Annex C

Hydrology

ANNEX C Hydrology

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C.1. Discharge of River Indus

The catchment area of River Indus and its tributaries is 944,600 sq.km (364,700 sq.miles), of which, 561,300 sq.km (216,700 sq.miles) lie in Pakistan. The basin can be divided into various units keeping in view their physiographical features. Catchment area of River Indus at the Taunsa Barrage is approximately 414,800 sq.km with about 1,770 km river length. Annual inflow at the Taunsa Barrage is 105,650 million m^3 (85.65 MAF), namely 86,090 million m^3 (69.79 MAF) in Kharif and 19,560 million m^3 (15.86 MAF) in Rabi, of which water quantities are based upon recent five years discharge data.

(1) Discharge-Duration Relation of River Indus

Run-off of River Indus is greatly fluctuated along with seasons. Discharge-Duration Curve of River Indus at the Taunsa Barrage is shown in Fig.C1.1.1. According to the discharge-duration curve, high-water flow of the range of more than 200,000 Cs. varies with great deviation, while low-water flow is considerably stable in every year. Lowest flow is recorded at less than 10,000 Cs.

(2) Correlation Relation between Discharge of Taunsa Barrage site and Others

Chashma Barrage (Catchment area: 339,400 sq.km) is located in 270 km upstream of the Taunsa Barrage. Discharges of both sites are compared in Fig.C1.1.2 with data in 1996. Fair correlation between both series of discharge is recognized, and certain flow delay is identified. Delay-time of runoff to reach Taunsa Barrage site from the Chashma site is identified at 2 days in high-flow and 3 days in low-flow. The delay-time can be analyzed by cross-correlation coefficient for the subjected runoff sequences. Cross-correlation coefficient between runoff sequences of Taunsa and Chashma is obtained as shown in Fig.C1.1.3. Value of the cross-correlation coefficient varies as shifting one runoff sequence by several days against another. Shifted days which shows highest value of cross-correlation coefficient might be regarded as the actual delay-time of runoff at Taunsa Barrage from Chashma Barrage site. The delay-time being fluctuated by magnitude of runoff, is obtained at 3 days for low-flow of less than 80,000 Cs., 2.5 days for medium-flow of greater than 80,000 Cs. and less than 200,000 Cs., and 3 days for high-flow of greater than 200,000 Cs.

(3) Water Right of Feeding Canals of Taunsa Barrage System

The allocation of irrigation water is regulated by the Water Apportionment Accord agreed in

1991. At the Taunsa Barrage, three canals, namely D.G.Khan Canal, Muzaffargarh Canal and T.P.Link Canal, are fed by River Indus giving certain water rights. Both canals of D.G.Khan Canal and Muzaffargarh Canal are fed in a manner of "non-perennial", while T.P.Link Canal is perennial supply. Authorized quantity of water right of each canal is as follows:

Water Rights	Kharif Season	Rabi Season	Annual	Remarks
Taunsa				
Taunsa *	4.19 MAF	1.50 MAF	5.69 MAF	D.G.Khan C. & Muzaffargarh C.
Panjnad*	3.40 MAF	1.52 MAF	4.92 MAF	T.P.Link C.
Punjab Province	37.07 MAF	18.87 MAF	55.94 MAF	
Downstream of Taunsa	36.79 MAF	15.84 MAF	52.63 MAF	Balochistan Prov. & Sindh Prov.

* : Water allocaation of these water rights are shown in Table C1.1.1..

As following above water right in quantities in water, off-taking water is used to be done within the maximum capcities as below table.

	D.G.Khan Canal	Muzaffargh Canal	T.P.Link Canal	Total
Jan./ 1 - Apr./14	-	-	12,000	12,000
Apr./15 - Oct./15	8,301	8,285	12,000	28,586
Oct./16 - Dec./31	-	-	12,000	12,000

Taunsa Barrage was in function in 1959. At the time, irrigation water supply had commenced temporarily without supplying water to Dajal extension area. After the inauguration of the Project, all water uses concerning the Taunsa barrage except such Dajal extension were authorized and approved those water rights on the Indus Water Treaty in 1991. Still present, water right of the Dajal extension was not authorized and no prospect for its approval. This Dajal extension issue is not affected to present water uses of existing areas, but having great deal with canal operation of D.G.Khan canal. Though provisional discharge of 8,301 Cs is provided to D.G.Khan canal, canal section had been constructed with full capacity of 14,200 Cs. Silt deposition in D.G.Khan canal are accelerated due to small velocity caused by these reasons. This water right issue is looking forward to settle as earlier as possible.

Canal feeding in Rabi season is fulfilled by the approval of Sind Province as far as not exceeding 18 % of actual inflow at the Barrage pond. Due to low flow of River Indus in Rabi

season, the provisional supply and authorized feeding in Rabi season is not always satisfied against indents.

(4) Notation of Discharge Calculation of Taunsa Barrage

Discharge of River Indus at D/S of Taunsa Barrage is calculated by a drowned weir formula on the basis of observed water levels of U/S and D/S of the Barrage. Discharges of off-taking canals are also calculated directly. U/S Discharge of Taunsa Barrage is estimated adding the D/S Discharge, those discharges of off-taking canals, considering other balances such as additional inlet to the D.G. Khan Canal and release through silt ejectors. Being under the pond level situation stable, estimating U/S discharge in such manner is beyond question. However, storage effect on the estimation of U/S discharge may not be negligible when pond level be changed considerably. Through a simulation for storage effect on the estimation of U/S discharge, a few percent difference was obtained between actual discharge and calculated discharge by present notation during rapid moving pond level.

C.2. D.G.Khan Canal Discharge

Historical record of off-taking discharge of D.G.Khan Canal is shown in Fig.C2.1. High discharge in Kharif stuck a water right limit out, and events of feeding canal at frequent intervals in Rabi while no constant certain water right approved, come to the fore. Though D.G.Khan Canal irrigation is non-perennial, several times' supply of irrigation water in Rabi for wheat cultivation are usual practices in the D.G.Khan Canal, besides continuos domestic water supply. According to the figure, very frequent feeding has been identified.

Due to blocking water off-taking by heavy siltation, irrigation water has been not enable to be supplied sufficiently under standard regulation rules. It has had no choice to dam pond level up over the high water level in order to off-take irrigation water to the D.G.Khan Canal as required. High off-taking discharge record expanding over the water right limit must be apparently inflated by applying rating curve without consideration of area reduction of canal section by siltation. On the contrary, actual off-taking discharge may not exceed the water right limit.

During field survey in Phase I, current measurement was done at RD.7000 of D.G.Khan Canal. Of-taking discharge of 6,700 Cs. was obtained by the current measurement on October 14, 1997. Even having pond level of RL.446.7 feet being higher than the high pond level and with full opening of regulators of D.G.Khan bays on the date, observed discharge was incomparably low rather than design maximum off-taking discharge of 8,301 Cs.

Chronological changes in relation between pond level and off-taking discharge into D.G.Khan canal are shown in Fig.C2.2., in which envelope lines indicate actual those relations free from effects of gate operation. According to the results, difficulties can be identified in off-taking water by ruled pond level especially in recent years. In 1997, it is shown that pond level must be rised higher than RL.446.7 in order to feed water of designed discharge 8,301 Cs.

C.3. Muzaffargarh Canal Discharge

Historical off-taking discharge of Muzaffargarh Canal is shown in Fig.C3.1. On the contrary with the D.G.Khan Canal, off-taking discharge in Kharif is within water right limit. As no remarkable siltation problem has been found, design discharge seems to be kept at present. Very frequent feeding in Rabi has been also identified as well as D.G.Khan Canal.

C.4. T.P.Link Canal Discharge

Historical off-taking discharge of T.P.Link Canal is shown in Fig.C4.1. T.P.Link Canal irrigation is in perennial supply basis. In comparison with other canals' water supply, scattered feeding is prominent. Because feeding T.P.Link Canal is to supplement water when river water of Chenab is in short, small water taking is required even in Kharif depend upon flow regime of River Chenab.

C.5. Study on Allowable Head Across

Head across between U/S and D/S of Tanusa Barrage is provisionally allowed at 22 feet. For the water use side, greater head across than 22 feet as provisional has been required particularly in Rabi in order to off-take water sufficiently. While applying non-perennial irrigation in the Study Area, irrigation water supply is in eager wish by beneficiaries even in Rabi. Desire for increasing allowable head across is to desire for the beneficiaries taking water sufficiently in Rabi.

