JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

IRRIGATION AND POWER DEPARTMENT
GOVERNMENT OF PUNJAB
THE ISLAMIC REPUBLIC OF PAKISTAN

# THE STUDY ON THE LINING OF DISTRIBUTARIES AND MINORS IN PUNJAB IN THE ISLAMIC REPUBLIC OF PAKISTAN

Volume I

## MAIN REPORT

JULY 1997



NIPPON KOEI CO., LTD.
NIPPON GIKEN INC.

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# PREFACE

In response to the request from the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a feasibility study on the Lining of Distributaries and Minors in Punjab and entrusted the study to Japan International Cooperation Agency (JICA).

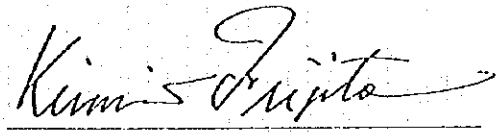
JICA sent to the Islamic Republic of Pakistan a study team headed by Mr. Toshihito Otani, Nippon Koei Co. Ltd., twice between March 1996 to June 1997.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Pakistan, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

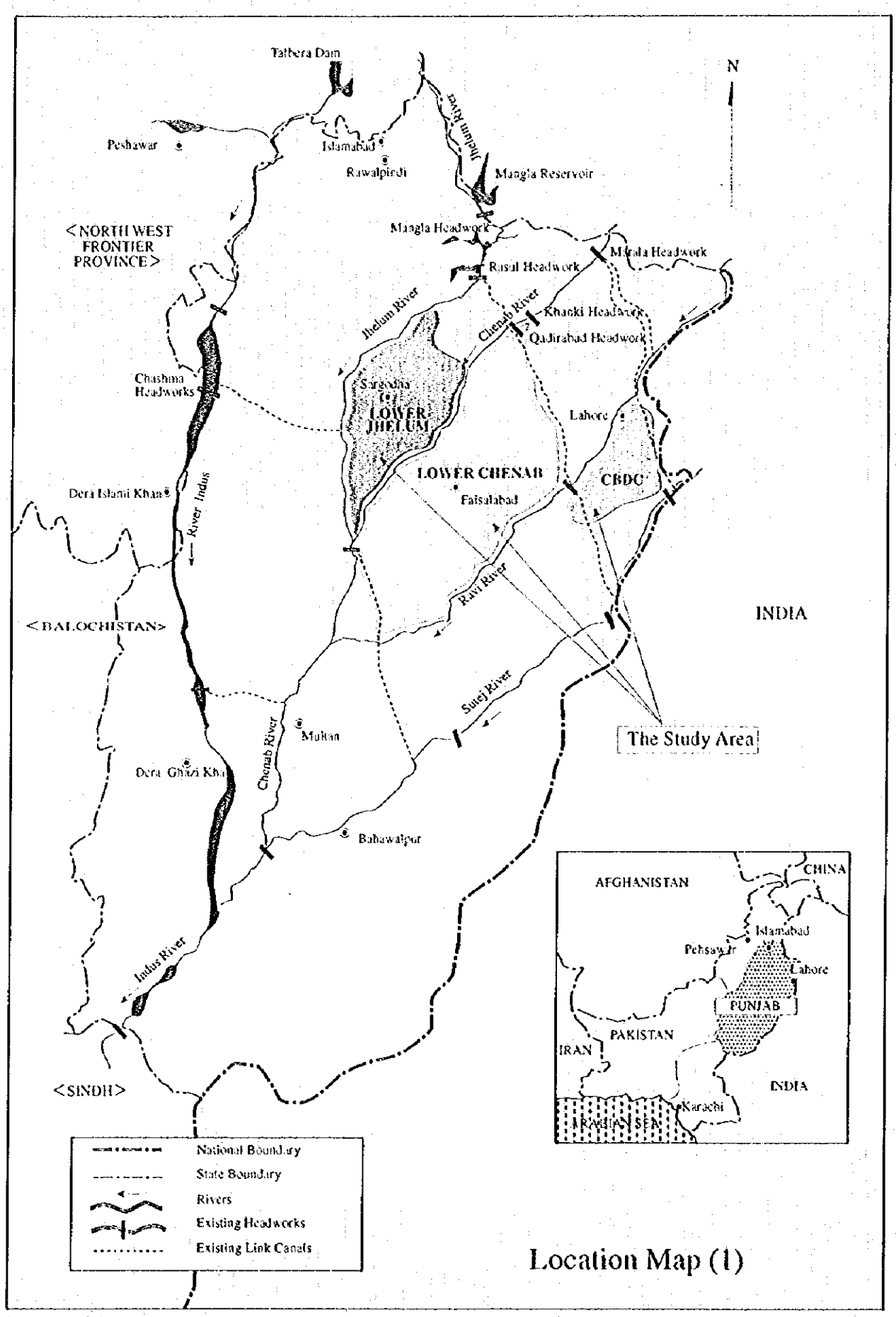
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Pakistan for their close cooperation extended to the team.

July, 1997



Kimio Fujita
President
Japan International Cooperation Agency




Location Map (1)

N

W E

S

LJC SYSTEM

CBDC SYSTEM

LCC SYSTEM

| Selected Channels and Command Areas | | |
|---|---|---|
| LJC | 78,286ha | |
| A | Pindi Distributary | (2,285 ha) |
| B | Hajjan Distributary&Minors | (25,236ha) |
| C | Kirana Distributary&Minors | (50,765ha) |
| LCC | 120,558ha | |
| D | Sarangwala Distributary | (6,627ha) |
| E | Nasrana Distributary&Minors | (34,677ha) |
| F | Gojra Distributary&Minors | (7,540ha) |
| G | Mungi Distributary&Minors | (19,161ha) |
| H | Jantwala/HamzaDistributary&Minors | (6,513ha) |
| I | Pirmahal Distributary&Minors | (18,242ha) |
| J | KillianwalaDistributary&Minors | (27,798ha) |
| CBDC | 42,267ha | |
| K | Thanunan Distributary&Minors | (25,877ha) |
| L | China Distributary&Minors | (16,390ha) |
| | Total Command Area | 241,111 ha |

JHELUM RIVER
CHENAB RIVER
RAVI RIVER
SUTLEJ RIVER

Rasul
LOWER JELUM CANAL
SHAHPUR BR
NORTHERN BR
SOUTHERN BR
KHUSHAB
SULKE BR
SARGODHA
Khanki
Qadirabad
LOWER CHENAB CANAL
HAFIZABAD
QADIRABAD BALLOKI LINK CANAL
GUJRANWALA
SHEIKHUPURA
UPPER JHANG BR
RAKH BR
UPPER GUGERA BR
FAISALABAD
DEG NALA
LAHORE
LAHORE BR
B.R.B.D. LINK CANAL
JHANG
LOWER JHANG BR
LOWER GUGERA BR
Balloki
C.B.D. CANAL
L.B.D. CANAL
KASUR
Trimmu
TOBA TAK SINGH
BURALA BR
BALLOKI SULEMANKI LINK-1 CANAL
BALLOKI SULEMANKI LINK-2 CANAL

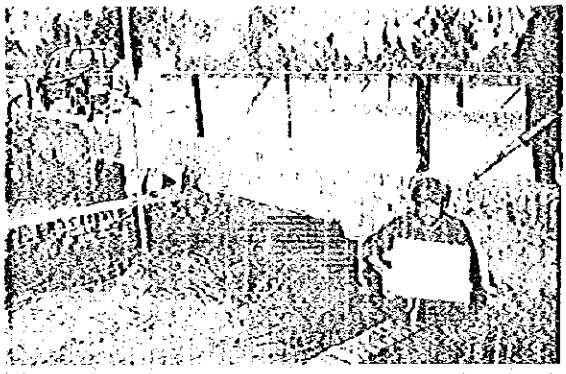
LEGEND

- Project Boundary
- International Boundary
- Main, Link, Branch (BR), Freeder (FR) Canal
- Disty, Minor
- Selected Distributaries
- Barrage
- River
- District Capital
- Irrigation Command Area

