MANAGING IRRIGATION SYSTEMS TO MINIMIZE WATERLOGGING AND SALINITY PROBLEMS

INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE - PAKISTAN

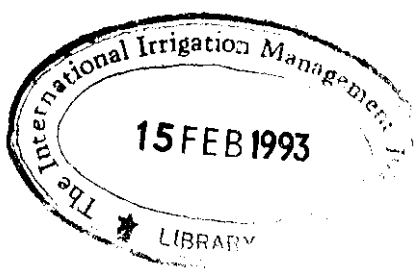
EIGHTH PROGRESS REPORT

ON

MANAGING IRRIGATION SYSTEMS

TO

MINIMIZE WATERLOGGING AND SALINITY PROBLEMS



LAHORE, JANUARY 1993

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EIGHTH PROGRESS REPORT

1. INTRODUCTION

This Progress Report on the Project "Managing Irrigation Systems to Minimize Waterlogging and Salinity Problems" covers the half yearly period ending December **31,** 1992.

During the Report Period field research activities at the established research locales on the Upper and Lower Gugera Branch canal of the Lower Chenab Canal (LCC) system and on the Fordwah Sadiqia Canal System were completed for the Kharif (summer) season and extended, with modifications, for the following Rabi (winter) season.

The analytical work based on the field data, focussed on the identification of management interventions which could improve the canal operations in conjunction with groundwater use and also mitigate the adverse impacts of emerging secondary soil salinization. The result of this work were presented in substantive papers presented at IIMI's **1992** IPR (IIMI Internal Program Review).

The management intervention: taken up with the Punjab Irrigation Department (PID) in one Division of the LCC were extended to another Division of that system and proposals were drawn up **for** initiating similar work on the Fordwah Branch from early **1993.** Progress was also made with the development of Decision Support "Tools" to be used in managing the irrigation systems.

The use of GIS was advanced by developing base maps at different scales and with progressively greater detail down to the tertiary level for the areas for which field research data had been collected.

A number of reports were brought out during the report period and work progressed on the forthcoming publications.

This Progress Report, following the format of the earlier Reports, describes all the above activities in greater detail.

2. PROGRESS

2.1 Data Collection and Analysis

The field research activities under the Project, complementing other IIMI-Pak research activities, were continued at the three established locations in the Punjab. These consisted of the follow through of the Kharif season program and the initiation of the activities for the following Rabi season starting from October 1992. In addition, special research activities were carried out at the main system and tertiary levels. A brief description of these activities is given in the following sections.

2.1.1 Upper and Lower Guaera Sites

In the data collection program taken up for the Rabi season for the Upper Gugera and Lower Gugera sites, the collection of irrigation application data was terminated except for the Kharif crops yet to be harvested and at the main system level the focus was shifted to canal performance. At the watercourse level in the Upper Gugera area, continued monitoring of the tubewells was restricted to four watercourse on the Mananwala distributary. Watercourse level work in the Lower Gugera was confined to the monitoring of groundwater levels only and collection of rainfall data.

The data on canal performance, which would relate to the on-going interventions, includes the measurement of the water surface elevations and flow velocities at selected locations on the distributaries including a complete hydraulic survey of the Pir Mahal distributary.

In addition to this data collection program a Rapid Appraisal to extend the results of earlier research findings, has been proposed for the Mananwala distributary which will involve a tubewell census and a surface salinity survey. This is expected to refine RA techniques for wider application in Punjab.

The analysis of the data collected from these research locales resulted in a substantive paper entitled "***Conjunctive Use*** of ***Canal and Groundwater in Punjab, Pakistan: Management and Policy Options***" by D. Hammond Murray-Rust and Edward J. Vander Velde. This paper was presanted at the IIMI's Internal Program Review (IPR) in Colombo, Sri Lanka in November 1992. The abstract of this paper is attached as Annex- I. The main findings of this paper are:

- farmers apply water efficiently with Relative Water Supply close to 1.0 irrespective of location;

- groundwater accounts for 50-70% of the total irrigation supplies;

- the present conjunctive use of surface and groundwater contributes to secondary salinization.

Another important analytical work based on the IIMI-Pak field activities in L.C.C. was a paper produced by Edward J. Vander Velde and Dr. Hammond Murray-Rust and entitled ***"Impact of Physical and Managerial Interventions on Canal Performance in Pakistan: A Review of Five years of Field Research Studies".*** This paper was also presented at IPR at the IIMI Headquarters in Sri lanka. The paper reports on performance changes in several secondary canals in Pakistan as a consequence of different types of interventions (lining, desilting and operational management). An abstract of this paper is attached as Annex - II.

In another study, presented in an internal seminar by a Field Research Professional the effect of farmers' organizations on the irrigation management at watercourse and farm level was determined. The main findings of this study were:

- farmers organizations (often with a limited objective) were observed to exist, both formally and informally organized;
- issues that were addressed by these farmers' organizations ranged from watercourse cleaning, obtaining favors from ID (eg illegal irrigation), settling disputes, purchase of farm inputs (cooperative);
- 'casts' and 'braderies' play an important role in the organization of farmers, often disruptive when iter-braderi strife exists.

As mentioned in the previous Report, the analysis of the data pertaining to the role of tubewells in a conjunctive environment was carried forward, with additional data covering the Karkan Minor of the Mananwala distributary. In this work, apart from the physical aspects of groundwater development as related to the availability of canal supplies (tubewell characteristics, densities, usage, water quality) attention was also directed to the socio-economic factors and in particular to water markets. Secondary information on cropping patterns and cropping intensities was collected for this purpose. While the preliminary analysis did not establish clear trends, it was apparent that tubewell water quality was a major determinant of tubewell operation time - with lower usage rates related to groundwater of higher salinities. Similarly, the results indicate that both the availability of the irrigation water from the canals and the quality of groundwater determine the extent of water trading. The results of this work would be reported in early 1993 after all the analyses are completed.

