Pre-rehabilitation Diagnostic Study of Sehra Irrigation System, Sind, Pakistan

Water Management Synthesis Project

WMS Report 53

PRE-REHABILITATION DIAGNOSTIC STUDY OF SEHRA IRRIGATION SYSTEM, SIND, PAKISTAN

INTERDISCIPLINARY REPORT

Prepared by

M.I. Haider, T.S. Sheng, R.L. Tinsley,
R.A. Mohammed, J.W. Warner, W. Clyma, and O.B. Nayman

WMS Report 53

Prepared in cooperation with the United States Agency for International Development, Contract DAN-4127-C-00-2086-00.

WATER MANAGEMENT SYNTHESIS II PROJECT
University Services Center
Colorado State University
Fort Collins, Colorado

in cooperation with the
Consortium for International Development

May 1987

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table | Page

APPENDIX B

ACKNOWLEDGMENTS

We, the authors of this report, are grateful to Mr. John Foster, Project Office, USAID/Islamabad, and Mr. Navid Nasri, Joint Secretary, Ministry of Water and Power, for making this pre-rehabilitation diagnostic study possible. We wish to thank the interdisciplinary staff of the Subproject Management Office of the Command Water Management Project in Sind for their involvement in the pre-rehabilitation diagnostic analysis. Finally, the efforts of Mr. Aziz-Ullah Tunio, Mr. Allah Newaz Ansari, and Mr. Jamali from CWM Project, Sind, in planning, organizing, and seeing the study through its various stages is much appreciated.

I. INTRODUCTION

The feasibility report for the CWM project places crop yield in Pakistan considerably below most other countries with similar agricultural resources.[1] The low yields were attributed to a broad spectrum of constraints which included inefficiencies and inequities in water distribution, a poor extension program, low application of agrochemicals, and difficulties in the marketing system. In light of this, the CWM Project was conceived to employ an integrated approach to defining constraints and potential improvements in delivering and applying irrigation water and other inputs and services.

To develop and implement an effective rehabilitation program, it is essential that a pre-rehabilitation diagnostic study of the irrigation system be made. The interdisciplinary and field-oriented approach of the diagnostic analysis (DA)[2,3] allows identification of important constraints that affect the performance of the irrigation system and the underlying causes. With up-to-date and site-specific knowledge of the irrigation system, appropriate improvement plans and a management plan can be formulated.

---

[1]WAPDA, 1983. Feasibility report -- Command Water Management -- Sind. Pakistan Water and Power Development Authority. Project Planning Organization, Southern Zone, Hyderabad, Pakistan. Forward.

[2]Podmore, C.A. (ed.) 1983. Diagnostic Analysis of Irrigation Systems, Volume 1: Concepts and Methodology. Colorado State University, Fort Collins, CO. 188 p.

[3]Podmore, C.A. and D.G. Eynon (ed.) Diagnostic Analysis of Irrigation Systems, Volume 2: Evaluation Techniques. Colorado State University, Fort Collins, CO. 349 p.

II. STUDY AREA

The Sehra Irrigation System in Sind was one of four subprojects in the four provinces that were selected for the first round of DA studies. The Sehra Irrigation System lies on the left bank of River Indus in the district of Nawabshah (Figure 1). The Sehra command are encompasses 93,843 acres, of which 93,474 acres are cultivable. The Sehra branch canal receives perennial irrigation supplies from the Rohri Canal. The irrigation supply is continuous except for 2 to 3 weeks during late December and early January when the system is cleaned and maintained. The 150 Salinity Control and Reclamation Project (SCARP) tubewells were installed by 1977 at the head of the watercourses downstream from the moghas to lower the watertable, control salinity, and supplement the canal water with 750 to 900 ac-ft/watercourse.

The Sehra Irrigation System was completed in 1932. The water distribution network consists of one branch canal, one distributary, 12 minors, and 261 watercourses. The Sehra branch canal is 63,100 ft long, and the initial design discharge for the branch canal was 330 cfs. The designed water duty for the cultivable command area was 200 ac/cfs in rabi and 100 ac/cfs in kharif. In the original plan, 27% of the total cultivable acres was estimated to be cropped in kharif and 54% ini rabi.

The discharge in the Rohri Canal has gradually increased since 1932. The designed discharge of 10,887 cfs was reached in 1952, and a peak level of 16,000 cfs was attained in 1975. The discharge rate into the Sehra branch canal has also increased over time. The discharge rate into the Sehra branch was measured during the DA study to be 556 cfs, which is 69% higher than the original level. To accommodate the added discharge and counter the siltation problem, 2 ft of freeboard were added to the branch canal in 1975. In response to additional canal water and the addition of the SCARP tubewells by 1977, the average cropping intensity had increased to about 118% in 1983.[4] The designed cropping intensity is 81%.

The climate in the project area is semi-arid and hot.[5] May and June are the hottest months, with a mean, monthly, maximum temperature of 100°F. The temperature drops to 70°F in December and January. The mean annual rainfall is 5 inches and mainly occurs in July and August. Annual temperature variation divides the year into two distinct cropping seasons, kharif and rabi.

Wheat is the dominant rabi crop, followed by berseem. A small amount of oilseed is also produced in rabi. Cotton, rice, and jawar

---

[4]WAPDA, 1983. pp. 2.37-2.40.

[5]WAPDA, 1983. p. 2.4.

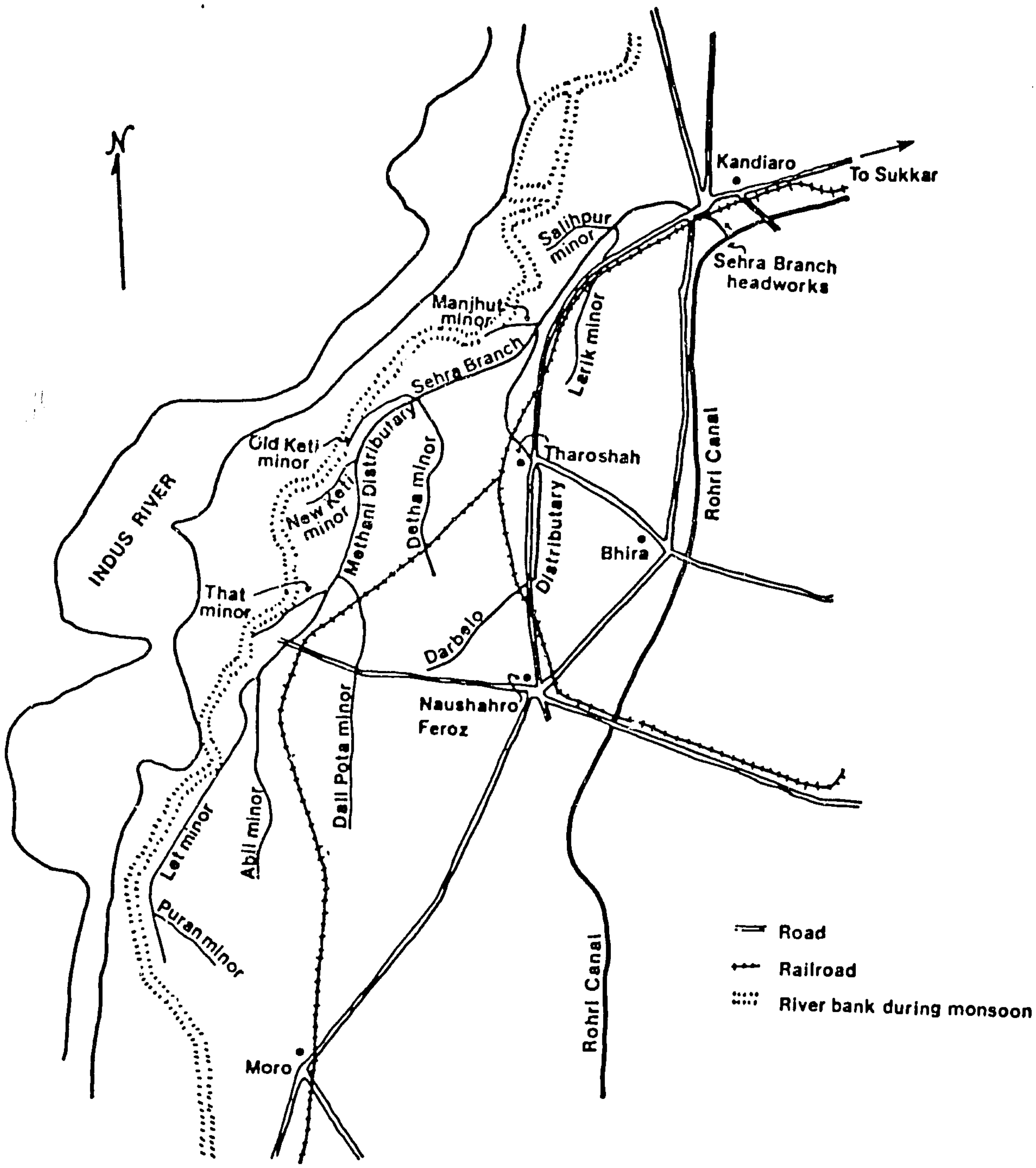


Figure 1. Sehra Irrigation System During the 1985 Pre-Rehabilitation Diagnostic Study in Sind, Pakistan.

are produced in <u>kharif</u>. Sugarcane, which is a perennial crop, is increasing in importance and is primarily produced in the areas near sugarmills. Rice production is permitted only as a reclamation crop (for which additional water is provided).