However, to meet demand for increasing head across is insufficient for fulfilling their desire. Besides increasing head across in such manner, allowable quantity of water should be still available in Rabi because allowable flow is limited in River Indus in Rabi. It will be of no use to fulfill increasing head across if no additional taking water is permitted any more. Fig.C5.1 shows actual head across and remaining allowable river water to take additionally. According to the figures, high head across values have identified in Rabi only. Allowable discharge in the figures is 18 % of River Indus runoff at U/S of Taunsa Barrage which is allowable limit for off-taking in consideration with downstream water right. Difference between the actual intake

discharge and the allowable discharge shows remaining allowable water quantity for taking additionally. These figures indicate the fact that scarce allowable water to be taken additionally remain still more. Even if head across is increased more, additional off-taking can be hardly fulfilled. By these reasons, no taking measures for increasing head across is recommended.

C.6. Channel Sediment

C.6.1. Sediment Condition of D.G.Khan Canal

Risen bed of D.G.Khan canal by siltation has caused great difficulty in feeding of D.G.Khan canal. The siltation problem on the bed of D.G.Khan canal is the most highlighted issue concerning the Study. Some findings on the problem of silt entry into the D.G.Khan canal have been obtained referring long standing observation data available.

Risen bed of D.G.Khan canal by siltation can be assumed following two assumptions of reason. One assumption is to be settled by suspended sediment due to slow velocity in canal. Another assumption is to be entered by bed-loads in Indus river through canal regulator gates due to uncontroling by under-sluice. Previous observation data show the fact that the silt deposition in the right pocket vis-à-vis silt entry in D.G.Khan canal has been increased. D.G.Khan canal chocked up mainly due to oblique approach on up-stream of the Barrage with some reasons. Improper flashing of the pocket of under-sluice, and mal function of silt ejector, besides non closure of D.G.Khan canal during floods, are reasons for remediless present situation. Silt level in the right pocket frequently rises to R.L.433.0 of the crest of D.G.Khan canal regulator due to such oblique approach on up-stream of the Barrage. Though flashing efforts by under-sluices opening is attempted, essential resolution can not be obtained due to mechanical difficulties on gates operation and water users complaint against stoppage of water. In Fig.C6.1.1, silt flashing operation in resent three months by operating under-sluices can be schematically identified. Each under-sluice gate seem to be not opened all together. It can be recognized that accumulated silt in the right pocket changed with opening of under-sluice. For instance, flashing effects can be identified on July 1, August 7, and September 1 in the figure. A figure of "Accumulated Silt of Right Pocket" of the Fig.C6.1.1 shows reducing silt in right pocked by such opening under-sluice. These data evidence that under-sluice opening is much effective for flashing silt in pocket.

Silt distribution in the pocket on several dates are shown in Fig.C6.1.2. On June 4, little silt could be found in the entire area of the pocket except back of under-sluice No.65, because the gate was in difficult situation for regulation due to mechanical problem. On June 28, huge siltation was observed so that the silt level was higher than the crest level of canal regulator.

Decreasing of siltation behind regulator gates denoted entering silt into canal through regulator. It was just after flashing on July 5, little siltation was observed in the entire area of right pocket. On August 1, increasing of silt deposit could be observed. Separate high opening of under-sluice gate No.63 made groove behind the gate. On August 9, little silt could be found in the entire area of the pocket due to flashing by under-sluice opening.

C.6.2. Sediment Analysis

(1) General view of sediment transport

In the duration of annual closure period of the Taunsa Barrage, sediment load on the surface of river and canals bed were sampled under the drying condition at 10 sites as follows:

Abbreviation	Site
BR-0	Taunsa Barrage Right Bank
DG-0	D.G.Khan Canal RD.0000
DG-7.5U	D.G.Khan Canal RD.7500-Upstream
DG-7.5D	D.G.Khan Canal RD.7500-Downstream
DG-40	D.G.Khan Canal RD.40000
DG-88	D.G.Khan Canal RD.88000
DG-345	D.G.Khan Canal RD.345000-Downstream
MZ-0	Muzaffargarh Canal RD.0000
MZ-64	Muzaffargarh Canal RD.64000

Grain Size Analysis for the samples was done as showing in Fig.C6.2.1. Mean diameter of particle is identified at about 0.2 mm in every samples by the result of the analysis, of which distribution range are almost limited from 0.1 mm to 1.0 mm consisting of mainly Medium sand and fine sand.

Tractive Shear Velocity (u_{*c}) of the greatest particle of 0.1 mm diameter within the samples is calculated at 0.035 m/sec by Krey formula (u_{*c} = 124.4(s/1.65)d). On the other hand, hydraulic condition in Right Pocket of Taunsa Barrage, D.G.Khan and Muzaffargarh Canals are shown in Table C6.2.1, where shear velocity is calculated in the design condition. The shear velocity in every sections under the design condition is possibly more than the tracive shear velocity. From the view of these observations, it can be stated positively that almost all of transported particles reaching to the Taunsa Barrage are still transportable.

Most notable fact is a coincide with grain size distribution of samples taken at BR-0 being in right pocket, and DG-0 being within fed canal. This match explains that siltation problem in D.G.Khan Canal is caused by direct entry of sedimentation in right pocket with full quantity of

bedload, as furthermore researched in next section.

Difference of the particle distributions at different reaches of the canal, is an attractive fact. For the both of D.G.Khan canal and Muzaffargah canal, particle of channel bed become more fine, the more going downstream. It can be considered as being reasonable in view point of mechanism of sediment transport. Though there is an exception for the sample taken in the tail of D.G.Khan canal of which show much rough distribution rather than upstream, it can be assumed due to other silt entry from the alluvial area into the canal.

(2) Quantity of Sediment Transport in D.G.Khan Canal

Even though being laborious, quantum analysis of sediment transport is essential for the discussion of canal sediment control. Total sediment transport (S) including bedload and suspended load of D.G.Khan Canal can be estimated at by the following Brown formula .

$$(S/B)u^*d = 10\{u^{*2}/(s/r-1)gd\}^2$$

Hence;
- B : canal width of D.G. Khan canal at entrance (in m)
- u* : friction veracity (in m/s)
- d : mean diameter of particle (in mm : $D_{50} \fallingdotseq 0.2$)
- s : density of sediment (2.65)
- r : density of fluid (1.0)

On the hydraulic condition of D.G.Khan Canal, it should be considered in following three phases:

Case 1: Designed condition

Case 2: Actual condition in initial completion stage considering future Dajal extension

Case 3: Present codition

Hydraullic condition in each case can be refered data concerning sections from RD.000 to RD.40000 of the D.G.Khan Canal in Table C.6.1.1. Sediment transport in each case applying the Brown formula is obtained as follows:

Sediment Transport of D.G.Khan Canal applied by Brown Formula

Case	B (m)	u* (m/s)	d (mm)	Specific sediment ($cm^3/s/m$)	Total sediment (m^3/s)	Total (kgr/s)
1	54.9	0.060	0.2	164.01	0.0090	23.850
2	79.3	0.042	0.2	26.69	0.0021	5.565
3	79.5	0.049	0.2	60.92	0.0048	12.826

Above estimation of sediment transport of D.G.Khan Canal include suspended load within. In order to assese effectiveness of silt ejector, quantity of suspended load should be analyzed separately. Rouse's notation presented below is much applicable for the estiomation of suspended load.

$$C/Ca = ((a(h-y)/(y(h-a)))^z, \quad z = w0/(k\,u^*)$$

Hence;
- C: Concentration at distance y above bed
- Ca: Concentration at distance a above bed
- h: Water depth
- y: Variable distance y from bed
- a: A reference distance above bed
- w0: Settling velocity of particular grain size
- u*: Friction veracity (in m/s)
- k: Karman constant (=0.4)

Case 1:

	Percent (%)	Content (gr/l)	dmean (mm)	w0 (m/s)	u* (m/s)	w0/u*	z	Total quantity (gr/m/s)	(kgr/s)
d> 0.84	0.00	0.00							
0.84 >d> 0.42	0.02	0.006	0.594	0.07	0.060	1.17	2.912	1.3	
0.42 >d> 0.074	0.93	0.270	0.176	0.02	0.060	0.33	0.832	207.2	
0.074>d	0.05	0.015						11.0	
Total	1.00	0.290*1						219.5	12.04

*1: total content of suspended load is a value at 0.10 m ditance above bed, which was refered observed data adjusting by the difference of shear velocity

Case 2:

	Percent (%)	Content (gr/l)	dmean (mm)	w0 (m/s)	u* (m/s)	w0/u*	z	Total quantity (gr/m/s)	(kgr/s)
d> 0.84	0.00	0.00							
0.84 >d> 0.42	0.02	0.004	0.594	0.07	0.042	1.66	4.156	0.5	
0.42 >d> 0.074	0.93	0.177	0.176	0.02	0.042	0.48	1.188	63.4	
0.074>d	0.05	0.010						3.4	
Total	1.00	0.190*1						67.3	5.333

