Irrigation and Power Department
Government of Punjab Province
The Islamic Republic of Pakistan

NO. 2

Japan International Cooperation Agency
Japan

FEASIBILITY STUDY
ON
TAUNSA BARRAGE IRRIGATION SYSTEM REHABILITATION
IN
THE ISLAMIC REPUBLIC OF PAKISTAN

MAIN REPORT

August 1998

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PREFACE

In response to a request from the Government of the Islamic Republic of Pakistan, the Government of Japan decided to conduct a Feasibility Study on Taunsa Barrage Irrigation System Rehabilitation and entrusted the study to the Japan International Cooperation Agency (JICA).

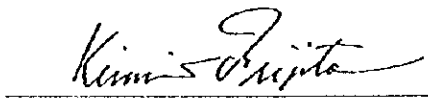
JICA sent to a study team headed by Mr. Katsuhiko Kimura, to the Islamic Republic of Pakistan, 3 times between August, 1997 and August, 1998.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Pakistan, and conducted field survey 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.

August, 1998



Kimio Fujita
President
Japan International Cooperation Agency

August, 1998

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

Dear Sir,

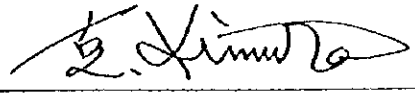
We have the pleasure of submitting herewith the feasibility study report on Taunsa Barrage Irrigation System Rehabilitation in the Islamic Republic of Pakistan, in accordance with the terms of reference issued by your Agency.

The Study was carried out for a total period 13 months from August 1997 to August 1998. The Study was basically formulated with the principal aim of sustenance and prosperity of irrigated agriculture and the improvement of farmers' living standards in the Study Area through rehabilitation of Taunsa Barrage and its related irrigation facilities.

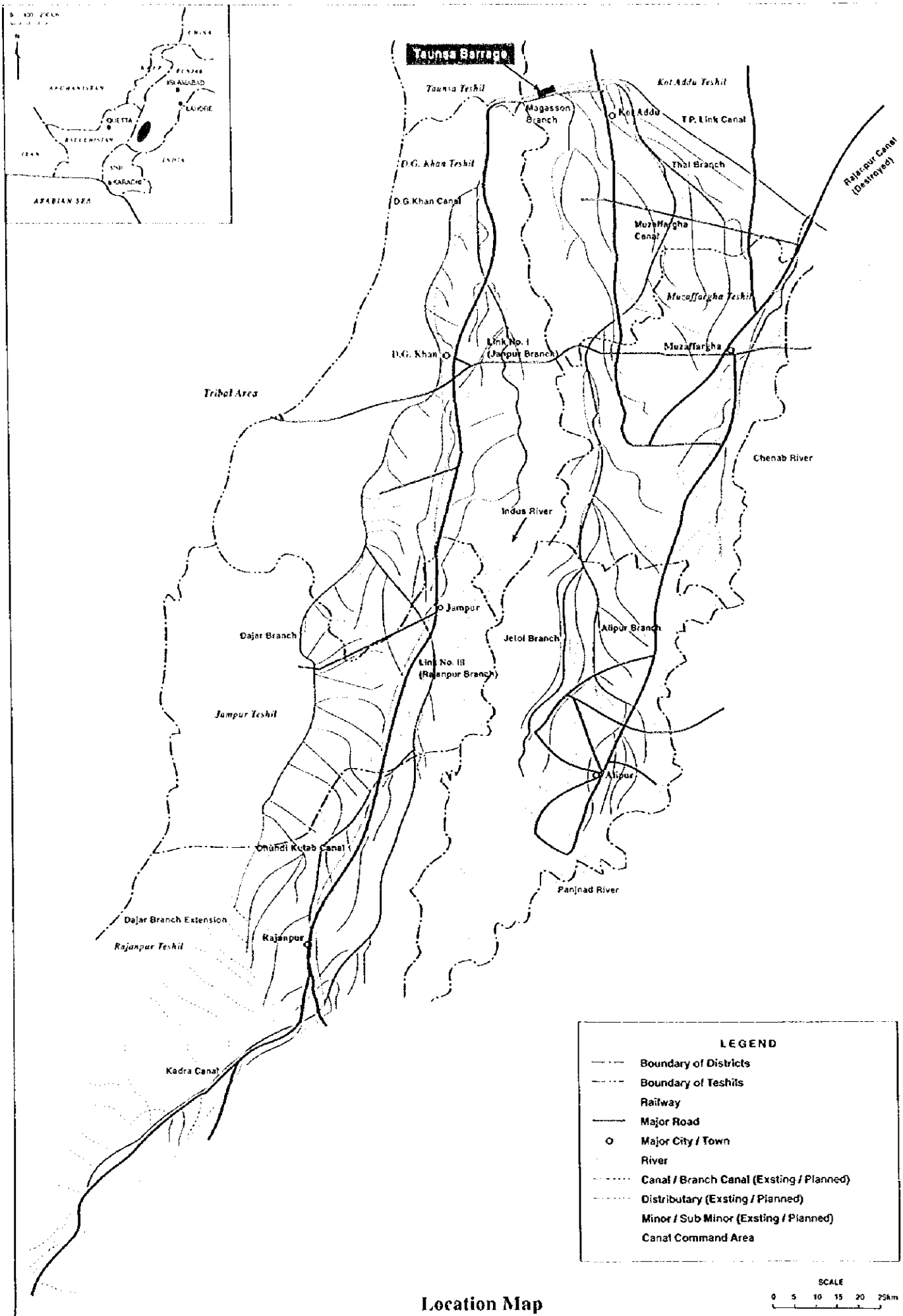
The Study is judged to be quite technical sound, economically feasible and innocuous in the aspect of environment. In the light of deteriorated situation of the irrigation system of Taunsa Barrage, we would recommend that the Project soon be implemented in line with the conclusions presented in this report.

We wish to express our deep appreciation and gratitude to the personnel concerned of your Agency, your Pakistan Office, the Embassy of Japan and the Authorities concerned of the Government of Islamic Republic of Pakistan for the courtesies and cooperation extended to us during our field surveys and studies.

Very truly yours,



Katsuhiko Kimura
Leader of the Study Team
for the Feasibility Study on Taunsa Barrage
Irrigation System Rehabilitation



Location Map

=== SUMMARY ===

This report has been prepared in accordance with the Scope of Work (S/W) for the Feasibility Study of Taunsa Barrage Irrigation System Rehabilitation, in the Islamic Republic of Pakistan (the Study) agreed upon between Irrigation and Power Department (IPD) of the Government of the Punjab and Japan International Cooperation Agency (JICA) on April 14, 1997.

[Background of the Project]

Agriculture is the economic back bone of the Islamic Republic of Pakistan and accounts for 24 % of gross domestic produce (GDP), 47 % of labor force and more than half of exports. The key technology in the Pakistan agriculture is large-scale irrigation development in the history. In recent years, however, a deterioration of the irrigation facilities and poor water management have brought the irrigation efficiency down to about 40 % or less. This is one of the restraints on the growth of crop productivity in the country.

The average annual discharge at rim stations is about 181 billion cu.m. and the diversions to canals are 131 billion cu.m. At the Taunsa barrage, the annual discharge is 105.7 billion cu.m. out of which about 85 % is recorded during Kharif season from April to October and the rest during Rabi form November to March. The three large reservoirs, namely Tarbela, Mangla and Chashma, have been constructed to provide a storage of 18.6 billion cu.m. but still their regulating capacity is far from satisfactory.

Sixteen large barrages have been constructed over the Indus river and its tributaries, Jhelum, Chenab, Ravi and Sutlej rivers. The Taunsa barrage is the most important irrigation facility in the southwest farm lands of the Punjab province.

[Study Area]

Before construction of the Taunsa barrage, many inundation canals were excavated in the study area along the Indus river in the lower Punjab province, and primitive irrigated agriculture was practiced dependent upon inundation / high water discharges in summer season only. With the advent of barrage controlled irrigation and construction of Taunsa barrage, two irrigation canals namely Muzaffargarh canal and D.G. Khan canal off-taking from left and right flanks of Taunsa barrage were constructed .

The gross canal command area (GCA) of Muzaffargarh canal system is about 391,000 ha, lying between the Indus and Chenab rivers. The GCA of D.G. Khan canal system is 401,000 ha, lying on the right bank of the Indus river. On the west of D.G. Khan canal lies a vast piedmont plain served by several hill torrents. In addition, the lower chunk of 51,000 ha of Rangpur canal command area, is directly irrigated by T.P. link canal because of the collapse of the middle reach of Rangpur canal due to a heavy floods in 1992. The total GCA of these irrigation sub-systems sums upto 833,000 ha and the culturable command area (CCA) is 747,000 ha. The extension of Dajal branch canal is planned at the southern end of D.G. Khan canal command area. Besides, T.P. link canal carries water from the Indus to Chenab river, which eventually irrigates Panjnad barrage command area.

The present cropping patterns and intensities in the study area shows that the main Kharif crop is cotton and the main Rabi crop is wheat. Rice, sugarcane and various fodder crops are the secondary important field crops in the study area. Mango is the most important fruit crop and high quality mango is produced in this area. The cropping intensities in D.G. Khan and Muzaffargarh canal command areas are 103 % and 101 %, respectively.

The Taunsa Barrage Irrigation System consists of D.G. Khan canal, Muzaffargarh canal and T.P. link canal. Total length of the canals including main and minor canals is 2,791 km. The present design discharges of the D.G. Khan canal on the right bank, Muzaffargarh canal on the left bank and T.P. link canal are 9,180, 8,285 and 12,000 cusecs, respectively.

In addition to regulation of irrigation supplies, the Taunsa barrage plays important rolls as an arterial road bridge, a railway bridge and an oil pipeline crossing over the Indus river.

[Difficulties and Problems on Taunsa Barrage Irrigation System]

Taunsa Barrage Irrigation System consists of the barrage itself, canal systems, distribution systems, irrigation management systems and so on. Results of the investigation under-taken during the field survey for damages and deterioration of the concerned systems, are summarized in following table:

Structure		Damages and Deterioration
Gate Structure	Gate Leaf	- Undersluices are in severely deteriorated and difficult to operate. - Odd gate leaf structure of undersluices having two plates causes difficulties in operation. Abrasion was observed in lower gate leafs of undersluices. - Large bending buckling and large cracks at joints of end girders of undersluices were found out. - Deformation of flanges at bottom portion of weir gates were observed.
	Shoe at Grooves	- Severe abrasion was observed in every track plates of all gates. - Some rollers are missing, and rubbing with groove due to deformation of roller train. - Drawbacks such as lost, or fallen out roller guard.
	Gate Seal	- Almost all metal seals are missing. - Abrasion of sill beams reducing in reduction of width and damage to the flange were observed.
	Hoist Structure	- In reduction gears, many mal-adjustment, broken bearing and chattering were commonly found. - Covers for drum and interim gear were disturbing the lubrication and accelerating corrosion of the frame. - Cog fitting was considerably bad and slipping out of position and shallow/loose fittings were frequently observed. - Odd design of hoist obstructs is adequate operation and maintenance. - Inconvenience and delay of operation was recognized because of manual gate operation.
	Hoist Deck	- Wooden deck was deteriorated, and pay load capacity and safety have been adversely affected.
	Maintenance Gallery	- Odd design of maintenance gallery obstructs regular operation and maintenance processes.
Hydraulic Structure	Glacis	- Heavy erosion of skin concrete and reinforcing bars were observed on D/S glacis of almost all bays. - Substantial pitching was recognized in sill beam of all gates.
	D/S Concrete Floor	- Ripping up of skin concrete was observed. - Significant separation of skin concrete from mass concrete was identified, in which inter-surface flow was noticed. - Spouting water was observed at some points along the joints.
	Friction Blocks	- Uprooting and deformation of some blocks was observed. - Destruction of skin concrete with which blocks were anchored were observed. Reinforcing bars of skin concrete were found bent up.
	Protection Stone	- Loss, deformation and rolling of loose stone were observed.
Barrage Foundation	Barrage Foundation	- Spouting water was found at some points along joints. - Sub-surface problem which compel to restrict head across to 22 ft, was identified.
	Barrage Abutment	- Pavement settlement due to sub-surface removals was observed.
Canal System	Canal	- Severe silt deposition was observed in D.G. Khan canal. - Remarkable erosion was observed downstream of canals.
	Canal Structure	- Some deterioration on concrete structure and gates were observed. - Insufficient canal escape function was noticed due to deterioration of existing escape structure and inadequate design of structures.

Taking above deteriorated condition into consideration, Taunsa barrage is a prominent system among whole concerned sub-systems to be rehabilitated immediately.

[Rehabilitation Plan of Taunsa Barrage System]

Damages to gate structure are concentrated around bottom of grooves, in rocker assembly and roller trains, etc. Those damages and abrasion are giving rise to a phenomenon of difficulty in gates operation, requiring excessive force / power for operation. This malfunction enhanced by other defects in hoist systems, "soundness and adequacy of gate operating function" as an essential role of the barrage is being hampered.

Such inconvenience can not be mitigated by ordinary activities of operation and maintenance, because general deterioration and progressive damages are irreversible phenomena which warrant resolution of the essential problems. If the damages are left as they are, the difficulty and hardness of gate operation would worsen exponentially, accelerated by forcible gate operation. At present, about 41 kgm torque on an average as equivalent of eight to twelve persons manpower is required for gate lifting, while the design value was 29 kgm. In near future, gate lifting may become an impossible due to irrational increase of requirement of manpower for gate operation, or damage to some portions of gate by excessive force's operation.

The Study made a forecast of increase of gate operation force, on the basis of measured value of required force as of 1997, after a period of 40 years since commissioning of Taunsa barrage. Providing that 87 kgm as equivalent of twelve manpower force is a limit of gate operation as is the case under present manual operation, inoperative gates will be a nasty constraint by 2001, as the gates will be damaged one by one.

It is concluded that urgent rehabilitation is required in the Taunsa barrage system in consideration with present damaged status. The rehabilitation project envisages repairs and rehabilitation of damages as a top priority, and improvements of its function shall be an additional achievement. Conceptually Taunsa barrage rehabilitation proposal would require:-

1) Rehabilitation work should be taken-up as earlier as possible.
2) Rehabilitation scale and method must be selected in a manner to meet with availability and capacity of implementation organization.
3) Present Stony type gate shall be continued within the rehabilitation project.
4) Bulkhead gate is proposed to be used for gate rehabilitation work.
5) Some faults in present design for hoist system and superstructure may also be improved to a maximum possible extent.
6) Minimal remodeling as of hydraulic structure corresponding to hydraulic condition changes, such as progress of retrogression shall be considered.
7) Head across is limited to less than 22 ft provisionally, due to danger in uplift risk. Head across of more than 22 ft is not required in Rabi because of substantial discharge in the river run to meet requirement of water use in

8) Gate rehabilitation should be implemented prior to hydraulic structure rehabilitation. The hydraulic structure rehabilitation shall be done by bay groups after completion of seals and gate rehabilitation.

9) Principal benefit of this rehabilitation project is to improve agricultural benefits through assurance of irrigation water supply.

10) Railway structure is put outside of the rehabilitation project as it is maintained at and operated by P.W. Rail way another agency..