For the two minors studied (Larik and Let), 66% to 77% of the sample farms were owner-operated. The remaining farms were rented for cash or crop-share. Sixty-six percent of the farmers had landholdings under 10 acres, 20% of the farmers owned 11 to 20 acres, and 14% of the farmers surveyed owned and operated more than 20 acres. The overall average landholding was 10 acres. More than half of the farmers are illiterate. Farming was the major source of income for 92% of the population in Sehra command area.

III. METHODOLOGY

A pre-rehabilitation DA study of the Sehra Irrigation System was conducted by Sind Command Water Management with the assistance of the Water Management Synthesis II Project. An interdisciplinary team consisting of representatives in irrigation engineering, agricultural engineering, groundwater engineering, agronomy, economics, and sociology conducted the DA. The DA field study was carried out over four weeks (November 1-27) and was followed by 10 days of data analysis and report writing.

The field study consisted of two phases. In the first phase, a reconnaissance was conducted to get an overview of the system. The reconnaissance information was used to focus and plan the detailed study. In the second phase, detailed field studies were conducted by all disciplines involved to gain an understanding of the Sehra Irrigation System and identify constraints that have prevented the system from achieving its potential productivity. Two minors, Larik and Let, were selected for detailed study. Larik minor is near the head and Let minor is the tail of the Sehra branch canal. Three watercourses on each of these two minors -- one at the head, one in the middle, and one toward the tail -- were identified for further detailed study. Observations and inflow measurements of the branch canal and selected minors and watercourses were made daily to learn about the condition and performance of the canal system. Information on the operation of canals and minors, the tubewells, and the warabundi system was obtained from the local Irrigation Department, tubewell operators, and farmers.

On each watercourse a number of studies were conducted. These included measuring conveyance losses, full supply level of the watercourses, field levelness, soil salinity, and cultivation practices. Information on seed varieties were obtained and seed germination tests were made. A sample of farmers at the head and at the tail of each watercourse was interviewed by the economists and sociologists. The economic questionnaire gathered information on cropping pattern and intensity, use of agrochemicals, cultivation practices, and crop output and disposition. The sociology questionnaire for the farmers and key informants focused on the farmers' perception of equity in water distribution and appropriate cultural practices, information seeking by farmers, and problems faced by farmers in their efforts to increase crop production.

Information on groundwater level, groundwater quality, and tubewell operation and performance was obtained from WAPDA and the Irrigation Department. As part of the DA, actual measurements of groundwater depth and quality were made and pump efficiency tests were done. Data on tubewell operation was gathered from the tubewell operators.

Results and discussion of the field data and secondary information gathered during the DA were used to identify the important constraints that have prevented the Sehra command area from achieving a higher level of productivity and income, and hence, where the potential for improvements lies. The impact of irrigation water and other factors affecting productivity was examined. The inequity in water distribution in the Sehra Irrigation System and the factors contributing to it were also explored.

IV. FINDINGS AND CONCLUSIONS

A. ADEQUACY OF IRRIGATION WATER

A review and evaluation of the original irrigation system design indicates that the Sehra system was designed to distribute a limited supply of irrigation water equitably among farmers throughout the system. The system was not intended to provide an adequate amount of water for the total cultivable command area to achieve 200% cropping intensity. The original discharge of 330 cfs to the Sehra branch canal was designed to allow the cultivation of 27% and 54% of the cultivable area in _kharif_ and _rabi_, respectively.

Over time, the amount of irrigation water in the Sehra system has increased through increased canal water from the Rohri canal and from groundwater development. The current supply of canal water is 380,000 ac-ft/year. The tubewells have added about 124,000 ac-ft/year (750 to 900 ac-ft/watercourse). The net result has been an increase in the area under cultivation. The cropping intensity for the six watercourses studied during the DA was 122% for the 1984/85 crop year (Tables B-1 and B-2).

Based on calculations of crop water requirements for the existing cropping pattern and intensity (Figure A-1) and water supplies effectively meeting those requirements at the field level (Figure A-2), the water shortage periods for 1985 were January during the canal closure and mid-June to mid-September during the peak water requirement periods (Figure A-3). With the 40% irrigation efficiency for the existing system, only 65% (on the average) of the peak requirements could be met if the water supplies effectively used at the field level were distributed equitably (Figure A-4). The water supplies at the source (head of the canal and at the tubewell) compared to the crop water requirements also are shown in Figure A-4. The supplies at the source exceed the crop water requirements for all periods except in January during the canal closure period. Improved management could improve the efficiency of water delivery to more nearly provide the water supplies needed at the farm to satisfy the crop water requirements. In addition, farmers in all six watercourses that were studied reported considerable loss in crop yields in 1983/84 due to water shortages. Therefore, water shortage during the peak periods can be clearly established as one constraint to increasing crop yields at Sehra system.

Water inadequacy can be attributed to three factors in the Sehra system. Due to the deteriorated condition of the canal and minors, even if more water was provided from Rohri, the canal system would not have the capacity to convey it. The Sehra canal has a low freeboard. The 2 ft of freeboard added in 1975 to accommodate increased flow has diminished due to siltation and the erosion of the canal banks.

Restrictions imposed on the operation time of the tubewells and a decline in the pump discharge rate also contributes to inadequacy. The north Rohri SCARP tubewells were installed to control waterlogging and salinity and, incidently, to provide fresh groundwater for irrigation. The official operating policy for the government tubewells is that they are to operate 8 hours/day. This schedule is shifted by 8 hours once a week so that each farmer receives an equal share of tubewell water over each three-week period under the warabundi rotation. The official policy is rigid and not coordinated with peak crop requirements. However, in practice, the tubewells are operated less rigidly. The guiding criteria appears to be that of maintaining a one-third total operation time over the year. The peak pumping periods are January to February during canal closure and May to September during the time of high evapotranspiration (Figure A-5).

Although the unofficial adjustments in tubewell operation have begun to make more water available during peak demand periods, the one-third total limitation time still remains in effect. Serious questions regarding the differences in influence that different farmers have on tubewell operators and, hence, the equity and reliability of tubewell water can be raised.

Depth to groundwater over most of the Sehra subproject varies from 8 to 12 ft below land surface. Measurements made during the DA indicated no significant change in groundwater level since the tubewells were installed. In a few areas, groundwater level has even risen. Mining fresh groundwater is not taking place, which indicates the potential for increased pumping and further groundwater development. However, the high cost of electricity was noted by irrigation officials as a reason for not increasing tubewell operation time.

The government tubewells have a design discharge of 2 to 5 cfs. The larger tubewells typically supply water to more than one watercourse. The measured well efficiencies are typically 30 to 60%. A gradual deterioration of tubewells has occurred with time, and the pumping capacity of many tubewells has declined by 10 to 20%. This decline is probably due to wear and tear on the motors and pumps. The specific capacity of the tubewells has similarly declined by about 10 to 30%, which may be related to encrustation and corrosion of the well screens.

The final factor contributing to inadequacy of irrigation water is low irrigation efficiency. The conveyance losses in the branch canal and minors are measured to be 10 and 15%, respectively. The conveyance losses in the watercourses were excessive and varied between 14% (6L, Larik minor) to 56% (4L, Larik minor) when tubewells were operating, and between 6% (1AL, Larik minor) to 42% (4L, Larik minor) when only canal water was flowing in the watercourses. With a field application efficiency of 74%, as indicated in Sind's Feasibility report,[6] the overall irrigation efficiency could be as low as 25% when the tubewell is operating, with the average for the existing system being about 40%.

---

[6]WAPDA, 1983. p. 5.2.

To meet the crop water requirements with the current supplies at the source during the peak period in *kharif*, the irrigation efficiency needs to be between 40% and 80%; with the average being around 60% (Figure A-4).

Level basin irrigation can be very efficient and effective if certain conditions are satisfied. One of the most important conditions is that the basins be level. The detailed field topographic survey revealed that most of the fields did not conform to the engineering standard of ± 2 cm of precision land leveling. Using available tools, the farmers have managed to level most of their fields to within 4 to 8 cm.

Cotton, which is the dominant *kharif* crop, is cultivated in flat basins, as opposed to on ridges and irrigated through furrows, which is the generally recommended method. Poorly leveled fields, lack of farm channels, and inappropriate land preparation can lead to inefficient water use during irrigation. Lack of equipment for better land leveling and preparing furrows and the high cost of land preparation were noted as the reasons for growing cotton in basins by farmers, who were aware of the problem. It was also learned that many farmers were unfamiliar with the practice of preparing ridges and furrows for cotton.

B. EQUITY AND RELIABILITY IN WATER DISTRIBUTION

If the Sehra system was initially planned to distribute water equitably in the command area, that has not happened. The overall increased discharge in Sehra is not proportionately distributed among the minors and watercourses studied.