The analysis of canal water otiservations for Mananwala distributary (4 years) and its minor Karkan (2 years) was concluded and an internal report was prepared by Erik van Waijjen entitled: ***Performance of Mananwala Distributary and Karkan Minor.*** This paper discusses in detail the observed trends along the canals of (variations in)

water levels and outlets discharges, using many graphs to show the results of different ways of aggregation and analysis of the data. Several factors are identified that affect the amount and variability of the water supply to the outlets, such as outlet design, siltation of the canals and diverse interventions such as temporary pipes, cuts by farmers, breaches of 'ghat' points, etc., and their relative importance for different canal reaches are discussed.

2.1.2 Fordwah Eastern Sadigia Sites

Apart from the continuing Kharif data collection activities, a data collection program for Rabi, similar in scope to that at the other field sites, was taken up. At the main system level, the canal performance of the Fordwah Branch was included and at the watercourse level the focus was on the monitoring of tubewells in 5 sample watercourses and a tubewell census for three distributaries. In addition, it was proposed to monitor water tables along the Chistian Drain in collaboration with WAPDA Planning (Central).

In continuation of the work executed by 2 groups of research associates from Delft University in Rabi 1990/1991 and Rabi 1991/1992, reported upon in previous progress reports, a study was initiated on the performance of the Fordwah Branch and its off-taking secondary canals in Kharif 1992. Because the system is non-perennial, hydraulic conditions and requirements are distinctly different in both seasons. Clearly the stress on the system is greater in Kharif than in Rabi as the main canal in Rabi carries only 30% of the average discharge of Kharif. The results of this study were presented at IIMI's Internal Programme Review (IPR) in Colombo, Sri Lanka in a paper entitled ***"Irrigation Management in the Fordwah Branch Command Area South East Punjab, Pakistan"*** by Marcel Kuper and Jacob W. Kijne. The abstract of this paper is attached as Annex III. The authors found that the information on which operational decisions by the system managers are made are not reliable and even fictitious in some cases. Gauge readings often reflect the official situation rather than actual conditions. Operations are often not transparent, both for the operating agency and for the farmers. As a consequence operating instructions are often contradictory. farmers put pressure on personnel at various levels of the ID and ID does not have the data to counter requests from influentials.

Another finding is that while operating staff appears very independent, guidelines to operate the various structures in the system by the system managers are very limited, resulting in a high variability in the discharge throughout the system and a declining amount of water delivered to secondary canals going from head to tail due to limited local objectives of staff. On top of this it was found that most structures in the study area do not have rating tables or have rating tables that are outdated. Finally it was established that farmers are irrigating very efficiently with Relative Water Supplies between 0.8 and 1.0 both in Kharif 1991 and in Kharif 1992.

Early in **1993,** a collaboration will be initiate with the Irrigation Department on a number of issues that were raised in this paper. A management intervention, focussing on the information system, will be designed with the Irrigation Department to assist in improving the performance of the irrigation system. Along with that, modelling of the Fordwah Branch will continue to assess the impact of present operational practices and to forecasl the effect of management interventions.

The Discussion Paper No. **6** (the Appropriateness of Canal Water Supplies: the Response of the Farmers1 has highlighted the importance of water trading in the 5 watercourses studied by IIMI. To gain a better understanding of water markets, further data analysis was undertaken since the last Progress Report. The first draft of a forthcoming Discussion Paper on water markets was prepared.

It seems very important now to go further into the analysis of these water markets. Data collected by IIMI in other field stations has shown that water markets are common but quite diversified according to the quality of the groundwater or the supply of canal water. Of first impotance will be to understand the impact of water markets on the allocation of water of different qualities within watercourses, on the process of salinization and eventually on the agricultural production.

2.2 Special Investiaations

The progress on the continuing special activities mentioned in the last Progress Report is detailed hereunder:

2.2.1 Annual Canal Closure Maintenance & Repair

The study that was mentioned in the last progress report, on the processes of planning, coordinating and implementing the maintenance and repair (M&R) activities during the annual canal closure perioc, was finalized. The results were reported in the form of a Discussion Paper, ***"The Punjab Desiltation Campaign During 7992 Canal Closure Period: Report of a Process Documentation Study",*** IIMI Pakistan Discussion paper No. 7. 1992 (Erik van Waijien and Bandaragoda), and was distributed locally among a selected number of people including the Secretary of Punjab's Chief Minister.

2.2.2 Land Reclamation Operation by PID

The Study of the land reclamstion operations of the PID undertaken by the Department jointly with the Directorate of Land Reclamation (DLR), through the provisionof 'reclamation shoots' was initiated before the onset of the operational Kharif season, as brought out in the last Prcgress Report. The study was intended to bring out the organizational and operational constraints of the DLR and PID which detract from the realization of the fullest benefits from the additional irrigation supplies sanctioned for the reclamation of saline soils. It was expected that the study would

help to define management interventions which could be undertaken cooperatively to address the problems of emerging secondary soil salinization manifested by the past IIMI work.

This study covering both the institutional and physical aspects, was taken up jointly by the IIMI Irrigation Management Specialist and the Principal Irrigation Engineer, in close collaboration with the staff of the DLR.