11) Taunsa barrage road bridge is proposed to be rehabilitated in a later / subsequent phase of the Project.

On the basis of the above concept for the formulation of rehabilitation plan, alternatives comprising some improvement works and repair works shall be compared in order to set optimum project scale and project period.

Through the alternative study, optimum rehabilitation has been prepared as follows and the actual construction work will be completed in 6.5 years using six bulkhead gates.

Component	Purpose	Quantity
Gate Structure		
Gate Leaf		
Undersluice Gate	Replace double / Twin gates with one single gate	11 Bays
Weir Gate	Repair damages of bottom lip	54 Bays
Regulator Gate	Replace T.P. Link gate only	1 Bay
Shoe at Grooves	Totally repair	65 Bays
Gate Seal	Water stop rubber lining to be attached	65 Bays
Hoist Structure	Repair and adjust the damages and hindrances	65 Bays
Electrify of Hoisting arrangements	All gates except that of canal regulator shall be provided with electrical hoisting and control	65 Bays
Hoist Deck	Renew the grating	85 Bays
Maintenance Gallery	Install new gallery	85 Bays
Superstructure	Fully painting	85 Bays
Bulkhead Gate	Procurement of bulkhead gates	6 nos.
Hydraulic Structure		
Skin Concrete	Repair of D/S skin concrete	10,400m3
Friction Block	Repair of all friction blocks	1,728 nos.
Protection Stone	Enlarge C.C. blocks	8,218 nos.
Guide Wall in Right Pocket	Extension of its length	L.S.
Pressure Pipe	Install 12 number of pore pressure meters par 13 piers	156 nos.
Barrage Foundation	Grouting over the D/S glacis	1,325 m
Barrage Abutment	Repair barrage abutment	2 nos.
Canal Excavation	Canal bed excavation D.G. Khan canal, 12.192 km long	1.27 mil.m3
Canal Structure	Repair canal escapes	2 nos.
Equipment Procurement	O&M and monitoring equipment	L.S.

[Project Cost and Implementation Plan]

Direct construction cost has been estimated at Rs. 1,964 million and the total construction cost including indirect cost and physical contingency comes to Rs. 2,610 million, as presented below:

Item	Cost (Rs. million)
Direct Construction Cost	1,964.0
Indirect Cost	294.6
Tax and duties	155.4
Physical Contingency	196.4
Total Construction Cost	2,610.4
Price Contingency	1,983.8
Interest and Service Charge	78.3
Project Cost	4,672.5
O&M Cost (Annual base)	28.81
Replacement Cost (10 years base)	22.18

Gate rehabilitation shall be implemented using floating bulkhead gate. The bulkhead gate shall be made in foreign country, and transported to the site in separate components with some spare parts prior to the Taunsa barrage gate work. Gate rehabilitation will be commenced to right side bays which is in severe condition, then proceeding to left side bays, and central part of weir bays.

Civil works on hydraulic structure rehabilitation will be started following the gate rehabilitation work. Coffer dams will be required for sequential working in unit of 13 bays at a time. After stopping seepage water by the drying work, civil works will be taken-up for skin-concrete repair, friction block rehabilitation and concrete block works.

IPD shall be an implementation body of the rehabilitation Project, using contract based implementation. Contract will consist of 6 phases of, 1) detailed design, 2) gate works, 3) bulkhead gate procurement, 4) civil works, 5) equipment procurement, 6) offices building construction. Detailed design of the Project will immediately commence after setting project formation, taking 18 months duration.

After implementation of the Project, the barrage system shall continuously be maintained and operated by Taunsa barrage O&M office (TBO), which will be re-structured for new operational responsibilities.

[Project Evaluation]

The direct beneficial areas of the Project are the command areas of the D.G. Khan canal, Muzaffargarh canal and lower part of the Rangpur canal. Original function of the T.P. link canal, to divert water into Panjnad command area, is taken as an indirect benefit of the Project. Dajal extension project is not accounted for as direct benefit to the area due to uncertainty in realization.

Cropping patterns in the area are assumed to be continued in case of "With Project condition" also. Under Without Project condition, intake discharge as well as irrigated area will diminish due to failure of weir gate operation. In the abandoned farm lands some rainfed cultivation of crops except rice, cotton and sugarcane can only be continued. If rehabilitation works are delayed, irrigated area is likely to reduce to 50 percent within 5 years.

Anticipated cash flow provides economic indicators of NPV as Rs. 26,681 million, B/C as 26.1, and EIRR as 50.2 %. As the annual benefit derived from irrigated agriculture is significantly large compared with the Project cost, these economic indicators are extremely high. As a conclusion, the Taunsa barrage irrigation system rehabilitation project is judged as a economically feasible project.

	Indicator	Result
1	Net Present Value (NPV, 12 % discount rate)	Rs. 26,681 million
2	Benefit Cost Ration (B/C, 12 % discount rate)	26.1
3	Economic Internal Rate of Return (EIRR)	50.2 %

Source: JICA Study Team

This highly feasible Project will provide considerable impact on socio-economic conditions such as 1) supplemental irrigation water supply to Panjnad barrage irrigation system, 2) mitigation of flood damage, 3) improvement of farm economic condition by stable water supply, 4) possibility of Dajal branch canal extension plan, and 5) assurance of non-irrigation functions.

Since proposed rehabilitation work of Taunsa barrage is a preventive measure for existing irrigation system and it does not include expansion of irrigation area, impact of this rehabilitation on environment in the study area is expected to be minimal. However, the impact on the wildlife sanctuary during construction should be taken into account in order to avoid any negative effects on the previous inhabitants.

[Conclusion and Recommendations]

Significant rehabilitation plan of Taunsa Barrage Irrigation System targeted to improve system function, was formulated through this study, with active cooperation of the Irrigation & Power Department, Government of the Punjab.

Through the field survey, present situation of the study area was recognized as having good social life and active agriculture activities under severe natural conditions, which is definitely a gift/boon of Taunsa Barrage Irrigation System. The system, especially Taunsa barrage stands in severe damaged condition just 40 years after its inauguration. If such damages are left as they are, the problems in gate operation will multiply exponentially, and go out of control rendering the discharge regulation as impossible.

Taking these circumstances into consideration, possible methods and alternatives of rehabilitation plan were investigated, sub-system by sub-system for the whole Taunsa Barrage Irrigation System, and then, final rehabilitation plan was formulated.

Soundness and feasibility of this rehabilitation plan in every field i.e.social, economic, financial and environmental are fully established. Economic IRR is indicated at 50.2 %, showing great strides of investment effects, and great loss if the rehabilitation is not taken-up.

Following recommendations are therefore made for implementation:

1) It is recommended to implement the Project as early as possible for the reasons of excellent feasibility.
2) Negotiation with a foreign donors as Japan is recommended to commence as soon as possible.
3) Preparation for establishment of implementation organization for the Project should be taken immediately.
4) It is recommended to propagandize the necessity and urgency of the Project implementation to the beneficiaries, and establish cooperative relation with them for the Project.
5) Damages on the Taunsa barrage system shall be taken care of so as not to hinder the rehabilitation work.
6) Taunsa bridge rehabilitation is proposed to be implemented after completion of the present rehabilitation programme. It is recommended to schedule and prepare the bridge rehabilitation as the second phase of the Project.
7) After success of this rehabilitation project, further high-grade development proposition could be scheduled.
8) Satisfactory actions in O&M in consideration with monitoring result of sediment in right pocket should be taken. After implementation of the Project, installation of a silt

excluder should be reconsidered if necessity of introduction of a silt device is indicated through monitoring of sediment in right pocket. However for installation of a silt excluder, hydraulic mode tests have to be conducted prior to the designing.

9) IPD is recommended to promote a provincial-wide rehabilitation program of existing barrage on the basis of technical outcomes on this Study.

10) Prior to the commencement of detail design, detailed investigation on the damages to downstream portion of hydraulic structure and monitoring of the conspicuous damages is needed for an effective detailed design.

11) Existing data and information should be arranged for convenience of usage for further programmes.

12) Necessary training of concerned personnel and securing land for the Project is recommended to be commence immediately.

13) Water regulation during project implementation should be arranged with concerned offices.

14) Hydraulic model tests are required to be conducted such as macro-scale model tests for Indus river works, model test on hydraulic jump on the glacis of the barrage, model tests for friction block's behavior, model tests for silt problem in the right pocket of the barrage, model tests for adequacy of gate operation rules, and model tests for canal bank erosion downstream of canal structures.

15) As a wildlife sanctuary lies in the pond area upstream of Taunsa barrage, changes in natural conditions is not recommended. If necessary, fish ladders of Taunsa barrage may be improved to suit Indus dolphin's mode of life.

16) It is recommended to strengthen present O&M organization for better function.

17) Rules and regulations shall be improved.

18) New equipment for O&M and monitoring use shall be procured, and training provided to the users/operators.

19) River training works are recommended to follow and continued according to existing programmes.

20) Periodical canal excavation and repair of canal structure is strongly recommended.

21) Workshops should be re-structured for meeting actual demand and future prospectual requirements.

22) Six number of bulkhead gates to be utilized in the rehabilitation work shall be used effectively in maintenance work and rehabilitation work at other barrages in conformity with a certain work schedule, after the completion of the Project.

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ATTACHMENT

DRAWINGS

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Abbreviations

ADB	Asian Development Bank
ADBP	Agricultural Development Bank of Pakistan
ADP	Annual Development Program
AO	Agricultural Officer
ARI	Agriculture Research Institute
AWB	Area Water Board
B/C	Benefit-Cost Ratio
CCA	Culturable Command Area
C.C. (Block)	Cast in situ Concrete (Block)
CE	Chief Engineer
D/S	Downstream
DGK	D.G. Khan
EADA	Extra Assistant Director of Agriculture
EEC	European Economic Community
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EL	Elevation
EPA	Environmental Protection Agency
ETo	Potential Evaporation
FA	Field Assistant
GCA	Gross Command Area
GOP	Government of Pakistan
HYV	High Yield Variety
IEE	Initial Environmental Examination
IPD	Irrigation and Power Department
JICA	Japan International Cooperation Agency
M&R	Maintenance and Repair
MGH	Muzaffargarh
NDP	National Drainage Programme
NESPAK	National Engineering Services Pakistan (pvt) Limited
NPV	Net Present Value
NWFP	North West Frontier Province
O&M	Operation and Maintenance
OECF	Overseas Economic Cooperation Fund
OFWM	On-Farm Water Management
PAD&SC	Pakistan Agricultural Development and Supplies Corporation
PASSCO	Pakistan Agricultural Supplies and Storage Corporation
PC	Prestressed Concrete
PHED	Public Health Engineering Department
PIDA	Provincial Irrigation and Drainage Authority
PSC	Pakistan Seed Corporation
RD	Reduced Distance
RJP	Rajanpur
RL	Relative Level
Rs.	(Pakistan) Rupee(s)
RWSS	Rural Water Supply and Sanitation
S/W	Scope of work
SCARP	Salinity Control and Reclamation Programme
SDO	Sub-Divisional Engineer
SE	Superintending Engineer

T.P. (Link Canal)	Taunsa-Panjnad Link Canal
T-V System	Training and Visit System
TBO	Taunsa Barrage Office
U/S	Upstream
UNDP	United Nations Development Plan
WAPDA	Water and Power Development Authority
WUA	Water Users' Association
XEN	Executive Engineer

Units

mm	millimeter
cm	centimeter
m	meter
km	kilometer
inch	inch
ft	feet
sq.m (m2)	square meter
sq.km (km2)	square kilometer
acre	acre
ha	hectare
cu.m (m3)	cubic meter
MCM	million cubic meter
MAF	million acre feet
kg	kilogram
ton (t)	ton
sec (s)	second
hr	hour
cm/sec	centimeter per second
m/sec	meter per second
cu.m/sec	cubic meter per second
cusec	cubic feet per second
cumec	cubic meter per second
kgm	kilogram meter

1. INTRODUCTION

1.1. Authorities

This report has been prepared in accordance with the Scope of Work (S/W) for the Feasibility Study of Taunsa Barrage Irrigation System Rehabilitation, in the Islamic Republic of Pakistan (the Study) agreed upon between Irrigation and Power Department (IPD) of the Government of the Punjab and Japan International Cooperation Agency (JICA) on April 14, 1997. The S/W is attached to this report as Attachment 1.

This report describes the results of the survey and study during Phase 1 and Phase 2 Study periods. The main issues of the report are background of the Study in chapter 2, present conditions of the Study area in chapter 3, design data of Taunsa barrage in chapter 4, improvement concept in chapter 5, improvement plan in chapter 6, project component and cost estimate in chapter 7, project implementation plan in chapter 8, project evaluation in chapter 9, preliminary study on Taunsa road bridge rehabilitation in chapter 10, and conclusion and recommendations in chapter 11.

1.2. Background of the Project

Agriculture is the backbone of the economy of the Islamic Republic of Pakistan and accounts for 24 % of Gross Domestic Product, 47 % of labor force and more than half of exports. The production of the main crops such as wheat, rice and sugarcane is mostly short, except cotton. According to the forecasting of 2009-10 crop production, all of the main crops are quantitavely deficient by 8.82, 2.95, 21.42 and 0.67 million ton in the country. To meet the growing crop demands, the irrigation water development and efficient water use should be made continuously.

The key technology in the Pakistan agriculture is large-scale irrigation development in the history. The irrigation facilities over the Indus river and its tributaries have contributed to agricultural production. In recent years, however, a deterioration of the irrigation facilities and poor water management have lowered irrigation efficiency downt to at 40 % or less. That is one of the restraints on growth of crop productivity in the country.

Taunsa barrage, one of the 16 barrages in the country, was constructed across the Indus river in 1959. The barrage serves a gross command area of some 900,000 ha through the Muzaffargarh canal and D.G. Khan canal, and diverts water into the Chenab river through the Taunsa Panjnad link canal. The non-perennial irrigation areas of Muzaffargarh and D.G. Khan canal lie on the left and right bank of the Indus, respectively.

Table 1.2.1 Main Function and Features of the Canals

Canal	Function	Feature
Muzaffargarh Canal System	Non-perennial irrigation of GCA 380,000 ha on the left bank.	Design discharge: 8,300 cusec 5 regulator gates at Taunsa
D.G. Khan Canal System	Non-perennial irrigation of GCA 520,000 ha on the right bank.	Design discharge: 8,800 cusec 7 regulator gates at Taunsa
T.P. Link Canal System	Diversion from the Indus river to the Chenab river.	Design discharge: 12,000 cusec 7 regulator gates at Taunsa

The barrage structure has deteriorated specially gates allowing large leackage of water through damaged gates, non-reliable gate control against flood, and lower off-taking capacity than the original design. The Irrigation and Power Department of the Punjab,the owner agency of the Taunsa Barrage, recognizes that the rehabilitation of the barrage is very important and urgent and the studies on stability of the barrage and sediment control around the inlets are necessary for its sustainable operation.

In these circumstances, the Government of Pakistan requested a technical cooperation for the feasibility study on the "Taunsa Barrage Irrigation System Rehabilitation" in January, 1996. In response to the request, the Government of Japan through JICA sent the preparatory study mission to Pakistan to confirm the S/W of the Study in April, 1997. Based on this S/W, the present survey team was dispatched by JICA.