The original designed water duties were 200 ac/cfs in *rabi* and 100 ac/cfs in *kharif*. A revised water duty for the system was set by the Irrigation Department at 286 ac/cfs. The official water duties of the minors studied, however, varied from 215 ac/cfs (Abji minor) to 318 ac/cfs (Let minor) as calculated using the design cultivable command areas and the design flow rates. Therefore, according to the official design, certain command areas are to receive more water per acre than other command areas.

Flow measurements made on the minors and watercourses during the DA indicated that flow rates varied substantially from design levels. The minor flows varied, on average, from 33% higher (Salihpur minor) to 72% higher (Abji mincr) than design, the mean being about 55% higher than design (Figure A-6). Therefore, the actual water duties for the minors, as calculated using the design cultivable command areas and the measured flow rates, were less than the official levels. For the watercourses, the flow rates varied, on average, from 6.4% lower (1AL, Larik minor) to 234% higher (1AL, Let minor) than design (Figure A-7). Therefore, the actual water duties for the watercourses also varied considerably from the official water duties. These findings not only indicate that the system is not operating as designed, with most outlets receiving more water than intended, but also that there is inequity in the proportional distribution of water between outlets.

Inequity in water distribution among minors and watercourses can be attributed to structural deficiencies, system operation, and the authorized and unauthorized adjustments made in the mogha sizes. Sedimentation has raised the bed level, reduced the available freeboard, and changed the longitudinal profile of the minors. Sedimentation and poorly functioning or non-existant gates on the minors have reduced the ability to control water in the system. Low freeboard and higher flow rates have restricted the use of the cross-regulators along the branch canal. The cross-regulator gates are forced to stay open above the water level, and the existing structures have limited capability to control the canal flow to achieve equitable water distribution.

There are no flow measurement devices or structures on the system; therefore it is not possible to distribute water in the system based on flow rate. According to the operating procedure, the Subdivisional Office (SDO) staff instruct the gatekeepers to make adjustments in the gate opening to maintain a fixed depth of water at the mogha of the tail watercourse on each minor. Minor gates and cross-regulators usually have staff gauges installed downstream of the structure to help monitor water levels. The result of this operating procedure is the supply of water in which the more water used, the more is supplied to the minors over time.

The moghas used in the Sehra system are open flumes. The roof blocks have been removed or adjusted by the farmers and so variation in flow rate cannot be proportionately distributed over the minor reach. When minor flow rate increases, the watercourses near the head of the system receive more of the water.

In addition, siltation has raised the bed of the upper reaches of the minors, resulting in increased hydraulic head and increased flow at head moghas. At the same time, farmers' efforts to remove silt along the tail sections of the minors have led to lowering of the bed below the design level, resulting in a lowered full supply level and reduced flow at tail moghas. It was reported by the key informants that during periods of peak water requirement, some farmers have installed temporary weirs in the minor to divert more water to their watercourse. This unauthorized practice increases the discharge through upstream moghas and reduces the flow through downstream moghas.

For the watercourses studied during the DA, five of six moghas were operating under free-flow conditions when the tubewells were off. However, in three of the six moghas studied, the moghas were submerged during tubewell operation. Mogha submergence is caused by water backing up from the operating tubewell, which reduces the head of the mogha beyond the required minimum for free flow. The DA team members also observed that other moghas on the watercourses were submerged. Submergence results in reduced flow from minors to watercourses and an inability to distribute water proportionally through moghas. At the tail of the Dali Pota minor, a reverse flow from the watercourse into the minor was observed during tubewell operation. At the watercourse closest to the tail of this minor, the flow from the minor into the watercourse was completely stopped during tubewell operation.

As indicated, the current water duties for watercourses varied considerably from the design. Garden crops and rice receive special water allocations. Part of the difference in water duties between watercourses is because of these special allocations. The area in garden crops and rice is designed to not exceed 15% of the cultivable command area on a watercourse. Increased allocations to the water-course for garden crops and rice production benefit only a small group of farmers. The exact considerations used in altering the supply rate and water duty due to these special crops are unclear. As a result, moghas are often modified by farmers and SDO officials in an ad hoc manner.

Water distribution among farmers within a watercourse in terms of volume of water per unit of land is also inequitable because of high conveyance losses. Currently, the warabundi rotation does not incorporate conveyance losses when calculating the roster time of farmers along the watercourse in order to ensure a reasonably equitable distribution of water.

The difference in the amount of water received by different minors and watercourses results in differences in cropping intensities, cropping patterns, and crop yields. The cropping intensities for Larik and Let minors were 120% and 117%, respectively. A third minor, Dali Pota, was evaluated during a short-term reconnaissance. The Dali Pota minor had serious water shortage and structural problems. The cropping intensity for this minor was considerably lower than the other two minors studied (93% at the head end and about 25% at the tail). Rice, noted by farmers as a highly profitable crop requiring more irrigation water compared to cotton and other kharif crops, was more prevalent in Larik than in Let minor.

The impact of high conveyance losses on equity of water distribution along the watercourses is evidenced by differences in the cropping intensity and crop yield from head to tail in the watercourses. Cropping intensity for the farms at the tail generally ranged from 50% to 80% of that for the farms at the head of the watercourses (Tables B-3, B-4, and B-5). The yield information gathered from the farmers by the survey questionnaire showed the wheat yield to be generally higher for farms at the head of the watercourse compared to farms at the tail.

Problems with water adequacy and equity are compounded by unpredictable water deliveries. The diagnostic analysis measurements over the two weeks indicated that there are great variations in daily flow rates at the minors and watercourses. The flow rates measured varied from 9% to 25% over Larik's design rates and 102% to 122% over Let's design rate. Watercourse flow rates along the minors varied from the design levels by -49% to 134% for 1AL, 4L, and 6L of Larik minor and 75% to 314% for 1AL, 7AR, and 11L of Let minor. Reliability at nakkas is further reduced by irregular tubewell operation on each watercourse. Irregular tubewell operation leads to variations in the flow through the moghas and in conveyance losses. Therefore, a farmer faced with such unreliable, inequitable, and inadequate water supplies would be hard-pressed to plan his irrigated farming operations from season to season.

C. RESOURCE CONSERVATION

In addition to examining poor water control and its impact on productivity, the impact of irrigation and farming practices on long-term production capability of the irrigation system was examined in the DA study. Currently, only a small part of the area studied is affected by salinity. Soil salinity appears to increase towards the tail of the individual watercourses, toward the tail watercourses on a minor, and along the tail minors. There is high variation in soil salinity over short distances. The soil conductivity can change from less than 1 mmohs (a favorable EC) to greater than 10 mmohs (a detrimental EC) within 20 to 30 m (Table B-6).

Lack of soil conservation to preserve the soil quality is one contributing factor for this emerging salinity problem (Table B-7). Also, the low hydraulic head at the field level has accentuated the salinity problem. Farmers said that salinity had become a problem over the last five years and had resulted in decreased yield for their farms. Farmers have been unable to reclaim saline land.

Soil pH tests made during the DA indicated that the soils were within the neutral range, between 6.5 and 7.8. This is a favorable soil reaction and indicates no problem with the availability of inherent soil nutrients.

The groundwater aquifer in this area is composed mostly of well-sorted, highly permeable, fine to medium sands interbedded with lenses of silt and silty clay. These deposits are in excess of 1,000 ft thick. However, the fresh groundwater lens is from 300 to 700 ft thick and is underlain by saline groundwater. Review of the data since public tubewells began operating in 1975 shows no significant change in the ground watertable level. Mining of fresh groundwater is currently not taking place.

The reported electrical conductivity of most of the groundwater is in the range of 700 to 1,100 mmhos and is very good for irrigation. Measurements made as part of the DA study indicated no significant change in groundwater quality has taken place since the government tubewells were installed. The fresh groundwater lens is thinnest near the town of Moro. In this area, the salinity of one tubewell has doubled due to upwelling saline groundwater.

D. CROP MANAGEMENT

The recommended seeding rate for wheat is 45 to 50 kg/ac. About 50% of the sampled farmers had used the recommended or more than the recommended rate. Use of excessive seed by some farmers is probably to compensate for the higher inert matter in the uncleaned seed. For wheat, 91% of the farmers used more than 80% of the recommended seed rate. For cotton, the seeding rate was rather low, with 32% of the farmers applying less than 70% of the recommended rate (Table B-8 and B-9). The farm management survey also indicated that for a long time farmers have been using their own wheat seed without rejuvenation. To assess the potential adverse impact of seed quality and seeding rate on yield, seed germination tests and plant population counts were carried out.

Germination tests were done on seed collected from the farmers, Sind Agricultural Supply Organization (SASO), and private dealers. In the tests on the farmers' seed, only 4 of 10 samples had an excess of 10% inert matter. The germination test showed that (except for one sample in which weevil damage had not been completely removed) all germination was in excess of 90%. The commercial seed all had less than 10% inert matter and 90% germination (Table B-10). Note that yield potential drops due to deterioration in genetic purity over time when seed is not rejuvenated. For rice, the deterioration in yield is about 3% and for wheat it is 1% to 2% each time the seed is reused.

The plant population tests on rice and cotton indicated that the intended plant populations were close to the recommended rate. However, when the bald areas caused by salinity, flooding and other adverse conditions are considered, the actual plant population falls short of the recommended level and, hence, lowers yield.

