested for the purpose:

a) Reallocation of canal water on a watercourse bv rnodifvina warabandi

On a watercourse command the sanctioned per acre irrigation time varies from 15 minutes to 30 minutes depending upon the available flow rate and the size of the command area. Since the irrigation time is fixed, less water is available in the tail reaches due to seepage losses. In order to promote equity in water distribution, it is suggested that per acre irrigation time in the middle and tail reaches of a watercourse be increased depending on the seepage loss factor as suggested by Chaudhry and Zia (1994).

b) Reallocation by installing shallow tube wells.

On a distributary level, reallocation of water is possible by installing shallow tubewells on canal outlets to encourage conjunctive use of surface and ground water, along with remodelling of outlets in the upper and middle reaches permitting reduced supplies of good quality canal water for transferring to tail reach command areas where it is badly required for leaching saline soils.

c) Reallocation of canal water within different distributaries

Reallocation of canal water on integrated canal subsystems can be done through development of optimal conjunctive use models. For the command area of each subsystem, the canal water deficit and total pumpage being done can be estimated. Thus, the net deficit of canal water supplies in comparison with crop water requirements can be determined. Then, depending upon the quality of the ground water, the percentage of drainage surplus (required for maintaining ground water at a certain depth) can be estimated for the area. In a particular canal subsystem area, where plenty of good quality drainable surplus is available, additional tubewells can be installed and conjunctive use can be encouraged among the farmers. This will help in reallocating the water of this canal command to other canal commands, where ground water is of poor quality and is not fit for leaching of saline soils.

This can be further explained by the data collected by Arshad (1988) for command areas of 4 canal subsystems of Command Water Management Project, Punjab (Tables 2,3,4). Table 2 indicates that in the Niazbeg canal command area, due to good quality ground water, farmers are pumping about 9.9% more water than actually required to meet the canal water deficit. There is still 8.2% more good quality drainable surplus available in this command area. On the other hand, at 6R Hakra canal command area, there is a net deficit of 43.1% of the crop water requirement. Unfortunately the ground water is of poor quality in this command area. Under this situation, total pumpage in the Niazbeg canal command area can be potentially increased with a proportionate reduction in the canal water supplies for diversion to the 6R Hakra canal command through the main irrigation system.

For this purpose, a conjunctive use model will have to be developed to implement this type of plan for reallocation of canal water to areas in the command of other distributaries where it is badly needed for mitigation of salinity through leaching.

TABLE: 1

VARIATION OF SOIL SALINITY WITH LOCATION OF FARM

HEAD	45
MIDDLE	66
TAIL	90

TABLE: 2

PUBLIC AND PRIVATE TUBEWELL PUMPAGE (000, ACRE-FEET)

CANAL COMMAND SUB-PROJECT	CANAL WATER DEFICIT	PUBLIC TUBEWELL PUMPAGE	PRIVATE TUBEWELL	TOTAL PUMPAGE	NET DEFICIT/EXCESS TOTAL	% OF REG.
Pakpatan	-148.83	--	54.3	54.3	-95.53	-22.5
6R Hakra	-189.37	--	--	--	189.4	-43.1
Shahkot	- 96.64	25.34	2.0	27.34	-69.5	-34.4
Niazbeg	-39.852	27.23	29.2	56.44	16.62	9.9

TABLE: 3

DRAINAGE SURPLUS IN VARIOUS SUBPROJECT COMMANDS (000.AF)

	RECHARGE	DISCHARGE	SURPLUS	DRAINABLE SURPLUS	% DRAINABLE SURPLUS
Pakpatan	124.96	65.61	59.36	53.42	12.7
6R Hakra	124.36	25.13*	99.23	89.31	20.3
Shahkot	57.18	41.00	16.18	14.57	7.2
Niazbeg	49.61	64.98	15.37	13.84	8.2

* ONLY EVAPORATION LOSSES

B) RIGID DELIVERY SCHEDULE (WARABANDI)

The warabandi at the tertiary level as defined by Singh (1981) is a system of equitable water distribution by turns according to a predetermined schedule specifying the day, time and duration of water supply to each share holder in proportion to the land holding in the outlet command.

The introduction of a fixed warabandi system in the Indo-Pakistan sub continent irrigation systems dates back to 1887. Malhotra (1982) indicated that the most important characteristic of warabandi is the imposed scarcity to achieve higher efficiency of water use.

The existing time allocation in warabandi does not consider the losses of water during conveyance. The filling and draining time of 5 and 3 minutes respectively per 67 meter length of watercourse were considered in developing the existing warabandi of a watercourse command. Although the system is operating since its birth, yet a number of limitations are constraining its efficient use.

Constraints with the design and operational aspects of warabandi

A number of constraints associated with the design and operational aspects of warabandi have been discussed by Malhotra (1982), Shahid (1992) and Chaudhry et al (1993). These problems/constraints have been listed below:

1. The system does not provide flexibility to accommodate farmers and crop needs. It is the farmer who has to adjust his cropping pattern and cropped acreage accordingly.

2. The canal system originally designed for 75 percent cropping intensity has to cater to the needs of 100 to 170 percent cropping intensity.

3. Decreasing land holdings and farm sizes presenta more difficulties in implementing improved irrigation practices.

4. The cropped area charging system presents a number of operational problems, including the use of tubewell water, malpractices of abiana assessment, encouraging inefficiency by over-irrigation practices, etc.

5. The present system lacks consideration of rainfalls or droughts and continues to deliver the same amount of water as scheduled.

6. Assuming 35% irrigation efficiency with one week rotation, the system supplies only about 0.25 acre inches/week which is approximately 1/4 of the peak requirements.

7. The water allocation to a farm in a watercourse command is based on the area of the farm and does not consider the location of the farm along the watercourse. Consequently, the existing water allocation/warabandi does not consider the water losses during conveyance. This results in serious inequity of water distribution among the farmers.

8. As the losses tend to increase towards the tail of the watercourse (Chaudhry and Zia, 1994), the farmers at the tail of the system lose more than those at the head. The existing distribution system pays no attention to such inequity.

9. The water loss status has changed significantly by watercourse improvement and lining, while the water allocation schedule remains unchanged. Therefore, the quantum of water received by the farmers has been affected differently.

10. The existing filling and drainage allowances have also been affected by lining/improvement of watercourses. Thus, these allowances must be reviewed and re-evaluated to improve the equity of distribution.

11. Cropped area as a basis for water charging has been criticized by a number of farmers and researchers (Chaudhry et al 1990 and Chaudhry and Zia 1994) Shahid (1992).

A number of recommendations have been given by Chaudhry et al (1990), Chaudhry et al (1993), and Chaudhry and Zia (1994), to relieve some of the above mentioned constraints and improve the equity among various share holders at a watercourse command. Some of the important ones related to equity arid improvement of the warabandi are given below:

1. Equitable water distribution models such as developed by Shahid (1992) and Chaudhry and Zia (1994) should be used to develop water allocation among the share holders at a watercourse command.

2. The transitional water losses in the watercourses should be assessed to reflect the proportionate time allocation to each water user.

3. The filling and draining time as affected by the watercourse improvement/lining activities should be reevaluated and reflected in the warabandi schedule.

4. The cropped area based water charging system should be replaced by a time-area based system to remove the bureaucratic bottlenecks and improve the water use efficiency.

5. The beneficiaries should be involved in water distribution at the watercourse command level.

6. The turn cycle should be increased to enable a farmer to accomplish irrigate his fields during a given turn.

7. Allow farmers to practice trading, purchasing or selling of irrigation turns to their neighboring farmers to induce a partial flexibility in the system.

8. The Provincial Irrigation Department must be approached to consider updating the rules of warabandi designed about a century ago when water was not so precious of a commodity as it is today.

C) CANAL WATER SUPPLIES AND ACTUAL CROP WATER REQUIREMENT DO NOT MATCH

On almost all canal commands, canal water supplies do not match with the actual crop water requirements. Development of tubewell technology has made up the deficiency to a considerable extent. However, the canal water supplies are still deficient. A comparison of annual water supplies and crop water requirements has been made for 4 canal subsystems of the Command Water Management Project, Punjab (Table 5). The canal supplies have been estimated to be deficient by 23.6% to 47.6%. This deficiency has been reduced to some extent by ground water development. Deficient water supplies are considered to be one of the major causes of low crop productivity in the country.

D) CONVEYANCE LOSSES ARE VERY HIGH

Watercourses over time have not been cleaned and maintained regularly and properly. Thus, these water channels have been badly deteriorated and silted. This has resulted in; (i) submergence of rnoghas and reduced rnogha discharge; and (ii) increased conveyance losses. These losses have been estimated in the range of 40 to 45%. This portion makes the highest water losses in the irrigation system. These water losses also result in inequity of water distribution in the watercourse command and salinity problem in the tail reaches. Reduction of the conveyance losses has been considered to be a low cost alternative for enhancing water supplies at the farm.

The following techniques are normally adopted to reduce water losses in the watercourses.

- Cleaning and maintenance
- Earthen improvement
- Watercourse lining.

These techniques represent progressively increasing costs and potential water saving alternatives.

TABLE: 4

AREAL DISTRIBUTION OF WATER QUALITY AT SHALLOW AND DEEPER DEPTHS

	EC SAR RSC	≤750 <6 <1.35	750 - 1500 6 - 10 1.25 - 2.50	1500 - 2750 10 - 18 2.5 - 5.0	>2750 >18 >5.0
Pakpattan	SHALLOW	13	39	24	24
	DEEP	24	32	24	20
6R Hakra	SHALLOW	7	58	16	19
	DEEP	--	--	--	100
'Shahkot	SHALLOW	--	--	--	--
	DEEP	--	--	11	59
Niazbeg	SHALLOW	--	9	73	18
	DEEP	--	75	23	--

TABLE: 5

COMPARISON OF ANNUAL WATER SUPPLY AND REQUIREMENT AT WATERCOURSE HEAD (000, ACRE-FEET)

CANAL COMMAND SUBPROJECT	NET CROP WATER REQUIREMENT	CANAL WATER SUPPLY	DEFICIT TOTAL	% OF REG
Pakpattan	419.97	271.14	148.83	35.4%
6R Hakra	439.06	249.84	189.37	44.1%
Shahkot	202.17	105.33	96.84	47.9%
Niazbeg	168.48	128.66	39.82	23.6%

a) Cleaning and maintenance of watercourse

Cleaning and maintenance" includes cleaning of vegetation from the wetted perimeter and removal of accumulated silt from the bed and sides, and repair of damaged portions and structures. Cleaning and maintenance involves no redesigning of channel elevations and cross sections and thus requires no engineering input.