1.3. Objectives of the Study

The objectives of the Study are;

1) to conduct a feasibility study on Taunsa Barrage Irrigation System Rehabilitation in Punjab, and

2) to carry out, in the course of the Study, technology transfer to the Pakistani counterpart personnel concerned through on-the-job training.

1.4. Study Area

The Study covers the Taunsa barrage and related facilities which are located in the southwest post of the Punjab province, 900 km upstream from the mouth of the Indus river.

On the course of the Study, the Taunsa barrage irrigation system which has approximately 900,000 ha of the gross command area and the surrounding areas are investigated and studied as technically required (see "Location Map").

1.5. Scope of the Study

The Study consists of two phases in the study term from August 1997 to July 1998. In the Phase 1, a basic concept on rehabilitation plan for the Taunsa barrage will be identified in the general information and inspection on the barrage and irrigation systems. In the Phase 2, an optimum rehabilitation plan for the Taunsa Barrage Irrigation System will be formulated through detailed survey and analyses, and the final study report will be completed (refer to the S/W in Attachment 1).

Table 1.5.1 Study Items and Outputs

Study Items	Outputs		
	Data Collection	Analysis	Planning
Review on PC-I, S/W, etc.	Background and Status of the Project		Project Implementation Plan
General Information	Background and Status of the Project		Project Implementation Plan
Review on Related Projects	Background and Status of the Project		Project Implementation Plan
Study on Socio-economy	Beneficiaries		Project Evaluation (Benefit)
Study on Agriculture (Remote Sensing Data Analysis under Subcontract)	Land Use, Farming, Crop Production		Project Evaluation (Benefit)
Study on Hydrology	Demand and Supply of Water		Project Evaluation (Benefit)
Study on Irrigation	Irrigation System, Demand and Supply of Water, Water Use	Constraints on Canal System/ Alternative Study on Construction Scale	Rehabilitation Plan (Canal System)
Study on Environment	Natural and Social Environment	Environmental Consideration	Project Evaluation (Environment)
Gate Mechanic Survey (Using Portable Engine Hoist)	Condition of Gate Facilities	Constraints on Gate Facilities/ Alternative Study on Construction Scale	Rehabilitation Plan (Gate Facilities)

Study Items	Outputs		
	Data Collection	Analysis	Planning
Study on Gate Operation	Gate Operation Operation and Maintenance Water Management	Constraints on Water Management/ Constraints on Operation and Maintenance	Rehabilitation Plan (Gate Operation)/ Rehabilitation Plan (O&M)
Survey on Barrage Foundation (Boring Test under Subcontract)	Stability of Foundation	Constraints on Foundation/ Alternative Study on Construction Scale	Rehabilitation Plan (Foundation)
Survey on Hydraulic Structures	Facility Operation	Constraints on Siltation/ Alternative Study on Construction Scale	Rehabilitation Plan (Canal System) / Rehabilitation Plan (Water Management)
Study on Construction Plan	Condition of Construction	Alternative Study on Construction Method	Rehabilitation Plan (Workshop)/ Construction Plan/ Cost Estimate
Study on Project Evaluation	Condition of Evaluation	Alternative Study on Construction Scale & Method	Project Evaluation (Economic, Financial, Environmental)
Study on Project Implementation Plan	Institutional Condition		Project Implementation Plan/ Recommendations

2. Background of the Study

2.1. Socio-economic Conditions in Pakistan

The Islamic Republic of Pakistan has an area of 796,000 sq.km lying between 25° 30' and 36° 45' north latitudes and between 61° 00' and 75° 30' east longitudes. The Indus river originating from Himalayan Mountains runs through the plains in the middle of the country, flows into the Sea of Arabia. The subtropical climate is dominant and arid areas widely spread out in the country.

The territory of Pakistan comprises the four provinces of Punjab, Sindh, Northwest Frontier and Balochistan, the Federally Administered Tribal Areas, and the Federal Capital Territory of Islamabad. The provinces are autonomous units and each has a Provincial Assembly empowered to make laws for that province. For administrative purposes, the hierarchical order is divisions, districts and tehsils.

The population of Pakistan is growing at 2.8 % per annum estimated at 135 million in 1997 and population density accounts to 161 person/sq.km. Main ethnic groups are the Punjabi (59.6%), the Sindhi (11.1%), the Pushtun (9.0%) and the Balochi (2.7%). Main regional languages are Punjabi (48.7%), Sindhi (11.8%), Pusht (13.1%) and Balochi (3.0%). Urdu is the National Language and is spoken and understood in all parts of the country. Ninety-four percent of population is Muslims.

The gross domestic product of Pakistan in 1996/97 attained Rs. 2.48 trillion at current price basis with a growth rate of 2.8 %, which was the same as the population growth rate. The share of agriculture, manufacture and service sectors made up 24.2 %, 26.4 and 49.4 %, respectively.

The balance of payments in 1996/97 was projected as a deficit of $ 2.1 billion with a export of $ 10.0 billion and a import of $ 12.1 billion. Leading commodities in export were cotton group, leather group and rice, sharing the total at 66.6 %, 7.3 % and 5.8 %, respectively. Petroleum products, machinery, foods and chemicals were the main import goods occupying 19.1 %, 19.0 %, 12.9 % and 10.0 %, respectively.

Eighth Five Year Plan (EFYP) is scheduled to be implemented from 1993/94 to 1997/98. Annual growth targets were set at 7.0 % in GDP and 4.1 % in per capita GDP. The annual growth rate of agricultural sector was expected to be 4.9 % during the EFYP period. The primary spectral goal is the achievement of a growth rate higher than the population growth, in order to ensure food security, self-sufficiency and large exportable surpluses. Emphasis was

laid on integrated management of agriculture, irrigation and drainage, efficient land management and efficient water management. The government is reviewing the achievements of the plan and preparing the next Ninth Five Year Plan which might start in July 1998.

2.2. Agriculture in Pakistan

Agriculture sector is the largest economic sector, contributing 25 % of the gross national product, employing 47 % of the labor force, and sustaining 75 % of the population.

The major food crops in Pakistan are wheat and rice, which were raised on 8.1 and 2.3 million ha respectively in 1996/97. The dominant cash crops are cotton and sugarcane, cultivated in 3.2 million ha and 1.0 million ha, respectively. The main vegetables are potatoes and onion, and important fruits are citrus, mango and apple. However, Pakistan has still not achieve a self-sufficiency in food, and 13 % of import constituted food items, such as wheat flour, sugar, tea and edible oils .

Since Pakistan mostly lies in arid and semi-arid climatic zones, its agriculture substantially depends on irrigation. The irrigated area was 17.2 million ha, out of 21.6 million ha of the total cropped area in 1996/97. The irrigated area widely spreads in alluvial plain of Punjab and Sind Provinces. Canal irrigation and canal/tubewell irrigation area occupy about 80 % of total. On the other hand, the rapid irrigation development has brought about water-logging and salinity problem. National Drainage Program and Salinity Control and Reclamation Project (SCARP) have been launched.

Table 2.2.1 Irrigated Area by Water Source in 1996/97

Item	Canals	Wells	Canals/ Wells	Tubewells	Canals/ Tubewells	Others	Total
Irrigated area (mil. ha)	7.51	0.17	0.1	2.83	6.41	0.18	17.2
Irrigated area (%)	43.7	1.0	0.6	16.5	37.3	1.0	100.0

Source: Economic Survey 1996-97, Government of Pakistan

Livestock sub-sector is vital for the overall agriculture sector. A large population of livestock is raised. The population of goats was especially high, standing at third rank next to China and India. About 1 million ton of mutton including goats' meat was produced in Pakistan, making it forth largest producer in the world.

2.3. System of the Indus River

The average annual discharge at rim stations is about 181 billion cu.m, and the diversions to canals are 131 billion cu.m. At the Taunsa barrage, the annual discharge is 105.7 billion cu.m, of which 85 % is recorded during Kharif season from April to October and the rest during Rabi form November to March. The three large reservoir, namely Tarbela, Mangla and Chashma, have been constructed to provide a storage of 18.6 billion cu.m, but still their regulating capacity is far from satisfactory.

The large-scale irrigation facilities over the Indus river and its tributaries, Jhelum, Chenab, Ravi and Sutlej rivers, are summarized in the following table.

Table 2.3.1 Salient Features of Major Irrigation Facilities

Major Irrigation Facility		Salient Feature
Reservoirs:		3 sites
Tarbela on the Indus river	Effective storage capacity	11.5 billion cu.m
Chashma on the Indus river	Effective storage capacity	0.6 billion cu.m
Mangla on the Jhelum river	Effective storage capacity	6.5 billion cu.m
Barrages:		16 sites
Canal irrigation system:		43 systems
Canal length under IPD*:		59,000 km
Link canal system**:		12 systems
Diversion structure:		100,000 sites
Length of watercourses and on-farm canals:		1,600,000 km
Irrigation command area:		16,800,000 ha

* Main Canal, Main Branch, Major Distributory and Minor Distributory

** Link Canals divert water from the Indus, Jhelum and Chenab rivers into the Ravi and Sutlej rivers. India has the prior rights on the waters of Ravi and Sutlej.

The Water Apportionment Accord was signed in March 1991 between the Federation and four provinces to distribute available water to provinces and to ensure increased availability of irrigation water for sustainable agricultural production. Since the Indus irrigation system is made of earthen canals constructed on porous alluvial soils, considerable seepage losses are observed. In addition, due to age, overuse and poor maintenance, canal delivery is inefficient. Average delivery efficiency is 35 to 40 % from the canal head to the root zone. The loss not only reduces available water for crops, but also brings about waterlogging and salinity. Although the cropping intensity has increased from 70 % at the initial planning stage in 19th century to 100 % at present in the Punjab province, the irrigation efficiency grows too slowly to support the cultivation progress.

2.4. Institutional Reform in Water Sector

The Government of Pakistan acknowledges that one of the most serious constraints is the colonial institutional system which does not allow the beneficiaries to participate in the development, O&M process of economic resources. 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.

The Government of Pakistan in 1991 undertook an environmental assessment study of irrigation related drainage of which National Drainage Programme (NDP) was a conceptual part. Then, NDP-I, a first phase of the 25-year World Bank assisted programme, has been commenced in 1995. The NDP-I envisages that the problems faced by drainage sector cannot be addressed in isolation by increased financial input. It, therefore, recommends multi-facet approach including institutional and policy reforms, initiating changes in the legal and regulatory framework to allow farmers and private sector participation in improving management of public expenditure to increase allocation for O&M.

Among the components as policy, institutional affairs, research and study, and investment in the NDP-I, institutional reforms concerning to the IPD are as follows.

(1) Provincial Irrigation and Drainage Authority

The proposal for institution reforms as given in the NDP-I is normally concerned with WAPDA and provincial IPDs. The forms in provincial IPD and the formation of farmer's association for O&M are stipulated in the ordinance which has been just legislated in July, 1997. Broadly the ordinance would establish Provincial Irrigation and Drainage Authorities (PIDAs) in each of the four provinces and Area Water Boards (AWBs) in the canal command areas.

The PIDAs are autonomous bodies controlled by a Board of Directors, the Chairman of which is the Additional Chief Secretary Planning and Development of the provinces. In case of the Punjab it is the Chairman P&D Board. The authority and its members will meet at least once in three months or earlier as the case may be and will be on a non-permanent basis. The authority will appoint a Managing Director and a Board of Management who will be responsible for day to day working of the authority.

However, the corporate body of PIDA will be fully empowered to hold property, to do planning and development of water sector projects within the provinces, to operate and maintain the irrigation, drainage & flood control systems. The autonomous PIDA will prescribe and collect fees and other charges from the farmers, obtain loans from national and

international financial institutions and formulate financial policies. The authority will be fully operational within an period not exceeding seven years.

With regard to the existing employees of the IPD, it is stated that the employees of such departments will become automatically employees of the authority. The authority would then prone and reduce the staff in rational manner. The authority will be financed through (i) water charges, sale proceeds etc., (ii) grant made by the Government, (iii) loan obtained from the Government; (iv) grant made by local bodies, (v) sale proceeds of bonds etc., (vi) loan obtained from the financial institutions with the general sanction of the Government; and (vii) foreign assistance or loans from foreign agencies with the approval of the Government.

(2) Area Water Boards

The Government will establish Area Water Boards (AWBs) under the control of the PIDA for canal command areas. Constitution of the AWBs will include a Managing Director, two elected representatives of farmer's organizations, a representative of the PIDA, Director Agriculture, two technocrats with proven background in water resources management and finances, and one member representing the Government.

Under the above board there will be established a Board of Management under the Managing Director with two or three members. The functions of the AWB are as follows.

- To receive water supplies from PIDA and deliver the same to the farmer's organizations at distributory/minor level.
- To receive drainage affluent from the farmer's organizations and convey the same through relevant drains.
- To establish the water rates to be charged from the farmers both for supply of irrigation water and proposal of drainage surplus. The AWB will be delegated the powers of PIDA both for managing, operating and developing water resources and recovery of charges from the farmers.

(3) Farmer's organization

The ordinance specifies that within one year of the formation of AWBs they will implement pilot program policies and take steps thereunder the ensure that farmer's organizations are formed at minor/distributory level in a phased and orderly manner. The farmer's organization so formed should be made financially self sustaining and self sufficient for the effective performance of their functions within a maximum period of four years. The authority shall within six months of its coming into being publish bye-laws and regulations relevant to the

formation of farmer's organization in the provinces. The functions of the farmer's organizations are as follows.

- To manage, operate and improve the irrigation and drainage infrastructure located within the area under their jurisdiction.

- To obtain water from AWBs concerned at the head of the distributory/minor and supply the same to water users.

- To receive the drainage affluent from the water users and convey the same through field/collector drain to designated nodal points of the drainage system.

- 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 AWBs concerned.

- To engage, hire and employ any consultants, advisors and employees for the performance of their functions and powers on their own prescribed terms and conditions.

- Any other powers which may be prescribed under regulations prepared by the authority.

The farmer's organizations will be corporate bodies but they have not been empowered to transfer or dispose of any assets given or transferred to them. The statutes also provide for appointment of Provincial Water Commissioner who will resolve disputes between the authority, the AWBs, the farmer's organizations and water users under a given procedure.

3. PRESENT CONDITIONS OF THE STUDY AREA

3.1. General Conditions of the Study Area

The Study area is located in the southwest part of the Punjab. Taunsa barrage constructed across the Indus river is located at 30° 31' N and 70° 51' E. The general layout of the irrigation system is shown in the following figure. The gross canal command area (GCA) of Muzaffargarh is about 391,000 ha between the Indus and Chenab rivers. The GCA of D.G. Khan canal system is 401,000 ha lying on the right bank of the Indus river. On the west of D.G. Khan lies a vast piedmont plain flooded by Hill Torrents. In addition, the lower part of Rangpur canal area, some 51,000 ha, is directly irrigated by T.P. link canal in these years because of the collapse of the middle reach of Rangpur canal by a heavy flood in 1992. The total GCA of these direct irrigation sub systems sums into 833,000 ha and the culturable command area (CCA) is 747,000 ha.