Relevant information was collected from a sample of 20 watercourses on the Upper Gugera, Lower Gugera and Burala Branches of the LCC, where the 'reclamation shoots' were operational in different stages of the 3-year cycle or where they had been terminated earlier. Flow conditions on the 7 channels on which 'reclamation shoots' were operational were monitored at the head and tails during the operational period July to mid October through periodic measurements to relate discharge with the sanctioned amounts. The respective! roles of the DLR & ID staff at different levels in the sanctioning, installation, operations and closure of the 'shoots' and for the distribution of the additional supplies were determined through interviews. Interviews with farmers and in particular with resource persons were conducted to collect information on the actual conduct of the reclamation operations through the 'shoots' and their impact.

With the completion of the field work the analysis of the data was taken up which would be reported in early 1993. The preliminary analysis so far undertaken has indicated many areas where improvements may be possible. Some of the relevant findings are:

- Although originally intended for lands with salinity, based on visual annual surveys, classed as Thur Juzvi (land salt affected to be extent of 20%) and Thur Nau (land gone out of cultivation during preceding five years) reclamation operations in practice cover all types of land.

- Against the officially prescribecl period (16th April to 15th October), reclamation supplies are restricted to a period of only 3 to 3 1/2 months from July 1 to Oct 15, with water allocation of 1.56 lit/s/ha in perennial and 1.16 lit/s/ha in non-perennial canal commands.

- Although the DLR prepares a comprehensive documentation for the selected watercourses for the reclamation of about 45 acres (in a compact block owned by one farmer, or scattered) to qualify for a pipe outlet of 1c/s capacity, the selection process is subjective and not strictly related to the salinity status of the soils.

- The superior role of the PID staff in sanctioning and installing 'reclamation shoots' results in deviations from the plans developed by the DLR.

- 'Reclamation shoots' are generally given in the upper half of the channels which impacts adversely on the equity in water distribution.

- The farmers are keen to get 'reclamation shoots' sanctioned for their lands as they contribute to greater agricultural production and improvement of the lands.

2.2.3 'Warabandi' Studv

On the warabandi study initiated by the Management Specialist two field visits were made by the Senior Field Research Economist, to the Punjab sites, and a detailed questionnaire was prepared for collection of more field data through the field teams. Meanwhile, data already collected by the field teams in connection with the normal field activities were reviewed on the corisideration that fresh data collection may not be necessary if the existing data base could be optimally used. This data base was scrutinized to find out which aspects of it could be used. This involved the

- identification of a common set of watercourses between those to which available data relates and those on which crop yield data had been collected for earlier studies,

- isolation of data that correspcnded to the same period as for earlier study,

- identification of the institutional variables included in this whole data set irrespective of the categorization given above, so that they can be used appropriately in the waraband study.

The objective of the warabandi study includes an assessment of the potential of farmer-managed water distribution at the watercourse level with a view to finding out ways in which farmers can be involved in solving salinity related problems. Another important issue under investigation is the operation of equity criterion embodied in the warabandi system as the inequitable water distribution is seen as a major cause of exacerbating the salinity problem at :he tail-end command areas.

Based on the review of the existing data, it has been established that additional data will have to be collected from the field for which a programme would be launched in Jan. **1993.**

2.2.4 Other Investigations

The work on the study of Salinity Prevention Flows which was to be initiated during the report period, could not be taken up, due to the engagement of the Irrigation Specialist on other more pressing assignments. This work would now be taken up from early **1993.**

The publication mentioned in the last progress report, titled, ***"Institutional Factors Affecting Irrigation Performance in Pakistan"*** (Bandaragoda and Firdousi), was issued as an IIMI Country Paper: Pakistan No. 4, and 160 copies were distributed among senior staff of irrigation related agencies in Pakistan, research institutes, libraries and among donor agencies.

Arising from the field interviews and literature surveys conducted under this project, a paper titled, ***"Importance of Irrigation Policy Analysis for Sustainability"*** was prepared and presented by IIMI-Pakistan Senior Management Specialist at the International Conference on 'Advances in Planning, Design, and Management of Irrigation Systems as Related to Sustainable Land Use' held during 14-17 September 1992 in Leuven, Belgium. The paper has been published in Jan Feyen et al (ed), Proceedinas of the International Conference on Irrigation as Related to Sustainable Land Use, Belgium, pp.81-92. September 1992.

An expanded version of the paper including some case illustrations from Pakistan was finalized to be published as a monograph related to the Waterlogging and Salinity Project.

Part of this work also enabled a contribution by Senior Management Specialist, D.T. Bandaragoda on the linkages of research and policy and the related role of IIMI, to be included in the paper titled, ***"Institutions, Policy, and National Programs"*** which was presented by co-author Doug Merrey at the August 1992 meeting of CGIAR Social Scientists.

2.3 Consultancies

During this report period, apart from the continuing consultancy of Ms. Nanny Gijsen on the application of GIS, a short consultancy was provided by Dr. David R. Purkey regarding the potential use of a Pump Irrigation Model for research on the Conjunctive use of surface and groundwater.

The consultancy of Ms. Nanny Gijsen continued upto the end of Sept 1992 at the conclusion of which she submitted a Discussion Paper entitled ***"Geographic Information System: Perspective for IIMI Pakistan - A Case study of the Fordwah-Eastern Sadiqia Irrigation System".*** As part of the work, the ILWIS 1.3 (Integrated Land and Water Information System) developed by the ITC (International Institute for Aerospace Survey and Earth Sciences, the Netherlands) which has been adopted by IIMI, was tested for the Fordwah . Eastern Sadiqia System at two levels - the distributary level (secondary) and the watercourse (tertiary). This work highlighted the need for accurate geo-referencing for the preparation of base maps and the requirements for field data for adequate spatial representation and analysis. The possibilities of analyzing available data with GIS were demonstrated and

recommendations were made for future data collection to make optimal use of GIS. (See also section 2.4 Geographic Information systems).