Extent of water saving

Although seepage loss rate through the bed and banks tends to increase slightly after cleaning, probably due to removal of the silt, the loss rate though the banks are greatly reduced due to lowering of water surface levels. A conservative estimate of how much water can be saved by a good and regular cleaning and maintenance program has been found to be 30 percent of the losses (Ali and Shakoor 1989).

Although the potential savings of this simple program may be large, but the benefits are of limited duration. If vegetative growth is rapid, the insects and rodents are active, and earthen improvement can be lost within a few weeks. Consequently, continued benefits require regular recleaning of the channels and periodic repair.

In spite of the regular required reapplication of a labour intensive cleaning and maintenance program, when organized and sustained, has shown the highest cost-benefit ratio of the three presented alternatives.

b) Earthen improvement

Earthen improvement of a watercourse involves the complete destruction of old banks and reconstruction to specifications based upon hydraulic design, and the installation of permanent structures at junctions and major outlets. This technique falls between the cleaning and maintenance program and channel lining in both costs and water-saving potentials.

Extent of water saving

Earthen improvement saves all the losses which cleaning and maintenance can save, plus additional losses associated with porous vegetation covered banks and uneven, irregular channels. Permanent structures also reduce outlet leakage and washouts. Measurement of conveyance losses in improved channels will determine the actual benefits. However, about 50 percent of the channel losses are normally found to be saved with an earthen improvement program (Ali and Shakoor 1989).

Although earthen improved watercourse will retain their improvement longer than those which are only cleaned and repaired, many of the benefits are still temporary, and continual maintenance is critical to maintaining the increased water supply.

c) Watercourse lininq

Watercourse lining is a high cost improvement technique which can achieve high delivery efficiency. However, in view *of* the high cost of construction materials, it is imperatively required that some low cost lining techniques be developed so that longer lengths of watercourse sections may be lined as against the existing allowance of 30% length under the OFWM programs.

Extent **of** water saving

Channel lining has the potential to eliminate nearly all conveyance loses in the lined portions provided these are carefully engineered and supervised during construction to avoid improper material apportioning or mixing, inadequate soils foundation preparation and compaction, as well as poor construction techniques (the tendency of the masons to leave holes between bricks) which are likely to allow leaks to form between bricks, and cracks to form between joints.

E) SEDIMENT INFLOW TO THE IRRIGATION SYSTEM

Inflow of sediment with the canal water in the conveyance channels is unavoidable under the existing gravity irrigation system. Evidently, the problem of sediment inflow has been responsible for the deterioration of the watercourse system. Evaluation of sediment inflow and assessment of possible remedies have not been investigated to the desired level. Thus, there is a need to focus research activities towards sediment associated problems of irrigation channels.

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PAPER III: IRRIGATION PRACTICES AT THE FARM LEVEL

by
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INTRODUCTION

Irrigation practices form a critical part of an irrigation management process. These practices at the farm level are the ***instituted actions*** which are aimed at achieving set goals and objectives of the on-farm subsystem without causing adverse effects. These opted irrigation practices can be categorized as improved actions if the differences between the measured goals and set goals are within an acceptable range. Otherwise, low performance of the farm level irrigation practices may suggest that the system is simply being ***operated*** but not ***managed.***

In the above stated context, the pivotal position of the irrigation practices at the farm level is obvious. Therefore, at the start of my presentation I have identified key irrigation practices for deliberations in the workshop. In doing so, the irrigation system is subdivided into four subsystems which are described in Section 2. **Also,** due to the scope of this workshop, my presentation is limited to the on-farm component of the irrigation system only.

The last part of this presentation (Section **3)** deals with the future challenges facing the researchers and managers in the field of irrigation management at the farm level. Presently, the irrigation management projects at the farm level are mostly limited to a couple of main activities, which are wrapped around a traditional concept of irrigation water conservation based on improving local irrigation efficiencies.

Recently, the basis of the traditional notion of water conservation has been challenged with a new concept of effective irrigation efficiencies. However, before changing the core premise for the on-farm water management actions, it seems appropriate that the implications of the shift are fully understood and evaluated.

KEY IRRIGATION PRACTICES AT THE FARM LEVEL

Each subsystem or component of an irrigation system is influenced **by** many elements and factors in performing certain functions. However, the degree of such influence is linked to the irrigation practices opted at each level of an irrigation system. In order to elaborate this point, the following discussion provides the functions and major factors of each component with examples quoted from different arid and semi-arid irrigated areas:

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On-farm Phvsical Subsvstem

Water Deliverv:

Lowdermilk et al. (1983) have described the component ***as to convey water from the water supply source by way of the main canal and distributary canals to a canaloutlet*** (main physical subsystem), ***and from there through farm and field channels*** (on-farm physical subsystem). The major function of this component is to deliver irrigation water in sufficient quantity and quality to the field. This process of water delivery is based on the following four steps (Walker et al., 1995): (i) assessment of water demand; (ii) water allocation; (iii) water distribution; and (iv) implementation (of the water delivery plan). However, the actual practices may differ from one setting to another.

In Sudan, as per design, the water delivery of 5000 m^3 per day, or 116 liters per second (lps), is provided for 37 to 38 ha for 7 days (12 hours in a day). It is supposed to have an off period of 7 days after which the delivery schedule is repeated. This water delivery practice implies a supply of about 7 mm (6.6 to 6.75) / day to meet irrigation needs which range from 1.6 to 4.8 mm / day (Adam, 1994) at the farm level. These figures are specific to the irrigation season which starts from June and ends in March.

Actual water delivery practices deviate from the one which ought to be followed. At the present time, the old night storage in the distributary canals (Minor Canals in Sudan) for 12 hours has vanished. With intensification and diversification of the crops grown, and within the prevailing economic conditions, the one week ***on*** and one week ***off*** schedule is difficult to follow. The farmers do not follow the old rules of the regimented agriculture anymore. Against the official procedures, water is withdrawn at will. At the watercourse (called Abu Ashreen) command area, there are no set rules to be followed; none one, more than one or even all (16-18) farmers may happen to use water at a time.

These practices have created a serious problem of water distribution. Although Sudan represents an example of abundant water-supply (hardly using 60-70 percent of its seasonal share of **18.5** billion m^3 at Aswan), inequitable water distribution creates pockets which end up receiving inadequate water deliveries.

In contrast to Sudan, most of the irrigated area in Paltistan is supposed to receive 28 lps for about 141 ha over 24 hours within a weekly turn system (warabandi). Based on the commanded area, it gives an average canal delivery of 1.7 mm / day. Obviously, this is **a** classic short supply situation where decisions regarding the area to be planted, crops to be grown, access to additional water supplies, and conjunctive use of groundwater and canal water each play a crucial role.

Original design assumptions have changed with time (e.g., cropping intensities). On-farm water delivery supplies are diversified with significant contributions from secondary sources (groundwater, drainage & sewage water). It is interesting to note that when the farmers have moved ahead by opting for different ways and means to avail new opportunities; we, in the research and development programs, have kept on repeating the initial couple of activities such as saving of seepage, excess percolation, and operational spillage from the watercourses. Obviously, there exists a huge potential for broadening the existing concepts of water delivery, application and use at the farm level.

In Egypt, like the central and northern parts of Sudan, the main water source is the River Nile. However, in the Nile Delta and Fayoum areas, some farmers do make use of the groundwater. In the new lands, the use of groundwater is quite common. At present, however, there is sufficient surface water available (55.5 billion m^3 for about 3 million ha). However, with slightly uncontrolled increases in the new lands and plans to irrigate some areas in the Sinai, this situation may change in the near future.

Perhaps the Egyptian farmers are the most experienced and innovative farmers in the irrigated world. Even the Government has a limited program for the mixing of drainage water with canal water; however, the unofficial reuse of the drainage water by the farmers is uery extensive (particularly in the Lower Egypt). As a result, the water delivery practices relate to three possible water sources: (i) canal water; (ii) drainage water; and (iii) groundwater. Again like Pakistan, the government programs at the farm level are mainly concerned with watercourse (meşqas) improvements only,.

In the Egyptian context, the Ministry of Public Works and Water Resources assesses water demands in order to allocate water supplies for different canal commands. Water distribution is planned, but implementation of the plan gets adjusted and re-adjusted depending upon the locality and degree of influence along the Nile and within canal command areas. Moreover, the liberalized cropping pattern has made the assessment of the demand questionable and therefore the rest of the process has lost its practical value too.

On-farm water delivery practices in the Grand Valley of Colorado and the Lower Sevier River valley in Utah are basically on-demand but within the limits of total shares of individual farmers. Because of the system of water shares, the inflows to the farms are commonly measured.

Water Application:

The main function of this component is to distribute water with the designed/desired uniformity over the field to meet the crop-water requirements and satisfy leaching and erosion considerations. Major factors which influence the process of water application are as follows (Lowdermilk et al., 1983): (i) field geometry; (ii) water supply rate; (iii) slope and levelness; (iv) infiltration rate; (v) surface roughness; (vi) irrigation methods; and (vii) management.

Selection of the water application techniques is the main concern for the farm managers. Because of the old traditions and familiarity, social acceptability within the existing management abilities of the farmers, and the prevailing economic environment, different countries with almost similar climatic conditions opt for different water application methods. However, it does affect the performance of the component in achieving its goals.