SCALE

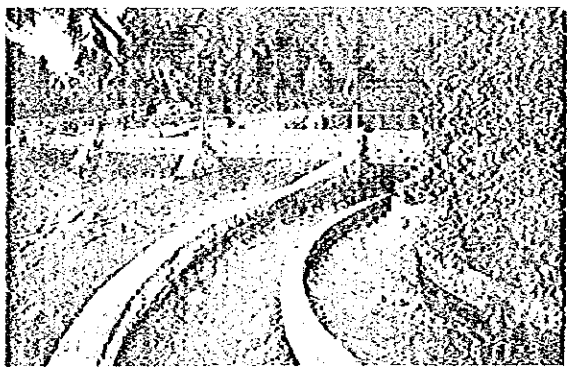
0 10 20 30 40 50 km

Location Map (2)
Selected Channels and their Command Areas

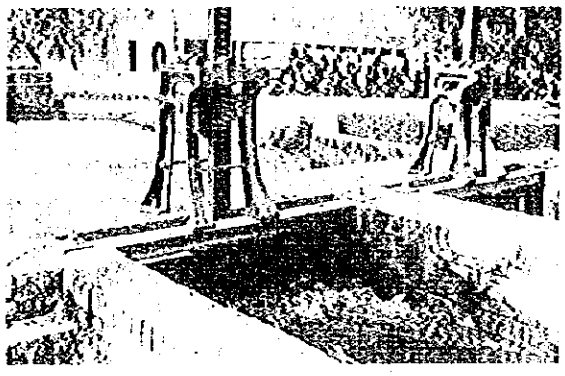


Intake of Mungi Distributary

Condition of the bridge nearby a distributary



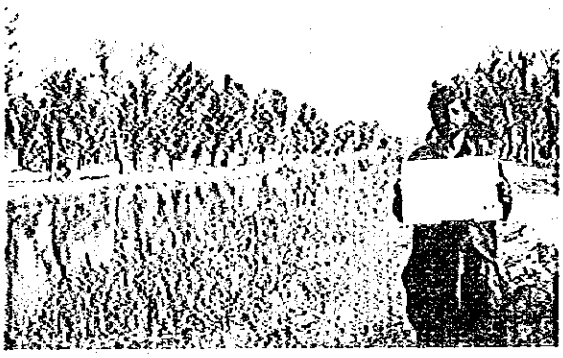
Diversion Facility



Regulating Gate

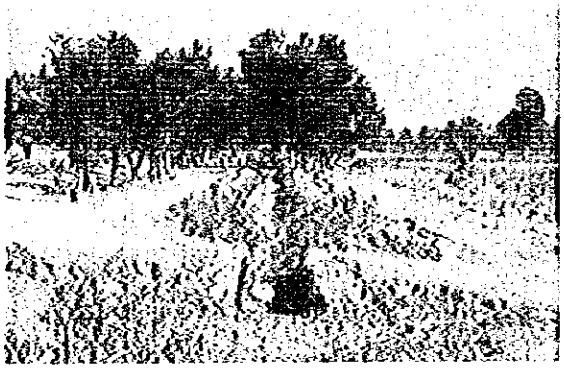
Pump house installed by the Punjab Government

Offtake from Distributary to Minor

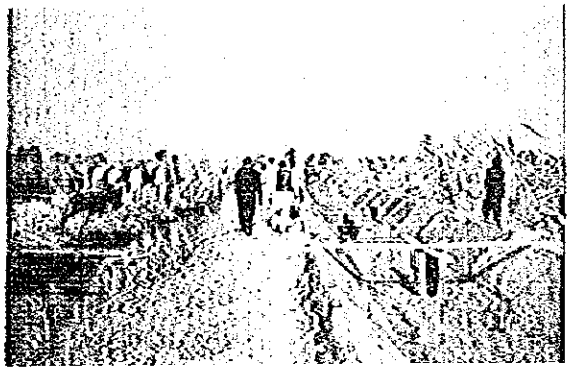


Middle Reach of Hujan Distributary

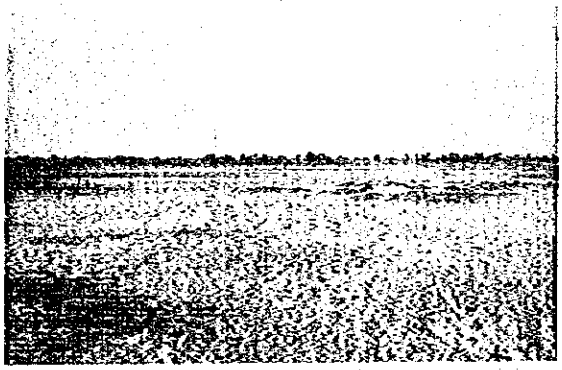
Tail-end of a Distributary



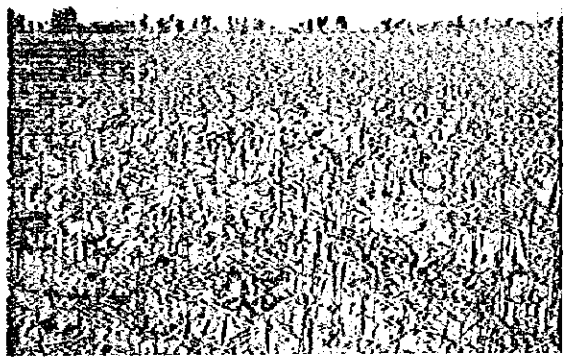
Lower Reach of Kirana Distibutary
(Irrigation water does not reach tail.)



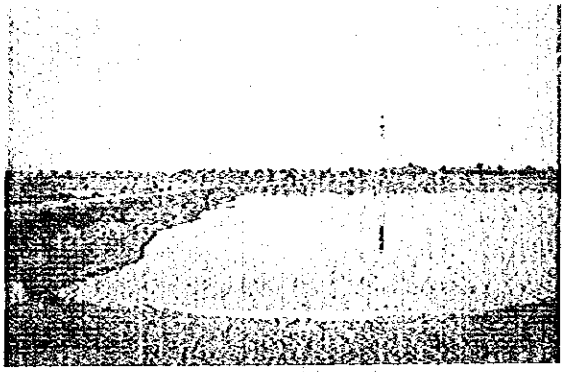
Lining Works nearby the Study Area



Abandaned Land Because of Salinity



Wheat in the severely salt affected area

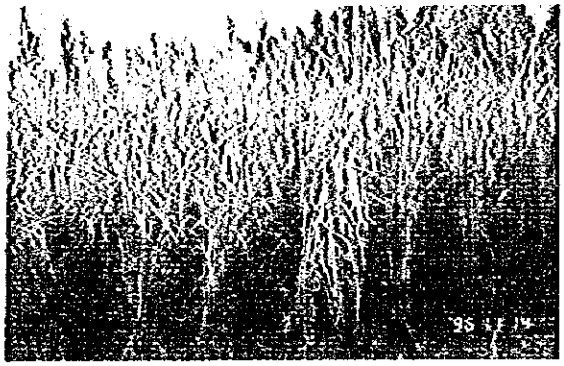


Waterlogging in the LJC Area

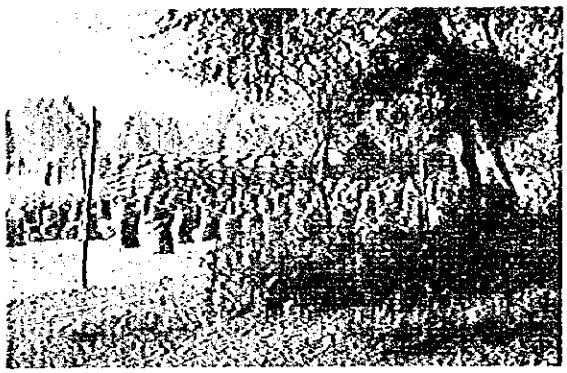

Semminar on Salinity and Canal Lining

Meeting with farmers
(LJC Area)

Site inspection with Farmers



Planting Condition of Paddy



Open-air Depot of Paddy

# SUMMARY

## I Introduction

The Study on "the Lining of Distributaries and Minors in Punjab" has been conducted during the period of 16 months from April 1996 to June 1997 according to the "Scope of Work" agreed between the Irrigation and Power Department, Government of the Punjab (PID) and the Japan International Cooperation Agency (JICA) in September 1995.

The Study area comprises three canal systems in Punjab province: the Lower Chenab Canal (LCC), Lower Jhelum Canal (LJC) and Central Bari Doab Canal (CBDC). There are 717 Distributaries and Minors in the Study area with a total length of 6,615 km and a total gross command area of 24,450 km2 (GCA) or cultulable command area of 2,116000 ha.

At present, it is the responsibility of PID to operate and maintain the irrigation system from the barrages to distributaries and minors. The Government of Punjab decided to bring about the institutional reforms in PID, which would be transformed into autonomous bodies, namely Provincial Irrigation and Drainage Authority (PIDA) under statutory arrangements.

The objectives of the Study under such circumstances are:

1) To select approximately 500 km of Distributaries and Minors, to formulate a canal lining project and to conduct a feasibility study of the project; and
2) To carry out technology transfer to the Pakistani counterpart personnel through on-the-job training in the course of the Study.

The Project broadly comprises two components: (i) physical works including the lining of 540 km of Distributaries and Minors belonging to 12 Distributary systems with a total command area of 241,111 ha and remodeling of related structures in the three canal systems, and (ii) formulation of farmers organizations in compliance with GOP's institutional reform program. The Project would be implemented as a pilot project under PID or its successor. The total cost would be Rs. 3,120 million (US$ 92 million). The Study revealed that the Project would create new water resources equivalent to 10.7 % of the authorized discharge and be economically viable with an EIRR of 19.9% based on a conservative evaluation.

## II Background

### 1. National Economy and Agricultural Sector

Although Pakistan's economy had grown rapidly during 1980-92 with an annual GDP growth rate of 6.1%, Pakistan's per-capita GNP is still low (US$ 420 in 1992). Primary objective of

five year development plans in the past has been to increase per capita income and alleviate poverty.

Agriculture is the key economic sector of Pakistan. Agriculture sector had achieved an annual growth rate of 4.5% during 1980-92. It accounted for one fourth of GDP, half of employment, and substantial share in export earnings. Agriculture supplies most of the country's food and raw materials for major domestic industries.

Pakistan covers about 79.6 million ha. The cultivated area is 21 million ha, of which 16.2 million ha (77%) are irrigated. Of the total cultivated area 10.4 million ha are single cropped, 5.7 million ha are double cropped and 4.9 million ha are fallow. Pakistan's climate is arid to semi-arid, which makes non irrigated agriculture difficult. Around 90 % of agricultural output comes from irrigated agriculture.

Pakistan's population was 82 million in 1980; it is estimated to have increased to 128 million in January 1995 with a growth rate of more than 3% per annum. The United Nation predicts that Pakistan's population will be 148 and 243 million in the years of 2000 and 2025, respectively, which is an alarming projection in view of the country's food production potential. Pakistan is a food importer even now. Imports of agricultural products such as wheat, sugar, tea and oilseeds amount to 12-14% of all imports, and agricultural inputs, mainly fertilizer, another 3-5% of imports. The Water Sector Investment Plan (1991) predicts that in the year 2000 food grain will be short by 40 % and other crops will also be greatly in short supply if the current rate of yield increase continues.