The extension of Dajal branch canal is planned in the lower portion of the area. Besides, T.P. link canal carries water from the Indus to Chenab river, then eventually irrigates Panjnad barrage command area.

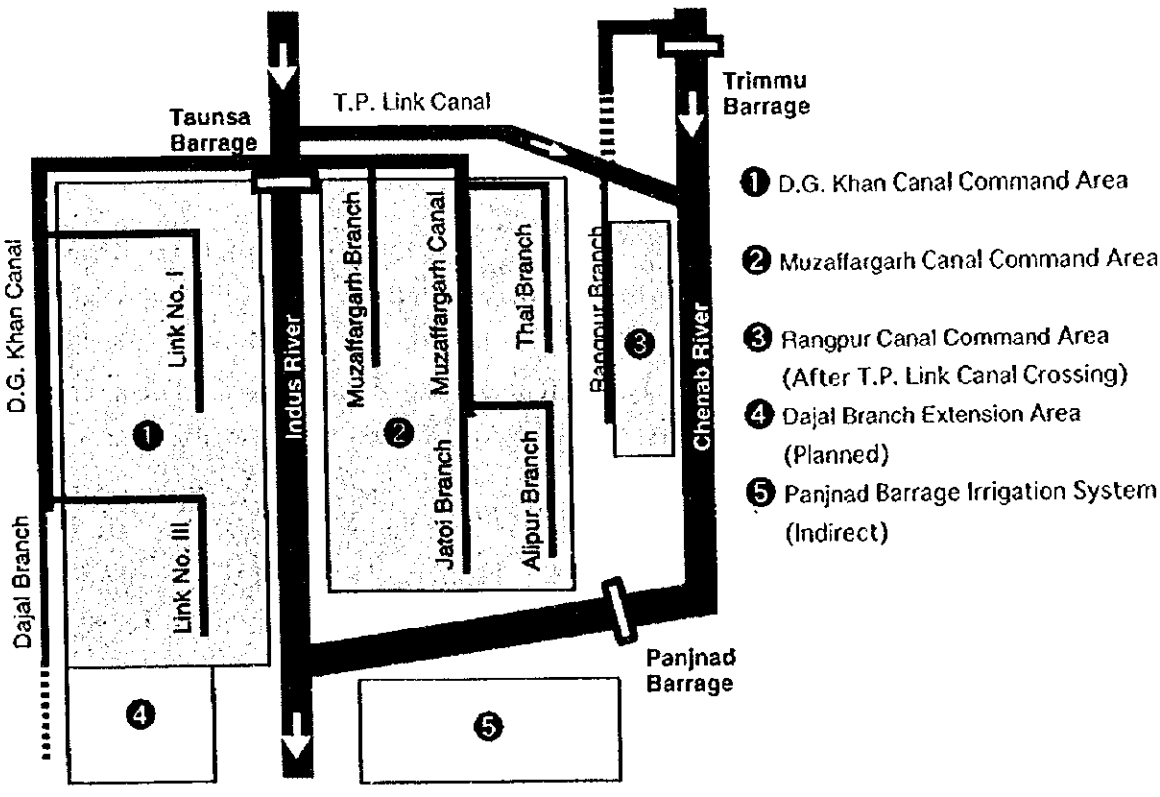

Fig. 3.1.1 General Layout of Taunsa Barrage Irrigation System

Table 3.1.1 Canal-wise Gross Canal Command Area and Culturable Commanded Area (1996-97)

(ha)

	Canal	Gross Command Area	Culturable Command Area
1	D.G. Khan Canal	405,000	385,000
2	Muzaffargarh Canal	367,000	314,000
3	Rangpur Canal	51,000	48,000
	Total	833,000	747,000
4	*Dajal Branch Extension (Planned)*	*132,000*	*126,000*
5	*Panjnad System (Indirect)*	*615,000*	*549,000*

Source: Canal Divisions of IPD Punjab (for 1, 2 & 4)
Punjab Irrigation Directory (for 3)
Punjab Development Statistics 1995 (for 5)

The climate of the Study area is characterized by extremely hot summer and scarce rain. The temperature of the area is about 26 °C in annual average, ranging from 41 °C in June to 5 °C in January. The average annual rainfall is about 200 mm only, of which 70 % is recorded from June to August. The pan evaporation is about 2,400 mm a year, much higher than the rainfall.

The flood discharge of the Indus river is observed in July and August at more than 10,000 cu.m/sec. The average maximum discharge during 1958 to 1995 is 13,600 cu.m/sec at the Taunsa barrage. On the other hand, the low river discharge is about 1,000 cu.m/sec occurring in January.

3.2. Socio-economy of the Study Area

The area is administratively covered by the 3 districts of Muzaffargarh, D.G. Khan and Rajanpur within the D.G. Khan division. The upper right bank area of the Indus is D.G. Khan district, the lower is Rajanpur district, and the left bank area is Muzaffargarh district. The number of tehsils is 11 in the districts, but four of those do not or scarcely concern the irrigation command area of the Taunsa system. The three districts have a total area of 32,489 sq.km and a total population of 3.1 million according to 1981 population census. The late population estimate shows approximately 5.7 million population settles in the districts. The population density is estimated at 174 per sq.km in average. For the 7 tehsils mostly overlapped with the Study area, the population is 4.8 million and the density is 291 per sq.km.

Table 3.2.1 Area and Population by Tehsil in the Districts Concerned

District/ Tehsil	Total Area (sq.km)	Population (Census 1981) ('000)	Population (End of 1995) ('000)	Population Density 1995 (/sq.km)
D.G. Khan	11,367	944	1,743	153
D.G. Khan	3,814	636	1,132	297
Taunsa	*2,769*	*226*	*418*	*151*
Tribal Area	*4,784*	*82*	*193*	*40*
Rajanpur	12,873	639	1,147	89
Jampur	2,322	276	494	213
Rajanpur	2,078	214	382	184
Rojhan	*3,742*	*127*	*220*	*59*
Tribal Area	*4,731*	*21*	*51*	*11*
Muzaffargarh	8,249	1,498	2,778	337
Alipur	1,391	244	457	329
Kot Addu	3,471	449	869	250
Muzaffargarh	2,378	575	1,023	430
Jatoi	1,010	229	429	425
Total (All tehsils)	32,489	3,081	5,668	174
Total (Tehsils concerned)	16,463	2,624	4,786	291

Note: Italic rows shows tehsil not or less concerned with the canal irrigation command area.
Source: 1996 Statistical Pocket Book of the Punjab

About 90 % of the population inhabit rural area. The labor force constitutes about 28 % of the total population. Major occupation group is "agriculture and animal husbandry", which constitutes more than 60 % of the labor force. The literacy ratio in the area is estimated at around 20 %.

3.3. Taunsa Barrage Irrigation System

3.3.1. Taunsa Barrage

Basic idea of the development of Taunsa barrage was initiated in late 1930s. In those days, many inundation canals were excavated in the Study area along the Indus river, and flood irrigated agriculture was prevailing with intake of high water discharge in Kharif season. At that time, waterlogging problems which would have been newly created by the intensive irrigation of the Taunsa barrage area was foreseen. Consequently non-perennial irrigation system was proposed.

Site selection of the barrage was made in early 1950s along the river course of the Indus between the vicinity of D.I. Khan of upstream and D.G. Khan on the downstream, considering joint enterprise with road bridge and railway bridge. The pond level of the barrage was

designed at El. 446 ft considering a sufficient head of 4 ft to feed existing inundation canals. An idea of hydropower generation plan using the drop head from the main canal to the secondary canal was studied to cope with coming waterlogging problem by means of the installation of electrified tubewells.

The construction of the barrage was completed in 1958, and the outline of the barrage is as follows:

Table 3.3.1 Outline of Taunsa Barrage

Facility	Nos. & Width	Dimension	
Barrage			
Total Length		4,346 ft (1,324.66 m)	
		Sill (El.)	Height of gate
Right Bank Undersluice Bay	4 unit * 60 ft (18.29 m)	425.0 ft	22.0 ft
Left Bank Undersluice Bay	7 unit * 60 ft (18.29 m)	425.0 ft	22.0 ft
Weir Bay	53 unit * 60 ft (18.29 m)	428.0 ft	19.0 ft
Navigation Lock	1 unit * 22 ft (18.29 m)	425.0 ft	
Fish Ladder	2 unit		
Pier Thickness	7 ft		
Head Gate			
		Sill (El.)	Height of gate
Right Bank, D.G. Khan Canal	7 unit * 24 ft (7.2 m)	433.0 ft	13.5 ft
Left Bank, Muzaffargarh Canal	5 unit * 24 ft (7.2 m)	433.0 ft	13.5 ft
Left Bank, T.P. Link Canal	7 unit * 24 ft (7.2 m)	433.0 ft	13.5 ft
Discharge			
Design Flood		1,000,000 cusec (28,317 cu.m/sec)	
Head			
D.G. Khan Canal		8,301 cusec (235.1 cu.m/sec)	
	interim	9,180 cusec	
Muzaffargarh Canal		8,285 cusec (234.6 cu.m/sec)	
T.P. Link Canal		12,000 cusec (339.8 cu.m/sec)	
Total		28,585 cusec (809.5 cu.m/sec)	
Bridge			
Road Bridge (Roadway 24.00 ft, Sidewalk 2 lanes * 6.75 ft)		l = 4,346 ft	w = 37.5 ft
Railway Bridge (Single broad gauge)		l = 4,346 ft	w = 5.5 ft
Pipeline (Gas)		l = 4,346 ft	ø = 16 inch
Pipeline (Oil)		l = 4,346 ft	ø = 16 inch

3.3.2. Canal System

D.G. Khan canal at the right side and Muzaffargarh and T.P. link canals at the left side are fed with water from the Taunsa barrage. The main canals supply the water into the canal systems. Branch canals which branch off from the main canals function as conveyance channels up to distributories and minors in the respective irrigation divisions. These channels distribute water to the watercourses. Small scale private pumping stations have been constructed along

the D.G. Khan main canal and Dajal branch canal at 1 to 2 km interval to irrigate the right side tracts of the both canals under the sanction of water right, where gravity irrigation is inapplicable because of high configuration of the irrigable areas.

T.P. link canal constitutes the last unit of 8 link canals constructed under the Indus Basin Development Plan. This link canal, as identified by its name, transfers the Indus water available within 12,000 cusec at Taunsa barrage into the Chenab river about 180 km upstream of Panjnad barrage, to meet historic requirements of the Panjnad and Abbasia canals off-taking from Panjnad barrage.

Type of the canals is totally earthen open canals from the head to the tail. The tremendous seepage water from the earthen canal causes not only lowering irrigation efficiency but also heightening the groundwater table to create waterlogging problems.

Table 3.3.2 Main Features of Main Canals at Head

Canal	Crest level of head gate (ft)	Bottom Width (ft)	Water Depth (ft)	Canal Slope	Design Discharge (cusec)	Remarks (cusec)
D.G. Khan Canal	EL. 433.0	260	12.0	1/10,500	8,301	14,200*1
Muzaffargarh Canal	EL. 433.0	200	11.8	1/8,000	8,285	
T.P. Link Canal	EL. 433.0	266	12.2	1/9,090	12,000	14,000*2

Remarks *1: Including Dajal Branch Extension
*2: Maximum Capacity

For the designing of the canal L-section, maintaining of allowable velocity and prevention of sedimentation of suspended load were carefully considered under regime canal concept, and the canal slope at the downstream is larger and drops were constructed on the steep canal alignments.

Table 3.3.3 Canal Length

(Unit: km)

Canal	Main Canal			Secondary Canal		Total
	Canal	Branch	Feeder	Disty	Minor	
D.G. Khan Canal	105.2	119.4	12.6	1,317.2	133.9	1,668.3
Muzaffargarh Canal	113.0	124.2	0	789.9	14.7	1,041,8
T.P. Link Canal	61.2	0	0	0	0	61.2
Total	279.4	243.6	12.6	2,107.1	148.6	2,791.3

Two silt ejectors on the D.G. Khan canal and one on the Muzaffargarh canal were constructed at the points about 2 to 6 km downstream from the Taunsa barrage head gate.

Adjustable proportional distribution type head regulators with standardized slide gates were provided at the key location of the main canals to distribute water to links, branches and major distributories. Moghas which have no water control device like gate are provided on the parent canals to distribute water into watercourses.

Escape canals are provided to secure canal system from accidents. In the case of D.G. Khan canal, hill torrent from the Sulaimam mountains sometimes attacks right side canal dike in summer, and the escape has the role to cope with the outbroken flood.

Table 3.3.4 Discharge Capacity of Escape

Canal	Location	Design Discharge of Escape Canal (cusec)	Design Discharge of Parent Canal (cusec)
D.G. Khan Canal			
Gajani	RD 88,500	5,000	7,744
Link No III	RD 227,820	1,000	1,224
Muzaffargarh Canal	RD 246,800	3,900	2,606

Along the D.G. Khan canal which is often attacked by hill torrent form Sulaiman mountains, the 20 hill torrent crossing structures were set to avoid its damage. The design flood discharge of the hill torrent crossing ranges from 200 to 40,000 cusec depending on the catchment. The crossing structures consist of 16 syphon super passage types, 3 super passage types and 1 syphon aqueduct type.

3.3.3. Available Water for Taunsa Barrage Irrigation System

The allocation of irrigation water was regulated by the Water Appointment Accord signed in 1991. The water right of the Taunsa barrage is provided for D.G. Khan canal and Muzaffargarh canal. The discharge of T.P. link canal is controlled as a part of the Panjnad water right, as shown in the following table.

Table 3.3.5 Available Water under Indus River Water Apportionment Accord

(Unit: MAF)

Irrigation Scheme	Water Appointment			Remarks
	Kharif Season	Rabi Season	Annual	
Taunsa				
Taunsa	4.19	1.50	5.69	D.G. Khan & Muzaffargarh canals
Panjnad	3.40	1.52	4.92	T.P. Link Canal
Punjab Province	37.07	18.87	55.94	
Downstream of Taunsa	36.79	15.84	52.63	Balochistan & Sindh provinces

The annual water use plans based on the standard water allocation and anticipated hydraulic circumstances are submitted to the Indus River System Authority (IRSA) by each province to be approved. The water of the Indus is used among the provinces under monitoring and coordination of the IRSA.

In Punjab, the Regulation Division of the IPD has a responsibility for the water of the Indus river. The division controls and monitors all irrigation schemes related to the Indus, reports the water use record to the IRSA, and coordinates with other provinces. The hydraulic facility operating offices of the IPD can adjust the intake discharge upon the indents, within the total quota of water supply of the Punjab.

The Taunsa barrage is also orderly operated by the Taunsa barrage office of the IPD under the above mentioned rule. To keep proper operation, the Taunsa barrage office regularly communicates other barrages to know intake and flow discharge at each site, and receives daily indents from the canal offices.

3.3.4. Operation of Taunsa Barrage Irrigation System

(1) Gate Operation of Taunsa Barrage

All gates of the Taunsa barrage are operated manually for the all purposes of 1) regular controlling of pond level and discharge, 2) controlling of flood flow, 3) flushing of sediment by the under sluice gates, and 4) opening gates during annual closure.