In Sudan, surface irrigation application methods are used. Tenancy units are divided into subunits called *hawashas* (2-8 ha) for each crop. These crop units used to be further subdivided into small plots / basins (*angays*) having only a fraction of a hectare. Considering the presence of high clay contents (75-80 % clay of montmorrilonite soils), the small basins were considered appropriate.

However, the *angaya* system has almost disappeared mainly to save labor requirements and relatively large basins (basic single-crop tenency units) are being used as such for water application. This, in turn, has lead to an unattended irrigation application practices which cause surface ponding due to extremely low infiltration rates of the swelling types of heavy clay soils.

In the case of the recently developed Rahad Irrigation Scheme in Sudan, an effort was made to opt for long furrows for irrigating using siphons. However, the adoption did not last long due to the difficulties associated with the priming of siphons for diverting water from the watercourse to the field and extra head requirements, which did not suit the flat topography of the area. But, it is interesting to note that a few progressive farms, operated by graduate farmers to demonstrate better irrigation and agricultural practices in the scheme, use the furrow system and provide surface drainage for growing vegetables and groundnuts.

On the other hand, sugarcane schemes/estates in Sudan are all using furrows as the water application method and have a good system of surface drainage for the excess water. This has been practiced by river-lifted water with enough head available to use siphons and by hiring labor instead of tenants for undertaking irrigation and drainage at the field level.

In Egypt, the border type irrigation method is used for the close crops such as wheat and fodder crops, but furrows are very common for other crops such as cotton and vegetables. In the new lands where soils are light-textured, official policy requires farmers to use pressurized irrigation methods only. However, not everyone follows the policy, which is a serious concern for the Ministry of Public Works & Water Resources (MPWWR).

Surface, drip and sprinkler techniques are commonly practiced irrigation methods in the Grand Valley of Colorado in the U.S.A., but still the surface irrigation methods are dominant in the area. Within the domain ***of*** the surface application modes, furrows are almost exclusively used for the two main crops of the valley: corn and alfalfa. In the latter case, inflows to each field can be monitored, but the flow measuring devices are mainly used for estimating the water shares of the farmers. Although the subsidy provided by the **US** government was intended to minimize deep percolation at the field level to control bad quality return flows to the Colorado River , the efforts remained largely confined to the farm delivery system to a greater extent.

In the Lower Sever River Valley in Utah, large level basins, mostly 4 to 16 ha in size, are the basic units for irrigation (as a matter of fact, the recent interest in the large level basin irrigation in the USA has resulted mainly due to the introduction of the laser technology in agriculture). Soils of the valley have heavy clay contents like those of Sudan, but the provision of surface drainage has helped to sustain productive farming in the area.

A couple of decades back, agricultural extension services in Pakistan used to recommend small basin systems (Khal Kiyari system having plots of about 0.05 ha) for irrigation. Perhaps, the advice was aimed at achieving uniform application of water in the small units. Although land leveling is not very common even today, standard irrigation bunded units are found in the range of 0.1 to 0.2 ha. In spite of the small size (as compared with the basins of the Lower Sever Valley), micro irregularities in the fields do exist which cause non-uniform irrigation applications.

In Pakistan, under the precision land levelling programs, efforts were made to reshape the basins into level borders. The change helped to increase control over the quantity and uniformity of irrigation application. However, due to the absence of land leveling services and problems associated with the existing system of revenue records, the change could not be sustained.

In the past, furrow irrigation was practiced for vegetables and other cash crops grown in the areas surrounding cities. However, with the improved rural economic conditions and access to mechanized farming equipment, furrow irrigation is spreading in many parts of Pakistan for other crops such as cotton and sugarcane. Apparently, the change is a positive development as the furrows are less sensitive to uneven field conditions when compared with basins.

Water Use:

This component aims at storing and supplying water to meet crop water requirements. In order to meet this function, the factors which influence the process for water use are as follows: (i) knowledge about the irrigation requirements; (ii) quantity and quality of irrigation water; (iii) soil type; and (iv) nutrient availability (Lowdermilk et al., 1983).

This is the one component which attracts a maximum of attention by many scientists in the irrigated agriculture of the developing world. In spite of this interest, the information generated by the scientists is not translated into a useable form that can benefit farmers. General irrigation practices under this component are based on either the visual condition of a crop, and/or water availability determined using the feel method by the farmers.

Water Removal:

The main purpose of this segment is to create and maintain conditions for optimum crop production by providing surface and/or subsurface drainage.

Water removal, surface and/or subsurface, is an essential part of irrigation. But the drainage component for many of the irrigation projects has not been considered important enough to be included in the development plans at the design stages. With time, however, the groundwater levels in many cases have come up within one meter or so from the ground surface. This development has made drainage an unavoidable requirement.

Like subsurface drainage, surface drainage is also equally important. The latter is particularly essential for heavy clay textured soils. A good example in this context is the irrigated schemes in Sudan. The central plains of the locality are formed by the swelling heavy clay soils which disperse and seal the soil pores after coming in contact with water. As a result, the water is mainly absorbed during the advance phase of irrigation, and thereafter, the infiltration rate becomes almost negligible. This causes a serious problem of surface waterlogging which is considered to be an important factor contributing to lower crop yields.

Most of the irrigated schemes in Sudan do contain a network of surface drains, but the provision is meant only for the disposal of the excess rain water. Although an official position is that the system is not designed and used for the surface drainage of excess irrigation water from the fields, in reality some progressive tenants do use the infrastructure against the stated intent. Similarly, for the heavy clay soils in the lower Sever Valley (Utah), surface drainage is extensively practiced to avoid surface waterlogging in the large level-basins.

However, the drains have another important but unofficial role in Sudan, which is to operate the main system by minimizing management costs. In practice, most of the time the major canals are kept running full. The managers at the lower levels divert water as per their experience and amounts necessary to minimize complaints, and the rest of the water is allowed to flow out of the project area through the drains.

After the introduction of perennial irrigation in Egypt, water tables rose fast, particularly in the Delta region, and it posed a serious threat to the sustainability of the productive agriculture. In order to meet the challenge, an autonomous drainage authority has been established within the Ministry of Public Works and Water Resources. Consequently, almost the entire irrigated area is provided with surface and/or subsurface drainage facilities.

However, Egyptian agriculture is now facing ***second generation*** drainage problems: deteriorated irrigation water quality due to the multiple reuse of the drainage effluent which is also mixed (not officially) with sewage and industrial wastes. There are laws passed to mitigate the situation but their enforcement under the existing setting is not an easy job. Another post-drainage concern relates to the practice of damming lateral and collector drains by the rice-growers, which causes unfavorable conditions for the non-rice crops.

Perhaps the Indus Basin has faced the most serious threat of waterlogging and salinity over the past 3 to 4 decades. Large scale drainage pumping (mainly tubewells) projects were initiated in the sixties and seventies which brought some relief to the situation. In this context, however, the main push has come from the private sector where the explosion of small tubewell technology is taking place. If the current rate of groundwater development and extraction continues, there is a possibility that we may start mining the aquifer in certain areas of Pakistan sooner than later.

In the private sector, however, the tubewells are installed with the sole intention of irrigation. This situation is very similar to Egypt where drainage water is reused to irrigate fields. An arbitrary use of the low quality drainage water for irrigation is being acknowledged as a major concern for a sustainable agriculture in Egypt and Pakistan. Perhaps it is more worrisome for the latter case due to the widespread problem of the soil salinity in the irrigated subsector.

Main contributors to the drainage problem are considered to be the existing on-farm irrigation practices. Had the practices been managed properly in the past, the need for drainage at present would have been very minimum. If the drainage requirements are to be kept under control in the future, efforts have to be directed now to improve the existing irrigation practices at the field level.

FUTURE CHALLENGES FOR IMPROVED IRRIGATION PRACTICES AT THE FARM LEVEL

Global / Effective vs. Local Efficiencies

Most of the irrigation improvement programs have been designed to improve generally low local irrigation efficiencies (E_i)[5] at the level of farms / fields. Such improvements are important for individual irrigators as they would like to be helped in managing their respective available water supplies in an efficient manner.

The concept is a useful tool for irrigation design and irrigation management (Keller & Keller, 1995). However, the concept of local irrigation efficiency does not help in understanding the status of irrigation water use at a larger scale as it ignores the contribution of return flows in its calculations. The irrigation water runoff and deep percolation are losses from individual fields, but may not be losses at a higher hydrological unit level . It is possible to divert surface runoff for reuse. Similarly, the deep percolation contributes to the underground aquifer and the groundwater can either be pumped for direct use or it gradually moves back to the rivers and streams for downstream diversions (Heermann et al., 1995)

In order to account for the reuse of the return flows, a concept of global or effective irrigation efficiency (E_e)[6] is introduced by some irrigation management experts such as Dr. Jack Keller[7] and Dr. David Seckler[8]. As the new concept also

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$$E_i = \frac{U_{ci}}{(1 - LR)\, V_D}$$

Where Uv_{ci} is the irrigation water consumed by crops, LR is the leaching requirementand V_D is the irrigation water delivered (Equation given by Keller & Keller, 1995)

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$$E_e = \frac{U_{ci}}{(1-LR_I)V_I-(1-LR_O)V_O}$$

where subscripts I & O denote inflow and outflow respectively for the terms already explained (Equation proposed by Keller & Keller, 1995)

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incorporates the effect of the reuse of the return flows, it is more suitable for formulating water allocation and transfer policies (Keller & Keller, **1995).**

A major concern expressed about the proposed base for the freshwater resource planning and allocation decisions is the degradation of the return flows by the pickup of salts and other pollutants such as sewage water, industrial wastes, etc. Keller and Keller (**1995)** have included leaching requirements in the definition of E_e (Eq. 2) to control soil salinity, but the environmental and health concerns have yet to be addressed. Moreover, it would be very difficult and expensive to apply and ensure the degree of salinity control as suggested.