## 2. Eighth Five Year Plan

The emphasis of the Eighth Plan is on using the agriculture sector as the main instrument of growth and development. The primary goal of the agriculture sector is the achievement of a growth rate higher than the population growth, in order to ensure food security, self sufficiency and large exportable surpluses. With the agreement on water accord, focuses will now be laid on (i) Integrated management of agriculture, irrigation and drainage; (ii) Efficient land management; and (iii) Efficient water management.

The major goal of policy and planning in the water sector continues to be that of uplifting the agro-based economy of the country by maximizing crop production. This goal will be accomplished through progressively increasing surface water supplies, replacing public tubewells with private ones, improving existing management practices using the latest technologies available, and protecting land and infrastructure from waterlogging, salinity, and

floods. Efforts will also be made to operate and maintain irrigation and drainage sub-systems at a high efficiency level.

Regarding the distributaries and minors, the following strategies are proposed for implementation:

(i) water conveyance efficiency of canals and drains should be improved by lining and remodeling;
(ii) existing irrigation and drainage systems should be rehabilitated;
(iii) fertile lands should be protected from waterlogging and salinity by giving priority to disastrous areas having saline groundwater underneath. The exploitation of groundwater resources in fresh groundwater zones should be left to the private sector;
(iv) borderline waterlogged areas should be treated with preventive measures such as lining of minors and distributaries, water regulation and management, OFWM and improved cropping pattern;

## 3. National Policy on Institutional Reforms

From the meetings with the farmers in the project area, officials of the Federal and Provincial Governments and in pursuance of the documented studies carried out by Government itself and with the assistance of international agencies such as World Bank, Asian Development Bank, and OECF, it is realized that the performance of agricultural sector has been dismal and poor. It is recognized that among the various constraints one of the most serious constraint is the old colonial institutional system which does not allow the beneficiaries to participate in the development, operation & maintenance process of economic resources. This lack of participation by the beneficiaries is more evident in the water sector which is having the highest influence on agriculture in the arid and semi arid region of Pakistan.

The water resource is increasingly becoming scarce in terms of per capita availability due to rising population. The increased pressure on land and water for maximum productivity by individual farmers has resulted in unauthorized use of water particularly by the influential farmers in the head reaches of the distributaries.

The national commission on agriculture (1988) also comments "Not only does the availability of canal water vary seasonally, the distribution process itself suffer from certain chronic inequities, the worst being tailenders i.e. farmers at the extreme end of the distributary system" The commission further comments "of all the inputs in agriculture the greatest gains can be expected from more efficient use of water, which also maximizes gains from other in-puts such as fertilizer. Increasing agriculture production will, therefore, depend crucially on the rational use of land, land improvement, increasing the supply of water by reducing the water losses, more efficient water use and better agronomic practices." It is therefore realized that it is highly

essential to improve the efficiency of this resource and one way would be through the full participation of the farmers - the beneficiaries.

In formulating strategy for implementation in the water sector the 8th five year plan emphasizes on transferring partial responsibility for O & M to farmers associations so that O & M financial burden on the public sector is eased. It recommends to implement a pilot program to evaluate the concept of transferring irrigation department into autonomous bodies with the ultimate aim of involving the private sector in irrigation management.

The Government has also given a clear mandate to the international financial institutions helping the National Drainage Program to implement institutional reform which would make the participation of the beneficiaries essential to achieve the twin objective of making the system efficient and transfer the burden of O & M expenditure to the beneficiaries. In discussion with Government Agencies at Federal and Provincial level the institutional reforms were clearly mentioned and recognized. The will of the Government was also indicated to implement institutional reforms on pilot bases.

## III Agriculture in the Punjab Province

The Punjab province has a total area of 20.63 million ha of which about 12.1 million ha (59 %) is cultivated and about 10.7 million ha (88.5 %) is irrigated by canals and tubewells, whereas the remaining 11.5 % is rainfed land. The total irrigated area in the Punjab province accounts for about 75% of the total irrigated area (17 million ha) in Pakistan.

There are two seasons for cropping, namely, Kharif in summer (April-September) and Rabi in winter (October -March). The annual crop intensity in the Study area is estimated at about 128 % (68 % in Kharif and 62 % in Rabi respectively). Generally, the farmers cultivate same farm land continuously without fallow. Put another way, more than 30 % of CCA are left uncultivated through both the seasons. Insufficient water is the main reason for uncultivated areas. Cultivable wastelands are due mainly to waterlogging and severe salinity.

In the Study area wheat cultivation for self-consumption forms a prominent part of cropping pattern in the Rabi season together with fodder. The proportion of farmers growing sugarcane in both Rabi and Kharif is low in the Study area. In Kharif paddy, cotton, and maize are grown in similar proportion. But, fodder is the main Kharif crop. Other than major crops, rapeseed, grams, vegetables are also grown to a small extent. Fruit crops (citrus) is more prominent in LJC than in LCC and CBDC.

Wheat is the main staple food crop in Pakistan. Punjab produces about 73 % of the national production. Rice is the second most important food cereal and export commodity. Punjab is

the leading rice growing province with about 59 % of cropped area and 44 % of total production. In Punjab, peak levels of cotton production were obtained in 1991 with about 11.4 million bales. However, both production and cropped area are on the downward trend from 1992 as a result of Cotton Leaf Curl Virus (CLCV) infestation which increased from 1989. Punjab with about 521 thousand ha under cane shared approximately 60 % of national cane acreage and about 53 % of total production.

The Punjab is the main granary area of Pakistan in practice as well as in name. However, the unit yields of major crops have not reached sufficient levels. The average yields of the major crops are lower than world average yields. The reasons are shortage of irrigation water, insufficient amount of fertilizer application, late sowing, saline soil and water, shortage of capital and credit etc. According to the farm survey conducted in this Study, 94 % of farmers reported shortage of irrigation water as the major cause for low productivity, followed by salinity.

## IV Present Conditions of Irrigation and Drainage

### 1. Distributary and Minor

Water source for the Study area is river waters of the Jhelum and Chenab rivers. Diversion of the waters into off-taking canals is made through headworks/barrage. The main canals divert water to the respective irrigation systems. Branch canals which branch off from the main canals function as conveyance channels up to distributaries and minors in the respective irrigation divisions. These channels distribute water to the watercourses.

The main canals and the branches have some sort of control structures to limit the distribution of water into the distributaries. There is, however, no control on the distributary/minor generally. When a proper quantity of water enters the head of these channels, it is distributed to each outlet automatically according to its capacity.

It is important to note that the canal system was designed in the second half of the 19th century during the British regime, with the objective of extensive irrigation to bring more areas under irrigation in order to settle more people without considering the crop water requirements. The perennial canal system, therefore, is not designed for maximum production on irrigated land but only to eliminate the possibility of famines. In order to maintain a cropping intensity of 75% the canal are generally allocated one cusec of water for every 333-350 acres of culturable command area (approx. 0.2 lit/s/ha).

The unlined channels are designed as regime or non-silting and non-scouring channels, requiring careful control on silt entry, and a continuous flows close to design discharges special in summer months when river waters are fairly silt laden. They are designed to operate successfully and distribute water equitably while flowing close to full supply (i.e. designed) conditions.

It is noted, however, that since the canal system is continuously deteriorating, the system is not functioning as expected in view of water conservation and hydraulic performance. In terms of water conservation, it is observed that breaching and overtopping of water frequently occur due to low freeboard of earth embankment, that steeling of water is a common practice near the upper reach of the channels either by breaking and increasing the size of outlets, and that considerable seepage losses are inevitable because of unlined condition. In fact, water does not reach to the tail in some channels due to the above reasons. In terms of hydraulic performance, it is observed that water is not appropriately conveyed to the downstream due to scoring/silting, sliding of side slopes, weed hazard and irregular cross section of channels. Distribution of water is not proportionally made due to deteriorating/breaking of structures.

## 2. Seepage Tests

Most of the channels in the Study area are unlined. Out of 6,611km in length, only 814km, or 12% has been lined for the distributaries and minors. A considerable seepage losses are expected from the viewpoint of soil mechanical condition and groundwater table. Seepage tests have been conducted in this regard.

Seepage measurement of distributaries and minors was sublet to the Irrigation Research Institute of PID. Seepage loss was measured by the two methods, inflow-outflow method (50 reaches) and ponding method (10 reaches).

Although the measured seepage rates disperse largely depending on the respective channels and their status, distribution ranges of values measured by the two methods (1 - 13 cfs/msf) are more or less the same regardless of the measuring method. In estimating the seepage rates of the existing unlined channels and the proposed lined channels, the average of the unlined channels (6.32 cfs/msf) and that of the newly lined channels (1.47 cfs/msf) are deemed to represent the Study area. The seepage amount is calculated based on the wetted perimeter of the existing and the planned canals. The balance between the former and the latter is deemed as saved water, which is estimated to be 10.7%.

## 3. Tubewells in FGW and SGW Areas

In the Study Area, in order to compensate deficit of surface water, groundwater irrigation through tubewells is extensively applied. Tubewells are broadly divided into two types; ones are SCARP tubewells owned by WAPDA with discharge about 85 lit /sec and the others are farmer owned private tubewells with discharge about 28 lit / sec. The nos. of tubewells in the Study area are 4,500 for SCARP tubewells and 84,900 for private tubewells. Total annual discharge is estimated at 16.9 billion m3. In fresh groundwater zone, utilization of groundwater is quite common, however, in saline groundwater zone, it is seldom used. Most of them are in fresh groundwater zone and one tubewell scatters every 20 ha on average. In line with Agriculture Census in 1990, the percentage of irrigated areas classified by irrigation method/source are 1) Conjunctive use, surface and tube well water: 52 %, 2) Surface water only: 28 % and 3) Tubewell water only: 20%.