Dr. David R. Purkey, of the Consulting Services in Water Resources and Development, Eugene, Oregon, U.S.A., visited IIMI Pak from October 24, 1992 to November 1, 1992. During the period he interacted with the IIMI-Pak research staff associated with research on the Conjunctive Use of Surface and Groundwater, to explain the I/E Pump Irrigation Model developed by him in collaboration with Dr. David Seckler of Winrock International. The basic objective of the consultancy was to establish the utility of the model in the on-going research by IIMI-Pak by carrying out such modifications which would take account of local conditions (overlapping command areas for tubewells and canals, drainage and irrigation functions and variable water quality). The secondary objective was to determine the adequacy of the currently available data and the need for additional data for use with the modified model. Based on his interaction, Dr. Purkey submitted a Report in November 1992, entitled ***"Waterlogging and Salinity Program - Potential use of the I/E Pump Irrigation Model for Research on the Conjunctive Use of Surface Water and Groundwater for Irrigation"***. This Report would be taken into consideration for the possible application of the model in the future research program.

2.4 Geoaraahic Information Systems (GIS)

During the report period activities related to the development of an operational Geographic Information System (GIS) progressed to a stage where the ability of generating value-added maps specific to irrigation concerns was satisfactorily established. Given the variety of data sets collected from the field pertaining to the physical performance of the irrigation system and associated farmers' practices, the task of spatial and temporal representations across a wide range of map scales was to be an important prelude to the geographic synthesis of GIS-related archives. As such, much of the initial work focussed on map-entry from originals as disparate as Survey of Pakistan map sheets, PID, irrigation system command maps, and SPOT Panchromatic satellite imagery.

Following operational set up of the GIS facilities at Lahore office, there was an early need (and expectation) within the IIMI-Pak Staff regarding some demonstrable utility of spatially-attributed irrigation-specific concerns, especially in respect of the data collected from a host of IIMI Field Staiions. Prior to any such undertaking, the primary requirements for geographical referencing for variables of interest had to be satisfied. Selection of appropriate variables for mapped/overlay representations had to encompass the following constraints:

* level of detail for a given variable of interest varied considerably amongst field sites;

- some sampling sites were too few and far between;
- watercourse plans for sampl ng sites required updates for their respective boundaries;
- coordinate referencing (through Survey of Pakistan topo map sheets) was unavailable for a geographic aiea covered by a field station (Hasilpur);
- irrigation system plans for some of the distributary commands had not been updated for over 50 years, and ones that did exist lacked geo-referencing and contained scale anomalies;
- the rigorous nature of detail (lathered from some watercourses necessitated minimum mapping unit of size of Ca. 1 acre, which when compared across Mauza (village maps) resulted n discrepancies of alignments and identification (according to irrigation revenue scheme)

These, and many other constraints conditioned choices of initial mapped products. Much work focussed on the collection of PID irrigation system plans, the aggregation of tabular data specific to the mapping units, and selection of control points for georeferencing PID maps for subsequent digitizing. The choice of inputs for the mapped inventory was inclusive of the following:

- crop census (for multiple Rabi and Kharif seasons) on watercourse basis
- land holdings (watercourse level)
- tubewell location and density (watercourse level)
- groundwater table depths (acrass distributary commands)
- groundwater quality (distributaiy command)
- soil associations (from Soil Survey of Pakistan regional classifications)
- soil salinity (field level)

Base map representation included system information on:

- roads
- railway lines
- towns and villages

* drains

* distributaries/watercourses

* main/branch canals

* village/distributary/watercourse bounds

A comprehensive effort in base map preparation covered parts of the Upper Gugera Division in Sheikhupura district. Primary inputs for an areal extant of 90 Km x 40 Km came from interpreted SFOT Panchromatic satellite imagery at a scale of 1:40,000. The coordinate referencing was against the 1:50,000 scale Survey of Pakistan sheets. The essential hydrologic parameters were, in turn, used to correctlupdate the PID command maps of Lagar and Mananwala distributaries. For Lagar distributary in particular, the complete tubewell census data (399 tubewells) was georeferenced for interpolation on significant physical and chemical parameters. Also as part of the support activity for the Rabi season 1992-93 data collection program, the preparation of watercourse-level maps was taken up *so* that the collected data sets could be absorbed within a spatial framework. Previously collected information on Lagar and Mananwala distributaries will also be referenced accordingly.

As an initial step in the spatial analysis of the variables of interest, a Case Study was undertaken for the Fordwah-Eastern Sadiqia System both at the distributary and watercourse level. This involved the preparation of working base maps using information from different sources and interpolating the point source information for spatial representation. The results, of this study were reported by the IIMI-Pak Consultant, Ms. Nanny Gijsen in a paper entitled; ***"Geographic Information System - Perspective for //MI-Pakistan"*** This study also indicated the approaches to be used for extending the utility of GIS by carrying out rapid appraisals to capture the variables of interest impacting on the cropping and soils through variation in irrigation water quantity and quality.

As part of projection of IIMI-Pak's emerging GIS capability and achievements to date, a Pakistan Corner was arranged at the inauguration in December 1992 of IIMI Headquarters at Sri Lanka. Poster displays were set up which depicted the irrigation system layout and its performance in the context of IIMI-Pak's field operations in the Hasilpur and Farooqabad Field Station coverages.