In a system which is government-managed, deep percolation and run off from one supply component is a gain for the other when the underlying condition is not a salt sink. However, at a point when the irrigation supplies are turned over to a privately managed unit, the flows in any form going beyond the unit boundaries are a loss to the stakeholders of the unit. Deep percolation to the underlying aquifer with useable water quality can be recaptured, but it involves pumping costs for some who can afford, and a **loss** to others who. cannot or do not do so.

Another hidden assumption (author's opinion) in the new concept is that the water distribution is executed as planned within a broader hydrological unit such as a river basin. Also, it alludes to conditions in which the resulting return flows will be distributed on an adequate, dependable and equitable basis for their reuse by the farmers. In other words, a selected system is operated as planned and hence the water resources planning and allocation decisions can safely be based on average values **of** a broader hydrological unit. However, all such conditions may or may not exist.

It is, therefore, a ***challenge*** for the researchers and the managers of the irrigated subsystem to use both concepts with caution for design, irrigation management, water resource planning and water allocation within commands, regions and national boundaries. They need to give serious consideration to the old concept of water conservation at the field level as proclaimed by the scholars in favor of improving local irrigation efficiencies. At the same time, it seems appropriate to deal with concerns raised about the productivity and cost of the reuse of water, as well as inequity due to water quality of the drainage water, when planning and allocation is based by using the effective or global efficiencies.

Commercialization of Watercourse Improvement Programs

Since the late seventies, extensive watercourse improvement programs are being implemented with huge public investments. Although the activities were initiated under the banner of either on-farm water management, like the one in Pakistan or irrigation improvement projects, such as in Egypt, the main thrust remained confined to the civil works related to the tertiary subsystems.

Perhaps in the beginning it was a proper strategy to put more emphasis on the ***hardware*** improvements as a main vehicle to create awareness and interest in the ***software component*** of the on-farm water management. In the case of Pakistan, for example, after following the hardware-oriented approach for the last two decades or so, the concerned quarters now need to change. Any further delay in this context may endanger the survival of the on-farm water management program itself.

There is a ***challenge*** for the researchers and the managers in the irrigated sector to help their respective agencies to move out of the ***hardware business*** to provide more time and resources to mend the ***software*** side for the sustainability of the programs.

Many countries, sooner than later, will find it extremely difficult to keep funding the civil works under the watercourse improvement programs forever. One way to reduce the financial burden would be to switch from the opted ***supply mode*** to an appropriate ***demand mode*** which may even improve the effectiveness of the physical improvements.

From one locality to another, the proposed switch may require different strategies to make the watercourse improvement programs sustainable. One option could be to find ways and means to commercialize these programs. For example, there is a good possibility to test the idea in Pakistan because of the following reasons: (i) the physical improvement program for watercourses has reached a mature stage; (ii) there seems to be a good demand created for the improvements; (iii) about a dozen private commercial outfits are already manufacturing and selling pre-cast lining and control structures to the farmers and to the relevant government agencies; and (iv) the financial sustainability for the continuation of the activity in the current mode is a major concern. Perhaps, by channeling the existing subsidies with a phase-out plan, the stated enterprises may help to make the watercourse improvement program a demand-driven commercial activity.

Commercialization of Precision Land Levelling Proarams

Keeping the land level is a major concern for the farmers. It is a basic need at the field level to avoid over or under irrigation due to the micro ground surface undulations. Even without any outside support, this happens to be a routine activity undertaken by the farmers within the confines of their known skills and facilities. Such an irrigation facilitating practice points to a built-in demand for land leveling on a regular basis.

In view of the demand, many irrigated countries like Pakistan and Egypt initiated land leveling programs. However, these efforts did not achieve a desired degree of success. For example, in Pakistan, in spite of the provision of incentives such as sound facilities, skills and subsidies, the precision land leveling programs in the public sector had a hard time to sell themselves. Reasons for the ***"cool reception"*** given by the farmers to a subsidized facility, for which they have a felt need, are difficult to pinpoint. But these reasons can only be speculated as follows: (i) the time-interval required for land leveling was too long to be adjusted within a short period available between two crops; (ii) complaints about the quality of the **job** undertaken; (iii) lack of incentives, both positive and negative, to accomplish quality work; (iv) not enough effort directed to adapt the precision land leveling technology for small land holdings; (v) the activity was also conducted to reshape fields without giving due consideration to the boundaries as per revenue records; and (vi) hardly any effort was made to make the service cost-effective and within the financial reach of the small farmers.

In the case of Pakistan, there is no need to create a demand for land leveling; it already exists as a regular on-farm practice. However, a real ***challenge*** for the researchers and the field managers is to ***cap*** the demand effectively. Perhaps there will be a need to have two packages of this service: one for small farmers and the other for large farmers. For small farmers, it may help if only practical technical service about ***cuts and fills*** are provided to enhance the accuracy of the traditional land leveling practice. On the other hand, the large land holders may require quick and quality service with appropriate means, like access to laser technology for land leveling.

Based on past experience, it seems that the ***official*** approach adopted for land leveling has to be adjusted; it may help to commercialize the operation. The relevant agencies and donors can play a pivotal role by promoting this idea in order to make it happen. In the beginning, the local government agencies could provide subsidies, technical assistance and training to a number of private groups to initiate the process. However, the support should be withdrawn in stages as the private groups are strengthened enough to take up the challenge on their own.

In Pakistan, it is encouraging to know that the private sector, about a half dozen companies, has already been actively involved in manufacturing the land leveling equipment such as scrapers and planners. More recently, two private firms have started producing laser equipment to facilitate land leveling operations. When the stated capacity is coupled 'with the availability of hundreds of private tractor and machinery owners who sell their services for other field operations regularly, the proposed commercialization of the land leveling operations becomes an accomplishable target.

Necessitating Flow Measuring by the Farmers

There are no two opinions about the necessity of flow measurements; it is a basic requirement for irrigation water management. For improving water delivery, application, use and disposal subsystems, the available quantity of water must be known.

However, in many irrigated countries, most of the above stated operations at different levels of the main system are conducted based on experience and adjusted based on complaints and influence only. At the field level, it is also the experience of different individuals which determines the way irrigation water is utilized.

But the management of irrigation operations without measurement of **flows** can not be generalized for each and every case; there are a number of exceptions too. For example, the farmers in the Lower Sever Valley have installed their own flow measuring devices to counter-verify the flows measured by their own elected irrigation company near the delivery points.

However, the above quoted case is such that the flow measurement is unavoidable as the farmers' shares are based on volumes. Other factors such as large holding sizes, commercial orientation and education level of the farmers make the flow measurements as a normal activity. In spite of the other factors, the main fact remains that there should be a built-in necessity for flow measurements. ***So,*** the ***challenge*** for the researchers and field managers is to come up with innovative ways and means to create such conditions which make flow measurements a necessary practice.

Applied Research in Irrigation

Over the past two decades or *so,* a tremendous amount of basic research in the field of irrigation has been conducted. Amazing mathematical tools have been reported which can facilitate the planning of operation and maintenance activities in the main irrigation system. At the field level, the research findings are extremely helpful in managing the surface and ground water supply, application, use and disposal components of the on-farm subsystem. Even in the case of surface irrigation methods, it is now possible to estimate resulting irrigation efficiencies within the existing conditions or to create conditions for achieving an acceptable level of irrigation performance at the field level.

However, progress towards the application of the irrigation research findings is not very encouraging. Generally, the research community is not found very eager to test the basic research findings for their field applicability. The lack of interest is not surprising as the applied research does not earn the same credit when compared with the basic research. **As** a result of the stated apathy, the findings of the basic research do not get translated for the benefit of the end-users.

Agencies like the International Irrigation Management Institute (IIMI) are undertaking applied research. **For** example, IIMI in Sri Lanka and Pakistan is field testing a set of decision support systems (DSS) for planning and operation of two main systems. IIMI in Pakistan also plans to apply mathematical tools to improve irrigation practices at the field level. **A** similar activity is also being pursued by the Soil Conservation Service in Arizona.

In spite of the limited but serious initiative taken by IIMI and others to improve on-farm irrigation practices, there is a lot more to do. **A** ***challenge*** awaits for the researchers to conduct applied research at the field level in the areas which may address issues like those listed below:

a) Application of mathematical models to predict or estimate adjustments needed to improve on-farm irrigation practices;

b) Testing of management innovations to control excessive deep percolation at the time of soaking and a couple of early irrigation events;

c) Methodology for surface irrigation scheduling which should also provide information about the time required to irrigate a field with the right quantity, at the right time, within a given set of field conditions (Shafique and Skogerboe, 1987);

d) Preparation od guidelines for the conjunctive use of surface water, groundwater and drainage water at the field level;

e) Development of appropriate irrigation technology which may include the following ideas: (i) for the brackish groundwater zones with an upper thin layer being of relatively acceptable quality, use of fractional skimming wells or application of multi-strainer shallow wells; (ii) trying of **low** pressure irrigation application methods; and (iii) testing of new irrigation water measuring techniques for pressurized flow (tubewells) and flat gradient open channel flow at the farm level;

f) Application of on-farm surface and subsurface drainage; and

g) Institutional arrangements required for improved irrigation water use below the canal outlets.

Irriaation Advisorv Service (IAS)

Practical and user-friendly on-farm irrigation water management techniques can be developed, but their field adoption will require appropriate disseminating arrangements. Such a need will be met essentially by providing. irrigation advisory services at the farm level.

For example, an irrigation advisory service is being established in Egypt within selected commands of the irrigation improvement projects. However, the scope and capacity of the institutional arrangement is limited; it is mainly confined to organizing farmers at the tertiary level and provide assistance in managing the finances of these groups. However, there is a common concern in the MPWWR about the future role and perhaps justifications after the completion of civil works related to single point water-lifting arrangement at the tertiary canal level. It is feared that if the role of the service is not reviewed, this unit may become dysfunctional as has happened with the water users' associations in Pakistan after the completion of watercourse improvements.