Regular controlling of pond level and canal discharge is done by adjusting operation of the barrage gates (both weir and undersluice gates) and the head gates. In Kharif operation, to

secure intake water of D.G. Khan canal, the pond level is often set more than 447 ft, which exceed 1 ft higher than design level, because of shrinking of the canal section caused by heavy sediment.

In flood time, the barrage gates and canal head gates are operated properly and smoothly to minimize the flood damage. Those openings of all gates should be the same, and differences of openings between adjoining gates are limited by 2 ft.

During flushing of the sediment pocket by undersluice gates, all head gates should be closed for about 3 days.

During annual closure period in every Rabi, maintenance works such as repainting or changing broken roller trains and beams are done intensively by workshop staff in the condition of all fully-opened gates. At the same time, changing broken bearings of hoisting equipment and adjusting the length of chains are done.

(2) Rules and Regulations on O&M

The Taunsa barrage is orderly operated by the Taunsa barrage division on the bases of the Rules and Regulations for the Maintenance and Working of Taunsa Barrage (L.B. No. 112, April 17, 1965) with an certain organization.

1) Regulations on undersluice bays

The maximum intensity per foot run permissible is 320 cusec which should never be exceeded. As soon as the average sediment level in the pocket rises to RL 429, the undersluices should be opened and silt flushed out to below RL 425.

2) Regulations on weir bays

The maximum intensity per foot run permissible is 250 cusec which should never be exceeded. The weir bay No. 35 is the symmetry axis for regulation and the opening is spread out towards the two divide walls on either side of bay No. 35. The difference between the opening of two adjoining gates should never exceed 2 ft.

The various discharge limits indicating the flood conditions at Taunsa barrage are; normal discharge of up to 300,000 cusec, low flood of between 300,000 and 450,000 cusec, medium flood between 450,000 and 600,000 cusec, and high flood of over 600,000 cusec.

3) Regulations on divide walls, lock gate and fish ladder

The head across permissible between both sides of divide wall is 3 ft and should never be exceeded. The main lock gate on the crest is to remain closed usually up to 500,000 cusec discharge (450,000 cusec as original).

4) Regulations on upstream pond

Raising or lowering of pond level during the varying conditions of head across should be at a speed of 0.25 to 0.5 ft/hr and may in real emergency be exceeded with reason.

5) Mode of placing and receiving indents

The indenting officers, executive engineers in charge of Muzaffargarh canal and D.G. Khan canal, issue indents to the sub-divisional officer headworks. The Taunsa barrage office control the canal discharge based on the indents.

6) Regulations of silt ejector

When difference in water levels between upstream and downstream of the silt ejector is more than 1.0 ft the silt ejector be closed.

7) Regulation of gates and gearing

All gates should be worked in turn, up and down at least once a week to check up the hoisting machines and remove and wash out any obstructions. The roller trains should be thoroughly inspected, cleared and greased periodically and repaired. Lubrication is provided with grease which is to be inserted on periodical inspection. The suspension ropes should be thoroughly cleaned and greased once a year during winter. All the iron works which remain under water should be painted annually with Khankl mixture. For all other iron work gray graphite paint is done.

(3) Monitoring of Taunsa Barrage

The log books; namely operator charge book (in vernacular), operator log book (in vernacular), overseer's log book (in English), and log book for gates and gearing and other mechanical install sections are recorded daily or periodically.

Besides, the occasional and periodical observation; namely discharge observations, silt soundings in each undersluice pocket and canal, silt observation through silt analysis, pressure pipes in the barrage area are made, and proper record of the same is kept in the appropriate registers.

Furthermore, the annual reports, namely annual headworks report, annual survey report, annual closure report, and history of headworks are completed and circulated.

(4) Operation of the Canal System

The executing water management of the Taunsa barrage irrigation system is supply oriented so called "available supply" targeting the demand within available water. The canals are of earthen, extensive water distribution of "adjustable proportional module" and less sophisticated. The canals were designed as "regime canal" to minimize siltation throughout the route considering the water flow at the design discharge during Kharif season.

The low discharge and slow velocity in Rabi season, however, causes considerable siltation on the canal bed. The canal warabandi, rotation system among canals is carried out aiming at fair water distribution and easy weed control in canal, even though the operation of regulator gates is relatively complicated.

The IPD uses its own communication system in operation of the canal system. The telegraph system was replaced by wireless telephone in 1992. All information of discharge of the canals is gathered from and distributed to all irrigation engineers concerned every day.

The canals should be kept in good conditions to achieve fruitful performance of the irrigation system. The main points of canal maintenance in the Taunsa barrage irrigation system are sedimentation, weed, O&M road, side slope and seepage.

(5) River Training Works

The IPD has constructed a number of river training works from time to time, in order to execute an effective control over the river.

Recently, due to being masked with "Pacca Bela" in the upstream of the Taunsa barrage, there is no appreciable central single creek, thus the river water approaches the barrage from right and left arms. The right arm creek carries most of the discharge during higher floods. Since almost entire river discharge is coming from right side, spur No. 5 has created an unprecedented complex hydraulic flow phenomena. The turbulence caused around the spur is carried towards right pocket in which bed-loads is pushed up to suspended loads. The bed load and suspended load pushed up by turbulence is drawn towards the right pocket and into D.G. Khan canal.

The left arm of the Indus river downstream of the barrage is now active, since the right side of the river has been masked with bela. Efforts to check the left arm by construction of series of spurs have been taken during the previous years.

Furthermore, in order to secure the safe passage of floods through Taunsa barrage, the Flood Fighting Plan of Taunsa Barrage has been launched by Taunsa barrage division, Muzaffargarh circle, IPD since 1977. In the plan, details of readiness and capabilities to face various flood stages in terms of men and materials are proposed.

3.3.5. Administration of Taunsa Barrage Irrigation System

The Irrigation and Power Department of the Punjab has all responsibility of O&M on the Taunsa Barrage Irrigation System. Operation and maintenance of the irrigation systems in the Punjab province are divided into six zones, and the Taunsa barrage irrigation system is under D.G. Khan zone office. The four circles under D.G. Khan zone office are divided into two or three divisions with installation of field officers, and closely related to the project. The organization charts of the IPD are shown in the following figures.

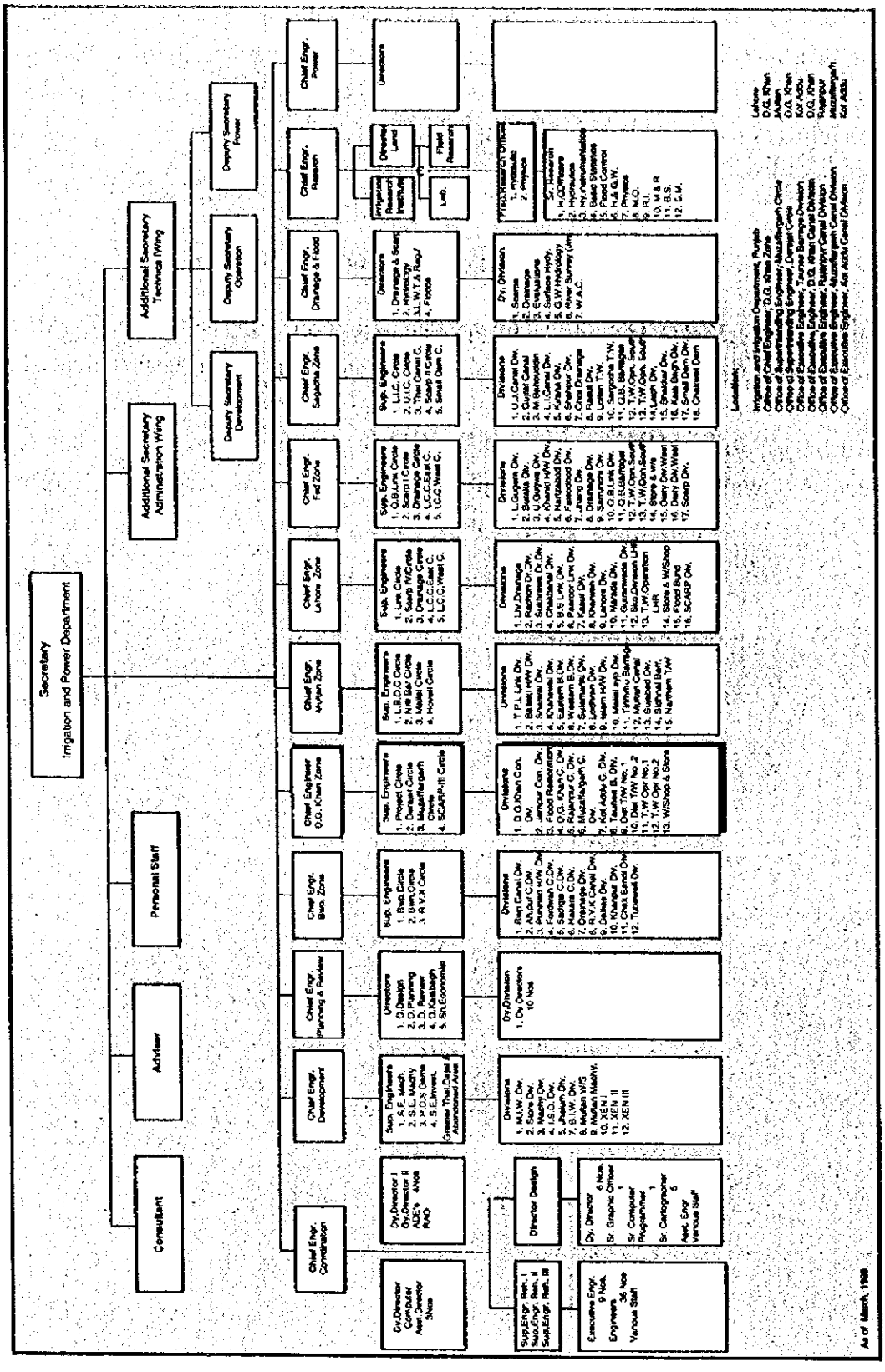

Fig. 3.3.1 Organization Chart of Irrigation and Power Department of the Punjab

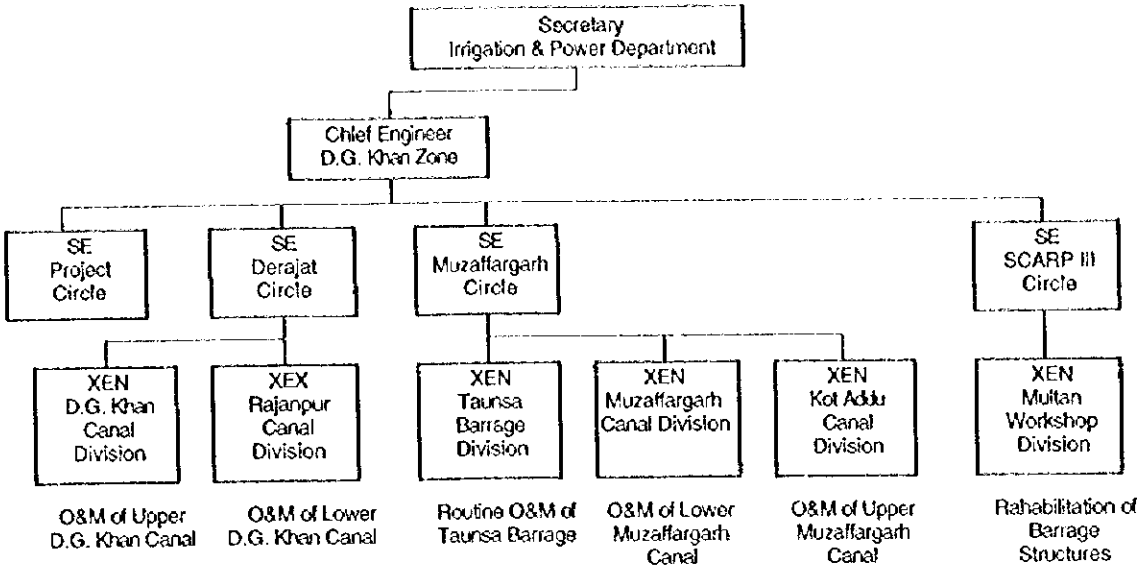

Fig. 3.3.2 Major Sections of IPD Related to Taunsa Barrage

The chief engineer (CE) of D.G. Khan zone controls the Taunsa barrage and both the canal irrigation systems. There are four superintending engineers (SEs) under the CE, managing Project circle, Derajat circle, Muzaffargarh circle and SCARP-III circle. Under the SEs, 11 executive engineers (XENs) are authorized to manage their specified divisions.

The Taunsa Barrage division is responsible for routine O&M of the Taunsa barrage and the related structures. There are three sub-divisional officers (SDOs) having responsibilities for bunds, headworks and workshop, respectively. The organization of SDO headworks, which directly operates O&M works of the Taunsa barrage, comprises 145 lower staffs. The large-scale rehabilitation works of the barrage gates in the Punjab are undertaken by the SE Mechanical circle at Lahore.