*1: total content of suspended load is a value at 0.10 m ditance above bed, which was refered observed data adjusting by the difference of shear velocity

Case 3:

	Percent (%)	Content (gr/l)	dmean (mm)	w0 (m/s)	u* (m/s)	w0/u*	z	Total quantity (gr/m/s)	(kgr/s)
d> 0.84	0.00	0.00							
0.84 >d> 0.42	0.02	0.005	0.594	0.07	0.049	1.42	3.548	0.8	
0.42 >d> 0.074	0.93	0.223	0.176	0.02	0.049	0.41	1.014	86.7	
0.074>d	0.05	0.012						4.5	
Total	1.00	0.240*1						92.0	7.313

*1: total content of suspended load is a value at 0.10 m ditance above bed, which was refered observed data adjusting by the difference of shear velocity

Summerizing above results, aportionment of bedload and suspended load in each case for D.G.Khan Canal is as follows:

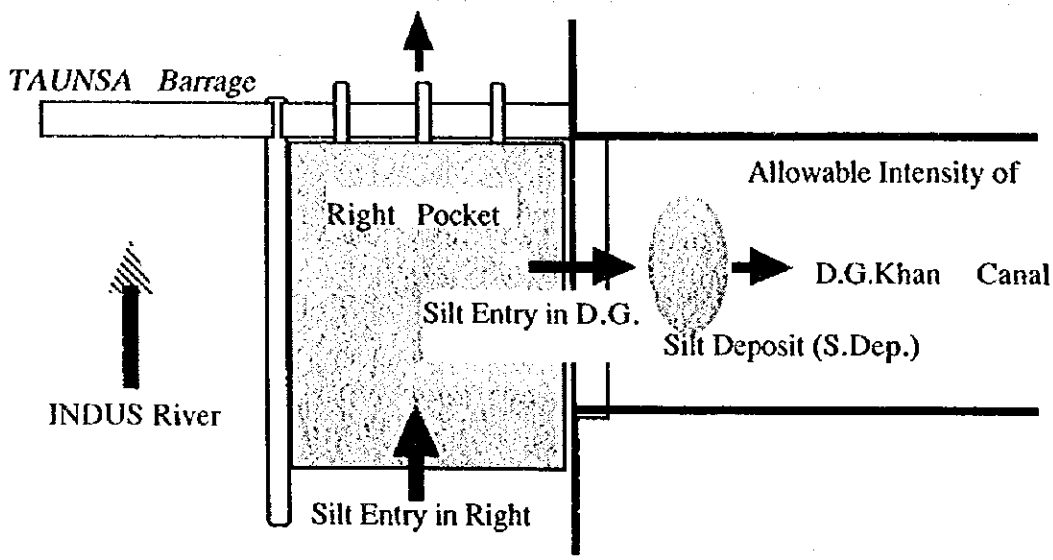
Apportionment of Sediment Transport of D.G.Khan Canal

Case	Total sediment (kgr/s)	suspended load content (kgr/s)	(%)	Bed-load content (kgr/s)	(%)
1	23.850	12.040	50.5	11.810	49.5
2	5.565	5.333	95.8	0.232	4.2
3	12.826	7.313	57.0	5.513	43.0

While it is difficult to assess due to missing original design data, existing silt ejector is supporsed to be designed having silt eject capacity to meat with more than 17.83 kgr/s of tractive silt in original design.

(3) Quantum Balance of Silt Transport on Right Pocket

Siltation problem in right pocket of the Taunsa barrage is one of highlighted aspects in the Study. In order to identify the silt entry mechanism into the right pocket, a quantum balance analysis for siltation on right pocket was done during this survey term. Siltation balance in the right pocket is schematically shown in below figure.



Silt entry in right pocket (S.R) can be estimated by silt sounding data. According to a datum on silt depth in right pocket (Line No. 1 to Line No. 6), silt deposit into right pocket during 22 days from June 4 to June 26, 1997, was measured at 19,820 m^3 (700,000 cf), being converted to the intensity of silt entry at 0.0104 m^3/s (U/S discharge of River Indus during such period is around 170,000 cs, off-taking discharge of D.G. Khan canal is around 9,000 cs). It is somewhat below estimation of silt entry in right pocket, because some quantity of transported

sediment into right pocket had been escaped to D.G. Khan canal and downstream of the barrage without depositing in the right pocket. Therefore, **S.R** is estimated at least 0.0104 m^3/s (27.56 kgr/s). At the worst situation, after reaching silt depth of right pocket to the crest level of D.G. Khan canal regulator, silt entry in D.G. Khan canal (**S.C**) may nearly be the figure of **.S.R.** However, allowable intensity of sediment transport of D.G. Khan canal (**S.t**) is definitely smaller than the **S.C.** The **S.t** can be applyed 0.0048 m^3/s (12.83 kgr/s) of sediment transport in the Case 3 of above analysis .

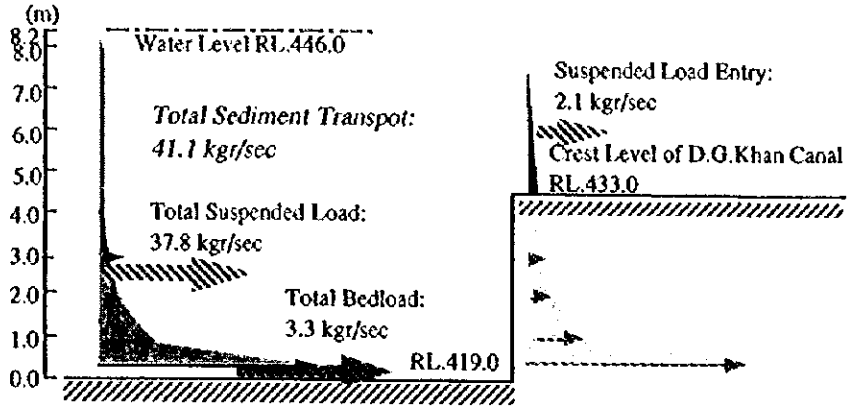
Difference between **S.C** and **S.t** of 0.0056 m^3/s (14.73 kgr/s) is to be deposited on the canal bed as **S.Dep.** The Case 3 introducing such consequence is in present situation of the D.G.Khan Canal, of which bottom silted up about 4 feet. In order to secure design flow capacity in the condition of the Case 3, silted bottom of the canal have to be excavated as it was. However, if being excavated into the condition of Case 2, silt deposit must be increased because of reducing sediment transport capacity of the channel form 12.826 73 kgr/s to 5.565 73 kgr/s as shown in above table. It will be anticipated to be silted in a moment. A measure for reducing silt entry from right pocket is essencial.

In above discussion, the silt entry in right pocket (**S.R**) was applied roughly assessed value. Quantity of the silt entry can be hydraulically calculated if some assumptions be allowed. Refering to the hydraulic data concerning right pocket on the Table C.6.1, following total sediment transport was calculated adopting Brown formal as same manner mentioned above.

Sediment Transport in Right Pocket applied by Brown Formula

Case	u* (m/s)	d mean (cm)	Specific sediment ($cm^3/s/m$)	Total sediment (m^3/s)	Total (kgr/s)
at Design Flood	0.225	0.020	121,696.9	9.6810	25,654.60
at high flood	0.135	0.020	9,479.5	0.7461	1,977.27
at nomal flow	**0.062**	**0.020**	**194.7**	**0.0155**	**41.05**
canal feeding only	0.024	0.020	1.5	0.0001	0.32

Among above cases, nomal flow condition with 23,000 Cs discharge into right pocket may be considered as the most probable situation. Total sediment transport of 41.05 kgr/s was obtained, which is a reasonable figure in comparison aforesaid estimation of **S.R** of 27.56 kgr/s in consideration with silt outflow. Suspended load can also be calculated by the Rouse formula. It was obtained estimation of total suspended load at 37.77 kgr/s. Suspended distribution by water depth is shown in figure below.



If direct bedload entry into the D.G.Khan Canal is hindered successfully, sediment transport of the D.G.Khan Canal is drastically reduced as illustrated in above figure. Measures and sediment management must do never so as to rise silt bed of the right pocket near and above the crest level of D.G.Khan Canal regulator. Throgh above study, following founfings were brought out.

- Under the normal flow as being most probable situation, silt will enter right pocket at about 41 kgr/sec (0.0155 m^3/sec) taking the forms of tractional transport, or suspended transport. Providing that allowable deposit margin of right pocket floor is about 10 feet, silt flashing of the pocket should be done at least once par 16.2 days. Much frequent flashing is required in Kharif, if considering the fact that bigger discharges rather than that are appeared repeatedly.