Another concern relates to the location of such an irrigation advisory unit. One easy solution is to let the government provide the service. However, it is a costly option for a public sector to shoulder, while the lack of cooperation between relevant agencies makes the choice difficult to make. Moreover, when a decision is made to pick one agency, others refuse to cooperate. For example, IAS in Egypt is located in the MPWWR and the existing lack of cooperation between the MPWWR and the Ministry of Agriculture and Land Reclamation (MOALR) does not help the effectiveness and usefulness of the service.

Possibly, such a service could be located with a neutral outfit, or non-governmental organizations (NGOs). However, such groups in the choice area are almost non-existent in most of the irrigated countries. Perhaps, the idea could be tried to gauge the level of interest in the NGOs' domain.

Another option in the context of Pakistan is to make use of the agricultural input vendors to take up the assignment as a bonus to attract customers. However, in this case public agencies will have to provide training, materials and support (incentives) to institutionalize the service. As these dealers are located everywhere in the country, the mechanism provides an excellent cost-effective network to test the implementation of the model. Of course, it is going to be a real ***challenge*** for the researchers and public sector to devise an effective irrigation advisory service.

Sustainable Farmers' Participation

Farmers' participation in the operation and maintenance of the on-farm irrigation subsystem is crucial. Obviously, this requires a group action which is conventionally secured by organizing farmers on a formal or informal basis.

Informal group action is for a specific purpose, which is usually built around a felt need by the farmers themselves. Examples in this context are the regular cleaning of watercourses and the fixing of irrigation schedules (warabandi) by the farmers in India and Pakistan. Such an informal collective arrangement still works and ensures farmers' participation on a sustainable basis.

In general, farmers have also been organized on a formal basis to secure ***farmers' support*** for implementing certain on-farm activities. As it is obvious from the water users' associations organized in Pakistan and Egypt, these groups were ***designed*** to provide only ***support*** to a public agency in implementing a specific improvement activity: there appears to be no real intention to ensure farmers' participation by incorporating their clear role in planning, design, construction and management of an improvement activity. Consequently, with the completion of an improvement activity, like watercourse lining, the need for farmers' support faded and *so* did the need to keep the water users' associations functional. This might be one important reason for having dysfunctional water users' associations in Pakistan.

Although the water users' associations in Egypt were also intended to seek support from the farmers to improve tertiary channels (mesqas), the built-in single-point pumping requirement in the mesqa improvement is keeping the groups functional. Perhaps, it is this day-to-day operational interdependence which may keep the farmers' organizations working. Likewise, initial positive reports about the sustained functioning of tubewell committees established under a community-well program might have been helped by a similar operational interdependence. In both cases, the farmers have an active role in the operation and maintenance of the water lifting systems.

In order to achieve positive impact by improving irrigation practices below the canal outlet, farmers have to act together. A few individual actions in this context may not suffice. However, it is a challenge for social scientists and community organizers to suggest models which create conditions and an environment suitable for seeking sustainable farmers' participation and collective actions.

Addressina Environmental and Health Concerns

That irrigation development has created environmental and health problems has long been acknowledged. These concerns are listed as follows: (i) waterlogging and salinization; (ii) disposal of the drainage effluent; (iii) water quality concerns due to the disposal/mixing of sewage and industrial waste in the irrigation and drainage systems and irrigation return flows; and (iii) diseases such as malaria, river blindness and bilharzia.

For the most part, the above stated concerns stem from the low irrigation efficiencies and inappropriate irrigation practices at the farm level. Therefore, the future ***challenge*** for the researchers and the managers of the irrigated sector is to improve irrigation efficiencies by introducing appropriate irrigation practices at the farm level.

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PAPER IV: ECONOMIC ASPECTS OF IRRIGATION MANAGEMENT AT THE TERTIARY LEVEL

by
Akhtar A. Hai[9]

The issue of water use efficiency in Pakistan's irrigated agriculture is of paramount importance from the viewpoint of long term sustainability of the Indus Basin. The complexity of the issue involves several disciplines which is further aggregated by the sheer size of the Basin. The tertiary sub-system (i.e. below the mogha) requires due attention of researchers since it involves the end users and may provide information on the basis of which appropriate arrangements can be suggested to improve users' participation in the management of the sub-system and subsequently the system of irrigation.

A brief account of several issues that have been observed in the Indus Basin are presented below:

i) Interlinkages

In order for the conducive production environment to evolve at the tertiary sub-system level, the interlinkages between the irrigation system (at mogha) the field and the village(s) have to be clearly understood. This would require an understanding of the irrigation bureaucracy, the agrarian structure and the socio-cultural values that affect irrigation water management at the farm/mogha level.

ii) Informality of Water Distribution

The effectiveness of water apportionment at the watercourse level among the users will be reflected by the level of formality or informality maintained in the process. A strict formal system maintained/supervised/controlled by the irrigation bureaucracy will show lack of coordination/mutual trust among the users. On the contrary, an informal system free from the control of the irrigation department and completely governed by the rules/norms as established by the users will reflect consensus and mutual trust. The former arrangement will be weak and subject to tensions and conflicts whereas the latter will carry flexibility and a rational structure to maximize the overall benefits to the users and will thus sustain the system.

The factors determining any system of water apportionment within the boundaries formed by the extreme situations mentioned above would depend

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on factors including farm size, location, pattern of sharing maintenance responsibilities of the watercourse and adherence to the rules of the Canal Act.

iii) Role of Rehabilitation Work

The fate of the interventions from outside (i.e. by the government development projects e.g. On-Farm Water Management etc) to improve irrigation water management at the watercourse level will depend on the following:-

- Choice of lining work i.e. whether this was determined politically or technically.

  Sustainability of the leadership role.

  Impact of interventions on the pattern of maintenance of the watercourse.

  Whether the program/project was completed fully or partially.

- Whether the interventions obstructed or facilitated the flow of water.

  The degree to which the agrarian structure acts as a constraint.

iv) Infrastructure Development

The stability of any such sub-system heavily depends on the irrigation infrastructure development. Installation of tubewells, for example, minimizes the constraints imposed by the rationing of the surface water supplies and helps create flexibility to adhere to crop-water requirements in terms of time and amount. It further helps in creating a local market for irrigation water.

Similarly, provision of drainage helps in reducing the ill effects of additional water-applications to the field and raises the desire of the users to cooperate.

v) Water Use Pattern

The choice of crops depends largely on the relative price structure of possible crop combinations, soil type, and augmented supplies of water, which determines the levels of deficit irrigation, and land fragmentation.

The water application to crops depends on how porous the soil is, level of economic importance of the crops grown, access to irrigation and the level of water theft.

vi) Available Alternates

There seems a clear need to carry out precision land levelling keeping in view the environmental aspects attached to such as activity.

- There is a strong need for improvements in the land resource base through measures like extension services to increase the awareness of farmers in sustaining the adoption of technically feasible and economically viable technology, use of appropriate crops combinations, etc.

- The rapid fragmentation of land (from an operational point of view) needs to be controlled through appropriate legislation that is politically insensitive and socially professed.

- In order to improve the effectiveness of the warabandi system, it seems appropriate that the snags in the operations and maintenance work sharing be removed, and efforts are made to make water distribution more equitable.

At the end, it would be relevant to argue that without improving water use efficiency in agriculture, which. will heavily determine the resource use efficiency in agriculture, it would be extremely difficult for Pakistani farmers to improve their land productivity and cost effectiveness in order that they can compete in the international markets, particularly, in the context of Structural Adjustment Program, GATT Agreements and Tariff Reforms that will liberalize international trade before the end of the twentieth century.

2. DISCUSSION

GENERAL DISCUSSION

The papers reproduced in the previous section were presented in the first session of the workshop. Wrapping up this session, the Chairman, Mr. Tahir Malik, underscored the point made earlier by Prof. Skogerboe in his presentation that institutions, rather than civil works, should play a leading role in future water management programs and civil works should support and strengthen the institutions. He also stressed the importance of issues pertaining to upper level system, such as the need to develop more storage capacity on rivers. He was of the view that workshop scope should not have been limited to tertiary level issues.

In the second session, chaired by Dr. Chandio, the key issues raised in the four presentations were summarized. The floor was then opened for general discussion.

The participants started with the issue of conveyance losses on the watercourse. It was suggested that lining the watercourse would help reduce these losses. This proposition was quickly countered by others who pointed out that seeping water was not ,completely lost (especially in fresh groundwater zones) and can be pumped at a more appropriate time, thus, providing additional flexibility to the farmers. Although the merits and the demerits of both options were discussed, no consensus could emerge over which option should be preferred.

The discussions moved on to the next issue with the observation made by a participant that on-farm drainage was not included in the workshop agenda. Several participants emphasized that on-farm drainage was an important issue in tertiary sub-system management. Dr. Shafique alluded to his paper presented earlier where he had mentioned that irrigation system was not complete without drainage.

The next issue to be taken up was that of low and declining agricultural productivity and whether it could be attributed to water scarcity. Several aspects of this issue were discussed. It was pointed out that yields were low because a very small percentage (30%) of the available water was applied to the fields. According to one suggestion, the magnitude of this problem could be somewhat reduced if pipes replaced open channels, especially in sandy areas.

Other participants felt that the issue was not only the scarcity of water per se. but also its inequitable distribution. They pointed out that there were considerable differences in water availability between the head and tail reaches of the watercourse. A suggestion was made that lining at the watercourse head would benefit tail enders by preventing seepage losses which are substantial in volumetric terms in that region of the watercourse.

In addition to seepage losses, many other reasons of inequity of intra-watercourse distribution were discussed. These included farmers adaptation of official warabandi whereby some farmers have longer turns than others and inclusion of new land in the culturable command area.