Most farmers surveyed were using fertilizers. This included both basal application of the nitrogen-phosphorus mixture and top dressing with urea. Farmers used less insecticide or other pesticides.

For wheat and sugarcane, the application of nitrogen and phosphorus on the average was close to the recommended rate. For cotton, 77% of the recommended nitrogen and 96% of the recommended phosphorus was applied by the farmers. Only 30% of the farmers had used pesticides on cotton in <u>kharif</u> during 1985. Inadequate knowledge about pest problems and uncertainty of the benefits of using pesticides when crop damage is already manifest, may be the reason many farmers did not use pesticides.

Availability of agronomic inputs, their relatively high costs, lack of credit or other funds, the overall profitability of crops, and farmers' knowledge limits the use of essential farm inputs. In the following sections these factors will be briefly explored.

E. MARKETING AND CREDIT SYSTEM

A visit to local fertilizer dealers in the area revealed that fertilizers and pesticides are readily available. The government is heavily involved in importing and distributing fertilizer to the retailers. The role of the private sector in distributing and marketing fertilizers has grown rapidly over the past few years. Currently, only 15% of the fertilizers are sold by the government provincial distribution agencies to the farmers. The rest are sold by private dealers.

Fertilizer prices are controlled by the Government of Pakistan at several levels. The retail and supplier prices are fixed. Imports are subsidized by about 50%, and subsidies are also provided for local producers. Fertilizer prices are subsidized by the government to encourage greater use by the farmers.

Private traders also perform an indispensible function in purchasing outputs from the farmers. Private traders sell cotton to the local cotton gins and wheat to the government. Sugarcane is sold directly by the farmers to the sugarmills. The purchase price of these crops are also influenced by the government. The prices set by the government for major crops were found to be slightly below the international market prices. Whether or not the private traders are making an excessive profit for the intermediary function they are providing needs to be studied.

Shortage of funds to purchase inputs was noted frequently by most farmers as a constraint. Thirty-eight percent of the farmers had borrowed during the last two cropping seasons. Of those that had borrowed, only 10% had borrowed from institutional sources. The other 90% of the farmers borrowed from private traders who extended loans in the form of seed, fertilizer, and other agrochemicals. For fertilizers, the private traders charge Rs. 25 to Rs. 30 per bag as interest for six months. This is equivalent to an annual interest rate of 40 to 45%. The interest rate charged by the Agricultural Development Credit Bank for short-term cultivation loans is 12%.

The Agricultural Development Bank can provide loans for purchase of tractors and other farm machinery for up to 8.5 years, and for commercial livestock operation up to 10 years. The loans are issued in the form of supply orders to dealers. In the case of farm machinery and tubewell loans, the dealers provide specifications and the cost to the bank, on which basis the loan is processed. For all loans issued by ADB, the farmer has to present his passbook. The passbook, which is the verification document of the farmer's landholdings and credibility, is issued by the Revenue Department. The farmer's land is noted as collateral for the bank loan in the passbook.

The third source of credit in this area is crop processing industries. They provide fertilizers and other agrochemicals to the farmers registered with them at the beginning of the season and deduct the cost from the value of the crop procured after the harvest. Only one farmer in the study sample had acquired such a loan from the sugarmill. The ADB and commercial bank credit is used to a greater extent by the medium and large farmers. The small farmers are reluctant to borrow from the banks due to complicated administrative procedures.

F. AGRICULTURAL INFORMATION SYSTEM AND FARMERS' KNOWLEDGE

All farmers surveyed needed agricultural and irrigation-related information of one kind or another. The information needed varies by the subject matter and the availability and willingness of the source to provide information. Also, the farmers' perception of reliability of information provided by the source is a critical factor. Most of the farmers in the sample were active in seeking information on agricultural input and output prices (75% and 95%, respectively). Of the farmers who sought information on market prices, 66% found the information obtained "useful" to "somewhat useful." For input prices, the situation was somewhat better in that 71% of the respondents thought information obtained was useful.

The inability to receive satisfactory information on agricultural inputs is partially caused by the Extension Service. There is almost unanimous agreement among the sample farmers and the key informants that field assistants (FA) from the agricultural extension department are not knowledgeable and do not visit the village on a fixed schedule to talk to farmers and provide necessary information.

Interviews with extension officials revealed some of the serious problems this agency faces. Based on interviews, the DA study revealed that the FAs had received two years of training after high school, but had not received refresher courses on the new technologies required to increase agricultural production. One field assistant reported that about 50% of the field assistants do not visit the villages that they are assigned to. They are not motivated, and they have limited transportation. For example, the field assistant stated that there were three broken bicycles for 24 FAs in his unit.

Also during interviews, the farmers noted their concern about the lack of information on fluctuations in the volume of canal water. This uncertainty made it difficult for the farmer to appropriately plan the area to be cultivated in a particular season and plan for irrigation of different crops and fields.

G. INVESTMENT AND PROFITABILITY

Profitability analysis was carried out for wheat, cotton, rice, and sugarcane. Using crop enterpise budgets, the return above all costs (including opportunity cost for family labor and rental cost for land) and the return to land and family labor were estimated.

Using an average yield of 22 mounds/ac for wheat, the return above all costs was a Rs. -21/ac. The return to land and family labor, which the land-owning farmers achieve in the form of grain for household consumption and cash from sale of the wheat crop is Rs. 438/ac (Table B-11).

Cotton, which is the major <u>kharif</u> crop, generates a return above all costs of Rs. 469/ac and a return to land and family labor of Rs. 749/ac. This estimate is based on an average yield of 9 mounds/ac and the current price o Rs. 190/mound. The estimated return above all costs for rice is Rs. 350/ac and the return to land and family labor is Rs. 830/ac. More farmers considered rice to be more profitable than cotton as a <u>kharif</u> crop.

The average yield for the limited number of sugarcane producers in the study sample was 800 mounds/ac. Average yield for the area is reported to be about 400 mounds from two cuts over a year. Using this average yield figure, sugarcane generates a return above all costs of Rs. 1,288/ac, which is higher than the wheat and cotton crop combined in annual rotation. However, sugarcane production is limited to farmers who have a contract with the sugarmills.

The profitability estimates based on the average yield have serious implications when the large variation in yield between farmers are considered. In the case of wheat, which is the major rabi crop, about 40% of the farmers reported yields considerably below the overall average of 22 mounds/ac. When considering the low yield and the information that about half of the wheat output is kept for household consumption, the inability of small farmers to generate funds for investment in the next season becomes apparent. The smaller farmers find themselves in a perpetual cycle of low productivity and inability to invest in short- and long-term improvements.

V. SUMMARY OF SYSTEM CONSTRAINTS

The major constraints for the Sehra Irrigation System, based on the pre-rehabilitation study, are:

* Inadequate irrigation water during crop peak requirement periods.
* Inequitable and unreliable water distribution.
* Poor on-farm water application.
* Crop production is less than the potential for irrigated lands with the climatic condition of the area.
* High soil salinity towards the tails of the system.
* Lack of agricultural information and training for farmers.
* Farmers' inability to invest.