- If adequate silt flashing is done as such manner, silt entry into the D.G.Khan Canal must be drastically decreased.

- Enormous silt entry is expected to be transported when flood come. During flood passing, any intercept of flood moving even in gate operation is never allowed.

- Small silt transport of 0.32 kgr/sec was calculated in condition of "at full canal feeding only" of above analysis, in which under-sliuce is assumed to be closed completely. Its figure seems to bring about no any siltation problem in D.G.Khan Canal. However, it should be emphasized that its figure is not actual quantity of silt transport, but a sediment transport capability. Much quantity of silt must be transported in the water course flowing upstream side of the right pocket entry, and such high silt dencity flow is surely entering into the right pocket. By these reasons, almost same silt entry with the case of " at nomal flow" can be expected even in the cace of the "at full canal feeding only".

C.6.3. Sediment Management in Right Pocket

(1) Introductory

The management of sediment at Taunsa Barrage and specially in D.G.Khan Canal has remained a chronic problem since 1965. The Taunsa Barrage was constructed on the left(East) of the main active channel of River Indus which was later diverted through the Barrage. The river flow has generally approached the Barrage with an oblique curving entry into the Guide-Bank Zone, throwing the right pocket and D.G.Khan Canal on the intrados of the approach curve with resultant increase in sediment entry and deposits in the right half of the Barrage. This phenomenon also causes imbalance in the Flank Gauges at the Barrage resulting in lower pond level on the right flank. This imbalance in the pond level and increased sediment entry into the right pocket and in-turn into D.G.Khan Canal results in silting up the canal and reduction in discharge capacity of the channel.

(2) Performance of Head-regulator of D.G.Khan Canal

The Head-regulator of D.G.Khan Canal with a clear water-way of 168 ft was originally designed with following data:

- Pond level (R/Flank) = 446.0
- FSL in the D.G.Khan Canal = 444.0
- Crest level of Head-regulator = 433.0

The Head-regulator with this data can draw more than the final capacity of D.G.Khan Canal (14,300Cs). Long section of the D.G.Khan Canal was amended for a discharge of 11,549 Cs and FSL of 444.90 and a revised pond RL 447.0 in 1992, but this raising of pond level was not incorporated in the regulation / operating rules of the Barrage. The Head-regulator even with this data can take full discharge. However, due to silting in the canal, the working head reduces and the capacity of Head-regulator is impaired as described in previous paragraphs. For the bed configuration of December 1997 in the Canal, the discharge through Head-regulator reduces to 6,554 Cs for a raised FSL of 445.77. The present demand on the canal is around 9,000 Cs and local officers, therefore supplement this discharge through direct withdrawal from the river pond through inlet at RD.19700 which was never meant for this purpose. This additional discharge let into the canal at this location, raises the water level by over a foot and causes reduction in slope in the upstream reach increasing sedimentation in the canal bed, thus triggering the vicious circle of siltation and reduction in the canal capacity.

(3) Performance of Silt Ejectors in D.G.Khan Canal

The D.G.Khan Canal was provided with a silt ejector at RD.20800 for abstracting substantial quantity of sediment (about 13 % of sediment charge which amounts to almost the whole bed load). This ejector after running for a few seasons lost its function because of choking of its out-fall channel which was about 18 miles long. The need for another Silt Ejector at a better location was therefore felt. The Irrigation Research Institute, after conducting model studies, recommended that the optimum location for the second silt ejector is at RD.7500. This silt ejector was constructed in 1974. Both these ejectors are of vortex-tube type which loose their efficiency for froude numbers less than 0.80.

As pointed above, the working of inlet at RD.19700/R, reduces the slope in the head-reach and also froude number at ejector at RD/7500 which becomes ineffective. The solution for sediment management and improvement of discharge capacity of D.G.Khan Canal, therefore lies in the Barrage pond.

(4) Reasons for Higher Silt Charge in D.G.Khan Canal

As already expressed earlier the excessive sediment and grade in D.G.Khan Canal is due to:

- Excessive sediment concentration in the right pocket and D.G.Khan intake being located on the inner side of the river approach curve.

- There are quite a few potent hill torrents which join the river, a short distance, on the upstream right side of the Barrage which bring very heavy coarse sediment and thus increase sediment concentration in the right half of the river channel.

- The capacity of right pocket apparently seems to be on the lower side than required.

- Under the present system of regulation, right pocket gets silted up quickly and D.G.Khan Canal receives the supply direct from the river channel with the same heavy concentration of sediment. This aspect is clearly exhibited in Table C6.3.1 to C6.3.3 besides Fig.C6.1.2.

- Under-sluices do not function adequately for flashing sediment in the right pocket as shown in Fig.C6.1.1.

(5) Remedial Measures

A comprehensive analysis of the whole scenario of the sediment issue, the following remedial measures are needed:

- Construction of a tunnel type silt excluder is recommendable, however improving under-sluices mechanism and appropriate gate operation will be expected to be remedial for the sediment problem of right pocket.
- Extension of right divided wall is recommended to cure oblique approch of River Indus.
- Proper training of River Indus on the upstream of the Barrage is recommended to obtain a central and straight approach.
- Stopping the use of inlet structure at RD. 19700 D.G.Khan Canal which should better be demolished or closed permanently.

(6) Capacity of Right Pocket

Right pocket at Taunsa Barrage has a total-way of 261 ft. and a design depth of 27 ft. with a clean floor and design pond level. In such ideal conditions the pocket has an ample capacity of 21,141 cft. with normal velocity of 3 ft/sec which is adequate. However, on account of oblique river approach, masking of right pocket and sediment deposits, the depth of the pocket reduces to as low as 14 ft. Reducing the pocket capacity substantially. Due to lowering of pond level on the right side to almost RL 444.0, the pocket capacity reduces further to even lower than the canal discharge as explained below.

Capacity of Right Pocket

Total water-way at the divide wall nose	=	60 x 4 + 7 x 3 =	261 ft
Pond level (designed)	=		RL 446.0 ft
Pond level (actual)	=		RL 444.0 to 445.0 ft
Pocket floor leval	=		RL 419.0 ft
Depth of water (ideal conditions)	=	446.0 - 419.0 =	27.0 ft
Taking velosity (non scouring value)	=		3.0 fts
Pocket capacity (ideal conditions)*	=	261 x 27 x 3 =	**21,141 Cfs**
*: This is a similar case of "at normal flow" in previous paragraph of C.6.2.			
Silt level in the pocket (worst conditions)	=		RL 432.0 ft
Depth of water (worst conditions)	=	444.0 - 432.0 =	12.0 ft
Taking velosity (allowable value)	=		5.0 fts
Pocket capacity (worst conditions)	=	261 x 12 x 5 =	**15,660 Cfs**

Even the pocket capacity in worst conditons is not below the final canal requirement of 14,300 Cs. But in view of oblique approach and silting tendency, the water-way increase may appear to be necessity. This will require, addition of one more bay to raise the no. of pocket bays to 5 by shifting the divide wall to pier No.61 with extended length to be determined in detailed design stage if necessary. However, the final dimensions could be established after model studies.

C.7. Rainfall Characteristics in the Study Area

Rainfall phenomena in the Study Area has a localized characteristic particularly in Kharif. Fig.C7.1.1 shows off-taking discharge of D.G.Khan Canal, rainfall data of Taunsa Barrage Station and Jampur Station in 1995. In comparison between both rainfall data, remarkable difference is identified for which those stations are away from approximately 100 km.

Fluctuation of off-taking discharge can be explained by growing stage of crop and effective rainfall. Stoppage of irrigation water supply on July are concluded due to sufficient effective rainfall in the Study Area. These facts evident to conduct adequate water management in which appropriate response for actual indents have been taken.

C.8. Flow Regime of River Indus

River training on the upstream of Taunsa Barrage including bela control is essential in order to protect country side from flood, and to form sustainable river approach in the upstream of Taunsa Barrage. Fig.C8.1.1 shows existing river training works consisting of a battery of several spurs and marginal bunds, and recent historical river courses moving. At the moment, the left arm is inactive and prominent discharge flows in the right arm.

Training of River Indus at Taunsa Barrage has been handled in piece-meal fashion, which has resulted in in-efficient working and vulnerability of the training structures on the right bank. In brief the location and orientation of the heads of training spurs should follow the two lines which make an angle of 30 degree with barrage axis on either side.

Even though extensive difficulties exists, proposed and on-going river training works are appreciated and recommended to promote as plan as continuously watching actual change of flow.