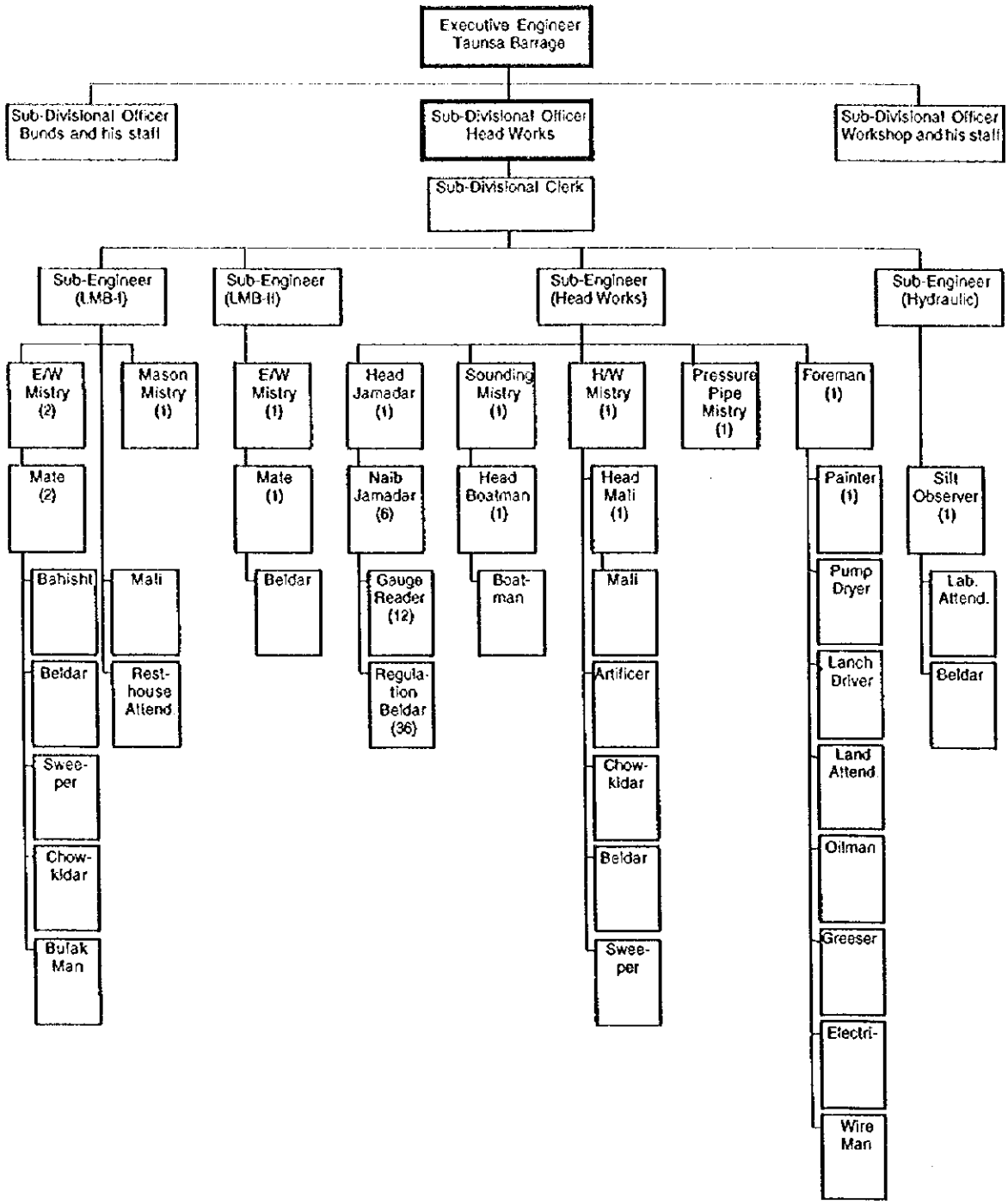

Fig. 3.3.3 Organization Chart for SDO Headworks of Taunsa Barrage

The D.G. Khan canal irrigation system is maintained by the XEN D.G. Khan canal division for the upper portion and by the XEN Rajanpur canal division for the lower portion. The Muzaffargarh canal irrigation system is the responsibility of the XEN Kot Addu canal division for the upper portion and the XEN Muzaffargarh canal division for the lower. The XEN Kot

Addu canal division also manages T.P. link canal diverting authorized discharge from the Indus river into the Chenab river. Further, the XEN Muzaffargarh canal division manages the Rangpur canal irrigation system after the regulator at the crossing with T.P. link canal.

The budget of the IPD consists of "Annual Development Program (ADP)" and "Maintenance and Repair (M&R)" budget. The ADP budget is used for the project implementation. For example, D.G. Khan construction division of the IPD requested about Rs. 2 billion of ADP for the works under the National Drainage Programme.

The M&R budget consists of M&R-works for direct construction costs and M&R-establishment for the administration costs and wages and salary. The "work plan" is prepared for the annual M&R-works budget by XENs then adjusted at a zone level every fiscal year. The budget is estimated on the basis of the "yardstick", a standard unit rate. The annual O&M budget of Taunsa barrage division is about Rs. 17 million. Of which, the cost on maintenance and repair works of the barrage is approved as Rs. 6.8 million and that on embankment of spurs and banks is as Rs. 5.3 million for 1997-98. The M&R-works budgets of D.G. Khan, Rajanpur, Kot Addu and Muzaffargarh canal divisions range from Rs. 12 million to Rs. 22 million.

The M&R-establishment amounted to Rs. 460 million for Muzaffargarh irrigation circle and Rs. 200 million for D.G. Khan circle according to the 1996-97 allocation record. Most of the M&R-establishment spent for wages/salary and many kinds of allowances. The M&R-establishment for the Taunsa barrage division was Rs. 15.0 million in 1996-97.

The major revenue of the irrigation system is from water rates (Abiana) recovered from the farmers. The IPD has many revenue staff assessing Abiana, which is fixed by the government for each crop. The revenue staff measures the area correctly under each crop every six months. The assessed water charge is reported to the Deputy Collectors of canal divisions, then the charge is collected by the Revenue Department. In case of crop failure the IPD has the powers to remit quarter, half or full water charges.

3.4. Agriculture in the Study Area

3.4.1. Land Use and Cropping Pattern

(1) Soil and Land Use

Most of the Study area is included in the active flood plains on both sides of the Indus river. A part of the Study area on the right bank comprises the piedmont plains extended upto

Sulaiman mountains. The piedmont plains are dominated by the alluvial fans developed along the several hill torrents located to the west of the D.G. Khan and Dajal branch canals. In order to avoid the destruction of the D.G. Khan and Dajal branch canals by the floods of these hill torrents, there are crossings on the canals which are open rectangular concrete channels. In case of large floods, the flow at some crossings may be backed up which results in overtopping of these canals and breaching of their banks. Floods that cross into the command area cause extensive damage to crops and infrastructure and contribute to the waterlogging in the area. These floods from hill torrents are, therefore, considered to be the main constraints for the development of agriculture in the area. On the contrary, the northern part of the left bank is mostly covered with rolling sand plains/dunes and the shifting sand sometimes causes the negative effect to the regional agriculture. Furthermore, the salt affected soils can be found on the interdunal depressions. The considerable part of such sandy area is, however, currently under cultivation.

Remote sensing data of the Study area was employed in the analysis of the land use. Field reconnaissance survey was carried out for the ground trace of the Study area. Special attention was paid to distinguish the forest, swamp vegetation and saline area. The present land use map was created as a series of the analyses. According to thus prepared present land use map, most of the Study area is covered by the cultivated area with seasonal canals and tubewell irrigation. The reserved forests and the swamp areas are distributed along the Indus river and also along the main canals. Saline area, sand dune and other barren land occupies about 9 % of the gross area.

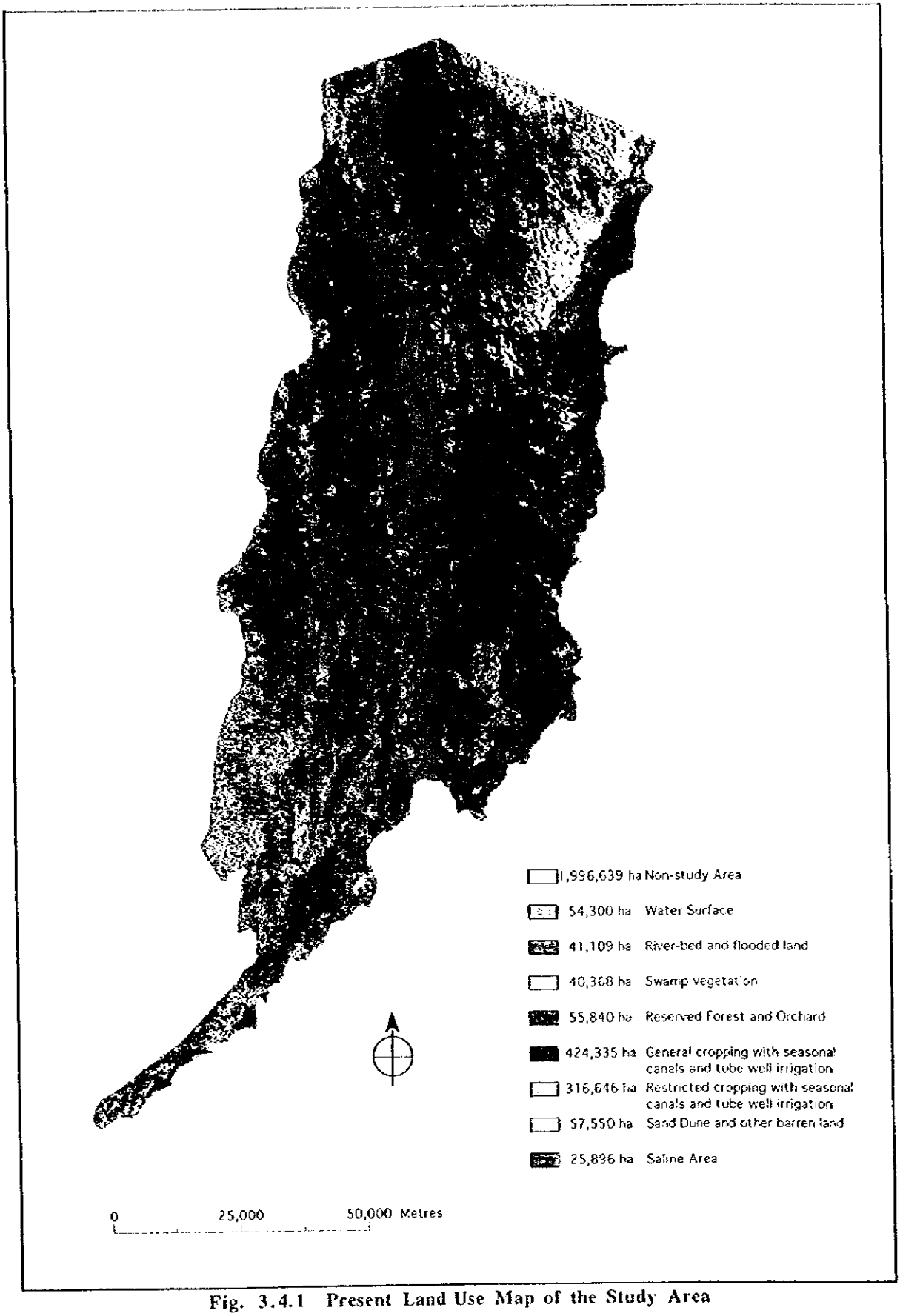

Fig. 3.4.1 Present Land Use Map of the Study Area

Table 3.4.1 Present Land Use of the Study Area

Canal	D.G. Khan		Muzaffargarh and Rangpur		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)
Gross Area	456,715	100.00	505,029	100.00	961,744	100.00
Cultivated Area	363,691	79.63	377,290	74.71	740,981	77.05
Reserved Forest/Orchard	17,552	3.84	38,288	7.58	55,840	5.81
River bed/Flooded land	17,456	3.82	23,653	4.68	41,109	4.27
Swamp Area	16,201	3.55	24,167	4.79	40,368	4.20
Sand dune/Barren land	21,632	4.74	35,918	7.11	57,550	5.98
Saline Area	20,183	4.42	5,713	1.13	25,896	2.69

Source: Remote Sensing Data

(2) Salinity and Waterlogging in the Farm Land

WAPDA has carried out the survey on water table and surface salinity for the selected area of the D.G. Khan canal command as a part of the feasibility study of Integrated Drainage and Irrigation Project. NESPAK has carried out a similar survey for the Muzaffargarh canal command as a part of the feasibility study on the Control of Waterlogging Hazards. The maps showing the depth to water table and the surface salinity were prepared based on the results of above mentioned studies and summarized as under.

Table 3.4.2 Depth to Water Table

(% of area)

Area	Shallow (<75cm)	Medium (75-150cm)	Deep (>150cm)	Permanent Swamp
D.G. Khan Canal Command	31	33	33	3
Muzaffargarh Canal Command	12	21	63*	4

* includes sand dunes

Table 3.4.3 Surface Salinity

(% of area)

Area	Non Saline	Slightly Saline	Moderately Saline	Strongly Saline	Permanent Swamp
D.G. Khan Canal Command	55	16	9	17	3
Muzaffargarh Canal Command	68*	15	4	9	4

* includes sand dunes

The permanent swamps are mainly distributed around the foot of the fan on the right bank of Indus River and it shows that the groundwater is mainly recharged by the infiltration from hill

torrents at the eastern border of the mountain range. The recharge is further augmented by the seepage from the irrigation system from the mountains to the Indus. More than 60 % of the surveyed area is thus having a depth to groundwater less than 150 cm in D.G. Khan canal command area. On the left bank of Indus River, the permanent swamps and shallow water tables with a depth to groundwater less than 150 cm are observed along the Muzaffargarh main canal at about 30 % of the area.

According to the results of surface salinity on the right bank, strongly saline soils are mainly distributed between Fazilpur and Rajanpur and between Umar Kot and Rojhan occupying 17 % of the survey area. As for the left bank, the surface salinity between Sanawan and Gujrat and between Jatoi and Alipur is high and has effected about 9 % of the area. The distribution of the salt affected soils mentioned above coincides with the result of the present land use map obtained through remote sensing survey.

(3) Cropping Pattern

The existing cropping pattern and intensities in the Study area, collected from the revenue offices of the canal divisions, is given in the table below. It shows that the main Kharif crop is cotton and the main Rabi crop is wheat. Rice, sugarcane and various fodder crops are the secondary important field crops in the Study area. Mango is the most important fruit crop and high quality mango is produced in this area. According to the division wise cropping pattern, the percentage of cotton is high in D.G. Khan canal command area specially in Rajanpur division. Sugarcane is remarkable in Kot Addu canal division in Muzaffargarh canal command area. Tobacco as Kharif crop and gram as Rabi crop are only cultivated in D.G. Khan canal command area. The high percentage of Kharif and Rabi fodder is outstanding in Rangpur canal command area. It was observed through the field survey in Muzaffargarh canal command area that cotton has been replaced by rice and sugarcane in the area affected by high water table.

Table 3.4.4 Cropping Pattern in the Study Area

Canal	D.G. Khan		Muzaffargarh		Rangpur		Total	
	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
GCA	1,001,821		907,171		126,200		2,035,192	
CCA	950,372		777,095		119,584		1,847,051	
Kharif 1996	561,119	59.0	412,781	53.1	57,721	48.3	1,031,621	55.9
Cotton	411,322	43.3	219,487	28.2	14,793	12.4	645,602	35.0
Rice	51,464	5.4	27,880	3.6	5,864	4.9	85,208	4.6
Sugarcane	5,695	0.6	17,178	2.2	449	0.4	23,322	1.3
Oilseeds	32	0.0	3,233	0.4	11	0.0	3,276	0.2
Fodder	74,946	7.9	102,804	13.3	20,413	17.0	198,163	10.8
Tobacco, Vegetables	4,743	0.5	596	0.1	14,945	12.5	20,284	1.1
Orchard, Forest, etc.	12,917	1.4	41,603	5.4	1,246	1.0	55,766	3.0
Rabi 1996/97	415,349	43.7	368,372	47.4	61,502	51.4	845,223	45.8
Wheat	331,610	34.9	263,425	33.9	28,227	23.6	623,262	33.7
Gram	12,847	1.4		0.0		0.0	12,847	0.7
Oilseeds	19,133	2.0	253	0.0		0.0	19,386	1.0
Fodder	41,782	4.4	58,828	7.6	14,645	12.2	115,255	6.3
Vegetables	769	0.1	410	0.1	310	0.3	1,489	0.1
Orchard, Forest, etc.	9,208	1.0	45,456	5.8	18,320	15.3	72,984	4.0
Kharif and Rabi		102.7		100.5		99.7		101.6

Intensity = % of CCA

Source: IPD Canal Division

Since the data have been collected from the revenue offices of the canal division, the results only indicate the situation of the area irrigated by the canal network. An extra area is irrigated by tubewells in addition to the above mentioned cropping pattern. According to the area irrigated by mode of irrigation shown below, the tubewells might contribute to irrigate about 30 to 40 % of the total irrigated area. It means that the annual intensity including the tubewell irrigation is expected to be 140 to 160 %.