VI. APPENDICES

APPENDIX A: FIGURES FOR PRE-REHABILITATION DIAGNOSTIC ANALYSIS

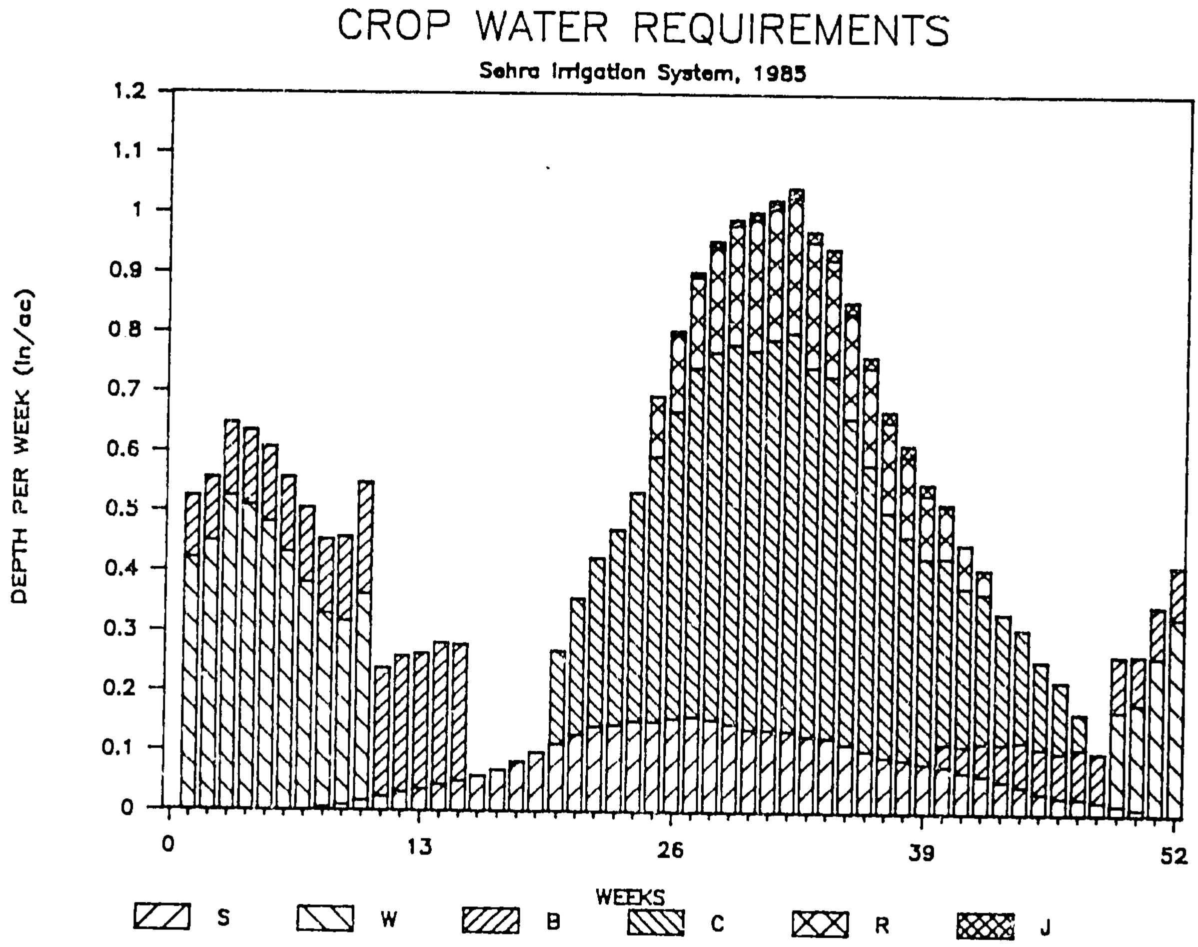


Figure A-1. Cumulative Crop Water Requirement Normalized Over the Entire Cultivable Area for 1985.

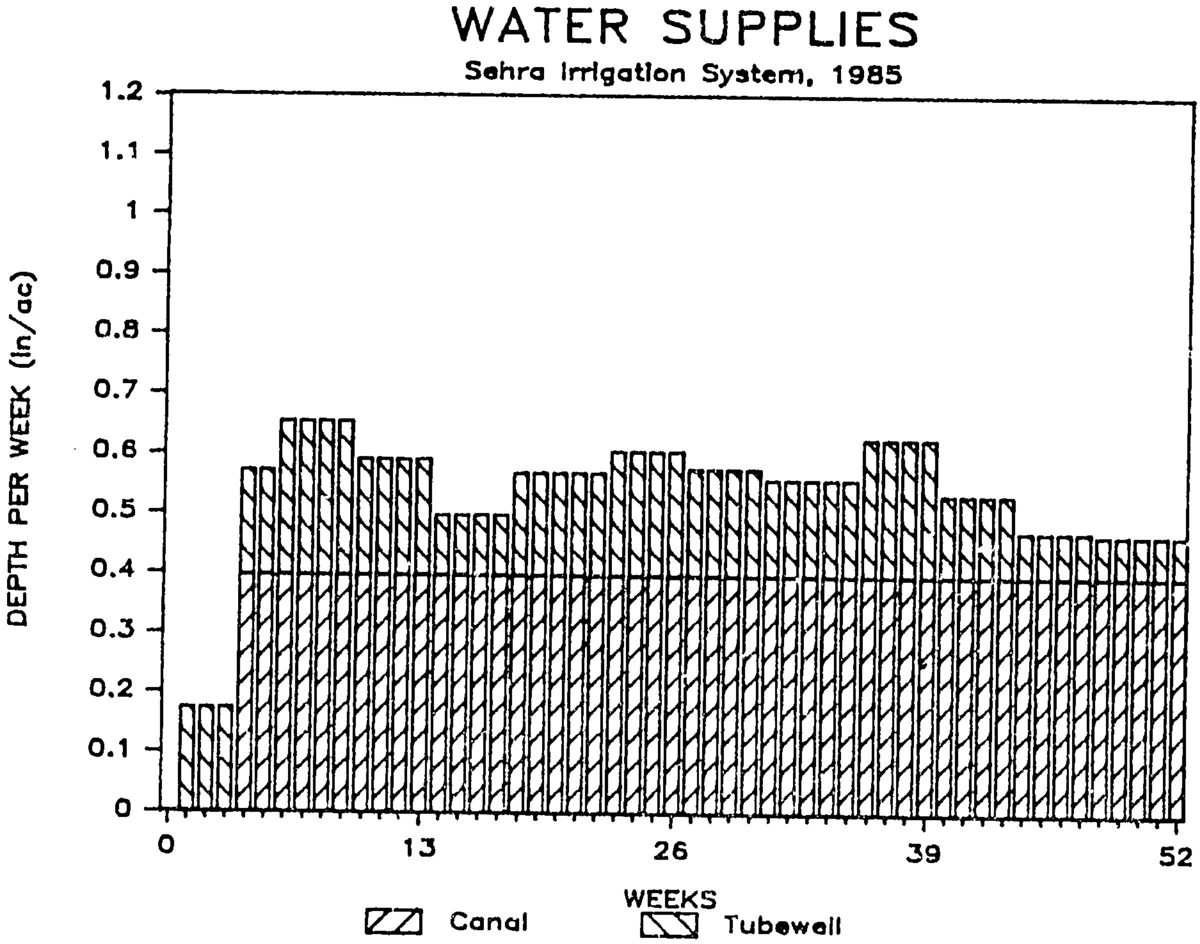


Figure A-2. Weekly Water Supplies Normalized Over the Entire Cultivable Command Area for 1985 (40 and 53% Irrigation Efficiencies were Used for Canal and Tubewell Water, Respectively).

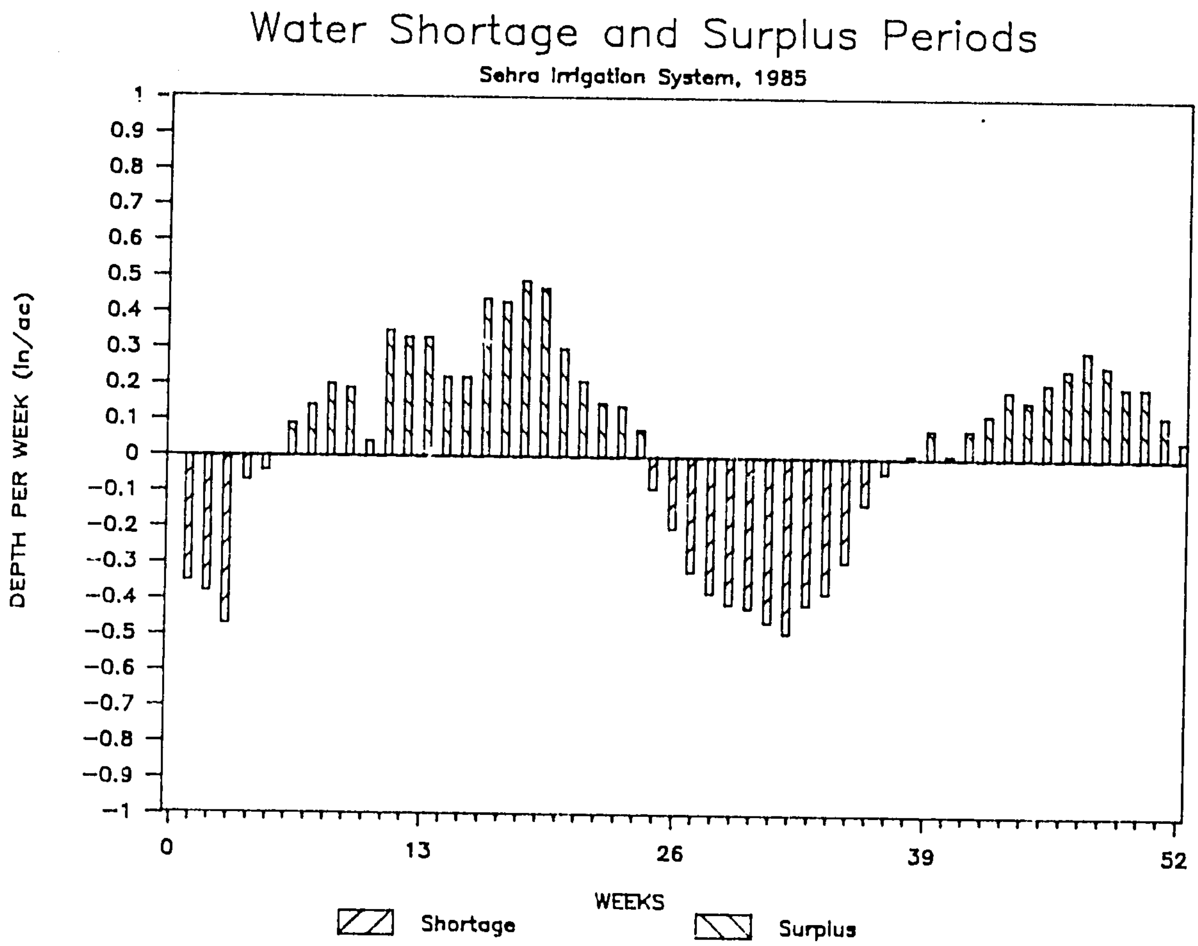


Figure A-3. Water Shortage and Surplus Periods for 1985 (40% and 53% irrigation efficiencies were used for canal and tubewell water, respectively).