Table C6.1.1 Hydraulic Dimensions Concerning Taunsa Barrage

Design Dimensions of Right Pocket of Taunsa Barrage

Length (feet)	Bed Level (feet)	"N"	Slope (0/00)	Design Dicharge* (Cs)	(m3/s)	Pocket Width (feet)	(m)	Water Depth (feet)	(m)	Area of Section (m2)	Hydraulic Section (m)	Mean Velocity (m/s)	Shear Velocity U. (m/s)	Remarks
L.6 293	419.00	0.025	0.630	83,520	2365.3	261.0	79.55	27.00	8.230	654.696	6.819	3.6128	0.2254	at Design Flood
L.6 293	419.00	0.025	0.227	50,000	1416.0	261.0	79.55	27.00	8.230	654.696	6.819	2.1628	0.1352	at High flood
L.6 293	419.00	0.025	0.048	23,000	651.4	261.0	79.55	27.00	8.230	654.696	6.819	0.9949	0.0622	at normal flow
L.6 293	419.00	0.025	0.007	8,757	248.0	261.0	79.55	27.00	8.230	654.696	6.819	0.3788	0.0236	at full canal feeding only

*: Design discharge is the discharge passing through right pocket

Design Dimensions of D.G.Khan Canal

Length (feet)	Bed Level (feet)	"N"	Slope (0/00)	Design Dicharge (Cs)	(m3/s)	Canal Bed Width (feet)	(m)	Water Depth (feet)	(m)	Area of Section (m2)	Hydraulic Section (m)	Mean Velocity (m/s)	Shear Velocity U. (m/s)	Remarks
RD 000	431.30													
		0.031	0.095	8,757	248.0	180.0	54.86	12.73	3.880	227.934	3.462	1.088	0.0601	Designed
		0.031	*0.046*	*8,757*	*248.0*	*260.0*	*79.25*	*12.70*	*3.871*	*321.596*	*3.566*	*0.771*	*0.0418*	actual 260.0'width condition
		0.031	*0.091*	*7,000*	*198.2*	*260.8*	*79.49*	*8.96*	*2.731*	*216.47*	*2.592*	*0.876*	*0.0493*	Observed(14/Oct/97)
RD 40000	427.90	0.031	0.095	7,744	219.3	172.0	52.43	12.30	3.704	207.896	3.305	1.055	0.0587	(230.0ft.)
RD 88500	423.30	0.029	0.095	6,124	173.4	186.0	56.69	9.77	2.978	177.643	2.728	0.976	0.0527	(200.0ft.)
RD 131500	417.39	0.030	0.095	5,944	168.3	182.0	55.47	9.82	2.993	175.013	2.737	0.962	0.0528	(190.0ft.)
RD 148000	415.83	0.029	0.095	5,868	166.2	180.0	54.86	9.71	2.960	171.133	2.706	0.971	0.0525	(190.0ft.)
RD 175,000	414.74	0.030	0.095	5,722	162.0	179.0	54.56	9.70	2.955	169.961	2.701	0.953	0.0525	(185.0ft.)
RD 191500	414.32	0.030	0.095	5,598	158.5	178.0	54.25	9.60	2.926	167.329	2.676	0.947	0.0522	(185.0ft.)
RD 228500	410.90	0.029	0.095	5,498	155.7	176.0	53.64	9.47	2.885	163.075	2.639	0.955	0.0518	(180.0ft.)
RD 242215	409.62	0.030	0.095	5,315	150.5	174.0	53.04	9.53	2.905	162.495	2.653	0.926	0.0520	(180.0ft.)
RD 283000	405.82	0.030	0.095	5,132	145.3	170.0	51.82	9.37	2.856	156.111	2.607	0.931	0.0516	(175.0ft.)
RD 315000	402.88	0.030	0.095	5,057	143.2	169.0	51.51	9.32	2.841	154.378	2.593	0.928	0.0514	(170.0ft.)
RD 341000	400.51	0.030	0.095	4,884	138.3	166.0	50.60	9.32	2.841	151.777	2.589	0.911	0.0514	(170.0ft.)
RD 345030	400.11	0.030	0.111	4,857	137.6	163.0	49.68	8.97	2.734	143.227	2.495	0.960	0.0545	
Dajal Branch														

Design Dimensions of Muzaffargarh Canal

Length (feet)	Bed Level (feet)	"N"	Slope (0/00)	Design Dicharge (Cs)	(m3/s)	Canal Bed Width (feet)	(m)	Water Depth (feet)	(m)	Area of Section (m2)	Hydraulic Section (m)	Mean Velocity (m/s)	Shear Velocity U. (m/s)	Remarks
RD 000	433.50	0.031	0.111	8,285	234.6	218.0	66.45	10.48	3.193	222.339	2.946	1.055	0.0589	
RD 67500	433.25													

The values of "n" in above tables were calculated back from indicated figures of discharge, canal bed width, and water depth.

Table C6.3.1 Taunsa Barrage Silt Sounding of Right Pocket Dated

Bay No.	Distance from the Toe of U/S Glacis (Ft.)						Remarks	
	50	100	150	200	250	293		
	Line No.1	Line No.2	Line No.3	Line No.4	Line No.5	Line No.6		
04-08-1996								
62	14.0	13.0	11.0	13.0	13.0	14.0	Gauge:-	447.2
63	10.0	14.0	13.0	13.5	12.0	10.0	Floor Level:-	419.0
64	9.0	10.0	12.0	12.5	14.0	10.0	Clear Sounding:-	28.20 (a)
65	11.0	8.5	13.5	14.5	13.0	9.5	Total of Averages:-	=71.98
Total	44.0	45.5	49.5	53.5	52.0	43.5	Mean Sounding	±11.99 (b)
Average	11.0	11.4	12.4	13.4	13.0	10.9	Silt Depth Average (a-b)	=162.0 ft
21-08-1996								
62	11.0	12.0	13.0	14.0	15.0	16.0	Gauge:-	447.2
63	12.0	10.0	11.0	12.0	11.0	10.0	Floor Level:-	419.0
64	10.0	12.0	9.0	13.0	12.0	11.0	Clear Sounding:-	28.20 (a)
65	11.0	10.0	12.0	12.0	13.0	9.0	Total of Averages:-	=71.98
Total	44.0	44.0	45.0	51.0	51.0	46.0	Mean Sounding	±11.99 (b)
Average	11.0	11.0	11.3	12.8	12.8	11.5	Silt Depth Average (a-b)	=162.0 ft
17-07-1997								
62	11.0	16.0	17.0	13.0	13.0	15.0	Gauge:-	447.5
63	18.0	18.0	16.0	15.0	12.0	9.0	Floor Level:-	419.0
64	15.0	16.0	14.0	14.0	12.0	12.0	Clear Sounding:-	28.50 (a)
65	17.0	16.0	14.0	16.0	12.0	13.0	Total of Averages:-	=86
Total	61.0	66.0	61.0	58.0	49.0	49.0	Mean Sounding	±14.50 (b)
Average	15.3	16.5	15.3	14.5	12.3	12.3	Silt Depth Average (a-b)	=14.0 ft
25-06-1997								
62	12.0	17.0	18.0	14.0	14.0	11.0	Gauge:-	447.2
63	17.0	17.0	15.0	14.0	11.0	13.0	Floor Level:-	419.0
64	16.0	17.0	15.0	13.0	12.0	13.0	Clear Sounding:-	28.50 (a)
65	16.0	15.0	13.0	17.0	12.0	12.0	Total of Averages:-	=86.00
Total	61.0	66.0	61.0	58.0	49.0	49.0	Mean Sounding	±14.50 (b)
Average	15.3	16.5	15.3	14.5	12.3	12.3	Silt Depth Average (a-b)	=14.0 ft

Table C6.3.2 Taunsa Barrage Silt Levels in Right Pocket

Date:

Bay No.	Distance from the Toe of U/S Glacis (feat)					
	50	100	150	200	250	293
	Line No.1	Line No.2	Line No.3	Line No.4	Line No.5	Line No.6
62	433.20	434.20	436.20	434.20	434.20	433.20
63	437.20	433.20	434.20	433.70	435.20	437.20
64	436.20	438.70	433.70	432.70	434.20	437.70
65	437.20	438.70	433.70	432.70	434.20	437.70

H.R.D.G. Khan Canal Crest R.L 433.00

Date:

Bay No.	Distance from the Toe of U/S Glacis (feat)					
	50	100	150	200	250	293
	Line No.1	Line No.2	Line No.3	Line No.4	Line No.5	Line No.6
62	434.50	433.50	432.50	431.50	430.50	429.50
63	433.50	435.50	434.50	433.50	434.50	435.50
64	435.50	433.50	436.50	432.50	433.50	334.50
65	434.50	435.50	433.50	433.50	432.50	436.00