## 4. Inequitable Distribution of Water

Inequitable distribution of water in terms of head and tail reaches of distributary and minor canals are often complained about by local farmers. In order to clarify the situation, data of seepage tests performed for selected canals in LJC, LCC and CBDC were used. Ratios between measured and designed discharge were taken to show the extent of water sufficiency. Ratios between reduced distances of test sites from canal heads and the total distances of corresponding canals are also taken to indicate the location of test sites quantitatively. In each irrigation system, correlation factors between the former and the latter parameter show negative values. Besides the ratios at downstream are as much as 30 or 40% of that at upstream. Consequently, it is appropriate to conclude that inequity of water is prevailing in the Project Area as was pointed out by local farmers.

## 5. Watercourse

There exist 2,946, 6,636 and 1,905 watercourses in LJC, LCC and CBDC areas, respectively. Of these, number of water users associations so far organized and accomplishment of lining made fully or partially are 717 and 24% in the LJC System, 1,305 and 20% in the LCC System and 404 and 21% in the CBDC. System, respectively.

## 6. Water and Salt Balance

Net Irrigation Water Requirement was estimated based on potential evapotranspiration calculated with modified Penman equation. Necessary meteorological data from 1986 to 1995 for the calculation are collected from three stations, Sargodha for LJC, Faisalabad for LCC and Lahore for CBDC. Based on the results of calculation, comparison of net irrigation requirement to the actual water supply was made for the three canal systems from canal discharge, cropping

calendar, crop area, meteorological data and irrigation efficiency. Actual surface water application is far from sufficient as compared with estimated net irrigation water requirement. The degree of sufficiency is 36% in LJC, 39% in LCC and 47% in CBDC. Consequently, it was clarified that farmers in the Study Area would be in serious shortage of irrigation water without supplemental supply from tubewells.

Balance between irrigation water supply including ground water and water requirement was also performed. In LJC and LCC, even with supplemental supply of ground water, water requirement is not satisfied. On the contrary, 17% surplus water was found in CBDC, since the area is blessed with relatively sufficient rain as compared with the other two areas.

There is a salt accumulation in the soils of both, the fresh water zones (average 4.7 tons /hectare) and the saline zones (average 3.1 tones /hectare). In the ground water of the fresh water zones and in the saline zones there is a reduction of salts.

## 7. Present Conditions and Problems of Lined Canals in the Study Area

The canal is to the extent of 12% or 814 km out of 6,611 km has been lined within the study area. Brick lining is predominant and covering 58% of total length ,concrete lining covering 30 % and brick side protection covering 12%. Canal lining ratio for distributaries and minors in LJC, LCC and CBDC systems are 5, 15 and 20%. Specifications of canal lining are 3 inches thickness is for concrete lining and 4.5 inched for brick lining on edge supported on 0.75 inched mortar plaster.

APM (Adjustable Proportional Module) is predominant and open flume type follows. Total numbers of outlet surveyed are 1,085, out of which only 35 outlets are in good condition and keep initial function, 725 outlets are observed somewhat damaged and need repair and 324 outlets seem to have lost functions and need replacement.

Regarding construction period, there are two types 1) construction through year round and 2) only in irrigation closure period. For most of distributaries and minors inspected, construction period are 1 year to 1.5 years through. Repair work and lining work for the larger canal have been made in the irrigation closure period of about one month in December and January. Canal diversion method has been applied where perennial construction are possible since there are enough right of way. Adoption of narrow and hydraulically ideal canal section to maximize the velocity and to make the canals free from siltation are necessary for canal lining works. Proper selection of lining material and methodology is also important.

## V Constraints for Irrigation System Management

In order to confirm the constraints for institutional reforms for irrigation system management, the team asked for interviews with the farmers in the Study area and the officials of the provincial government, in addition to collection of information and field investigations.

### 1. Farmers Argument

During the team meetings with the farmers the constraints in irrigation system were high lighted in the following order of importance.

(a) The water supply in the system is deficient to respond to the increased cropping intensity which in turn is essential to fulfill the food requirements of the increasing population. It was argued by the farmers that whereas their parents and grand parents had more land to look after the requirements of the same family size, the farms got subdivided among their sons and grand sons to almost 1/10 th of the original size and therefore this small plot of land has to grow enough to fulfill the needs of a similar size of family. To do so more intensive irrigation is needed to grow two or three crops per year and consequently more water is required.

(b) The irrigation management which was efficient and equitable has deteriorated in the last 30 to 40 years with the result that the canals are in disrepair and desilting of the system is usually deferred. The water distribution which was proportional to the land holding has become highly inequitable to the detriment of the tail farmers as a result. The head farmers and the large farmers using their political and economic influence interfere with the system and draw three to four times more water than their authorized share at the cost of the tail farmers. They resort to use of pipe siphons in the distributary, breaking and lowering the crests of their water courses, making their animals stand in distributary just below their out lets to raise the water level in the distributary enabling their out lets to draw more water or some times even breaching the distributary. They complained that the irrigation canal officers and staff which used to be highly professional in the exercise of their legal powers, a quarter of a century back, have been rendered power-less by the interference of the political system and therefore, the legal framework used for equitable distribution of water has been totally dismantled and is rarely applied. They stated that during the last ten years no farmer has ever been punished under the canal and drainage act despite more frequent commission of crime of misappropriation of water. It was desired that the law should not only be made applicable but should be seen to have become applicable.

(c) Some farmers interviewed stated that they have to pool their resources in order to make informal payments required for obtaining somewhat regular supply at their water courses. Such informal payments are equal or same times more than the formal payments of water charges and are on the increase.

(d) Because of the shortage of water, their lands have become saline due to lack of leaching and higher use of tube wells, pumping water with far more salinity than canal water. At the same time the tube well water is many times more expansive than the canal water.

(e) The lining of distributary and minors was preferred more for system efficiency and equitable operation than for saving the water lost by seepage.

### 2. PID's Opinion on the Constraints

The Department of Irrigation on the other hand commented about the constraints that

(a) The canal system has gone into decay because of lack of O & M financing by the government year after year resulting into deferred maintenance. The fixation of yard stick for financing the O & M, has not kept pace with the inflation on one hand and on the other the availability of funds lag far behind even the present yard stick revised some times in eighties. The Finance Department complains that since there has been no revision in the water charges since early eighties, it is not possible for them to provide the necessary funds for O & M. They argue that return from agriculture to the farmers has increased more than twenty times since the sixties but water rates have only been doubled. In real terms the water rates have declined to one fifth or one sixth of the water rates paid in sixties.

(b) The irrigation department also accept the fact that there is enormous political interference in the legal, functional and administrative responsibilities of the department resulting into overall deterioration of the system. They are however, confident that the stoppage of such interference by political system, the provision of adequate finance for O & M and corresponding increase in water charges could revive the department to its old glory.

## VI Farmers Meeting and Proposal for Improvement

Meetings were held at 24 villages in November, 1996 in addition to the seven meetings held in May-June 1996 jointly involving about 1200 to 1300 farmers. These meetings were intended to elicit an articulate response from the farmers regarding their under standing of the current situation and their prospective for a more equitable and sustainable system of water management at the distributary and minor level. This participatory appraisal involved direct dialogue with farmers.

Dialogues with farmers indicated that their desired objectives were clearly articulated, even if the mechanism for achieving these objectives was not. Farmers were unanimous about their felt needs. After concluding the initial dialogue on grievances and desired situations, attempts were made to develop a farmer consensus about a workable solution to the constraints and moving towards a realistic attainment of desired goals. The farmers were, therefore, asked to

comprehend and perceive various management options that could bring about such an attainment. After a great deal of time and patience the following three perspectives emerged which were discussed one by one to arrive upon the best solution: (a) Improvement of the Existing System; (b) Contracting Out the Distributary / Minor; (c) Farmer Management;.

After discovering flaws in the first two options, the discussion moved on to the novel approach of farmer-managed surface water supply. Farmers were confident that if the management of the distributary / minor was given to them, they would be able to manage the water adequately. The farmer consensus resulted in the formation of a tentative plan for farmer management of water resources up to the distributary / minor level. Framers created and agreed to this plan with the three main reservations that;

- comprehensive training and initial technical assistance was to be provided to them by neutral people ("such as you (JICA team)")
- the plan should enjoy complete legal cover under notification by law
- the farmers committee should have funds for operation and maintenance of the distributaries.

## VII Development Concept

### 1. Objectives of the Project

GOP's principal policy for the water sector is to restore environmentally sustainable irrigated agriculture which would increase per capita income and alleviate poverty. Complying with the GOP's policy, this Project is formulated with following objectives:

(1) To increase agricultural production through lining of Distributaries and Minors which would create new water resources;
(2) To develop participatory water management system for sustainable O&M of irrigation and drainage systems; and
(3) To realize equity of water distribution.

To achieve the above objectives and according to the S/W, the Project has been formulated broadly comprising of two components: (i) physical works including the lining of 540 km of Distributaries and Minors belonging to 12 Distributary systems with a command area of 241,111 ha and remodeling of relevant structures and (ii) formulation of farmers organizations under the GOP's institutional reform program. The Project would be implemented on a pilot basis.