Within the context of lower agricultural productivity resulting from scarcity of water aggravated by poor distribution, the system of warabandi drew substantial comment from the participants. One proposal was to adopt a longer warabandi rotation of 14 days. This was motivated by the realization that the duration of turn in the current weekly rotation was too short for efficient irrigation, especially, for small land holdings.

The proposal for longer rotation also drew some criticism. One participant said that with longer gap between irrigation turns under the proposed warabandi, there was a risk of moisture stress to the plants during periods of high evapotranspiration. This he said could depress yields.

However, a more fundamental criticism was that the weekly warabandi had been seen as more constraining because a limited view was taken of the water distribution problem. The participant who made this point, drew attention to the fact that farmers could rely on tubewell water markets and canal water trading for supplemental supplies. A switch to a 14-day rotation might reduce water trading. It was noted, however, that possibilities to augment surface water supplied, existed mainly in fresh groundwater areas. In other areas farmers would need to build storage tanks or re-allocate canal water.

GROUP DISCUSSIONS

Following the general discussions, the participants divided into **4** groups to deliberate on the following issues. Group **A** considered water supply and use at the watercourse level while group **B** discussed irrigation methods and practices at the farm level. The economics of water transactions were taken up by group **C.** The institutional and social factors affecting water use were the topic of discussion **by** group **D.**

Each group was given two specific questions, in its respective area, to deliberate upon. At the end of the session each group submitted the results of its deliberations to the general audience. The issues that each group considered and a summary of the main conclusions reached are presented below:

GROUP A: WATER SUPPLY AND USE AT THE WATERCOURSE LEVEL

1. **Is** the warabandi system able to achieve an acceptable level of equity within the watercourse ? How can warabandi be modified to achieve greater equity **?**

Inequity within the watercourse command area is a problem.

Factors other than seepage losses are responsible for inequity.

Measures (for example, equal volume allocation) that can be taken to remove inequity would be fraught with many complexities.

Thus, **a** pilot study is required to diagnose warabandi problems and identify practical improvements.

2. What are the efficiency and cost-effectiveness issues. associated with watercourse improvements (earthen improvements and lining) under different environments ?

There is **a** need to assess the cost-effectiveness of different types of lining (including pipe-lines).

More research is required to better establish increased efficiency due to partial lining in combination with earthen improvements.

GROUP B: IRRIGATION METHODS AND PRACTICES AT THE FARM LEVEL

1. In areas with scarce surface water and marginal quality groundwater, what are the issues related to irrigation practices for sustainable agricultural production ? How can farmers be induced to adopt more sustainable practices ?

   Conjunctive use of both waters is the critical issue.

   Development of a strategy should include technological aspects (use of fractional skimming wells), irrigation practices and agricultural practices (brackish water not used at the early stages of crop development, use of salt-tolerant crops).

   In trying to introduce any package, socio-economic status of farmers is to be taken into account.

   Water Users Associations and Agricultural extension services should be mobilized for dissemination of improved irrigation practices.

   Research results should be first tested (with farmers' involvement) urider practical conditions.

2. Is water measurement important for the farm ?

   Water measurements are required at the farm level, as it helps farmers to take decisions for proper allocation and use of irrigation water.

   Simple gauges should be first devised, and then installed at the watercourse level near farms (or group of farms).

   Information collected by research institutes should be shared with farmers.

GROUP C: ECONOMICS OF WATER TRANSACTIONS

1. **Do** farmers benefit from participation in water transactions ? What factors influence farmers decisions to participate in canal and tubewell water transactions ?

   Yes, farmers benefit from water transactions.

   The expected productivity (higher yields, improved cropping pattern) is an important factor explaining farmers' participation.

   The importance of uncultivable area in a watercourse, the development of villages and houses, the location of farms, etc are other factors to be considered.

   Social relationships influence farmers' involvement in water transactioris.

2. Should warabandi be modified to facilitate water transactions among farmers, and how ?

   Canal water transactions should be legalized (change of the Canal and Drainage Act).

   However, the basic water rights as defined in the warabandi should remain the same.

   For tubewell water transactions, mining of the aquifer and water quality issues are to be considered.

   Groundwater right issues are to be analyzed (with focus on quantity, equity and quality aspects), and considered in the context of the long-term sustainability **of** the management of the aquifer.

GROUP D: INSTITUTIONAL AND SOCIAL FACTORS AFFECTING WATER USE

1. What factors influence the emergence of collective action (organized or otherwise) among farmers ?

   Collective action related to water use refers to water use activities (allocation, distribution, maintenance) and organization activities (to avoid conflict and limit free riding).

   Factors influencing the emergence *of* collective action are numerous and include homogeneity of the farming community, the importance of tenants, biraderies, the existence of shared problems within a watercourse command area, the importance of groundwater use, canal water scarcity, etc.

2. What are the criteria for assessing the effectiveness of farmers collective action?

   Objectives of collective action are to be defined before identifying appropriate criteria for assessing effectiveness.

   Two types of criteria should be considered: process related criteria (control of free riders, conflict resolution, ability to mobilize resources) and product related criteria (maintenance state, actual distribution of water).

   Criteria and performance indicators for assessing the effectiveness of collective action are still to be identified.

3. RECOMMENDATIONS OF THE WORKSHOP AND FUTURE COURSE OF ACTION

I: RECOMMENDATIONS OF THE WORKSHOP

Before the last session of the workshop, a select committee of the participants met to prepare a tentative list of recommendations based on the ideas and opinions expressed by the participants during the days proceedings. This list was circulated among the participants who were asked to discuss the tentative recommendations, propose amendments or add a new recommendation to the list. The participants, indeed, modified statements of some recommendations and proposed additional recommendations. After discussion, these modifications and additions were included in the workshop recommendations. The list of these recommendations is presented below:

1. The institutional aspects should play a leading role in water management programs, while civil works should support and strengthen the institutional measures.

2. Research should be conducted on conjunctive use of surface and ground water, giving proper consideration to quantity and quality aspects.

3. There is need to develop institutional mechanisms to regulate the exploitation of ground water resources SO that their quality is preserved and equity among users is maintained.

4. Canal water transactions among farmers should be legalized and canal water rights should be clearly defined.

5. Irrigation advisory services should be developed and its recommendations be provided/disseminated to farmers in easy and understandable language.

6. Modifications in the existing warabandi system is a complex issue. Therefore, a pilot study should be conducted in order to diagnose the warabandi problems and to identify practical solutions.

7. A seminar on warabandi should be organized, involving researchers and line agency staff. The objective of this seminar will be to identify practical changes in warabandi.

8. A research study should be conducted to investigate cost-effectiveness and optimum lining (including buried pipe lining) at the watercourse level in combination with earthen improvements

9. There is a need to mobilize water users associations and agricultural extension services to disseminate improved irrigation practices for increasing agricultural production.

10. Research should be conducted to develop simple flow measuring devices to be used within the tertiary system, including the farm level. IIMI and OFWM will develop joint research and field-testing activities. Other collaborators would be welcome to participate in this joint effort.

11. Research should be focused on the institutional and social aspects which result in the emergence of collective action among farmers.

12. At the farm level, drainage and salinity are important issues to be included in research on irrigation management.

13. Research should be conducted on the issues related to farmers responses to excess water allowances.

II: FUTURE COURSE OF ACTION IN MANAGEMENT OF TERTIARY SUB-SYSTEMS

by
Khalid Riaz[10]

This section draws some broad conclusions from deliberations of the one-day workshop on tertiary sub-system management. The material presented here relies heavily on the recommendations of the participants but it goes one step further by analyzing the participants' ranking of individual recommendations.

In the last session of the workshop, after the recommendations were drawn up, they were printed on forms and distributed among the participants. Each participant was then asked to rank the recommendation in order of priority from 1 though 12 (with 1 indicating the highest and 12 the lowest priority). These forms were collected and, later, the information contained therein was tabulated.

This section presents a simple analysis of the participants' ranking based on their tabulated responses. The objective of the analysis is to determine if some recommendations were regarded by the participants as being more or less important than others. To do this, four degrees of importance were defined. These were (aj **most important,** (b) **important,** (c) **less important** and (d) **least important.** If a participant ranked a given recommendation 1 through 4, his response was assigned to the "very important" category. Similarly, the ranks 4 to 6 were assigned to the category titled "important" . The following. 3 ranks constituted the "less important" category and the bottom 3, the "least important" category.

Next, for each recommendation, a frequency count of responses in al! 4 categories was taken. The distribution of these counts across categories indicated the ***relative*** importance of recommendations *vis-a-vis* each other. For example, if the frequency of responses falling in the first category (i.e. "most important") were high and those in other categories were low by comparison then it was concluded that the participants considered the recommendation very important. Similarly, if the frequencies were concentrated in categories 3 and 4, it indicated that the recommendation in question was regarded (comparatively speaking) not so important by the participants.

There were also other interesting distributions of responses besides the two polar cases described above. For instance, if most of the frequencies were concentrated at the two ends of the distribution (i.e. the distribution was bimodal with most of its mass concentrated in categories 1 *and* 4), it indicated a lack of consensus --- some participants regarded the recommendation very important while an almost equal percentage considered it least important. Another interesting

[10] Agricultural Economist, IIMI-Pakistan

situation arose when the frequency distribution across categories was flat, ie. all categories had more or less the same number of responses. This pattern indicated split-opinion but the recommendation in..question could be considered a "safe bet" compared to the "no-consensus" situation described above.

Two points should be noted before moving on to individual recommendations. First, the actual distribution of frequencies may not conform neatly to any of the patterns described above. So, in those cases, only a rough judgement is possible. Second, the various categories (most important, less important, etc.) show the *relative* importance of recommendations and not their absolute importance. The fact that participants "recommended" something underscores its importance even if they ranked it in the lowest category of importance. The categories of importance merely show relative importance within the set of recommendations under consideration. With these points in mind, lets proceed to the distributions of opinion regarding individual recommendations. For each recommendation, and for each importance category, Table 1 gives the percentage of participants who ranked the recommendation in that category. The total number of respondents was 30.