H.R.D.G. Khan Canal Crest R.L 433.00

Table C6.3.3 Statement Showing Silt Entry Data Observed at Taunsa Barrage during the Month of June 1997 (grams/litre) (1/3)

	D.G.Khan Canal			S/E RD 7500 D.G.Khan Canal			R.P.U/S			R.P D/S		
Date 6/97	C	M	C + M	C	M	C + M	C	M	C + M	C	M	C + M
1			-				-	-	-	-	-	-
2	0.03	0.06	0.09	Closed			0.02	0.07	0.09	0.02	0.03	0.05
3	0.02	0.06	0.08				0.02	0.04	0.06	0.03	0.06	0.09
4	0.03	0.06	0.09				0.02	0.03	0.05	0.04	0.06	0.1
5	0.03	0.07	0.1				0.03	0.06	0.09	0.06	0.05	0.11
6	0.02	0.09	0.11				0.02	0.05	0.07	0.02	0.04	0.06
7	0.02	0.08	0.1				0.02	0.04	0.06	0.02	0.03	0.05
8	-	-	-				-	-	-	-	-	-
9	0.03	0.08	0.11				0.03	0.06	0.09	0.02	0.05	0.07
10	0.02	0.09	0.11				0.02	0.04	0.06	0.02	0.05	0.07
11	0.02	0.11	0.13				0.03	0.03	0.06	0.03	0.06	0.09
12	0.03	0.15	0.18				0.03	0.1	0.13	0.03	0.07	0.1
13	0.04	0.28	0.32				0.04	0.16	0.2	0.04	0.14	0.18
14	0.05	0.31	0.36				0.02	0.15	0.17	0.04	0.14	0.18
15	-	-	-				-	-	-	-	-	-
16	0.07	0.38	0.45				0.04	0.2	0.24	0.05	0.28	0.33
17	0.04	0.3	0.34				0.04	0.48	0.52	0.09	0.62	0.71
18	0.06	0.35	0.41				0.06	0.58	0.64	0.06	0.68	0.74
19	0.08	0.23	0.31				0.04	0.48	0.52	0.04	0.63	0.67
20	0.08	0.34	0.42				0.06	0.5	0.56	0.07	0.52	0.59
21	0.07	0.38	0.45				0.07	0.7	0.77	0.07	0.63	0.7
22	-	-	-				-	-	-	-	-	-
23	0.1	0.33	0.43				0.11	0.65	0.76	0.09	0.51	0.6
24	0.28	0.39	0.67				0.14	0.49	0.63	0.08	0.48	0.56
25	0.19	0.33	0.52				0.12	0.44	0.56	0.08	0.5	0.58
26	0.21	0.3	0.51				0.14	0.55	0.69	0.22	0.78	1
27	0.25	0.39	0.64				0.14	0.88	1.02	0.1	0.56	0.66
28	0.17	0.39	0.56				0.2	0.76	0.96	0.28	0.7	0.98
29	0.11	0.33	0.44				0.25	0.68	0.93	0.17	0.56	0.73
30	Closed at flushing up						0.52	0.84	1.36	0.4	0.8	1.2
Total			7.93						11.29			11.2
Average			0.32						0.43			0.43

Table C6.3.3 Statement Showing Silt Entry Data Observed at Taunsa Barrage during the Month of July 1997 (grams/litre) (2/3)

	D.G.Khan Canal			S/E RD 7500 D.G.Khan Canal			R.P.U/S			R.P D/S		
Date7/97	C	M	C+M	C	M	C+M	C	M	C+M	C	M	C+M
1	-	-	-	-	-	-	0.6	1.4	-	0.48	1.4	-
2	0.07	0.19	0.26	0	-	0.26	0.1	0.42	0.52	0.25	0.62	0.87
3	0.08	0.25	0.33	0.28	0.52	0.8	0.07	0.21	0.28	0.1	0.21	0.31
4	0.06	0.33	0.39	0.25	0.4	0.65	0.07	0.38	0.45	0.06	0.31	0.37
5	0.08	0.45	0.53	0.14	0.56	0.7	0.08	0.4	0.48	0.07	0.31	0.38
6	-	-	-	-	-	-	-	-	-	-	-	-
7	0.05	0.25	0.3	0.2	0.64	0.84	0.08	0.2	0.28	0.08	0.16	0.24
8	0.03	0.21	0.24	0.34	0.67	1.01	0.03	0.22	0.25	0.03	0.17	0.2
9	0.04	0.22	0.26	0.12	0.62	0.74	0.06	0.24	0.3	0.04	0.2	0.24
10	0.04	0.22	0.26	0.17	0.61	0.78	0.03	0.33	0.36	0.04	0.24	0.28
11	0.05	0.28	0.33	0.19	0.71	0.9	0.07	0.38	0.45	0.06	0.28	0.34
12	0.08	0.34	0.42	0.38	1.76	2.14	0.08	0.46	0.54	0.07	0.34	0.41
13	-	-	-	-	-	-	-	-	-	-	-	-
14	0.07	0.35	0.42	0.7	1.75	2.45	0.12	0.64	0.76	0.24	0.8	1.04
15	0.09	0.53	0.62	0.42	1.63	2.05	0.19	0.7	0.89	0.24	0.88	1.12
16	0.12	0.4	0.52	0.77	0.84	1.61	0.6	1.4	2	0.32	1	1.32
17	0.07	0.42	0.49	0.37	0.52	0.89	0.2	0.64	0.84	0.24	0.72	0.96
18	0.08	0.34	0.42	0.22	0.53	0.75	0.12	0.42	0.54	0.2	0.48	0.68
19	0.07	0.28	0.35	0.39	0.7	1.09	0.08	0.28	0.36	0.14	0.37	0.51
20	-	-	-	-	-	-	-	-	-	-	-	-
21	0.08	0.34	0.42	0.35	0.7	1.05	0.12	0.4	0.52	0.35	0.42	0.77
22	0.14	0.56	0.7	0.28	0.67	0.95	0.28	0.48	0.76	0.28	0.45	0.73
23	0.08	0.45	0.53	0.25	0.61	0.86	0.1	0.42	0.52	0.08	0.44	0.52
24	0.14	0.42	0.56	0.22	0.78	1	0.83	0.56	1.39	0.4	0.48	0.88
25	0.08	0.34	0.42	0.12	0.68	0.8	0.62	0.5	1.12	0.44	0.62	1.06
26	0.08	0.28	0.36	0.19	0.68	0.87	1.07	0.87	1.94	0.56	0.9	1.46
27	0.08	0.31	0.39	0.12	0.6	0.72	0.19	0.37	0.56	0.33	0.45	0.78
28	0.08	0.28	0.36	0.19	0.56	0.75	0.16	0.28	0.44	0.17	0.33	0.5
29	0.06	0.31	0.37	0.11	0.45	0.56	0.2	0.4	0.6	0.12	0.4	0.52
30	0.07	0.28	0.35	0.44	0.16	0.6	0.32	0.72	1.04	0.25	0.62	0.87
31	0.06	0.45	0.51	0.15	0.62	0.77	0.2	0.32	0.52	0.17	0.31	0.48
Total			11.11			26.59			18.71			17.84
Average			0.41			0.98			0.69			0.66

Table C6.3.3 Statement Showing Silt Entry Data Observed at Taunsa Barrage during the Month of August 1997 (grams/litre) (3/3)