### 2. Necessity of the Project

GOP's primary policy for agricultural development is to achieve a growth rate higher than the population growth rate. Since water is the most important input for agricultural production,

continuous development of water resources is essential. As manifested in the Eighth Five Year Plan, GOP places higher priority on the small scale investment on existing infrastructures rather than the large scale dam and reservoir development as were implemented in the 1960s and 1970s. Measures will be taken such as the lining of watercourses and distributaries/minors, rehabilitation and remodeling of infrastructures, and improvement of water management in order to achieve the increase in water supply, enhancement of irrigation efficiency, protection of waterlogging and salinity, and sustainable expansion of agricultural production.

This project is aimed to increase water supply for crop production (10.7 % of authorized discharge or 163 MCM per annum), rationalize water management, and alleviate waterlogging and salinity through the lining of distributaries and minors. Since these objectives are identical to the above mentioned government strategies, this project exactly complies with GOP's policy.

GOP plans to execute a nation wide institutional reform regarding the O&M of irrigation and drainage system in the country and expects that a workable model of FO would be evolved based on the results of pilot projects for adoption on a countrywide basis.

In line with GOP's basic strategy for the institutional reform, the Study Team formulated a pilot project plan for O&M of Distributaries and Minors including the plan for organizational structure, setting up, finance, transfer of facilities, and water management. For this, the Study Team had a number of meetings with farmers and obtained farmers' opinion on the institutional reform.

## 3. Functions and Benefits of Canal Lining

Canal lining will have various functions such as the control of seepage, strengthening of levee, increased flow velocity, activated function of structures, environmental improvement, betterment of O&M, etc. Each function brings about a variety of benefits which are either quantifiable or unquantifiable. Among the benefits accrued from the Project, those quantifiable will be as follows: (i) increased crop production; (ii) cost saving of tubewells; and (iii) reduced O&M cost. In the assessment of economic viability of the Project only these three benefits will be taken into account. Other benefits including the equity of water distribution or improved water management will not be counted as economic benefit, because they are unquantifiable and it is better not to count them for conservative evaluation. Impacts of success of the institutional reform would be unfathomable. But its direct benefits are unquantifiable, too.

## VIII Outline of the Development Plan

### 1. Selection of the Priority Areas

Selection of the priority canals and areas is made in accordance with the following criteria:

(1) Degree of salt concentration of ground water and its level. Salt concentration is to be more than 1,000 ppm.
(2) Degree of seepage losses through distributaries and minors. Seepage rate should be more than 5 cfs/msf to be economically viable.
(3) Status of Water Users Association for watercourses. Condition of watercourses, lined or unlined is to be considered.
(4) A distributary with its minors is regarded as one system,. If the distributary is located in the saline area (more than 30% in length), its minors are deemed to be the same.

As a result, twelve distributaries were selected as shown in the following table:

| System/Distributary | Cultulable Command Area C.C.A. (ha) | Length of Distributaries and Minors (km) | Proposed Lining Length (km) |
|---|---|---|---|
| 1. Lower Jhelum | | | |
| Pindi | 2,285 | 6.86 | 6.86 |
| Hujjan | 25,236 | 80.13 | 78.18 |
| Kirana | 50,765 | 138.08 | 96.49 |
| Sub-total | 78,286 | 225.07 | 181.53 |
| 2. Lower Chenab | | | |
| Sarangwala | 6,627 | 25.04 | 24.74 |
| Nasrana | 34,677 | 81.42 | 75.77 |
| Gojra | 7,540 | 17.77 | 15.52 |
| Mungi | 19,161 | 41.29 | 37.31 |
| Janiwala/Hamza | 6,513 | 18.58 | 18.51 |
| Pirmahal | 18,242 | 82.13 | 82.13 |
| Killianwala* | 27,798 | 57.17 | 36.98 |
| Sub-total | 120,558 | 323.40 | 291.03 |
| 3. Central Bari Doab | | | |
| Thamman* | 25,877 | 64.54 | 33.87 |
| China | 16,390 | 33.27 | 33.08 |
| Sub-total | 42,267 | 97.81 | 66.95 |
| Grand Total | 241,111 | 646.28 | 539.51 |

Note: * shows the total commands including the area covered with channels not proposed for lining.

## 2. Water Management Plan

In the Project Area, irrigation water does not meet crop water requirement under the present cropping intensity of 130% despite the fact that supplemental ground water irrigation is extensively applied. Without new additional water resources to be developed in the future, there will be no complete solution for the water scarcity. Usually, water management system targets performing optimum use of irrigation water with respect to timing and quantity controlling surplus and deficit of water through gate operation, however, due to constant insufficiency of water it, is quite difficult to apply the concept to the irrigation system in the Project Area without complete reduction of irrigation area and change of cropping pattern. Consequently, it is the best tactics to maintain and operate the present water distribution system on Distributary and Minor canals with additional tube well irrigation under solid and practical operation and maintenance work to keep and maintain design factors and condition of canals and their related structures.

## 3. Design Discharge

The authorized discharge in the Study area is based on the so-called Irrigation Branch Method which was derived from the experience gained by the Department and was determined without considering crop water requirements. The number of cusecs required at the outlet to irrigate one thousand acres of area fit for irrigation, known as Water Allowance, was fixed to be 2.84 cusecs/1,000 acres or 0.2 lit/sec/ha.

It is noted that there is no master plan for the increase of application of water despite the fact that the area is suffering from shortage of water. Nonetheless it is proposed that the design discharge be increased by 10% of present authorized discharge at outlet considering the future development of water resources including utilization of flood water in the Kharif season and more rational water management of the existing reservoirs in the near future. In fact, recently, daily measured discharge shows 5% to 8% increase during the peak period.

The procedure for the calculation of the proposed design discharge for the priority canals for lining is as follows:

(1) The last updated authorized discharge at each outlet and CCA stated in the Outlet Register in the respective branch offices has been adopted as the basic figure.

(2) The authorized discharge stated above has been increased by 10% and accumulated from the tail to the head of the distributaries and the minors.

(3) The channel discharge has been designed by adding the standard absorption loss (Qab) stated in the guidelines for unlined channels;

$Qab = 0.0133 \times L \times Q^{0.5625}$,
where, L: length of section (1,000 feet) and Q: discharge of the section in cusec.

The canal thus designed will accommodate about 50 % more capacity than the present authorized discharge if the freeboard is utilized.

## 4. Design Criteria

Among canal lining method tabulated above, 1) Improved brick lining, 2) Concrete lining and 3) Protected thick membrane lining are pre-qualified consequently according to characteristic of each materials. In accordance with all study results of literature review, field inspection, technical discussions, pre-qualification study and rough cost-benefit evaluation above, concrete lining is basically proposed for the project.

The canal lining criteria was developed considering 1) Proportional distribution of water and silt, 2) Employment of hydraulically ideal section (narrowest section) and a regulation by maximum depth allowed, 3) Maximum removal of drops if possible and proper design of canal slope to acquire minimum allowable velocity of about 0.5 m/sec even at the tail of canals, 4) Setting of proper freeboard and 5) Employment of trapezoidal section with proper side slope. Proportional distribution of water and silt are discussed later in the structure planning. Principal elements of the criteria are summarized below. Connection between side slopes to bottom of channel is proposed to be done with circular line in accordance with the recommendation by PID design directorate.

| | | |
|---|---|---|
| Hydraulic Design | : | by Manning's Formula, value of n = 0.016 |
| Side Slope | : | 1: 1 (1: 1.25, water depth is more than 4 feet (1.22 m)) |
| Freeboard | : | 1 foot and 0.3 m (0.5 feet (0.15m), water depth is less than 2 feet (0.61m)) for lining portion and 0.5 feet (0.15m) for earth portion |
| B/D Ratio | : | 0.8 - 4.5 as shown in Figure 5.2.4-2 and minimum width of canal bed is set at 1.5 feet (0.46m) |
| Allowable Velocity: | | 4 feet (1.22 m/sec) Max., 1.5 feet (0.46m/sec) Min. |
| Lining | : | 3 inch (7.5 cm) concrete on 1 inch (2.5 cm) mortar |

The ideally required function of an outlet, is that proportional distribution of water and silt shall be achieved at all levels in the distributary. Adjustable Proportional Module (APM) Outlet

which has been used in most of cases at present has been observed to have weak silt extraction function and open flume Outlet is exposed and vulnerable. Adjustable Orifice Semi-Module (AOSM) is thus proposed in general for the project since AOSM, used for Command Water Management Project, showed good performance for proportional distribution of both water and silt. All outlets are to be renewed along with the construction of lining. Pipe cum AOSM with an outlet chamber is proposed generally. Operational heads are to be retained for the purpose of proportional operation of AOSM. In cases where operation head of outlet (water head between parent channel and watercourse) is not enough for proper function of AOSM particularly at tail, open flume type is proposed and Pipe Outlet is adopted in the case where the other types are inapplicable.

## 5. Construction Plan

Proper supervision on earthwork quality control is one of the most important factor to achieve longer life expectancy of canal lining. Having the advantage of temporary diversion which would make continuous construction a year round activity, such quality control will be possible. Temporary diversion method is proposed to be used for the project in general. Breaks in continuity of construction due to meteorological conditions would be negligible. Steel slip form, would give good control on cement mix and longer curing under wet condition and are therefore proposed to be emphasized to reduce the seepage to the minimum through canal prism. Designed total length came to be 539.51 km. Total acreage of temporary land compensation is estimated to be 138 ha for an average of 2.7 m width outside ROW. Average work volume per linear meter based on canal sections surveyed and designed is estimated to be 4.15 $m^3$ of excavation, 8.69 $m^3$ of embankment and 0.5 $m^3$ of concrete.