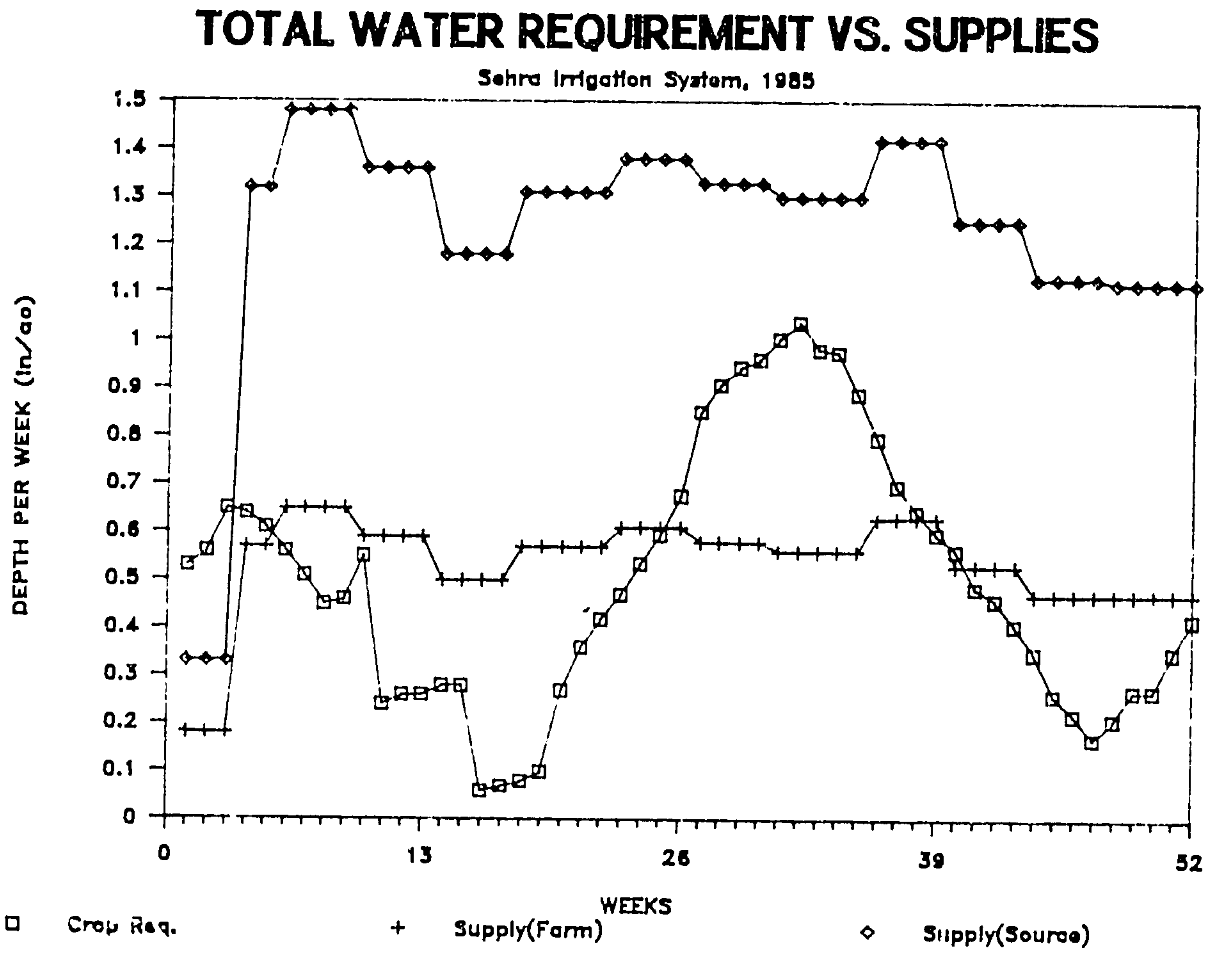


Figure A-4. Cumulative Crop Water Requirement and Total Water Supply (at head works and farm level) Normalized Over the Entire Cultivable Command Area for 1985.

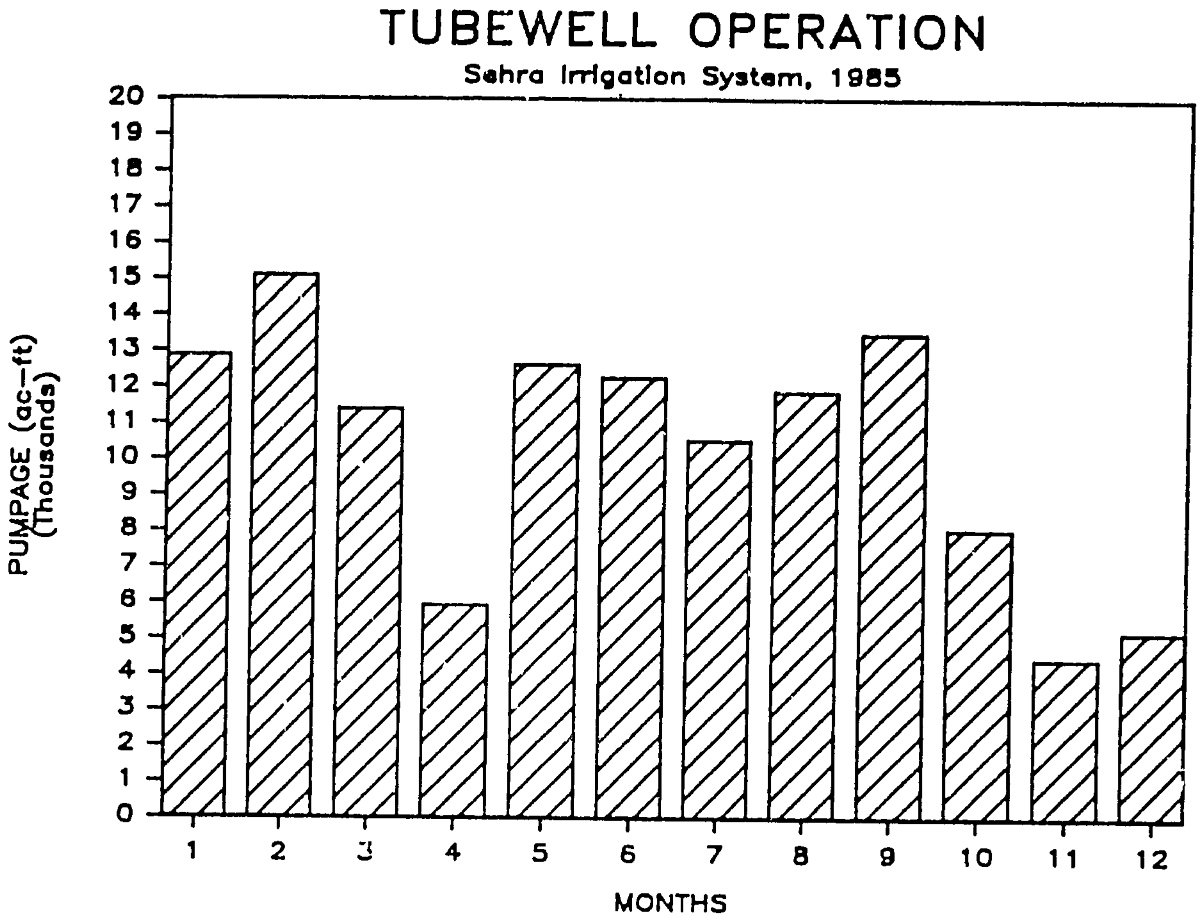


Figure A-5. Monthly Tubewell Pumpages for 1985.