In line with IIMI's theme on Improving Public Irrigation Organizations and Operational Management of Water delivery and Disposal, the Watercourse Monitoring and Evaluation (WM&E) Directorate of WAPDA approached IIMI for technical assistance in the adoption of GIS technology for the Fordwah/Eastern Sadiqia (South) Irrigation and Drainage Project. The Project has as its objectives to remove severe water supply constraints in the area by improving delivery efficiency besides lowering of the water

table through surface drainage. The objective of the TA component, spread over 5 years, is to enhance WM&E's monitoring and planning capabilities, and with its operationalizing, a cooperative programme of GIS applications is foreseen in the near future.

2.5 Manaaement Interventions

Deliverv Accountability

Relating to the management intervention of Delivery Accountability, the joint IIMI-ID program of discharge measurements and calibration of submerged structures was completed successfully in Lower Gugera Canal Division of LCC East Canal Circle during April, 1992 as reported already in the last Progress Report. As per decisions taken in Working Group meeting of IIMI-ID, held at Lahore on 23 June 1992, a seminar was arranged at the PID's Faisalabacl Zone headquarters on 30 July 1992. A total of **38,** ID professional (SE, XEN , SDO) and semi professional staff participated in the proceedings of the seminar.

The utility of the data for addressing the operational problems was fully explained to the participants of the seminar. The Executive Engineer Lower Gugera Division was requested to develop an Action Plan according to which the inventory of all control points in the Lower Gugera Canal was to be completed as early as possible and to be followed with the calibration of remaining structures. ID was also requested to assess the needs of structural remodelling.

ID completed inventory of remaining control points in Lower Gugera Division by the end of October 1992 and the same was submitted to IIMI for review in the first week of November 1992.

It was clearly mentioned during the execution of Stage I and Stage II of joint discharge measurements that the ID has to purchase a set of current meters for utilizing the built up capability and to calibrats the system as a whole. As the ID had to face procedural difficulties, IIMI decided to procure a complete current meter for loan to the ID. With the availability of the flow measuring equipment the follow-up on the activity of calibrating all the control points in Lower Gugera Division, was scheduled to be decided in a meeting with the Executive Engineer and his Sub Divisional Officers in early Jan 1993.

As per decision taken by the IIMI-ID working group to extend the program in LCC West Circle, a reconnaissance of the channels along the Jhang Branch of Faisalabad Division, West Circle was carried out on 29 July, 1992. A detailed visit of the control points in Faisalabad Division was carried out for two days, from 5 October to **6** October, 1992. The list of control points for calibration and the selection of participants for training was finalized during this visit. The start of the activity in

Faisalabad Division was fixed for 11 November through 13 November. This was however, not possible because of sudden transfer of the Executive Engineer. The revised program is to be chalked out in consultation with the new Executive Engineer. It is planned that it would be started immediately after the end of annual canal closure of 1993, from the 1st week of February 1993.

Decision Support Packaag

As mentioned in the Seventh Progress Report efforts were under way to select only one model for both Main and Secondary Canals. Accordingly, during the period under report, the use of SIC software was tested for the CRBC Canal and Lagar Distributary. This model like RAJBAH is a simulation model which has been used for many irrigation canals worldwide (CIEMAGREF-1990). The main feature of the model is to represent the canal hydraulics while at the same time possessing an interface that is user friendly. The model can provide answers to practical problems that the canal managers face.

The application of the software consists of three modules: a topographic module; a steady state module and an unsteady module. The application of this model to both CRBC main canal and Lagar distributary indicated that the model would require modifications/ additions for general use to Pakistan Canals such as proper structural representation of offtakes etc.

The operational aspects of Main Canal and optimal benefits of limited maintenance for the distributary were taken up for study using SIC model. Activities under taken during the period
comprised of the following:

1. The SIC model was used for studying the design limitations of the CRBC, a system intended for crop-based operations.

2. The SIC model was applied to Lagar distributary for testing of different operational and maintenance options. The model verification and calibration were completed and thereafter desiltation as a management option was tested. The preliminary results indicated that the impact of desiltation as a management activity can be fully simulated in terms of full desiltation from head to tail or partial desiltation with varied depth of excavation. The resulting improvement in tail supply and reduction in discharges of outlets in headreach can be monitored easily on the basis of which the final maintenance option can be selected.

3. Every year during Kharif season the Irrigation Department allows some temporary outlets along the distributary for reclamation. The present practice is to allow these temporary outlets without any regard to their effect on tail

supply. With the use of the model the flow distribution along distributary could be simulated by adding the proposed temporary outlets providing a rational approach for the authorization of these outlets,

4. The use of the model was taken up for the large Pir Mahal Distributary for simulating the maintenance options.

Also based on the work done on Decision Support, a paper was presented by the Pakistan staff of IIMI-Pak in a Workshop organized in October 1992, by CEMAGREF and IIMI on Modelling Techniques and their field applications, titled: ***"The Utility of Simulation Model for Pakistan Canal Systems: Application Examples from North West Frontier Province and Punjab."*** The paper describes preliminary results of SIC model applications for two different canal systems, a main canal system designed for crop based irrigation (CRBC) and a supply driven distributary system designed to distribute available water equitably. Simulation scenarios for the first system were related to the study of hydraulic evaluation, design limitations and operational problems while for the second system simulation technique was used to prioritize the maintenance requirements.

In the workshop the IIMI-Pak Pakistan team actively participated in group discussion which covered different aspects of the subject; e.g. the data requirements of mathematical models, their field calibration and cost effectiveness. Usefulness of the techniques for manual & auto - control system was discussed. The benefits of such models for research, training arid day to day operation were discussed by model developers; model users addressed the difficulties and problems faced at different stages of model applications.