Table 3.4.5 Area Irrigated by Mode of Irrigation

(Unit: '000 ha)

District	Total	Canal	Wells	Tubewells	Canal and Wells	Canal and Tubewells	Others
D.G. Khan	269	82	4	78	20	78	7
Rajanpur	259	116	2	52	2	85	1
Muzaffargarh	560	90	2	77	3	388	1
Total	1,088	288	8	207	25	551	9
(%)	100.00	26.47	0.74	19.03	2.30	50.64	0.83

Source: Bureau of Statistics, Punjab, Lahore

3.4.2. Farming Practice and Agricultural Production

(1) Farming Practices

The typical farming practices of the major crops in the Study area are shown below.

Table 3.4.6 Farming Practice for Major Crops

	Cotton	Wheat	Rice	Sugarcane	Rabi Fodder	Kharif Fodder
Main Varieties	CIM-1100 CIM-448 FH-634 Niab Krishma	Inqlab-91 Shahkar-95 Rohtas-90 Perwaz-94	IRRI-6	BL-4 BF-162 CO-1148	Berseem* Lucerne* Barley** Oat**	Maize* Sorghum** Millet***
Sowing/ Harvesting	May-Jun/ Oct-Dec	Nov-Dec/ Apr-May	May-Jun/ Oct-Nov	Jan-Feb/ Nov-Mar	Oct-Nov/ Apr-May	May-Jun/ Sep-Oct
Irrigation	each 15 days interval	Pre-sowing, Germinating, Earing, & Milking Stages	Standing Water	16-20 irrigation or 64-80 acre inch	15-20 days interval	each 15 days interval
Land Preparation	one deep plow followed by 3-4 tillage with planking	one deep plow followed by 3-4 tillage with planking	one deep plow followed by 3-4 tillage with planking	one deep plow followed by 3-4 tillage with planking	3-4 tillage with planking	3-4 tillage with planking
Fertilization (N-P-K)	60/70-23-25 kg/acre	46-46-25 kg/acre	55-32-32 kg/acre	100-46-50 kg/acre	23-23-25 kg/acre	23-23-25 kg/acre
Sowing (Seed Rate)	8 kg/acre	40-50 kg/acre	20-25 kg/acre for direct seeding	2,500-4,000 kg/acre	8-10 kg/acre* 25-30 kg/acre**	40 kg/acre* 20 kg/acre** 8 kg/acre***
Weeding	Manual Chemical	Manual Bar-Harrow Chemical	Manual Chemical	Manual Chemical	Nil	Nil
Harvesting	Hand picking	Manual or Harvester	Manual or Harvester	Manual	Manual	Manual
Major Problem	cotton leaf curl virus, bollworm, white fly	late sowing	insect pest	termite, pyrilla, borer, root rot	Nil	Nil

Source: Department of Agriculture

The Study area consists of the important part of the Cotton Belt and cotton is the most important cash crop among the major crops. Cotton, the major Kharif crop, sown in May/June and harvested usually in October/November but in December in some years.

Sowing is generally mechanized, whereas harvesting is 100 % hand picking. The department of agriculture is insisting that the early matured variety is needed because of successive wheat sowing in the same field. Wheat is the major Rabi crop in the Study area and the varieties cultivated are all bread wheat, sown in November and harvested in April/May. Since approximately 70 % of the cotton field is utilized for the successive cultivation of wheat, the late sowing of wheat is the prevailing problem in the area. The short duration variety is thus required by the farmers. Rice ranks next to wheat in acreage and production among cereals in Pakistan but is not grown as widely as wheat. Although most of the rice grown in the Punjab is the fine varieties (Basmati), the coarse varieties such as IRRI-6 are grown in the Study area. Sugarcane is usually cultivated for 2 to 3 years, planted in January/February and harvested during November and March. Various fodder crops are cultivated to feed animals raised by farmers and are sometimes utilized as green manure.

(2) Crop Yield and Production

The following table shows the area, the production and the yield of major crops for the last 5 years in D.G. Khan division. The cultivated area and the production of cotton, wheat and gram is increasing in recent years. The production of sugarcane is increasing in recent years due mainly to the improvement of the yield rate.

Table 3.4.7 Main Crops Cultivated in D.G. Khan Division

Kharif	---------- Cotton ----------			---------- Rice ----------			----------Sugarcane----------		
Crop	acre	tons	kg/acre	acre	tons	kg/acre	acre	tons	kg/acre
1991/92	663,200	185,584	280	183,000	81,440	445	68,655	737,200	10,738
1992/93	747,000	201,929	270	136,000	69,670	512	86,821	851,945	9,813
1993/94	756,000	159,936	212	147,000	76,720	522	62,700	747,200	11,917
1994/95	841,000	222,878	265	137,000	65,720	480	70,800	1,098,200	15,511
1995/96	930,000	243,017	261	130,000	65,270	502	68,200	1,107,300	16,236
Rabi	---------- Wheat----------			----------Gram----------			---------- Oilseeds----------		
Crop	acre	tons	kg/acre	acre	tons	kg/acre	acre	tons	kg/acre
1991/92	1,646,000	1,271,110	772	190,000	64,120	337	27,285	21,928	804
1992/93	1,758,320	1,422,900	809	191,070	64,980	340	49,030	18,931	386
1993/94	1,709,000	1,214,690	711	214,000	29,000	136	37,700	13,400	355
1994/95	1,756,000	1,378,970	785	258,600	50,500	195	56,200	19,100	340
1995/96	1,774,000	1,395,610	787	272,400	71,600	263	46,500	17,200	370

Source: Brief Note (Punjab Extension and Agriculture Development Project, D.G. Khan)

3.5. Irrigation in the Study Area

3.5.1. Irrigation Areas under Taunsa Barrage

The beneficial areas of the Taunsa barrage irrigation system consists of three culturable command areas of D.G. Khan canal, Muzaffargarh canal and Rangpur branch canal from T.P. link canal. The salient figures of the areas and water allowance are tabulated as follows.

Table 3.5.1 Water Allowance, Head Discharge and CCA by Canal

Canal	Water Allowance in Watercourse (cusec/1000acre)	Head Discharge (cusec)	CCA (acre)	CCA (ha)
D.G. Khan C.	6.36	8,301	950,372	385,000
Muzaffargarh C.	8.57	8,275	777,095	314,000
Rangpur B.	4.80	873	119,584	48,000
Total			1,846,067	747,000

The water allowance of D.G. Khan and Muzaffargarh canals are inherited the larger water allowance from the traditional inundation canal system as a historic water right. The water allowance is a gross water requirement at the point of Mogah from which irrigation water is distributed to a watercourse.

Average cropping intensities in CCA in 1930's were commonly both 35 % in Kharif and Rabi. At present, the cropping intensities have increased up to about 50 % in both Kharif and Rabi with the economic development and population growth. From the view point of irrigation efficiency, the efficiency is still low and there is considerable potential of the improvement of irrigation efficiency by means of canal lining and appropriate water management in future.

The water utilization of the Indus river basin irrigation system is a supply oriented "available supply" system greatly depending on its natural flow, and the water is supplied to the requirement within availability. Water supplies from the Taunsa barrage to three canals are authorized as non-perennial flow from 15th of April to 15th of October in Kharif. Due to the limited available flow in Rabi, quota of water within availability is allocated to each canal system without water right under allocated water in Rabi is less than a half of that for Kharif.

The principle of water distribution is "proportional module". Canal regulators as distribution facilities with check function were constructed at the point where canal water is distributed to the secondary canals. The head regulators were designed to fork water in a radial pattern toward two or three secondary canals. Each head gate for the secondary canal equips number

of slide gates in regular form. Because of the installation of the gate sills in same elevation, proportional water distribution can be maintained even if some fluctuation of discharge in the parent canal takes place.

When the canal discharge decreases down to about a half like in Rabi, the proportional distribution ratio is damaged as well as retrogression of conveyance efficiency. Therefore, Canal Warabandi, which is a canal system basis 10 days rotational discharge is sometimes taken place.

Diversion facilities from parent canals of distributory or minor are called Mogah, which are designed to allow proportional diversion without control devices and managed under the IPD.

The terminal ditch after the Mogah is watercourse under the management of farmers group. The command area of the watercourse is called Chak ranging 200 to 700 acre, and the receives irrigation water distributed by traditional Warabandi.

The farmer's group is usually unofficial and well known in the public, but if they cannot reach mutual agreement, the group will be officially established under the guidance from the IPD.

The entire discharge of watercourse is given to one farmer for specific period on a 7 days rotation. The water supply hours of 7 days are distributed proportionally to their land holding. The order of watering is prior to upstream along the watercourse and to the downstream in turn. However, some turn of Warabandi is allocated in mid-night due to 24 hour watering, the turn allocation is adjusted 12 hours from night to daytime every year. The watercourse is almost earthen ditch. The irrigation method varies by the crops, and border irrigation method is popular and furrow irrigation method is applied to vegetables. Through the highest field application efficiency is targeted as 60 % in some planning criteria, the overall irrigation efficiency seems to be considerably low due to large conveyance loss.

Another 20 % increase of cropping intensity is deemed to be possible in present canal system, if the water management will be properly conducted. Canal lining and promotion of On-Farm Water Management Project will promise further increment of cropping intensity and alleviate waterlogging problems in Taunsa barrage irrigation system.

3.5.2. Related Projects

(1) Groundwater Irrigation

Apart from the Taunsa barrage irrigation system, many small scale tubewell groundwater irrigation stations were exploited to supplement surface irrigation schemes.

Table 3.5.2 Distribution of Tubewells in the Study Area

District	Number of Tubewell			Study Area	
	Private	Public	Total	%	Number
D.G. Khan	4,986	8	4,994	60	3,000
Muzaffargarh	13,213	1,329	14,542	80	11,600
Rajanpur	7,112	30	7,142	80	5,700
Layah	16,349	45	16,394	0	0
Total	41,660	1,412	43,072		20,300

Source: Directorate of Agriculture Crop Reporting Service, Punjab, Lahore, 1993-94

Average command area of a tubewell is about 20 acre and total command area comes to about 400,000 acre in the Study area, equivalent to about 22 % to the total CCA. The cropping intensity of 101.6 % by canal irrigation and 44 % (22 % by 2 seasons) by groundwater irrigation makes the total cropping intensity in the Study area nearly 150 %.

(2) SCARP and National Drainage Programme

Huge irrigation projects including Taunsa barrage irrigation system in the Indus river basin have been greatly contributing to the agricultural development in Pakistan, but the projects have broadly created the serious waterlogging and salinity problems. In order to cope with the problems, Salinity Control and Reclamation Project (SCARP) since 1975 and National Drainage Programme (NDP) since 1991 have been implementing as nation-wide projects.

SCARP was designed to bring the lands back to their optimum level of agricultural production by applying vertical drainage, i.e., batteries of deep turbine tubewells bored in such identified area. The tubewells installed were not only meet for keeping the subsoil water at a safer depth from the ground but also to provide additional water from the underground reservoir for intensive irrigation, where the canal supplies were inadequate and led to soil salinity.

Major command areas of SCARP-III commenced since 1973 are coincident with the command areas of Muzaffargarh and Rangpur canals. The tubewell pumping stations were constructed by WAPDA and transferred to IPD in 1974, and the operation was commenced in 1975. The total number of the tubewells is 1,776 units, and among them 1,635 units are located in above mentioned command areas. The total command areas of SCARP-III is 10.5 million acre. The original waterlogging area of 1.37 million acre before project was reduced to 0.36 million acre in 1983 by the operation of SCARP-III. After that, extent of the waterlogged areas reverted back nearly to the original figures because of the reduction in annual pumping volume from 1987 MCM in 1982-83 to 959 MCM in 1995-96.

According to the water balance study reported by the SCARP-III, average annual off-taking of Muzaffargarh canal system and Rangpur canal system was 3,150 MCM, and consumptive uses were 390 MCM of evaporation from canal water surface and 1,380 MCM of crop evapotranspiration. The balance of 1,080 MCM comes as excessive water is almost same as the annual pumping water by the SCARP-III in recent years.

NDP being established based on nation-wide environmental assessment study is a 25 years programme of national drainage development, and the Government designated a NDP-I as a first stage of the NDP. The NDP-I envisages that the problems faced by drainage sector cannot be addressed in isolation by increased financial input. It, therefore, recommends multi-facet approach including institutional and political reforms to allow farmers and private sector participation in improving O&M. The main components of NDP-I are policy, research and study and investment.

The drainage improvement project under NDP-I has been implementing at a part of the D.G. Khan canal command area, where the agricultural productivity is considerably low due to the ill-drainage, hill torrent from the west, back water from the Indus river and excessive irrigation. Consequently, construction of drainage canals and planning of the countermeasure to hill torrents have been conducting.

(3) On-Farm Water Management Project

Recently, Third Punjab On-Farm Water Management Project (OFWMP-III) has been implemented with 5 year program since 1994 in the Study area. The basic concept of the OFWMP-III is beneficiary participatory approach and the main objectives are as follows.

- To reduce water losses in watercourse conveyance system by increasing delivery efficiencies through watercourse re-construction/re-modeling with complete earthen improvement, partial brick lining and installation of Nakkas, through water users associations in cost sharing basis.

  To reduce water losses by increasing water use efficiency in the farmer's fields through precision land leveling by extending technical assistance.

- To extend water management extension services through demonstration centers and demonstration farms.

- To train water users association, farmers, field personnel and extension staff for optimum use of available water and follow-up maintenance of improved watercourse.

- To reduce the waterlogging by removing excess surface water due to heavy rainfall and excess irrigation supplies through construction of open surface drains.

The main works of the OFWMP-III is the lining of watercourse, and 30 % of the cost for lining materials is burdened by the beneficiaries with 3 years amortization. The labor force necessary to the lining works is also supplied from the beneficiaries at free of charge. The OFWMP-III is highly appropriate as one of excellent projects, and the direction of the program is really coincide with the direction of further improvement of Taunsa barrage irrigation system. Then, further promotion of the OFWMP-III is expected.

3.5.3. Other Water Use

In addition to the irrigation purpose, canal water is used for many other purposes. Among those, main utilization is as follows.

(1) Domestic Water Supply

Canal water is used by the population residing around the canal system for their daily life such as cooking, washing and bathing. Furthermore, the canal water is indispensable for their animal husbandry activities to feed and wash their animals.

(2) Industrial Water Supply

As for the industrial water supply, considerable amount of canal water might be used as the coolant for the thermal power house distributed in various locations such as Kot Addu and Muzaffargarh. Other small and medium scale factories such as brick manufacturing factories, sugar mills, cotton ginning factories and reeling factories are also using the canal water for their operation.

(3) Water for Aquaculture

Aquaculture is one of the important activities for the effective utilization of the water resources in the area. Fisheries Department is therefore operating the hatcheries for fish breeding and the fry are distributed to farmers. Canal water is thus utilized for the operation of fish pond by the farmers.

3.6. Agro-economy in the Study Area

(1) Land Ownership

The Census of Agriculture 1990 reveals an unfairness of farm land holding in the area. Regarding farm size classification on private farms in the area, nearly half farms are less than 5 acre only and about 30 % is 5 to 12.5 acre in terms of number. While, those farms cover only 8.8 % and 21.8 % of the area. The more than 25 acre farms are only 9.6 % of all farms in number but cover 50.0 % of the area. The district-wise data expose that the number of small farms in Rajanpur district are 68.2 %, which is about 10 % lower than the other two districts.