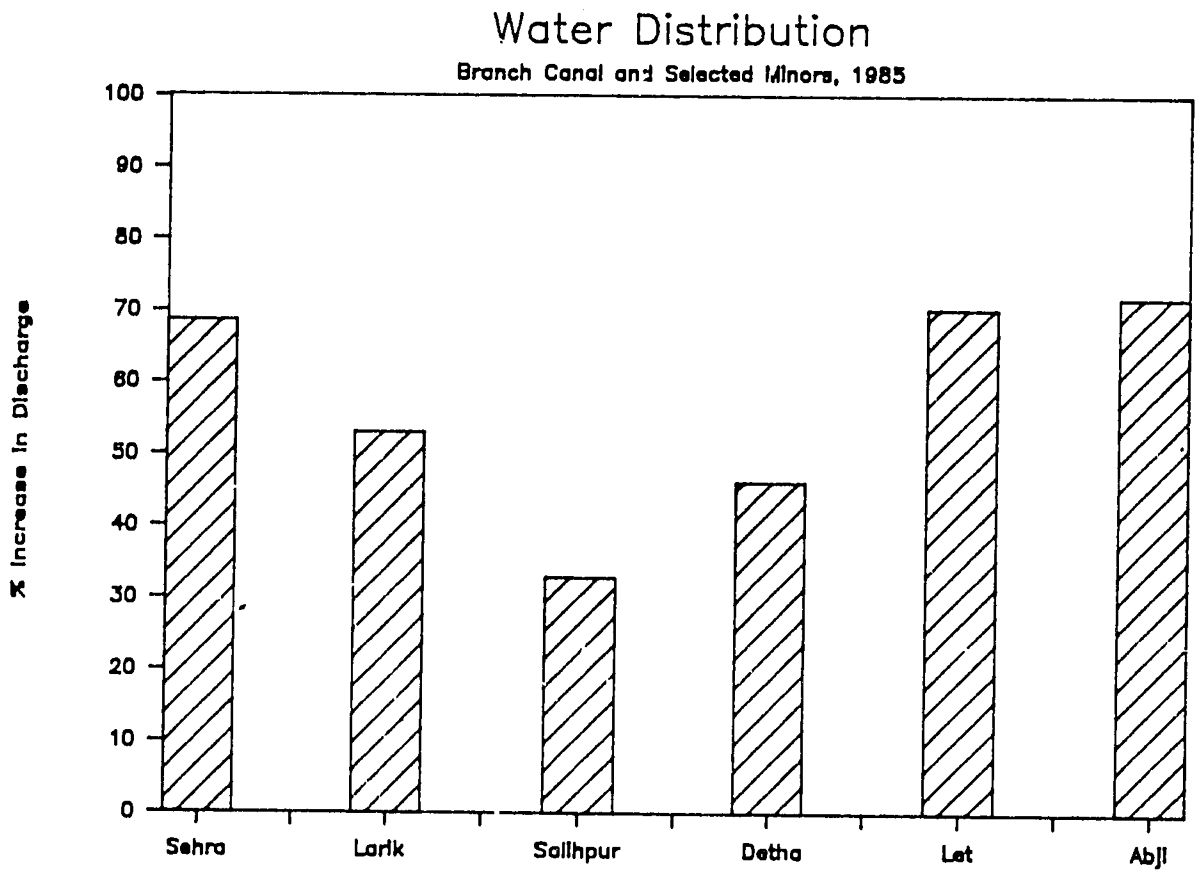
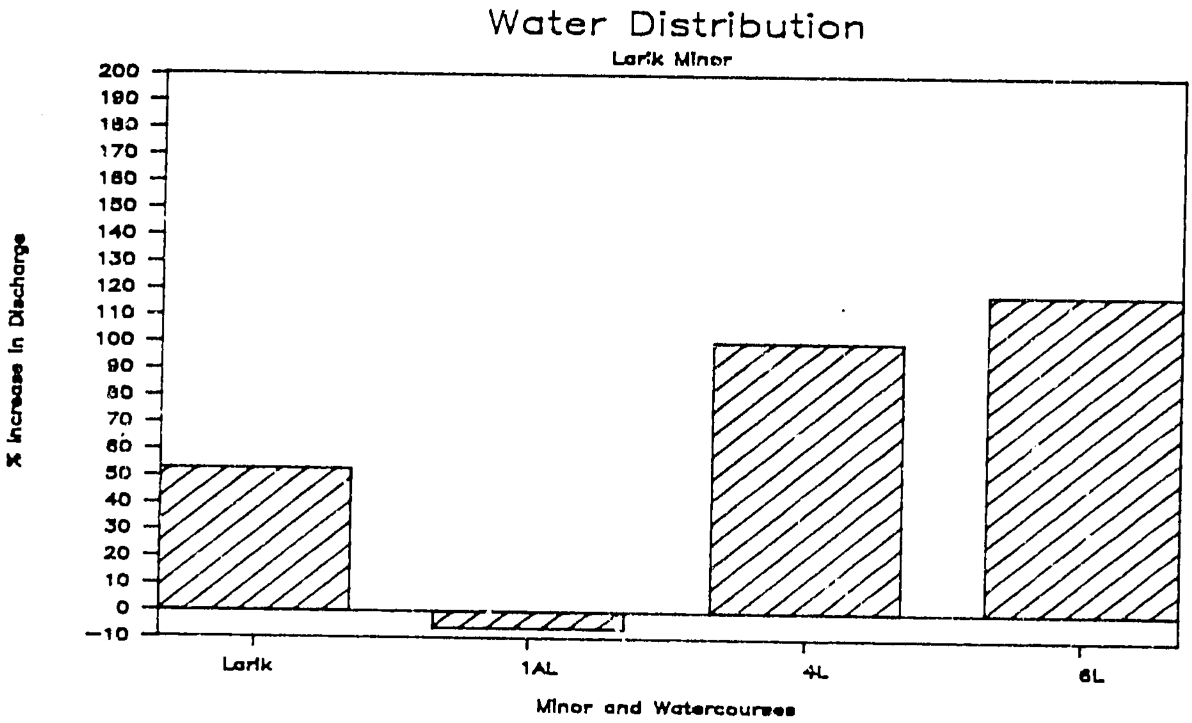


Figure A-6. Percentage Increase in Discharge Over the Design Specifications Based on the Daily Flow Rates Measured at the Head of the Branch Canal and the Five Selected Minors.



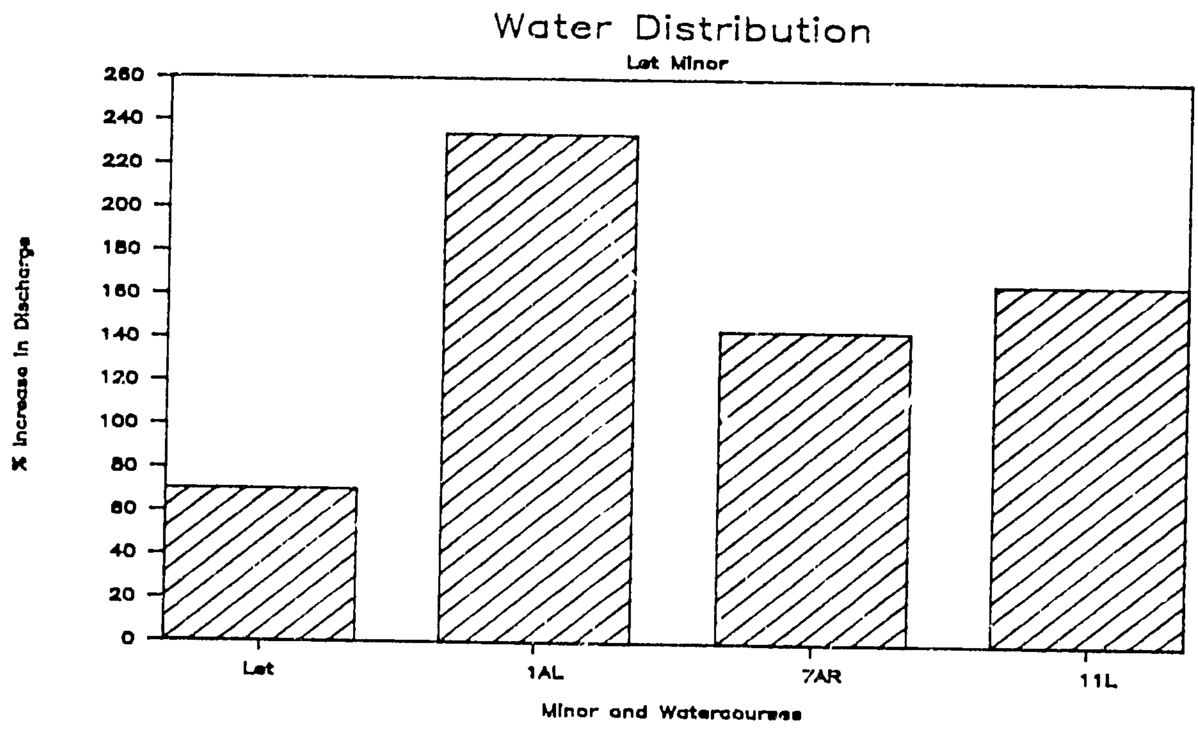


Figure A-7. Percentage Increase in Discharge Over the Design Specifications Based on the Daily Flow Rates Measured at the Heads of Two Selected Minors and Six Selected Watercourses.

APPENDIX B: TABLES FOR PRE-REHABILITATION DIAGNOSTIC STUDY

Table B-1. Cropping Pattern and Intensity by Sample Watercourse for the Larik Minor, *Kharif* 1985 and *Rabi* 1985/86.

Cropping Pattern	Head Watercourse	Middle Watercourse	Tail Watercourse	Minor
	-----------	-----------	Percent -----------	-----------
Kharif 1985				
Cotton	36.94	5.69	34.46	27.63
Jawar	10.45	22.34	9.26	7.33
Rice	5.58	10.62	23.54	17.39
Sugarcane	8.70	0.00	0.00	1.52
Fallow	38.33	53.34	32.74	46.06
Rabi 1985/86				
Wheat	63.42	60.03	75.98	65.34
Berseem	11.85	7.66	11.38	9.41
Oilseed	0.00	0.41	0.00	0.25
Sugarcane	8.70	0.00	0.00	0.00
Fallow	16.03	31.89	2.64	25.00
Cropping Intensity	146	114	155	120

Table B-2. Cropping Pattern and Intensity by Sample Watercourse for the Let Minor, *Kharif* 1985 and *Rabi* 1985/86.