TABLE **1.** PARTICIPANTS RANKING **OF** WORSHOP RECOMMENDATIONS

Recommendations	Importance categories			
	Most important (%)	Important (%)	Less important %	Least important (%)
1	56.3	12.5	21.9	9.4
2	37.5	12.5	34.4	15.6
3	34.4	21.9	28.1	15.6
4	12.5	15.6	37.5	34.4
5	37.5	28.1	**3.1**	31.3
6	28.1	25.0	21.9	25.0
7	25.0	18.8	15.6	40.6
8	21.9	25.0	25.0	28.1
9	43.8	21.9	9.4	25.0
10	21.9	28.1	18.8	31.3
11	31.3	18.8	12.5	37.5
12	9.4	37.5	31.3	21.9

Recommendation 1

> The institutional aspects should play a leading role in water management programs while civil works should support and strengthen the institutional mechanism.

This recommendation was clearly regarded as most important by the participants as more than 56% of them ranked it in the "most Important" category. A look at the raw scores (not shown here) revealed that the central role for institutional considerations in water management programs was the top priority[11] of the largest number of participants for any single recommendation..

Recommendation 2

> Research should be conducted on conjunctive use of surface and ground water, giving proper consideration to quantity and quality aspects.

Opinion was divided about the relative importance of this recommendation. Mort: than 37% of the participants thought it was most important while over 34% considered it "less important". However note that the "most important" category has more than double the frequency of the "least important" category. This suggests that the participants considered the recommendation somewhat important.

Recommendation 3

> There is need to develop institutional mechanism to regulate the exploitation of ground water resources *so* that their quality is preserved and equity among users is maintained.

The distribution of participants' opinions was skewed towards regarding it important relative to other recommendations. A full 34.4% considered it "most important" and another 22% consider it "important". Although there is a sizeable percentage of participants who regarded this recommendation "less important," this does not quite offset the higher frequencies in the first 2 categories. This conclusion was **also** reinforced by the fact that only about 16% of the participants put the recommendation in the bottom category (i.e. "least important".).

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[11] Ranked No. 1 in a priority ranking from 1 through 12.

Recommendation 4

> Canal water transactions among farmers should be legalized and canal water rights should be clearly defined.

Nearly two-thirds of the participants (68%) regarded defining canal water rights and allowing canal water sales and purchases (currently banned under the Canal and Drainage Act) less important than some other recommendations. Only about 12% considered it most important. Compared with this, more than 34% consider it "least important". This shows how thinking of the workshop participants contrasted with that of the proponents of the current reform package for the irrigation system.

Recommendation 5

> Irrigation advisory services should be developed and its recommendations be **provided/disseminated** to farmers in easy and understandable language.

Clearly, providing advisory services to farmers was ranked highly by a majority (64%) of the participants. Out of these, 37% regarded it "most important".

Recommendation 6

> Modifications in the existing warabandi system is a complex issue. Therefore, a pilot study should be conducted in order to diagnose the warabandi problems and to identify practical solutions.

This is a typical example of "flat" distribution of opinions with each category getting a quarter of the responses. So although most (75%) attached some degree of importance to doing a warabandi study, only 28% thought it was "most important". This is almost counter-balanced by the 25% who considered it least important among the workshop recommendations.

Recommendation 7

> A seminar on warabandi should be organized, involving researchers and line agency staff. The objective of this seminar will be to identify practical changes in warabandi.

Like the issue of a pilot study on warabandi (Recommendation 6, above), the participants appear divided about the idea of organizing a seminar on warabandi. But more people (40%) ranked it in the bottom category compared to 25% in the top category. This indicates a lack of consensus, although the polarization is not very acute.

Recommendation 8

> Research study should be conducted to investigate cost-effectiveness and optimum lining (including buried pipe lining) at the watercourse level in combination with earthen improvements.

The distribution of opinions is also "flat" for this recommendation. Roughly speaking, the frequency counts in each category are the same.

Recommendation 9

> There is a need to mobilize water users associations and agricultural extension services to disseminate improved irrigation practices for increasing agricultural production.

Participants considered disseminating information about improved irrigation practices quite important. Forty three percent consider it "most irnportant" and another 22% consider it important. The number of participants who put it in the "very important" categoy is the second highest of all recommendations..

Recommendation 10

> Research should be conducted to develop simple flow me suring devices to be used within the tertiary system, including the-farm level. IIMI and OFWM will develop joint research and field-testing activities. Other collaborators would be welcome to participate in this joint efforts

Research on flow measuring devices also failed to generate much enthusiasm arnong participants. Although 22% considered it "most important", this is more than offset by the 31% who considered it least important. Overall, the percentage of participants ranking it in the top two categories was almost exactly equal to the percentage of those who ranked it in the bottom two categories.

Recommendation **11**

> Research should be focused on the institutional and social aspects which result in the emergence of collective action among farmers.

There seemed to be little consensus about the importance of research on factors leading to collective action. Thirty one percent of the participants considered this research "most important" but nearly thirty seven percent consider it "least important."

Recommendation **12**

> At the farm level, drainage and salinity are important issues to be included in research on irrigation management.

Less than 10% of the participants thought research on drainage and salinity at the farm level was very important relative to other workshop recommendations. Over 50% thought this research was not so important (ie. 50% ranked the recommendation in the last two categories).

Recommendation **13**

> Research should be conducted on the issues related to farmers responses to excess water allowances.

This recommendation was suggested at the end of the session after the forms for prioritizing recommendations were handed out. So, no rankings are available for it.

Interpreting participants' rankings

Two general conclusions emerge from the above analysis. First, participants were unambiguous about the importance of recommendations that called for taking some action other than conducting research (eg dissemination of improved irrigation practices, legalizing canal water sales and purchases). Thus for Recommendations 1,3,4,5,and 9, which met this criterion, the participants' opinion clearly leaned in one direction or the other. From the pattern of responses, it was possible to, unambiguously, determine that the participants either regarded them important or less important.. In other words, there was a degree of unanimity regarding these issues.

Second, participants were ambivalent about the relative importance of recommendations calling for some research activity. This was either reflected in the distribution of opinions being "flat" or their being a lack of consensus. Thus, Recommendations 6,8, and 10 have more or less the same frequencies in each importance category. So, the participants attached some degree of importance to these research activities but there was neither a great enthusiasm nor complete apathy towards them. There was a lack of consensus about Recommendations 7 & 11. Participants tended to either regard them as "most important" or "least important," thus, reflecting a polarization of opinion.

Although the above observations describe general patterns, there are also some exceptions. These are, research on conjunctive use of ground water with proper attention paid to quantity and quality issues (Recommendation 2), and research on farm level drainage and salinity (Recommendation 12). The former is clearly revealed to be important and the latter, not so important.

Among the recommendations that were considered important, the greatest emphasis was on designing water management programs where institutional aspects played a leading role while civil works strengthened and supported the institutions. This is not surprising in view of the lessons learned from the mammoth effort undertaken since the seventies for improved watercourse management. It does show that those lessons are well internalized by the profession and there is a high degree of consensus about the role of institutions.

Another issue considered important by the participants was the dissemination of technical advice regarding irrigation to the farmers. This was to be done either through an irrigation advisory service (Recommendation 5) or through water users associations (Recommendation 9). Both options were rated important.

As mentioned earlier, research on conjunctive use of ground water was the only research activity rated important by the participants. This reflects a growing awareness of the environmental problems resulting from irrigation with bad quality tubewell water. These problems have assumed menacing proportions following the mushrooming growth of private tubewells in the last 10-15 years. Participants' concern about this environmental hazard is also reflected in their strong emphasis on development of institutional mechanisms for regulating the exploitation of ground water resources with a view to preserving aquifer quality and equity among users (Recommendation 3, which is rated important). The emphasis on regulation also suggests that the participants had an appreciation of the "common property" nature of aquifers and of the danger that uncontrolled exploitation by individual farmers might lead to socially sub-optimal outcomes --- a situation all too frequent in exploitation of common property resources.

It is interesting to note that all recommendations which emphasized some action other than doing research were revealed to be important, except Recommendation 4 (rated not important). This recommendation dealt with defining canal water rights and legalizing canal water transactions . Here, participants' thinking contrasted with the philosophy underlying the package recently proposed for irrigation system reform. Two important features of this package are definition of water rights and development of water markets."

General conclusions

The list of recommendations presented in the previous section provides broad guidelines for future courses of action in tertiary sub-system management. However, if one must discriminate between those recommendations, the following points should be noted. First, doing more research was seldom a high priority of the participants. Most important avenues for future action were considered to be the development of water management programs with emphasis on institutional aspects; regulation of common property resources, especially the aquifers; and, dissemination of technical information about irrigation to the farmers through various organizations, including farmers organizations. Participants did not consider defining water rights and allowing market transactions in canal water to be very important.

The above findings have implications for future courses of action by government planning agencies, IIMI, and other international and national organizations concerned with irrigated agriculture. Three broad areas are identified where focused and co-ordinated efforts could have potentially high pay-offs. These are: a) development of institutions for better irrigation management; b) dissemination of information; and c)research on issues resulted to conjunctive use of surface and ground waters.

[12] It must be noted, however, that at the time that the workshop was held, the details of the proposed reform package were not adequately disseminated even to the professionals and there were contradictory and insufficient understanding of what it contained. Opinions on this issue can change as more detail becomes available and are internalized by the profession.

ANNEXURES

ANNEXURE-I FINDINGS OF OTHER INSTITUTIONS

Before the workshop took place, the persons invited to participate were asked to send three most important research findings of their institution. The finding of that were received are summarized below:

CERWR

Rotational irrigation and equity in water allocation:

Rotational water supply systems which were designed to deliver a constant amount of water to all the users on a watercourse have failed to do so. There is a need to revise or modify the centuries old warabandi system.