Based on the work done *so* far it is proposed to hold two workshops at the end of April 1993, for the ID professionals from Punjab and NWFP where in the use of DSP in decision making process would be presented.

Following the agreement with the PID for the association of PID Engineers in the Development of the DSP, two engineers were nominated in Sept 1992 to work with IIMI-Pak for one day per week. These nominees however, could not report for work due to departmental exigencies. Subsequently, following efforts by IIMI-Pak, two other engineers started their association with the model development from October onwards.

Evaluatina Impacts

In IIMI Research area, ID during annual closure of 1992 desilted two main channels namely Lagar and Pir Mahal from head to tail with heavy investment. IIMI Pakistan therefore, decided to underlake a special research activity to determine the impact of this maintenance on the performance of the channel and also to know the

rate of deterioration with time. This would help not only in planning of timely maintenance but also for making effective use of maintenance investments.

The research methodology consisted of monthly measurements of velocity at various points along the length of ihe channel. The tail gauge was also monitored simultaneously. The preliminary analysis of data collected has provided a good insight as to the locations where the actual silt deposition is taking place. It is proposed to extend this activity following the canal closure at the end of the year.

3. REPORTS

During the period under review, the following reports were prepared in the form of in-house discussion papers, Discussion Papers of IIMI-P for local distribution, papers for presentation at the IIMI Internal Program Review and papers for publication by IIMI or other journals.

BANDARAGODA, D. J. AND GARCES-RESTREPO, C. *1992.* Crop-Based Irrigation in Pakistan, Initial Efforts in NWFP. Published in Irrigation Management Network, Overseas Development Institute, UK, Network Paper 18.

BANDARAGODA, D. J. *1992.* The Importance of irrigation policy analysis for sustainability. Published in the Proceedings of an International Conference organized by the Center for Irrigation Engineering of the Katholieke Universiteit Leuven, Sep 1992.

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4. WORKPLAN FOR 1993

In previous sections of the report references have been made to what we aim to accomplish during the last year of the project.

First and foremost is the continuatiori and strengthening of collaboration with system managers of the Irrigation Department in the implementation of management changes. These activities follow directly from the work done in preceding years on 'management interventions', particularly on accountability within the system with respect to the amount of water received and passed on to the next (sub-) division, and on the collaborative development of a decision support package for making management decisions on maintenance and operation of the systems. These activities include among others, the establishment of formal workplans with the SDO's and XEN's in

charge of the systems where these activities take place, in order to gain a degree of commitment from the concerned irrigation staff.

Another element of the same item of the Workplan is an assessment of the data need of system managers. In other words, what is the minimum set of data needed to operate rather than to administer the system. This would include listing of essential control points to be calibrated for distribution of flows in accordance with the objectives as specified by the system manager. The research question we aim to answer through this set of activities is whether it *is* possible to effect a management change that would lead to an alteration of water distribution and allocation within the system.

The second main part of the Workplan for 1993 is to synthesize the results of various studies of salt and water balances carried out at watercourse, farm and field level, The underlying question that needs to be answered to the extent that the available data allow, is: how do current management practices affect the development of secondary salinity, and what are the expected benefits and costs of suggested management changes. There is an obvious link with the work described in section 2.2.2, the collaborative study with the Directorate of Land Reclamation. From the results of this field study it is apparent that improvements in the management of reclamation flows could be attained. Strong data on the impact of current water management practices at farm level on the incidence and development of secondary salinity are expected to help bring about a desire to make changes in the management and allocation of reclamation flows. An economic analysis of expected benefits and costs is an essential component of the study for 1993.

Another element of the same set of activities under this part of the Workplan is a study of the water distribution at watercourse level, the *so* called warabandi. The objective of the study, which will be brought to closure during 1993, is to assess the potential of farmer involvement in the water distribution at watercourse level in order to mitigate the development of soil salinity. In theory, water distribution among farmers on the same watercourse is equitable, in proportion to the land holding, but in reality it is not. Power and influence are often decisive in the allocation of water. The resulting inequitable water distribution is seen as a major cause of secondary salinity in tail reaches of command areas. An important objective of the study, therefore, *is* to assess the effect of restoring equity of distribution through organized farmer behaviour on the development of soil salinity.

The next main area of the Workplan is the implementation of a rapid appraisal of the occurrence of profile salinity and water quality of pumped groundwater in areas where IIMI has not set up detailed field studies. The methodology for the rapid appraisal has been developed based on measuring techniques and data analysis of the detailed studies done in IIMI-P's research areas. It is expected that the results of the rapid appraisal study will help to understand the spatial distribution of the salinity effects. This knowledge is essential in dealing with sector-level management issues. In other

words, sector-level institutions (provincial irrigation department, or federal agencies such as the Ministry of Water and Fower and WAPDA) should react differently to a perceived threat to the sustainability of irrigated agriculture from secondary salinity if it occurs incidentally, or when it is widespread.

An additional study of IIMI-P. is to review the irrigation goals in Pakistan. The purpose of the activity is to document and critically examine the hierarchy of goals which presently govern irrigation operatioris and investment in Pakistan. The activity *is* central to a more comprehensive and systematic assessment of irrigation performance in the country. One of the componerits of the review is to document the goals for the water resources, irrigated agriculture, and irrigation subsectors. This part of the review deals separately with (a) official public goals, such as equity of distribution mentioned above, and (b) the interpretation given these goals by irrigation system managers. These can be regarded respectively as formal and operational goals. The operational goals might contain also some personal goals which do not have official sanction or legitimacy. The study is carried out ointly with staff of the International Food Policy Research Institute (IFPRI), and it is expected that the findings of the review will be presented at a workshop during the second half of 1993.