## IX Agricultural Improvement Plan

For the improvement of agriculture in the Project area, it is inevitable to raise and improve the unit yield of crops. With efficient use of irrigation water and application of recommended farming practices, improvement of agricultural productivity of main crops including fodder will be achieved.

The CCA without the Project is 241,111 ha, which will not be changed even with the Project. The crops cultivated are suitable for the Study area, which has similar characteristics with the Agro Ecological Zone. It is understood that the present cropping pattern has been evolved as a result of the past experience in agricultural practice reflecting the existing agro-climatic and socio-economic conditions of the area, and contributed to the promotion of the local industry reflecting the local economy. The farmers in the Study area have long cultivated and experienced in the major crops grown in the two seasons of Kharif in summer and Rabi in winter. Under such circumstances, it is not proposed to introduce any new crops in the Project

area, which does not, however, restrict the farmers' intention to modify their cropping pattern in the future.

The crop intensity is estimated at about 133%. Considering the perennial crops such as sugarcane and fruit trees, it may be more than that. In some areas, the cropping intensity is as high as 90% in Rabi. In due consideration of the high cropping intensity as such, it is not realistic to raise the cropping intensity any further. The cropping rotation system including fallow will be introduced after the implementation of the project through the utilization of reclaimed land. Improvement of the soil fertility will be also achieved by adopting the crop rotation system.

After the completion of the Project, it is expected that the yields of crops under the water stress condition would increase on account of increasing irrigation supply by saving seepage water loss. The anticipated yields after completion of the Project are estimated using the relationship between the yield response factor (Ky) for various crops and seepage saving rate.

The benefit derived from the Project is estimated on the basis of the increment of the unit yield corresponding to the increment of the saved water, but not to the improved farming practices, which results in a conservative estimate of benefit. It is noted that the Government of Punjab has a considerable reputation for agricultural supporting services such as agricultural research and extension. In this regard, it is anticipated that the increment of the unit yields would be much higher than the calculated figures owing to the multiplier effect of increased water and improved farming practices

## X Institutional Development Plan for O&M

### 1. Basic Institutional Development Concept

As stated earlier, the Government of Pakistan, the Government of the Provinces and the donor agencies are presently debating the transformation and reorganization of the irrigation departments of the four provinces into autonomous Provincial Irrigation and Drainage Authorities (PIDAs) who should have equally autonomous Area Water Boards (AWBs) for each canal command or a group of canal commands. The Farmers' Organization (FO) on a pilot basis should be set up at each of the distributary/minor with equal autonomy for the area under the distributary. These bodies should be self financing after an initial period of 3 to 7 years.

### 2. Proposed Farmers Organization

It is proposed that farmers should be organized at two levels for operation and maintenance of irrigation system at distributary level;

(i) Water Users' Associations at watercourse level (WUAs).

(ii) Distributary Farmers' Organizations (FOs).

During the meetings with the farmers along the 12 selected distributaries some of them suggested that instead of each outlet represented on the Distributary Farmers Organization (FO) one member from a group of outlets irrigating a village or a chuk, may represent such group of out lets. This was particularly a view of the farmers where the distributary was very long and had many outlets. The augment has a weightage for seven out of the 12 distributaries which have more than 70 outlets each.

### (1) Water Users Associations (WUAs):

The watercourses usually serve 20 to 100 farmers. The watercourse farmers' associations to be called the Water Users' Association (WUAs) should have all the farmers of the watercourses as its members. The formation of the water users associations will be a compulsory requirement for lining of the distributary. The farmers shall include the owner farmers and the lessee farmers and not the share croppers.

### (2) Distributary Farmers' Organization:

The distributary level Farmers' Organization should be called FOs. The chairman of the watercourse water users' association shall be the member of the distributary farmers' organization. Thus FOs will be federation of basic water users' associations. It will give equal representation to all the water users. The members of the distributary farmers' organization will elect their chairman, member technical, member finance and four more member to form managing committee subject to the conditions that at least four members of the seven members of the managing committee are to represent the tail half of the distributary.

Responsibilities and Powers of FOs:

a) To operate, manage and improve the irrigation and drainage infrastructure comprising of, minors, distributaries and drains together with any structure thereon located within the area relevant to the FO concerned.

b) To obtain irrigation water from the PID. or its successor concerned at the head of the distributary and to supply the same to their members and other water users, if any.

c) To receive the drainage effluent from their water users and to convey the same through field / collector drains to the designed nodal points of the drainage system.

d) To engage, hire or employ any consultants, advisors and employees as may be deemed necessary.

e) To collect the agreed water charges and other dues from its water users and pay the agreed consideration for the supply of irrigation water and conveyance of drainage affluent to the PID concerned.

f) The chairman of the farmers' organization shall have the same legal powers as that of Divisional Canal Officer (DCO) and the member technical as that of a Subdivisional Canal Officer (SDCO) within the jurisdiction of the distributary to deal with defaulters committing unauthorized use of water, interference with outlets, cuts in distributary banks, use of siphons, willful damage or ponding of water by animals and non payment of dues, etc.

Technical assistance required for institutional reforms

The technical assistant team responsible for the organization development of the FO would have the following long-term experts (for five years each), one of whom or an additional person may be the Team Leader.

i) A Sociologist, ii) A Management Socialist, iii) A Financial Management Specialist, iv) An Irrigation O&M Specialist, and v) Twelve Local Village Motivators (one for each distributary).

All the above experts could be engaged from amongst the local experts except the Team Leader.

## XI Initial Environmental Examination (IEE)

An Initial Environmental Examination (IEE) of the Study area was carried out during phase I to assess whether an Environmental Impact Assessment (EIA) was necessary or not, having taken into consideration 19 items that could cause impacts. It indicated that there will not be any major significant environmental impacts envisaged due to the project and that an EIA was not necessary. Further study during phase II on the following items, and the impacts on the selected project canal command areas due to proposed activities was carried out.

1. Land requirements and the Canal Right of Way (Reservation)
2. Restoration of equitable water rights
3. Institutional changes
4. Farmers income and living standards
5. Forest plantations on canal side
6. Health and sanitation
7. Drinking water supply
8. Impediment to Livestock
9. Ground water table

10 Water quality
11. Water quantity
12 Soil salinisation
13. Salt balance

## XII Implementation Program

The executive agency for the Project would be PID/PIDA, The implementation period would be 6 years (1999 -2004) from the loan agreement to the completion of the implementation. Establishment of FO should be finalized in accordance with the proposed schedule before completion of the construction work so as to take over the irrigation facilities on time.

The Institutional Reforms, being an integral part of main project of Lining of Distributaries and Minors in Punjab, shall be implemented along with the main project. The initial work shall be so started that the farmers organizations (FOs) are not only in place but are capable of taking over the distributary from irrigation department on its completion.

## XIII Cost Estimate

The project cost comprises investment cost, replacement cost and O&M cost. Institutional reform cost is included within the investment cost. Cost estimates are based on current price at the time of May, 1996. Exchange rate of Rs. 34 to US$ 1.0 is applied for cost estimate at the same time.

(1) Investment Cost

Investment cost consists of 1) Compensation Cost, 2) Direct Construction Cost, 3) Administration and Consultant Cost, 4) Institutional Reform Cost, 5) Physical Contingency and 6) Price Contingency. Project cost is thus estimated to be Rs. 3,120 million (US $ 92 million or 9.9 billion Yen).

(2) Replacement Cost and O&M Cost

The replacement cost is estimated to be 20% of the direct construction cost for every 20 years, namely Rs. 19.85 million and 1% of devaluation of canal is predicted and the replacement cost per 20 years comes to be Rs. 397 million. O&M cost is divided into facility maintenance cost and personnel cost and estimated to be Rs. 23 million per year.

## XIV Project Evaluation

The direct benefits to be expected from the canal lining, (1) increased production (Rs. 497.0 million), (2) reduction of tubewell operation cost (Rs. 10.1 million), and (3) reduction of operation and maintenance cost (Rs. 5.0 million) are calculated.
Economic Internal Rate of Return (EIRR) of the Project (12 distributaries) is computed as 19.9%. EIRR for each distributary is also computed and the result is shown in the Summary Table.

Farm budget on different farm size has been analyzed for "with project" and "without project" case. It is expected that the farm income will increase by 10% on average for all farm sizes after the implementation of the Project.

Farmers' capacity to pay for water charges is assessed by the comparison between farmers' net reserve and estimated water charge after the implementation of the Project. Water charge is computed by dividing the O&M cost and replacement cost (assuming 12% of discount rate) by CCA. The share of water charge against net reserve is less than 3% for all size of farmers, and no serious impact is expected.

## XV Conclusions and Recommendations

### A. Conclusions

1. The Project broadly comprises two components: (i) physical works including the lining of 540 km of Distributaries and Minors belonging to 12 Distributary systems with a total command area of 241,111 ha and remodeling of related structures and (ii) formulation of farmers organizations in compliance with GOP's institutional reform program. The total cost would be Rs. 3,120 million (US$ 92 million). The Project would be implemented by PID/PIDA for six years from 1999 to 2004 on a pilot project basis.

2. The study revealed that the Project would create new water resources equivalent to 10.7 % of the authorized discharge and be economically viable with an EIRR of 20 % based on a conservative evaluation. The Project would increase farmers' income by about 10 %. The high economic viability could be attributed to the short distance of Distributaries and Minors per CCA (2.2 m/ha) and the low unit cost (Rs. 12,940/ha or US$ 380/ha). In general, prerequisites for high economic viability of a canal lining project would be (i) most of the benefited area falls in SGW zones; (ii) average seepage rate is 6.3 cfs/msf or more; (iii) canal is designed suitable for lining.