	D.G.Khan Canal			S/E RD 7500 D.G.Khan Canal			R.P.U/S			R.P D/S		
Date7/97	C	M	C + M	C	M	C + M	C	M	C + M	C	M	C + M
1	0.06	0.34	-	0.11	0.57	-	0.12	0.52	-	0.21	0.35	0.56
2	0.1	0.51	0.61	0.9	0.93	1.83	0.16	0.4	0.56	0.28	0.56	0.84
3	0.12	0.65	0.77	0.14	0.79	0.93	0.19	0.56	0.75	0.32	0.88	1.2
4	0.58	0.84	1.42	0.19	0.61	0.8	0.84	1.12	1.96	0.62	0.87	1.49
5	0	0	0	Closed at Head 8 A.M			6.12	2.1	8.22	4.8	2	6.8
6	0	-	-	-	-	-	1.68	1.4	-	1.12	1.23	2.35
7	0.14	0.33	0.47	Flushing of Right Pocket			0.14	0.37	0.51	0.4	0.4	0.8
8	0.06	0.12	0.18	0.42	0.73	1.15	0.08	0.16	0.24	0.09	0.09	0.18
9	0.06	0.08	0.14	0.19	0.72	0.91	0.05	0.1	0.15	0.03	0.14	0.17
10	0.06	0.11	0.17	0.21	0.7	0.91	0.03	0.1	0.13	0.08	0.12	0.2
11	0.03	0.1	0.13	0.2	0.8	1	0.03	0.8	0.83	0.06	0.11	0.17
12	0.03	0.14	0.17	0.31	1.71	2.02	0.04	0.12	0.16	0.11	0.12	0.23
13	0.05	0.08	0.13	0.76	2.603	3.363	0.04	0.13	-	0.06	0.34	0.4
14	0.03	0.11	0.14	0.52	1.57	2.09	0.04	0.14	0.18	0.08	0.24	0.32
15	0.04	0.14	0.18	0.63	1.26	1.89	0.05	0.12	0.17	0.06	0.3	0.36
16	0.07	0.37	0.44	0.16	0.62	0.78	0.08	0.4	0.48	0.05	0.35	0.4
17	0.06	0.27	0.33	0.14	0.68	0.82	0.14	0.47	0.61	0.06	0.24	0.3
18	0.05	0.24	0.29	0.18	0.72	0.9	0.18	0.48	0.66	0.09	0.08	0.17
19	0.05	0.16	0.21	0.45	0.84	1.29	0.08	0.16	0.24	0.06	0.11	0.17
20	0.05	0.19	0.24	0.56	0.99	1.55	0.14	0.19	-	0.06	0.17	0.23
21	0.06	0.17	0.23	0.48	0.88	1.36	0.16	0.16	0.32	0.11	0.17	0.28
22	0.05	0.21	0.26	0.54	1	1.54	0.1	0.21	0.31	0.07	0.17	0.24
23	0.05	0.19	0.24	0.25	0.68	0.93	0.14	0.17	0.31	0.17	0.22	0.39
24	0.07	0.36	0.43	0.28	0.56	0.84	0.17	0.38	0.55	0.16	0.24	0.4
25	0.07	0.42	0.49	0.22	0.68	0.9	0.14	0.36	0.5	0.2	0.48	0.68
26	0.05	0.47	0.52	0.12	1.06	1.18	0.09	0.47	0.56	0.08	0.68	0.76
27	0.07	0.59	0.66	0.14	1.05	1.19	0.12	0.4	0.52	0.09	0.31	0.4
28	0.07	0.54	0.61	0.12	0.75	0.87	0.16	0.72	0.88	0.1	0.84	0.94
29	0	0	0	0	0	0	3.77	1.12	4.89	0.44	1.4	1.84
30	0	0	0	0	0	0	5.132	2.1	7.232	3.4	2.4	5.8
31	0	0	0	0	0	0	3.85	2.27	6.12	3.36	2.52	5.88
Total			9.46			31.043			38.042			34.95
Average			0.38			1.24			1.41			1.13

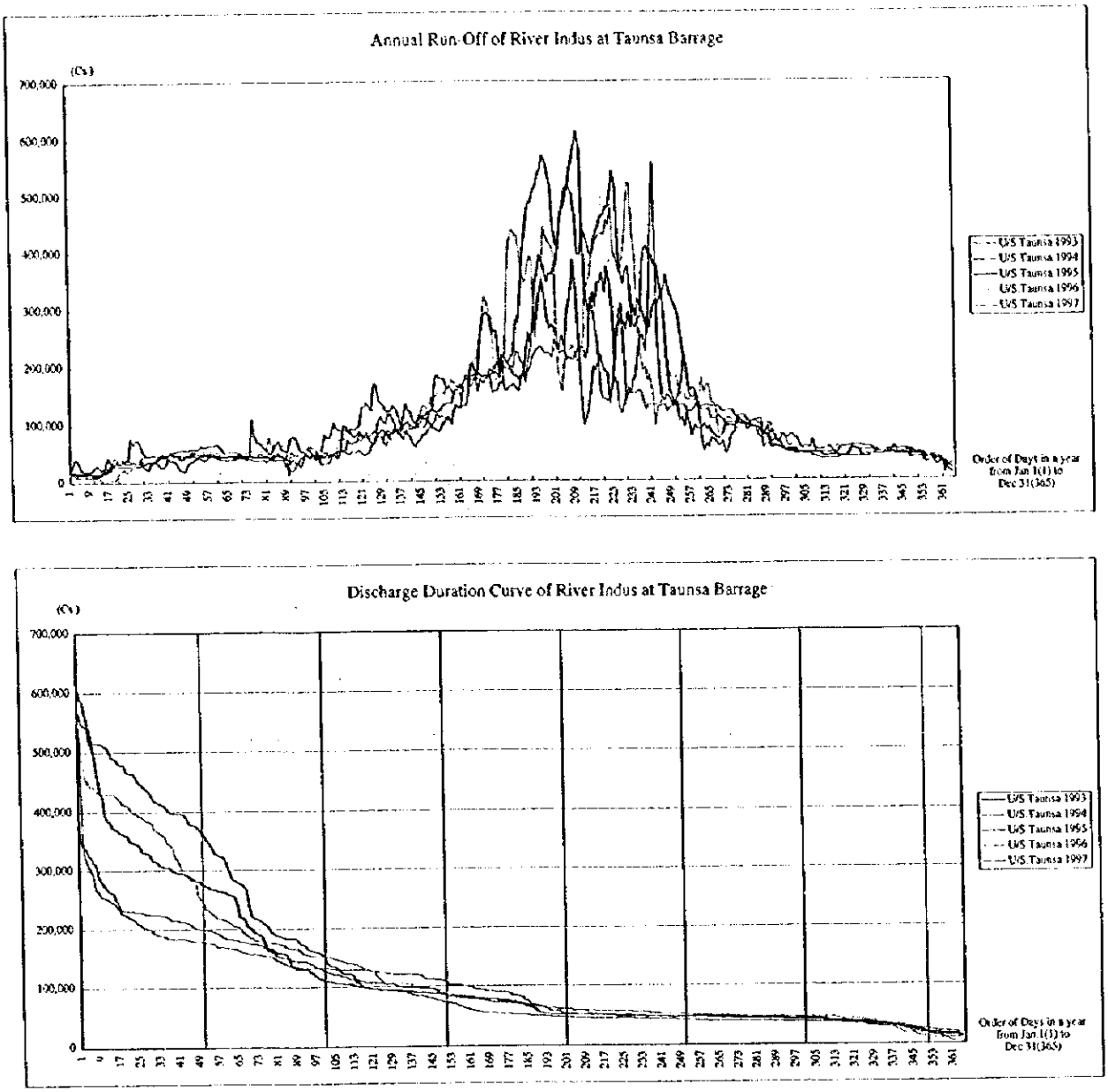


Fig.C1.1.1 Discharge and Discharge Duration Curve of River Indus at Taunsa Barrage