Another study by IIMI-P., also jointly undertaken with IFPRI, which has relevance for the salinity project, is a study of water markets. Preliminary work was done during 1992, and it is hoped that more extensive field work can be undertaken during 1993. It has been observed that informal water markets exist in Pakistan, mainly with respect to pumped groundwater, but some instances of a water market of canal water have also been recorded. While there is considerable interest from the Government of Pakistan and from donors in greater private sector involvement to stimulate agricultural production, not much is known about how water markets work, nor how they affect the quality of irrigation services, agricultural production, and environmental sustainability. Obviously, informal markets of pumped groundwater could compensate for inequity in water distribution and allocation of canal water, but not without a cost in terms of the quality of irrigation water.

5. FINANCIAL REPORTING

IIMI-PAKISTAN

MANAGING IRRIGATION SYSTEMS TO MINIMIZE WATERLOGGING AND SALINITY PROBLEMS

EXPENDITURE STATEMENT

AS AT DECEMBER 31, 1992

	BUDGET $	ACTUAL EXPENSES 1989 $	ACTUAL EXPENSES 1990 $	ACTUAL EXPENSES 1991 $	ACTUAL EXPENSES 1992 $	TOTAL $
SALARIES	1,529,000	135,464	300,005	398,072	374,135	1,207,676
TRAVEL	90,000	14,392	23,388	23,616	23,036	84,432
S&SERVICES	356,000	44,615	73,947	85,698	91,521	295,781
EQUIPMENT	155,000	21,381	12,707	20,262	43,097	97,447
LEASEHOLD	20,000					
CONTINGENCIES	77,000					
	2,227,000	215,852	410,047	527,648	531,789	1,685,336

CONJUNCTIVE USE OF CANAL AND GROUNDWATER IN PUNJAB, PAKISTAN: MANAGEMENT AND POLICY OPTIONS

D. Hammond Murray-Rust and Edward J. Vander Velde

ABSTRACT

This paper presents a retrospective analysis of existing data on conjunctive use of surface and groundwater use in four distributary canals in Pakistan. The primary findings are summarized as follows.

Groundwater accounts for between 70-90% of all irrigation water in the three peak months of the hot season, declining to less than 50% of total water use in the cooler winter season. Farmers with access to a higher percentage share of surface water also pump more groundwater than iarmers who have less surface water. Although the percentage use of groundwater increases from head to tail of each canal, there is a net decline in both surface water use (2.0 mm to 0.5 mm/day from head to tail) and total water use along canals (6.0mm/day to 3 mm/day). There is therefore no evidence of farmers substituting groundwater for declining surface water supplies: groundwater is used as an additive to surface water rather than a substitute source of water.

Cropping patterns show a consistert trend along each canal that reflects access to surface water. In the summer (kharif) season both cropping intensity (80% to 60%) and percent devoted to rice (50% to 33%) decline from head to tail, while cropping intensities of other crops remain more or less uniform. In the winter (rabi) season cropping intensities remain high (85-90%). Access to good quality surface water favors cultivation of higher value cash crops; as access to surface water declines, the area under wheat increases from 60% to over 80% of the cropped area). These patterns indicate that any effort to change water allocations between surface and groundwater either between head and tail of a single canal or between canals will result in significant changes in cropping pattern.

Once the basic cropping decisions have been made farmers use water very efficiently. Relative water supply remains at or close to 1.0 irrespective of location. This strongly suggests that farmers are avoiding pumping excess water, no doubt to minimize pumping costs. However, the trencl masks two important aspects. Firstly, relative water supply decreases as the percentage of rice decreases: farmers are apparently willing to forego maximum yield from other crops in order to maximize rice yields and hope that deficits in water supply to other crops will be made up by rainfall.

Secondly, there is no evidence that farmers are aware of leaching requirements. As a result there is a strong association between the percentage of increasingly poor quality groundwater used and levels of secondary soil salinity. The results suggests the process of soil salinization will continue unabated even in areas of better quality groundwater.

Solutions to the alleviation of continued salinization are hard to identify. One option is to redistribute canal water along a distributary to ensure more equitable distribution of good quality water. However, while it may arrest the rate of salinization in tail end areas it will not eliminate it. Calculations indicate that it requires an increase of at least 50% in surface water supplies and a reduction of pumping of 20% to provide the correct balance of poorer and better quality groundwater. Redistribution along canals cannot accomplish this.

A second alternative is to change water allocations between commands, primarily from areas with good groundwater to those with poor quality groundwater. It appears this policy would be catastrophic because it would increase salinization in the good quality areas without fundamentally improving conditions in other areas.

The third option is to rationalize the current trend of abandonment of tail end areas of distributaries and within watercourse commands. This negative trend is unlikely to be avoided given the intensity of use of poorer quality groundwater and the finite supplies of surface water.

National capacity to investigate conjunctive use of groundwater and surface supplies is extremely weak. Government agencies charged with monitoring of surface supplies, public tubewell supplies and agricultural data are completely uncoordinated. There is no organization collecting information on private tubewell use even though this now accounts for more than 50% of all water used for irrigation.

The organization of government agencies to properly manage conjunctive use is also a major constraint to alleviation of the problems identified. Both within and between agencies there are no common boundaries between divisions responsible for management of surface water, public tubewells, electricity supply, drainage, on-farm works, extension or agricultural reporting; data are not shared and plans made in isolation.