3. Judging from the dialogue at farmers meetings, farmers have a strong will and self-confidence to undertake the O&M of Distributaries and Minors. But they are also cognizant of necessity of technical assistance from experts. It is eagerly anticipated that the farmers' capability demonstrated in the management of watercourses will be exerted for Distributaries and Minors.

4. The Project will realize more equitable and rational water management through (i) physical improvement of canal system including the regularization of canal shape and remodeling of outlets and (ii) farmers' direct participation in water management which will effectively suppress illegal abstractions.

## B. Recommendations

1. The Project is economically feasible and technically sound. It is recommended that GOP/GOPunjab would implement the Project as soon as possible.

2. It is recommended that GOP/GOPunjab would procure technical services of engineers for the detail design, preparation of tender documents and construction supervision of the Project.

3. It is recommended that GOP/GOPunjab would make arrangement for the implementation of pilot projects including technical assistance for farmers organization to implement the participatory O&M including legal framework establishment and formation of organization, registration, transfer of facilities, formation of O&M plan, assessment and collection of water charges.

4. Reports concerned states that land acquisition outside the canal right of way is very difficult and need a long procedure even one year rent. It is recommended that the GOP and GOPunjab would make a comparative study on the original plan and alternative plans as shown below and adopt more practical ones for the canal reaches where land acquisition is unavoidable in the current design.

(i) Construction of diversion canal completely within the right of way using portable precast concrete flume to omit land acquisition and reduce diversion earthwork volume which may increase construction cost and require further study of working procedure of the concrete flume:

(ii) Lining work within the canal closure period using geomembrane and precast concrete panel to omit land acquisition as well as diversion work.

5. It is recommended that GOP and GOPunjab would execute the following research and tests prior to commencement of construction at certain stretches of canal and incorporate the results of the research and tests in detailed design and construction plan: (i) measurement of seepage rate (pre and post lining condition); (ii) construction speed and soil compaction test; (iii) measurement of required earth volume; (iv) measurement of hydraulic features of lined channel such as roughness coefficient, velocity and discharge; (v) experiment about temporary outlets; (vi) proportionality of each type of outlet; and (vii) improvement of water tightness and reinforcement of concrete at field condition.

6. Activation of agricultural extension activities is very important for dissemination of technologies on effective use of water and adequate farming practice. It is recommended that GOP/GOPunjab would enhance the efficiency of research and development, strengthen extension activities, and allocate necessary budgets.

7. Initial environmental examination (IEE) was conducted on 19 items. Environmentally the Project has more beneficial impacts than adverse impacts and possible adverse impacts that could occur. It is recommended that GOP and GOPunjab would take the following mitigative actions:

(i) Forest plantations in the right of way removed for the construction work should be reforested after the completion of the Project;
(ii) Drinking water supply should be continued during the construction stage and shallow hand pumps be reinstalled at suitable locations. Tubewell schemes should be monitored for loss in fresh water aquifer potential. If they are affected, alternate schemes should be provided;
(iii) Model studies should be undertaken to determine salt water intrusion into the fresh water and loss in aquifer potential;
(iv) The formation of a committee in PIDA to implement the monitoring plan and take corrective action.

8. The Project does not include such components as OFWM, drinking water supply and drainage, of which inclusion in the Project was requested by DOA and other Provincial Departments. The reason is that these items are out of scope of this Study. Nevertheless these items are important for farmers' living and production activities and may be dealt with by FO/WUA. It is proposed that GOP and GOPunjab would implement different projects for these items.

9. It is recommended that GOP and GOPunjab would make adjustments between this Project and NDP-I to avoid overlapping of works and any other inconsistency when detail designs of the latter are started.

## C. Recommendations for Institutional Reforms

In pursuance of the national policy indicated in the report of the agriculture commission (1988), national conservation strategy 1992, Eighth five years plan (1993) and the recent Punjab Ordinance of May 29, 1997 on reorganization of Irrigation institutions --- the world wide recognition that participation of the beneficiaries in the development of national resources has proved to be more beneficial then public sector unilateral handling, it is a great opportunity to introduce the institutional reforms into this project of lining of distributaries and minors in Punjab on pilot basis . The lining component (hardware) will serve to be a great incentive to the farmers to organize and prepare them selves for this responsibility which has hitherto been considered as an external utility run by the state for which they have been paying service charges .It will also relieve the provincial governments of subsidizing the O&M of the irrigation and drainage system and release its resources for other important social welfare sectors such as education, health and domestic water supply etc. which are starved because of the extreme necessity of diverting resources to keep this life line[irrigation system] of rural Pakistan in reasonable state of operation. It will also improve the investment efficiency on the O&M of the distributaries because of direct and immediate accountability.

The greatest social benefit will accrue from the equitable distribution of water among all the farmers irrespective of their geographic position along the length of the distributary. It is our firm belief that if the FOs and Water Users Association are set up according to our recommendations it will be possible to achieve the same standard of equity as is available on the water courses. The success of these institutional reforms will give a very strong signal, both to the government departments and the farmers, that it is in their interest to replicate the same reforms all over the country. The present skepticism that the farmers are ignorant and they will not be able to handle and operate complicated engineering works - a myth created by interested parties, will be dampened and farmers of other distributaries will come forward with the request for similar reforms. On the analogy of improvement of water courses under OFWM project , there is a strong likelihood of financial participation by the farmers in the future improvement of distributaries in the country. However, the implementation of these reforms in this pilot project is of paramount importance as it is feared that if left to government departments to implement the reforms, the vested interests, the lathergy and the "I know all" attitude of the government officials on one side and the lake of trust of the farmers in the present institutions on the other, there is much less likely-hood of its success.

It is, therefore, essential that an independent team as given in the report [technical assistance required for institutional reforms] is organized to handle these reforms at the grass root level. It will interact with the government on be-half of the farmers as a well informed body to plead their cause.. The drafting of by laws, rules and regulations, the water supply and financial agreements can not be left to the government departments who, the farmers feel, to be biased against the farmers as the opposite party. The farmers will only trust and confide in a party whom they consider to be speaking on their behalf. It is, therefore, recommended that the institutional reforms to be implemented by an independent body should be made an integral rather an essential component of the project . Without such reforms the investment efficiency even in this project would be doubtful as the outlets will be broken again and even the banks of the distributaries will be breached by vested interests.

## Summary Table

| Area | Distributary System | Length (km) Total | Length (km) Lining*1 | Authorized Discharge(m3/s) | Command Area (ha) FGW*2 | Command Area (ha) SGW*3 | Command Area (ha) Total | Seepage Saving Rate (%) | Investment Cost (mil. Rs.) | EIRR (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| LJC | Pindi | 6.86 | 6.86 | 0.46 | 752 | 1,533 | 2,285 | 7.32 | 20.62 | 18.5% |
| | Hujjan | 80.13 | 78.18 | 5.16 | 4,946 | 20,290 | 25,236 | 12.88 | 377.05 | 24.1% |
| | Kirana*4 | 138.08 | 96.49 | 10.52 | 16,238 | 34,527 | 50,765 | 11.43 | 665.78 | 16.5% |
| LCC | Sarangwala | 25.04 | 24.74 | 1.99 | 0 | 6,627 | 6,627 | 10.35 | 129.97 | 15.0% |
| | Nasrana | 81.42 | 75.77 | 7.02 | 0 | 34,677 | 34,677 | 12.64 | 434.06 | 26.6% |
| | Gojra | 17.77 | 15.52 | 1.64 | 0 | 7,540 | 7,540 | 10.19 | 69.51 | 31.2% |
| | Mungi | 41.29 | 37.31 | 4.05 | 965 | 18,196 | 19,161 | 11.46 | 243.25 | 22.9% |
| | Janiwala/Hamza | 18.58 | 18.58 | 1.31 | 0 | 6,513 | 6,513 | 10.52 | 62.91 | 29.7% |
| | Pir Mahal | 82.13 | 82.13 | 3.88 | 6,242 | 12,000 | 18,242 | 16.22 | 410.69 | 13.2% |
| | Killianwala*4 | 57.17 | 36.98 | 5.66 | 4,611 | 23,187 | 27,798 | 9.3 | 345.58 | 17.3% |
| CBDC | Thamman*4 | 64.54 | 33.87 | 7.27 | 7,976 | 17,901 | 25,877 | 5.93 | 196.77 | 11.3% |
| | China | 33.27 | 33.08 | 3.60 | 5,748 | 10,642 | 16,390 | 8.06 | 163.75 | 22.6% |
| Project Total | | 646.28 | 539.51 | 52.56 | 47,478 | 193,633 | 241,111 | 10.73 | 3,119.94 (US$ 91.76 million) | 19.9% |

Note; *1: Total length of lining portion in the distributary system
*2: Fresh Groundwater Area
*3: Saline Groundwater Area
*4: Total command area of Distributaries and Minors including the extent irrigated by portion of channels which are already lined or to be left unlined under the project.