Cropping Pattern	Head Watercourse	Middle Watercourse	Tail Watercourse	Minor
	------	------ Percent	------	------
Kharif 1985				
Cotton	55.26	32.13	3.16	39.81
Jawar	0.00	13.85	34.74	5.93
Rice	7.89	00.00	0.79	2.58
Sugarcane	26.31	1.11	2.11	8.80
Fallow	10.53	52.91	59.21	42.87
Rabi 1985/86				
Wheat	27.63	34.52	49.74	38.01
Berseem	15.79	9.32	12.70	14.41
Oilseed	0.00	2.47	0.00	0.86
Sugarcane	22.37	0.00	2.11	7.26
Vegetable Orchards	0.00	4.38	0.00	1.53
Fallow	34.21	49.31	35.45	37.93
Cropping Intensity	155	98	105	117

Table B-3. Cropping Pattern and Intensity by Location Along the Watercourse, Larik Minor, Kharif 1985 and Rabi 1985/86.

Cropping Pattern	Head Watercouse (1AL)		Middle Watercourse (4L)		Tail Watercourse (6L)	
	Head of Watercourse	Tail of Watercourse	Head of Watercourse	Tail of Watercourse	Head of Watercourse	Tail of Watercourse
	---------------	---------------	--------------- Percent	---------------	---------------	---------------
Kharif 1985						
Cotton	36.67	37.13	35.40	22.04	62.43	0.00
Jawar	15.00	7.19	7.45	4.84	0.00	20.67
Rice	13.00	0.00	44.72	5.92	35.62	8.65
Sugarcane	0.00	14.95	0.00	0.00	0.00	0.00
Fallow	35.00	40.73	12.43	67.20	1.95	70.68
Rabi 1985/86						
Wheat	81.67	50.31	64.60	57.15	92.50	54.81
Berseem	18.33	7.19	18.01	20.49	7.50	16.35
Oilseed	0.00	0.00	0.00	6.21	0.00	0.00
Sugarcane	0.00	14.95	0.00	0.00	0.00	0.00
Fallow	0.00	27.39	17.39	33.55	0.00	28.84
Cropping Intensity	165	132	170	86	199	99

Table B-4. Cropping Pattern and Intensity by Location Along the Watercourse, Let Minor, *Kharif* 1985 and *Rabi* 1985-86.

Cropping Pattern	Head Watercourse (1AL)		Middle Watercourse (7R)		Tail Watercourse (11L)	
	Head of Watercourse	Tail of Watercourse	Head of Watercourse	Tail of Watercourse	Head of Watercourse	Tail of Watercourse
	Percent					
Kharif 1985						
Cotton	62.50	42.85	61.11	24.91	17.94	46.42
Jawar	0.00	0.00	13.80	13.84	7.69	0.00
Rice	12.50	0.00	0.00	0.00	1.69	0.00
Sugarcane	16.66	2.85	5.55	0.00	0.00	3.57
Fallow	8.33	14.28	19.44	61.24	72.43	50.00
Rabi 1985/86						
Wheat	22.92	31.71	44.44	32.08	46.15	52.25
Berseem	25.00	0.00	13.89	8.19	5.13	18.02
Oilseed	0.00	0.00	0.00	3.07	0.00	0.00
Sugarcane	10.42	42.86	0.00	0.00	0.00	3.60
Vegetable Orchards	0.00	0.00	22.22	0.00	0.00	0.00
Fallow	41.66	25.43	19.45	56.66	48.62	26.13
Cropping Intensity	150	164	161	82	78	123

Table B-5. Cropping Pattern and Intensity by Location Along the Watercourse, Dali Pota *Rabi* 1984/85 and *Kharif* 1985.

Cropping Pattern	Head Watercourse		Tail Watercourse	
	Head	Tail	Head	Tail
Rabi 1984/85				
Wheat	47.42	85.52	40.63	12.42
Berseem	1.03	2.89	0.00	0.89
Fallow	50.52	38.59	59.37	86.03
Sugarcane	1.03	0.00	0.00	0.67
Kharif 1985				
Cotton	45.36	18.65	21.87	4.21
Jawar	4.12	1.29	0.00	0.22
Rice	0.00	1.29	0.00	0.89
Sugarcane	9.28	0.64	0.00	0.69
Fallow	41.23	78.14	78.12	91.01
Cropping Intensity	108	84	63	20

Table B-6. Analysis of Low Plant Population Areas Within a Field, Sehra Irrigation System, Sind.

Watercourse	Field Salinity Good	Field Salinity Poor	Depreciation	Elevation	Hydraulic Head	Remarks
	----mmohs----				--cm--	
Larik Minor						
1A-L Head	0.6	0.7	no	no	30	Unknown
1A-L Tail	0.8	32.1	no	no	12	Salinity
4-L Head	1.8	--	--	--	17	No blanks
4-L Tail	2.2C	14.4	no	no	2	Salinity
	1.4R	10.8	no	no		w/low head
6-L Head	1.2	4.8	no	no	12	Poss. Salinity
6-L Tail	0.8	6.8	no	no	20	Prob. Salinity
Let Minor						
1A-L Head	1.8	3.6	no	no	14	Poss. Salinity
1A-L Tail	1.3	--	--	--	12	No blanks
7A-R Head	0.4	1.0	no	no	17	Flooded at seedling
7A-R Tail	1.8	18.8	no	no	9	Salinity with poss. low head
11-L Head	0.8	1.7	Possibly	no	8	Unknown
11-L Tail	0.8	21.5	no	no	10	Salinity

Table B-7. Summary of Hydraulic Head Entering Fields, Sehra Irrigation System, Sind.

Watercourse	Field	Hydraulic Head (cm) < 10	10-15	15-20	> 20	Average
		--% of Fields--				
Larik Minor						
1A-L Head	8				100.0	30
1A-L Tail	14	42.8	28.6	28.6		12
4-L Head	9	14.3	42.8	14.3	28.6	17
4-L Tail	11	100.0				2
6-L Head	11	50.0	16.7	33.3		12
6-L Tail	20	12.5	25.0	12.5	50.0	20
Let Minor						
1A-L Head	30	14.3	57.1	28.6		14
1A-L Tail	20	46.1	23.1	30.8		12
7A-R Head	23	25.0	37.5	12.5	25.5	17
7A-R Tail	10	57.1	28.6	14.3		9
11-L Head	14	33.3	66.7			8
11-L Tail	12	77.8	11.1		11.1	10

Table B-8. Actual Seeding Rate for Wheat in Comparison to the Recommended Rate, *Rabi* 1984/85

Actual as % of Recommended*	Relative Frequency	Cumulative Relative Frequency
Above 100	15.38	15.38
100	38.85	49.23
90-99	27.69	76.92
80-89	13.85	90.77
Below 80	9.33	100.00

* Recommended Rate for wheat is 45 to 50 kg/ac.

Table B-9. Actual Seeding Rate for Cotton in Comparison to the Recommended Rate, *Kharif* 1985.

Actual as % of Recommended*	Relative Frequency	Cumulative Relative Frequency
Above 100	4.26	4.26
100	27.66	31.92
90-99	0.00	31.92
80-89	36.17	68.09
70-79	0.00	68.09
60-69	31.91	100.00

* Recommended rate for cotton is 12 to 15 kg/ac.

Table B-10. Seed Quality Analysis, Sehra Irrigation System, Sind.

No.	Identity	Weight (g)	Inert Material Weight (g)	Inert Material (%)	Germ. (%)	Remarks
Commercial						
1	B.S. & Sons ZA77	56.7	5.0	8.8	97	
2	SASO Pawan	62.7	0.8	1.3	99	
3	SASO ZA77	68.0	0.7	1.0	97	
Farmer						
4	4-L Tail Mexi-Pak	59.0	4.0	6.8	92	
5	7-AR Pak 70	58.1	4.0	6.9	95	
6	7-AR (head)	61.3	4.5	7.3	92	
7	11-L Blue Silver	67.1	17.3	25.8	97	Weevils
8	11-L Mexi-Pak	57.4	10.4	18.1	74	Weevils
9	6-L (tail) S-75	67.8	2.5	3.7	95	
10	4-L Yakora	63.7	6.8	10.6	92	
11	1-AL Pak 70	61.7	3.5	5.7	97	
12	6-L Blue Silver	62.7	23.1	36.8	93	Weevils
13	1-AL Blue Silver	60.6	22.3	36.8	93	Broken

Table B-11. Summary of Costs and Returns for Four Major Crops, Sehra Irrigation System, *Kharif* 1985 and *Rabi* 1985/86.

Crops	Gross Income*	Total Cost	Net Return	Return to Land & Family Labor
	----------Rupees----------			
Wheat	1,469.00	1,517.00	(21.32)	438.68
Rice	1,500.00	1,149.63	350.00	830.37
Cotton	1,710.00	1,240.93	469.07	749.07
Sugarcane	4,000.00	2,712.00	1,288.00	1,588.00

*Estimated using average yield of 22 mounds for wheat, 30 mounds for rice, 9 mounds for cotton, and 400 mounds for sugarcane.