The results presented in this paper are from a small sample of watercourses (40 out of 89,000). More research is critically required to verify the validity of the results and conclusions before workable recomniendations for policy makers and senior agency officials can be generated.

IMPACTS OF PHYSICAL AND MANAGERIAL INTERVENTIONS ON CANAL PERFORMANCE IN PAKISTAN: A REVIEW OF FIVE YEARS OF FIELD RESEARCH STUDIES.

Edward J. Vander Velde and D. Hammond Murray-Rust

ABSTRACT

This paper reports on performance changes in several secondary canals in Pakistan as a consequence of different types of intervention. The three interventions (lining, desilting and operational management) represent the most likely alternatives for irrigation agencies in Pakistan to restore and sustain water delivery performance targets.

The results are all based on long term comparisons of conditions before and after intervention centered around a carefully controlled field program.

Canal lining, at least in the form undertaken in two canals included in the study, proved to be the least effective type of intervention. Despite an initial investment of over $1.1 million (almost $30 per hectare) the water conditions in the tail actually declined from the pre-lined condition, and the tail of the canal was eventually abandoned. There were significant declines in water availability and large increases in variability of discharge at the tail. Reasons for this failure include poor construction and financial management, and significant interference in the dimensions of upper and middle reach outlet structures that deprived the tail of its fair share of water.

Desilting of canals proved significantly cheaper but resulted in significant performance improvements, A program of selective desilting based on the results of computer simulation of hydraulic changes following desilting gave the best performance increase and at the lowest cost ($0.52 per hectare). The ratio of head-tail inequity dropped from 4.20 to 1.29.

A more traditional approach to desilting, whereby almost the entire canal was desilted, yielded similar results: the inequity ratio of head-tail conditions fell from 6.11 to 2.59. The investment was more expensive ($2.20 per hectare) but the recurrence interval of this type of desilting is likely to be much longer than for the cheaper selective maintenance. There is a lack of daia on rates of sedimentation that would give an optimal economic solution.

Despite the improvements in performance following desilting canals remain highly sensitive to operational management. Before intervention both canals cold not handle the full design discharge, with the result that head-tail differences were exacerbated. The increased capacity as a result of desilting allows canals to be operated at or even above the initial design discharge, with favorable tail end conditions as a consequence. However, the result:; show that even in the desilted condition the canals show unfavorable head-tail differences when operated at less than 50% of design discharge. This indicates that physical intervention is not a substitute for effective operational management.

The results also indicate that there are marked seasonal variations in performance. Water conditions at the tail of the canal, the traditional measure of hydraulic performance, show that during the early part of the year in the transition from winter to summer crops, canals perform relatively well. Using regression analyses of actual tail end water conditions it is possible to predict what tail end conditions should be throughoutthe year. In reality, large deviations occur and tail portions of some canals dry up completely for several months at a time.

The main reason for the temporary drying up of tail end areas is illegal water extraction by head and middle reach farmers. In some cases these are water thefts caused by deliberate cuts in canal banks, siphons, and illegal pipe outlets. In others it is the sanctioning of outlets by irrigation agency staff for seasonal use only, even though this is not permitted if it is at the expense of tail end farmers.

The need to maintain equity is important in Pakistan because access to good quality surface water appears to dictate the cropping choices of farmers even though they may use more groundwater than surface water for irrigation purposes. Deprivation of good quality surface water leads lo faster rates of secondary soil salinization.

There is an urgent need for effective management of the Pakistan canal system. Current levels of performance are sufficiently poor as to jeopardize the sustainability of large areas of the irrigated area, and maintenance has deteriorated to a point where the capacity to deliver any water at all to some areas has disappeared.

Annex - III

IRRIGATION MANAGEMENT IN THE FORDWAH BRANCH COMMAND AREA SOUTH EAST PUNJAB, PAKISTAN[1]

Marcel Kuper and Jacob W. Kijne

ABSTRACT

Irrigation performance was studied at main canal, distributary and watercourse levels in the service area of the Fordwah Branch canal. The study was carried out in a part of Pakistan Punjab that is enclosed by the Sutlej river, Indian border and Cholistari desert, and is known to be severely affected by salinity and high water tables. IIMI was requested by the Government of the Punjab to study possible improvements in irrigation management to prevent further land degradation and to mitigate the effects of salinity on crop production. IIMI in Pakistan has taken on the study as part of its Waterlogging and Salinity Project.

The paper reports the research findings with respect to canal operation of the Fordwah Branch canal (design discharge 33 m^3/s where it enters the research area). Performance indicators have been used to quantify canal operations under present conditions, in terms of adequacy and dependability of supply and equity in distribution. It is evident from this study that the performance of the canal system in the research area is impeded by the irregular inflow. However, current operational practices have a negative impact on the performance of the system with all performance indicators generating a "poor" rating. The quality and appropriateness of routine information transmitted from field to system managers, is evaluated against the needs for a good canal performance.

The mutual dependence of main canal performance and distributary flow is illustrated. Head/tail differences within distributary commands, and the effects of variability of flow in the main canal on the water supply at secondary and tertiary levels is discussed. Farmers react to perceived deficiencies in canal water supply by utilizing groundwater resources, through a series of privately owned tubewells and by participating in a highly active water trading, with canal turns and tubewell water being transacted.

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[1] Paper prepared for the Internal Programme Review, December 1992. International Irrigation Management Institute, Colombo, Sri Lanka.

A number of (tentative) suggestions for the improvement of the management of the system are proposed. Trial implementation of these management innovations is foreseen through collaboration between Punjab Irrigation Department and IIMI. Constraints are discussed of both physical and institutional nature, which may prevent an easy introduction of the suggested changes.