# THE STUDY
# ON
# THE LINING OF DISTRIBUTARIES AND MINORS
# IN
# PUNJAB
# IN
# THE ISLAMIC REPUBLIC OF PAKISTAN

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## ABBREVIATION AND ACRONYMS

| | |
|---|---|
| AARI | Ayub Agricultural Research Institute |
| ADB | Asian Development Bank |
| ADBP | Agricultural Development Bank of Pakistan |
| AEZ | Agro Ecological Zone |
| AO | Agricultural Officer |
| APCOM | Agricultural Prices Commission |
| APM | Adjustable Proportional Module |
| AWB | Area Water Board |
| B/C | Benefit Cost Ratio |
| BRBD | Bhambanwala Rari Bedian Depalpur |
| CBDC | Central Bari Doab Canal |
| CCA | Cultivable Command Area |
| CEC | Cotton Export Corporation |
| CLCV | Cotton Leaf Curl Virus |
| CPE | Chlorinated Polyethylene |
| CWMP | Command Water Management Project |
| DAP | Di-Ammonium Phosphate |
| DOA | Directorate of Agriculture |
| DP | Digestible Protein |
| EC | Electrical Conductivity |
| EDC | Enterprise & Development Consulting |
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| EPA | Environment Protection Agency |
| EPDM | Ethylene Propylene Diene Monomer |
| ETo | Potential Evapotranspiration |
| EVA | Vinyl Acetate |
| FA | Field Assistant |
| FAO | Food and Agriculture Organization |
| FESS | Fordwah Eastern Sadiqia South Irrigation & Grainage Project |
| FO | Farmers Organization |
| FPA | Flexible Propylene Alloy |
| GCA | Gross Command Area |
| GDP | Gross Domestic Product |
| GNP | Gross National Product |
| HDA | High Density Polyethylene Alloy |
| HDPE | High Density Polyethylene |

| | |
|---|---|
| ICID | International Commission on Irrigation and Drainage |
| IDA | International Development Association |
| IEE | Initial Environmental Examination |
| IFAD | International Fund for Agricultural Development |
| IIMI | International Irrigation Management Institute |
| IRI | Irrigation Research Institute |
| IRSA | Indus River System Authority |
| ISRIP | International Sedimentation Research Institute, Pakistan, (Formerly ACOP) |
| ISRP | Irrigation System Rehabilitation Project |
| IWASRI | International Waterlogging and Salinity Research Institute |
| JICA | Japan International Cooperation Agency |
| LCC | Lower Chenab Canal |
| LDPE | Low Density Polyethylene |
| LJC | Lower Jhelum Canal |
| LLDPE | Linear Low Density Polyethylene |
| M&R | Maintenance and Repair Programme |
| MB | Measurement Book |
| MPA | Member of Provincial or Federal Assembly |
| NCS | National Conservative Strategy |
| NDC | National Development Consultants (Regd) |
| NDP | National Drainage Programme |
| NOC | No Objection Certificates |
| NWFP | North West Frontier Province |
| O&M | Operation and Maintenance |
| OECF | Overseas Economic Cooperation Fund |
| OFWM | On-Farm Water Management |
| P&D | Planning and Development Department |
| PAD | Provincial Agriculture Department |
| PAD&SC | Punjab Agricultural Development and Supplies Corporation |
| PASSCO | Pakistan Agricultural Supplies and Storage Corporation |
| PERI | Punjab Economic Research Institute |
| PID | Provincial Irrigation Department, (Irrigation and Power Department) |
| PIDA | Provincial Irrigation and Drainage Authority |
| PSC | Punjab Seed Corporation |
| PU | Public Utility |
| PV | Polyvinyl |
| PVC | Poly Vinyl Chloride |
| PWA | Provincial Water Authority |
| RAP | Revised Action Programme |

| | |
|---|---|
| RECP | Rice Export Corporation of Punjab |
| ROW | Right of Way |
| RSC | Residual Sodium Carbonate |
| SAR | Sodium Absorption Ratio |
| SCARP | Salinity Control and Reclamation Project |
| SMO | Salinity Monitoring Organization |
| STPP | SCARP Transition Pilot Project |
| T&V | Training and Visit |
| TA | Technical Assistance |
| TDN | Total Digestible Nutrients |
| USAID | United States Agency for International Development |
| USBR | United States Bureau of Reclamation |
| USDA | United State Department of Agriculture |
| WAPDA | Water and Power Development Authority |
| WB | World Bank |
| WHO | World Health Organization |
| WRMD | Water Resources Management Directorate |
| WUA | Water User Association |

## GLOSSARY

| | |
|---|---|
| *Abiana* | Water charge |
| *Chak* | Command area of a watercourse |
| Check | Means of blocking of the full flow of a watercourse to divert water into a farmer's field or channel through a 'turnout' |
| *Dikka* | Temporary means to restrict flow (used by irrigation department) |
| *Katcha* | Local/traditional/earthen/unimproved/not brick and concrete |
| *Khal* committee | Traditional committee of farmers on watercourse |
| *Kharif* | Summer |
| *Mogha* | Irrigation department's engineered uncontrolled turnout into a watercourse, designed to deliver a constant flow proportional to the level of the supply canal(hence designed to allocate water fairly between all watercourses on a canal, as canal flows) |
| *Pacca* | Improved/modern/high-quality |
| *Pukka Nucca* | Improved permanent concrete turnouts and checks on watercourses, comprised of a concrete lid to close it |
| *Rabi* | Winter |
| *Sarkari Khal* | Government channel, applied to the main stem of a watercourse |
| *Turnout* | Diversion point, a pukka nucca where modernized, but otherwise a earthen cut in the watercourse to farmer's channel or field |
| *Warabandi* | "Fixed turn," the roster whereby each farmer on a watercourse receives the full water flow in turn at a fixed period |
| *Watercourse* | Small channel from the mogha to farmer channels and fields |
| *Numberdar* | Village level officer who collects the water charge from farmers |
| *Patwari* | PID officer responsible for assessment of water charge |
| *Builder* | PID officer overseeing the canal system |

## CONVERSION FACTOR

| | | | |
|---|---|---|---|
| Numbers: | | | |
| | Lakh(Lac) | 100,000 | |
| Distance: | Canal mile | 5,000 ft | 1,524 m |
| Weight: | | | |
| | Pound (lb) | | 0.4536 kg |
| | Chattak | 0.128 lbs | 0.058 kg |
| | Seer | 2.057 lbs | 0.933 kg |
| | Maund (40 Seer) | 82.286 lbs | 37.324 kg |
| | Bushel | 60 lbs | 27.22 kg |
| | Kantar | 110.2 lbs | 50 kg |
| | Bale (unland raw cotton) | 392 lbs (prior to 1979/80) | 177.8 kg |
| | | 375 lbs(1979/80 on) | 170.1 kg |
| | Quintal | 220.4 lbs | 100 kg |
| | long ton | 2,240 lbs | 1.016 t |
| | short ton | 2,000 lbs | 0.907 t |
| Volume: | | | |
| | gal (Imp) | 4.546 liters | |
| | gal (U.S) | 3.758 liters | |
| | cubic foot per sec (cusec) | 28.32 liters per sec (lit/sec) | |
| | | 0.02832 cubic meters per sec (cumsec) | |
| | Million Acre Feet (MAF) | 1,234 million cubic meters (MCM) | |
| Area: | | | |
| | Marla | 1/20 Kanal | 0.0025 ha |
| | Kanal | 1/8 acre | 0.0506 ha |
| | Acre | | 0.4047 ha |

## Unit

| | |
|---|---|
| m | meter |
| km | kilometer |
| ft | feet |
| acre | acre |
| ha | hectare |
| $km^2$ | square kilometer |
| g | gram |
| kg | kilo gram |
| ton | metric ton |
| lb | pound |
| s | second |
| hr | hour |
| l | litter |
| $m^3$ | cubic meter |
| $Bm^3$ | billion cubic meter |
| MCM | million cubic meter |
| MAF | million acre feet |
| cfs/msf | cubic feet per second/million square feet |
| ppm | parts per million |

## Exchange Rate

US$ 1.0 = Rs.34=J.Yen 110
(as of end of June 1996)

## Fiscal Year

1st July ~ 30th June

## METRIC CONVERSION TABLE

| | | | |
|---|---|---|---|
| Length: | | | |
| | 1 inch | = | 2.539 centimetres |
| | 1 foot | = | 0.305 metre |
| | 1 yard | = | 0.914 metre |
| | 1 furlong | = | 0.201 kilometre |
| | 1 mile | = | 1.609 kilometres |
| | 1 nautical mile | = | 1.852 kilometres |
| | 1 centimetre | = | 0.39 inch |
| | 1 metre | = | 3.2808 feet |
| | 1 metre | = | 1.09 yards |
| | 1 kilometre | = | 5.00 furlongs |
| | 1 kilometre | = | 0.62 mile |
| | 1 kilometre | = | 0.54 nautical mile |
| Area: | | | |
| | 1 acre | = | 0.405 hectare |
| | 1 acre | = | 0.00405 $km^2$ |
| | 1 hectare | = | 2.4711 acres |
| | 1 square kilometre | = | 0.386102 square mile |
| | 1 square kilometre | = | 247.1047 acres |
| | 1 square mile | = | 2.589 $km^2$ |
| Weight: | | | |
| | 1 lb. | = | 0.454 kilogram |
| | 1 maund | = | 37.324 kilograms |
| | 1 metric ton (2205 lbs.) | = | 1000 kilograms |
| | 1 long ton (2240 lbs) | = | 1016 kilograms |
| | 1 short ton (2000 lbs.) | = | 907 kilograms |
| | 1 ounce | = | 0.028 kilogram |
| | 1 kilogram | = | 17.147 chattanks |
| | 1 kilogram | = | 1.07 seers |
| | 1 kilogram | = | 2.2046 lbs. |
| | 1 kilogram | = | 0.027 maund |
| | 1 quintal | = | 2.6792 maunds |
| | 1 quintal | = | 100 kilograms |
| Volume: | | | |
| | 1 cubic metre | = | 35.314724 cubic feet |
| | 1 pint | = | 0.568 liter |
| | 1 gallon (Imp.) | = | 4.546 liters |
| | 1 gallon (U.S.) | = | 3.785 liters |
| | 1 litre | = | 1.761 pints |