The farm operation type is divided into three groups; owner farm, owner-cum-tenant farm, and tenant farm. Their share in number is 72 %, 16 % and 12 % in the area, as well as the share in farm area is 63 %, 27 % and 10 %. It shows that the farm size of the owner farms are smaller than others. For the tenant farms, the share cropping system seems to be more common than the lease system. Rajanpur district shows a unique distribution pattern of the lower share of the owner farms among three districts.

Table 3.6.1 Size and Ownership of Farm in the Study Area

(Unit: %)

Description	Number of Farms	Farm Area
Farm Size		
Less than 5.0 acre	48.1	8.8
5.0 - 12.5 acre	29.7	21.8
12.5 - 25.0 acre	12.6	19.5
25.0 - 50.0 acre	6.6	19.2
More than 50.0 acre	3.0	30.8
Land Ownership		
Owner Farms	72.1	62.8
Owner-Cum-Tenant Farms	16.1	26.7
Tenant Farms	11.8	10.5

Notes: The Study area means D.G. Khan, Muzaffargarh and Rajanpur district area excluding tribal areas in the table.

Source: Census of Agriculture 1990

(2) Marketing

The farm products of the village farmers are commonly sold to village retailers, village merchants (Beopati) and public procurement center. The major agencies supporting crop marketing and prices are Pakistan Agricultural Storage and Service Corporation (PASSCO) and the Food Department of Punjab. About 20 % to 35 % of the total wheat production is

procured by PASSCO and Food Department in the Punjab. Prices of major crops and farm inputs are fixed by Agricultural Prices Commission.

Cereal and pulse crops are produced mainly for home consumption and surplus is sold to merchants or at markets in the village. Large scale farmers sell the products to procurement center besides the local market. Sugarcane is transported directly to sugar mill factories, or refined by farmers themselves for home consumption or village market. Seed cotton is sold to the ginning factories by either farmers themselves or merchants. Their selling rates are usually controlled by the middlemen at given rates lower than fixed rate.

As to input supply, Punjab Seed Corporation (PSC) under Agriculture Department and some private suppliers produce and market certified seeds of major crops. Punjab Agricultural Development and Supplies Corporation (PAD&SC) deals with imported fertilizers. For the marketing of agro-chemicals, the role of the private sector becomes more significant and important recently. Most farmers rely on local open markets for purchase of fertilizer. Actual market prices are often higher than fixed prices announced by the government. For seeds, about half of farmers seems to obtain them from their own products besides from open markets. Cooperatives as input supplier could seldom or never work in the rural area.

(3) Agricultural Credit

Financial supports for the farmers are crucial to maintain or increase their crop production. The institutional sources of credit are Agricultural Development Bank of Pakistan (ADBP), commercial banks and cooperative societies. ADBP provides both development loans for farm facilities and machinery and production loans for farm inputs, while commercial banks and cooperative societies provide only production loans. The total disbursement of the institutional agricultural credit was Rs. 19.2 billion in the Punjab during 1995-96. The ADBP had largest share of 54 %, followed by commercial banks of 26 % and cooperative societies of 20 %.

Data of 1990 Census of Agriculture show a situation on debt and investment in the districts concerned. In the three districts of D.G. Khan, Muzaffargarh and Rajanpur, 14 % of farm households were under debt and 38 % made investment. The amount of outstanding debt was Rs. 1,308 million, of which 53 % came from institutional sources and the rest from non-institutional sources. The non-institutional sources, such as family members, relatives, neighbors, merchants and land loads, play great role on rural credit. Annual amount of farmers' investment was Rs. 2,454 million in total, of which Rs. 974 million was borrowing from outside.

(4) Farm Household Economy

The same report also describes the typical crop budgets for major crops, as shown in the following table. Vegetables and fruits show very high profitability, producing at more than Rs. 14,000 per acre. Next profitable crops are cash crops; cotton, sugarcane and oilseeds giving net return of Rs. 6,900, 5,400 and 5,200 per acre, respectively. Compared with such cash crops, the net return of food crops are rather low, for example Rs. 4,500 per acre for wheat and Rs. 1,500 per acre for rice.

The net returns from unit area by crop were estimated in financial terms based on the volume and unit prices of farm inputs and outputs within the Study area. The results, which are shown in Table 3.6.2, indicates that orchard is the most profitable to the farm income, but very big initial investment may be a hurdle for the farmers to expand the orchard areas. The cash crops such as cotton, sugarcane and oilseeds are high profitable and cultivated widely. While, food crops of wheat and rice are economically disadvantageous but cropped to meet basic needs of diet. The fodder crops are also less profitable in terms of farm income.

Table 3.6.2 Net Return by crop in the Study Area

(Unit: Rs./acre)

Crop	Gross Income	Production Cost	Net Return
Cotton	18,100	4,300	13,800
Rice	3,200	1,900	1,300
Kharif Fodder (Sorghum)	4,100	800	3,300
Wheat	4,300	2,700	1,600
Oilseeds (Rape/Mustard)	4,900	1,100	3,800
Rabi Fodder (Berseem)	6,000	1,400	4,600
Sugarcane	12,100	2,900	9,200
Orchard (Mango)	40,400	23,000	17,500

Notes: All data are shown in financial terms.
Source: JICA Study Team

In the farm survey for "the Study on the Lining of Distributaries and Minors in Punjab; JICA; July 1997", the typical farm budgets for the canal irrigation area in Punjab are investigated. The dominant marginal farmers cultivating less than 5 acre depend on off-farm income but can not afford their daily life on farm and non-farm income. The on-farm income of the larger farmers become big along with their farm size but the off-farm income is stable around Rs. 35,000 a year. The middle and large farms with more than 12.5 acre of farm might be able to afford their household expenditure only from the farm outputs.

3.7. Social Infrastructure in the Study Area

Some district-wise statistic data show the conditions of social infrastructure such as education, public health, transportation and so on. The numbers of mosque schools (1st to 5th grades), primary schools (1st to 5th grades), middle schools (1st to 8th schools), high schools (1st to 10th schools) and higher secondary schools are 1,165, 3,878, 359, 269, and 34, respectively. As for primary schools, the number of schools, students and teachers per 1,000 inhabitants are 0.68, 41.64, and 1.96, respectively. The density of the schools in Muzaffargarh district, where the population density is relatively high, is lower than other two districts.

Regarding health institution, the numbers of hospitals, dispensaries, rural health centers, T.B. clinic, basic health unit and sub health center are 19, 67, 28, 152 and 75, respectively. The availability of hospitals and dispensaries is very low at 0.015 units per 1,000 people, as well as that of other health institution is only 0.045 units in the area.

For the road transportation, there are national high way of 864 km, high type provincial road of 699 km, low type provincial road of 275 km and agricultural road of 1,299 km. The overall road density is 0.086 km/sq.km.

3.8. Natural and Socio-Environmental Circumstances

3.8.1. Environmental Institutions and Environmental Protection

(1) Environmental Institutions

Environment and Urban Affairs Division started its function on the environmental protection under the Federal Ministry of Housing and Works in 1974. This organization was then strengthened under the coordination with Environmental Pollution Control Organization and Public Health Engineering Department. In 1983, Pakistan Environmental Protection Ordinance was declared and Pakistan Environmental Protection Agency and Pakistan Environmental Protection Council were established in 1984. Environmental Protection Department Punjab (EPDP) was established in 1987 and started its functions as an attached department which has now grown to an independent Ministry of Environment.

(2) Achievements of Environmental Protection Department Punjab

EPDP performs a wide range of activities aiming at the pollution control and the environmental protection. The main activities are; education and awareness activity, pollution load assessment activity, solid waste disposal activity, air monitoring and surveillance activity, and environmental impact assessment.

EPD office in D.G. Khan was established about 1 year and a few months ago with the full responsibility for the environmental protection in D.G. Khan division. This office is not fully functioned yet, the inspection activities on air and water pollution have just commenced. Especially, power was poured into the management of the noise pollution with the horn etc. of the vehicles. It is a big causing of air pollution as for smoke from the brick factory, the sugar mill and the cotton ginning factory in addition to the exhaust from the vehicles. The case where the old tire is mixed with the fuel causes a lot of generation of a poisonous gas. Moreover, the water pollution of the irrigation canal with an industrial waste water is worried about. The management of such air and water pollution will be an important subject in the future.

(3) Environmental Impact Assessment

The environmental impact assessment system have been established on December 1997. According to this new system, 5 copies of Initial Environmental Examination (IEE) report should be submitted to the EPDP upon decision of the execution of the rehabilitation work. The IEE report should include (i) the outline of the project, (ii) the examination of the local environment, (iii) the examination of the adverse effect on the environment, and (iv) the conceivable mitigation measures if any.

3.8.2. Initial Environmental Examination

(1) The outline of the project

Taunsa barrage was constructed on the Indus river in 1959. Through 40 years operation, the barrage has been deteriorated causing much leakage water through damaged gates, non-reliable gate control against flood, and lowering intake capacity compared with the original design capacity. The main objectives of this project is, therefore, to conduct a feasibility study on Taunsa Barrage Irrigation System Rehabilitation basically aiming at a renovation of the main body of the barrage and other improvement necessary for the proper operation and management. The agriculture and irrigation plan and the operation and maintenance system of the canal network should also be examined in the study when it is necessary.

(2) Examination of the local environment

1) Natural environment

The flood of hill torrents from Sulaiman mountains in the right bank and the sand dune encroachment in the left bank are the major constraints of the agricultural development in the

Study area. In order to prevent the destruction of canal network due to the flood, crossing structures were constructed in important parts. Moreover, the watershed management project is conducted to harvest as much amount of run-off water as possible on the upstream of the hill torrents. The afforestation activity for the dune fixation is executed and the part which has already been fixed begins to be used for agriculture in the dune area on the left bank.

Waterlogging and soil salinization are also the major constraints of the agricultural development in the Study area. Salinity Control and Reclamation Project (SCARP) has begun in 1960's and various studies and activities has already been carried out to solve this problem by drawing up underground water using tubewells. The activity of SCARP-III was commenced in 1973 and various works are executed especially on the left bank of the Study area. The total waterlogged area of about 55,000 ha at the beginning of the project decreased up to 15,000 ha in 1978 through the installation of 1,800 tubewells and also the construction of 250 km-long drainage canal. Most of the salt affected area extending over 130,000 ha was improved and rising tendency of the underground water table was settled down to some extent. With the passage of time, however, the waterlogged area again increased gradually and reverted back to 54,000 ha in the year 1996. The main conceivable causes are the increase of water allowance per unit area, the decline of tube well capacity, the inflow of flood into the irrigated area and so on. Since the strategy of the problem solving has already been clarified, the future practical planning including the establishment of the integrated regional irrigation schedule and the management program of tube well will become an important subject from now on.

The Taunsa Barrage Pond Area was declared as a wildlife sanctuary in 1972 and re-notified in April 1983 and was also declared as Ramsar Site on 1996. The sanctuary lies on the state land just upstream of the Taunsa barrage on the Indus river near the town of Dera Din Panah in Kot Addu tehsil, Muzaffargarh district with the total area of 6,567 ha. The most important fauna found in this sanctuary is Indus Dolphin (*Platanista minor*) which is listed as endangered species in the International Union for Conservation of Nature (IUCN) Red Data Book since 1976. This species is on Appendix 1 of the Convention on International Trade of Endangered Species (CITES) and it was added to the U.S. Department of Commerce endangered species list in 1989. It is protected under the Wildlife Act of Sindh (1972), Punjab (1974) and NWFP (1975). The maximum size of the dolphin is 200 kg in weight and 5.5 ft in length. Between Chashma and Guddu barrages, 99 dolphins were observed by the census survey in 1996 while 275 dolphins were observed in 1997. Dolphins living between any two barrages are permanently isolated from other subpopulations under the inherent risk associated with low population size such as stochastic effects of environmental flux, demographic structure and genetic problems. In order to improve such situation, a project is proposed for the research of ecological corridor for the dolphin under the cooperation with Sea Mammals Research Unit, Cambridge University, UK. A group of this cooperation project will visit the sanctuary in the

spring season of this year. Taunsa barrage wildlife sanctuary and the other wetland distributed in the Study area are very important (i) wintering areas for waterfowl, (ii) breeding areas for several species (particularly lesser whistling duck) and (iii) staging areas for cranes (*Grus grus* and *Anthropoides virgo*) and shorebirds. It is also the most important wintering area in Pakistan for bar-headed goose. Another important mammal in the area is hog deer (*Axis porcinus*) which can be found in the forests doting the river side.

2) Social environment

In order to investigate the public health condition in the Study area, the data on public health organization and out patient morbidity pattern was collected focusing on the water borne diseases which might be affected by the irrigation activity. According to the morbidity pattern of the Study area, the major diseases were respiratory diseases, fever and diarrhoeal diseases. The high percentage of the respiratory diseases can be attributed to the heavy air pollution pointed out by the EPD. Concerning the water borne diseases, it is thought that diarrhoea is mainly caused in the polluted drinking water. Moreover, malaria and typhoid fever was ranked within the major diseases. The other water borne diseases such as schistosomiasis (bilharziosis) and leyshmaniasis were not significant in the Study area.

A large amount of forest resource is used in the region as a necessary fuel supply source for the local population and also for the small and medium scale industry such as the brick factories and as a material for many other purposes. The conservation of the existing forest and the forestry activities are taking an important role to produce and supply such wood resources. The forest department classifies the forests in the Study area into 5 types which are (i) irrigated plantation, (ii) riparian forest, (iii) range land plantation, (iv) canal side plantation and (v) road side plantation. The main activities of the forest department consists of management of forests, marketing of forests products, maintenance of existing plantations and promotion of tree plantation on farm lands.

Approximately over 60 different species of fish including carp fishery and catfishes are found in the Study area. By such abundant fishery resources, the total production of fish in D.G. Khan division during the last year was equivalent to Rs. 10 million dealt through auctions. The pond area of River Indus within the Study area is of immense ecological importance for sustainable development of natural fishery. Especially, the pond created by barrage is an excellent breeding ground for these fishes. The existing barrage structure provides two fish ladders which facilitates the fish migration in the river. The main activities of the fisheries department are (i) control of illegal fisheries and (ii) hatcheries operation for fish breeding.

(3) Necessity of the environmental impact assessment and mitigation measures

Based on the present natural and socio-environmental circumstances of the Study area, it is expected that the environmental impact assessment is not necessary because the influence of this rehabilitation work on the environment is extremely negligible. In order to minimize the negative impact, however, the following mitigation measures can be conceivable during the construction period and also for the future operation.

- Awareness of the ecological importance of the area by the construction staff,
- Maintenance of the cleanliness of the working site and the worker's living quarter with special attention to the drainage,
- Appropriate handling of any chemicals including fuel, lubricant and paint in order not to pollute river water,
- Prevention of inflow of any pollutant into river water,
- Active involvement to the research project of ecological corridor for Indus dolphin, and
- Establishment of the barrage operation manual under the mutual cooperation with Wildlife Department, Fisheries Department and other concerned authorities.