In the present warabandi system, transient water losses are not considered adequately. This results in inequity in water distribution: more water to the head end farmers and less to the farmers located at the tail end of a watercourse. Something must be done to improve this situation.

The inequity in the tertiary system may be improved by modifying the present constant timing warabandi system to the variable timing warabandi. In the variable timing warabandi system, water distribution equity is achieved by increasing the irrigation time per unit area rather than fixed time per area as is presently done under the existing warabandi system.

WAMA

Irrigation in areas with high water allowances:

Farmers respond to increased water allowance by reducing irrigation application efficiency. In a tertiary unit with an average allocation of 12.2 cusec/1000 acres during the research period, irrigation application efficiency was less than 50%.

Farmers did not respond to varying crop water requirements by changing the duration of their irrigation turn. However, in the last 2 decades, adjustment to reduced crop water requirements were made by increasing the interval between irrigations.

Rainfall caused farmers to delay their next irrigation turn. The delay was inversely related to the time lag between the occurrence of rainfall and the time of the farmer's irrigation turn.

Although there was flexibility in terms of irrigation interval, the warabandi schedule was still followed in the sense of rotating turns among the farmers instead of adopting a share of flow allocation mechanism.

SIAP

Watercourse improvement:

Water users associations and/ or homogeneous groups within a watercourse area are the best means for achieving participatory watercourse renovation and improvement.

Precast parabolic sections have a very important role to play as an option for watercourse lining.

Whilst farmers nearly always cite water as a perceived problem, investigation frequently reveals that the problem is not quantity or timing. Very often it turns out to be an easy problem relating to a blockage or restriction in the watercourse (eg. culvert under the road) that individually farmers have been unable to solve. Collective action becomes simple.

PCRWR

Irrigation techniques for mountainous areas:
(research conducted by Water Resources Research Center, Peshawar)

The use of buried pipelines in hilly and undulating area is the best method of water conveyance and distribution at the farm level.

The brried pipeline increases the delivery efficiency and decreases delivery time to the field.

The participating farmer is satisfied with the buried pipeline and is planning to install a similar system in his other orchards entirely at his own cost.

Irrigation techniques and irrigation scheduling in irrigated areas

(Research conducted by Drainage and Reclamation Institute of Pakistan, Tandojam)

Irrigation and conveyance in the field through RCC buried pipe (dia 16") is better than a lined watercourse. It also utilizes less land than the watercourse. The higher cost can be offset due to high conveyance efficiency, weed and rodent control, better hydraulic performance, increases land savings, etc.

For lower Sindh, irrigation scheduling of wheat, cotton and sugarcane has been established on the basis of a rotational delivery system of irrigation (warabandi). These are:

i) **Wheat:** Soaking dose = 75mm then four subsequent irrigations each of 75 mm at interval of 3, 6, and 15 weeks after sowing . Total = 375 mm.

ii) **Cotton:** Soaking dose = 100mm, the 6 subsequent irrigations each 75 mm at intervals of 4, 7, 10, 13, 15, 18 weeks after sowing. Total = 550 mm.

iii) **Sugarcane:** Soaking dose = 100 mm., then 20 subsequent irrigations each 75 mm at intervals 1, 2, 5, 11, 19, 22, 26, 28, 30, 32, 34, 35, 36, 38, 39, 41, 42, 46, 49 and 51 weeks after sowing. Total = 2100 mm.

The consumptive use of water for shua variety rice was found to be 1500 mm, based on one year's data. However, the crop must remain submerged in water throughout its growing period.

ANNEXURE-II AGENDA OF THE WORKSHOP

JUNE 18, 1995

START OF PROCEEDINGS: 08.30 AM

FIRST SESSION 8:30-10:20 AM

Chairman Mr. Tahir Malik

08:30	Recitation from the Holy Quran (Mr. Saeed-ur-Rehman)
08:35	Introduction (Prof. Skogerboe)
08:45	Presentation of agenda (Ms. Robina Wahaj)
08:50	Presentations by speakers
	Prof. Skogerboe
	Prof. Arshad Ali Chaudhry
	Dr. M.S. Shafique
	Mr. Akhtar Hai
10:20	**TEA BREAK**

SECOND SESSION 10:45 am-1:15 PM

Chairman: Dr. Bashir Ahmad Chandio

10:45	Summary of presentations (Mr. M. Badruddin)
10:55	Discussion
11:30	Group Discussions (4 groups)
12:30	Groups present results of their deliberations.
01:15	**LUNCH**

THIRD SESSION 2:15-4:30 PM

Chairman: Mr. Mushtaq Ahmad Gill

2:15	Synthesis of group discussions(Mr. Pierre Strosser)
2:25	Discussion
3:45	**TEA BREAK**
4:05	Recommendations (Mr. Khalid Riaz)
4:20	Closing (Prof. Skogerboe)

ANNEXURE-III LIST OF PARTICIPANTS[13]

Sr.No.	Name	Organization
1	Mr. Akhtar A. Hai	AERC
2	Mr. Zubair	Agriculture University, Peshawar
3	Mr. Arshad Aziz	Agriculture University, Peshawar
4	Dr. Muhammad Latif	Centre of Excellence
5	Mr. S.M. Yasin	DRIP
6	Mr. Ashfaq Hussain Mirza	HALCROW
7	Mr. Mehfooz Ali Shah	HALCROW
8	Dr. Asghar Cheema	IIMI
9	Prof. Gaylord V. Skogerboe	IIMI
10	Ms. Ineke Margot Kalwij	IIMI
11	Mr. Jean-Daniel Rinaudo	IIMI
12	Mr. Khalid Riaz	IIMI
13	Mr. M. Badruddin	IIMI
14	Dr. M. S. Shafique	IIMI
15	Mr. Marcel Kuper	IIMI
16	Dr. Muhammad Aslam	IIMI
17	Mr. Pierre Strosser	IIMI
18	Ms. Robina Wahaj	IIMI
19	Mr. Saeed-ur-Rehman	IIMI
20	Dr. Waqar A. Jehangir	IIMI
21	Mr. Zafar Iqbal Mirza	IIMI
22	Ms. Zaigham Habib	IIMI
23	Mr. Ghulam Zakir	IRI
24	Mr. Hafeez-ur-Rehman	IRI
25	Mr. Irshad Ahmad	IRI
26	Mr. Muhammad Tahir	IRI
27	Dr. Nawaz Bhutta	IWASRI
28	Mr. Tahir Ahmad Malik	Irrigation Department
29	Mr. Variam Ali Mohsin	MONA

[13] Names of participants as well as organizations are in alphabetic order.

Sr.No.	Name	Organization
30	Mr. Gulraiz Akhtar	On-Farm Water Management Project
31	Mr. Javaid Mirza	On-Farm Water Management Project
33	Mr. M. Riaz Ahmad	On-Farm Water Management Project
33	Mr. Murid Hussain	On-Farm Water Management Project
34	Mr. Mushtaq Gill	On-Farm Water Management Project
35	Mr. M. Yasin	PARC
36	Dr. Bashir Ahmad Chandio	PCRWR
37	Mr. Gul Muhammad Shah	PCRWR
38	Mr. Micheal Long	SIAP
39	Mr. Abdul Khaliq	University of Agri. Faisalabad
40	Dr. M. Rafique Chaudhry	University of Agri. Faisalabad
41	Dr. B.A. Azhar	University of Agri. Faisalabd (ex.)
42	Mr. Micheal De Bont	WAMA
43	Mr. Agha Atta-ur-Rehman	WAPDA
44	Mr. Bashir Ahmad	WAPDA
45	Mr. Saleem A. Sial	WRRC

IIMI-PAKISTAN PUBLICATIONS

RESEARCH REPORTS

Report #	Title	Author	Year
R-1	Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan (Volume I: Synthesis of Findings and Recommendations	Carlos Garces-R D.J. Bandaragoda Pierre Strosser	June 1994
	Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan (Volume II: Research Approach and Interpretation)	Carlos Garces-R Ms. Zaigham Habib Pierre Strosser Tissa Bandaragoda Rana M. Afaq Saeed ur Rehman Abdul Hakim Khan	June 1994
	Crop-Based Irrigation Operations Study in the North West Frontier Province of Pakistan (Volume III: Data Collection Procedures and Data Sets)	Rana M. Afaq Pierre Strosser Saeed ur Rehman Abdul Hakim Khan Carlos Garces-R	June 1994
R-2	Salinity and Sodicity Research in Pakistan - Proceedings of a one-day Workshop	IIMI-Pakistan	Mar 1995
R-3	Farmers' Perceptions on Salinity and Sodicity: A case study into farmers' knowledge of salinity and sodicity, and their strategies and practices to deal with salinity and sodicity in their farming systems	Neeltje Kielen	May 1996
R-4	Modelling the Effects of Irrigation Management on Soil Salinity and Crop Transpiration at the Field Level (M.Sc Thesis-Pulished as Research Report)	S.M.P. Smets	June 1996

Report #	Title	Author	Year
R-5	Water Distribution at the Secondary Level in the Chishtian Sub-division	M. Amin K. Tareen Khalid Mahmood Anwar Iqbal Mushtaq Khan Marcel Kuper	July 1996
R-6	Farmers Ability to Cope with Salinity and Sodicity: Farmers' perceptions, strategies and practices for dealing with salinity and sodicity in their farming systems	Neeltje Kielen	Aug 1996
R-7	Salinity and Sodicity Effects on Soils and Crops in the Chishtian Sub-Division: Documentation of a Restitution Process	Neeltje Kielen Muhammad Aslam Rafique Khan Marcel Kuper	Sept 1996
R-8	Tertiary Sub-System Management: (Workshop proceedings)	Khalid Riaz Robina Wahaj	Sept 1996
R-9	Mobilizing Social Organization Volunteers: An Initial Methodology Step Towards Establishing Effective Water Users Organization	Mehmoodul Hassan Zafar Iqbal Mirza D.J. Bandaragoda	Oct 1996