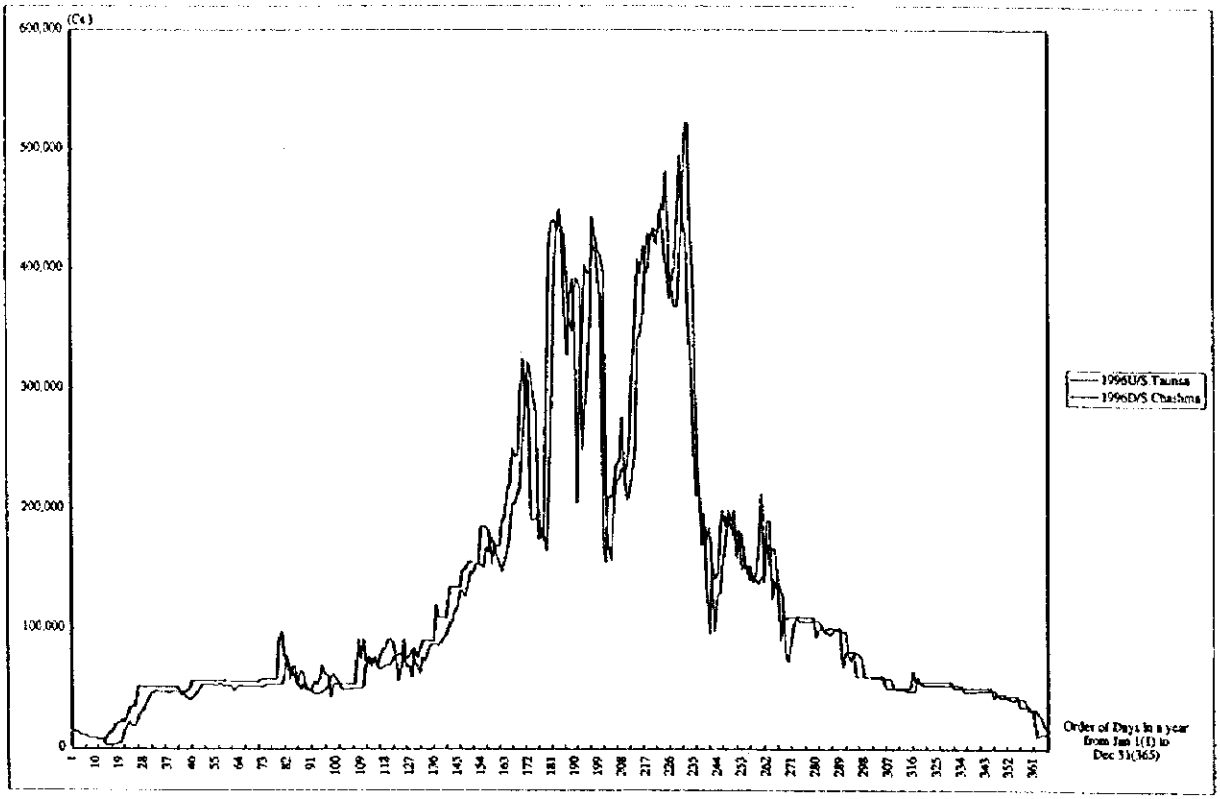


Fig.C1.1.2 Discharge Sequences of Taunsa Barrage Site and Chashma Barrage Site

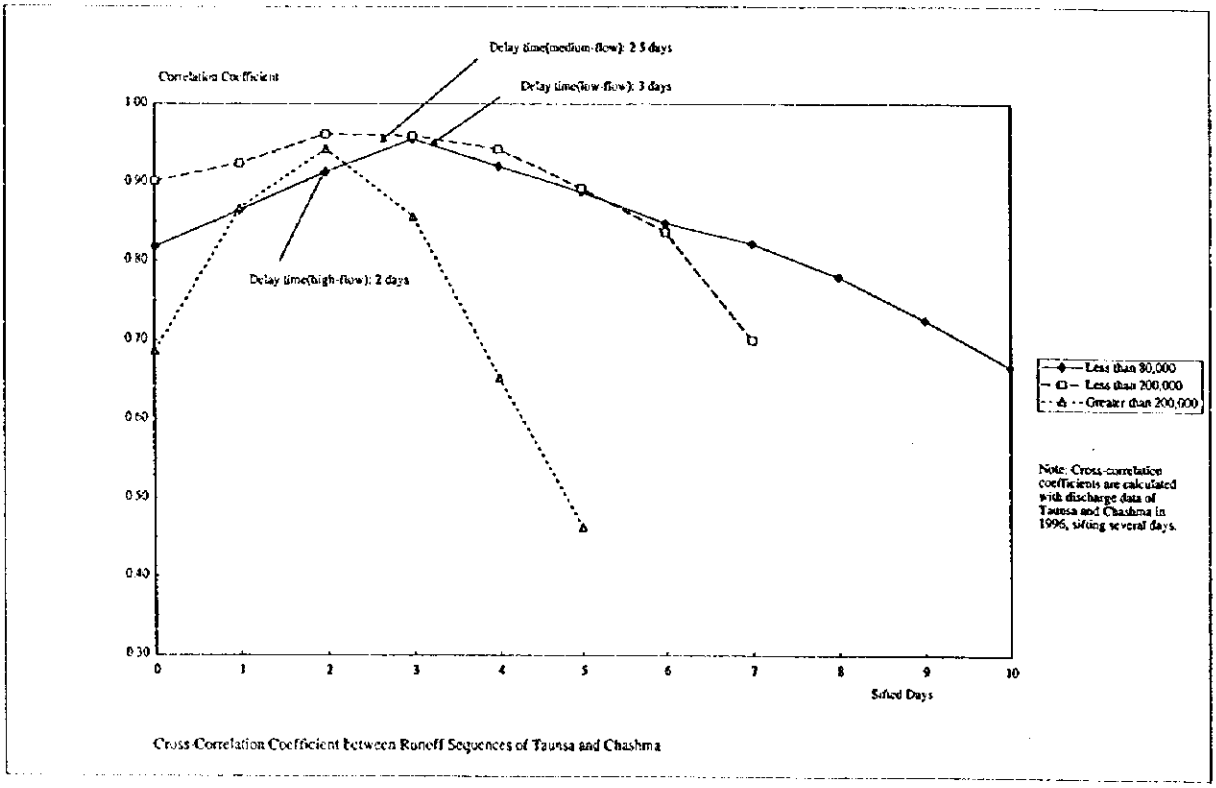


Fig.C1.1.3 Cross-Correlation Coefficient between Runoff Sequences of Taunsa Barrage Site and Chashma Barrage Site

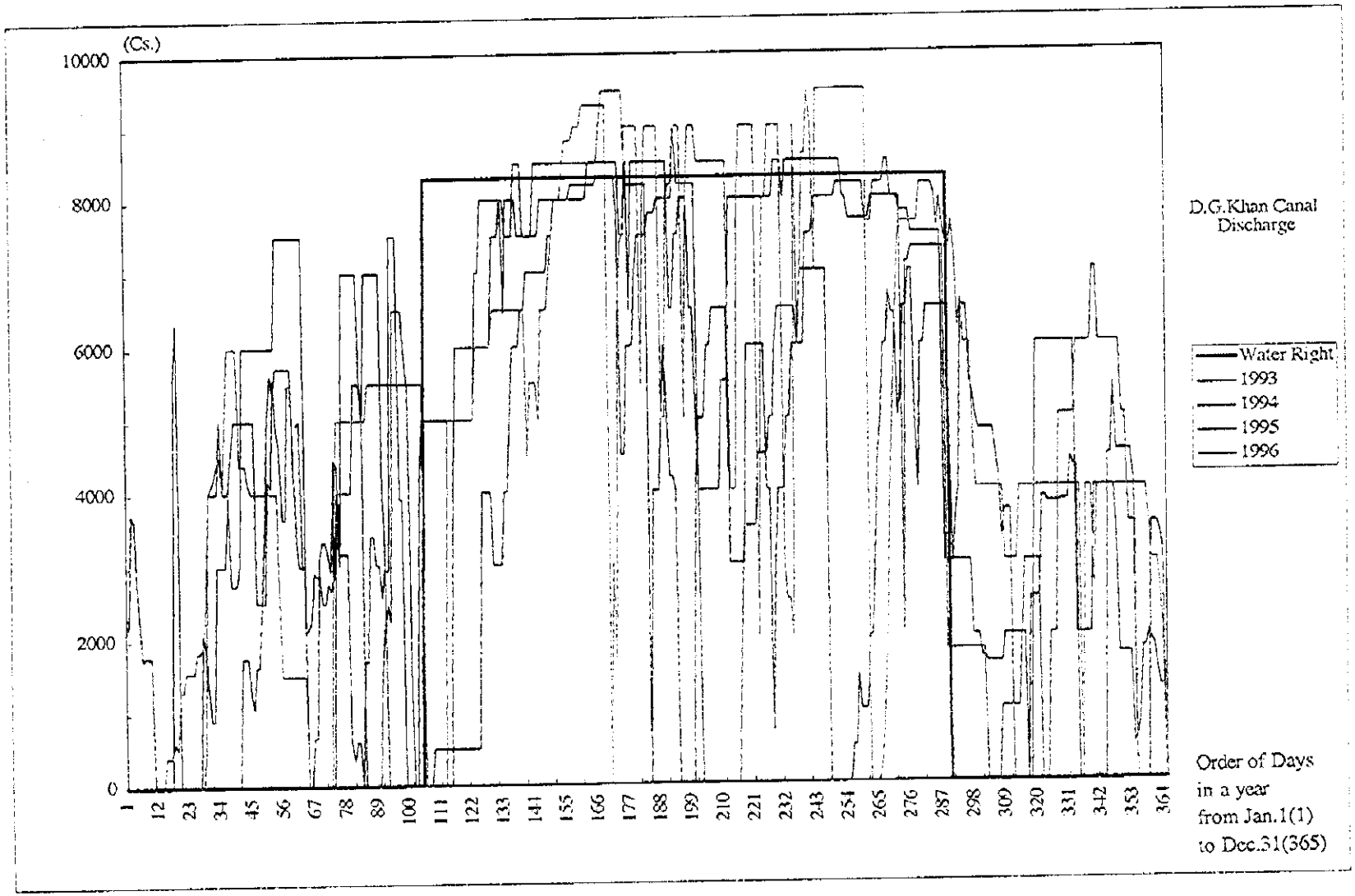


Fig.C2.1 Chronological Off-Taking Discharge of D.G.Khan Canal

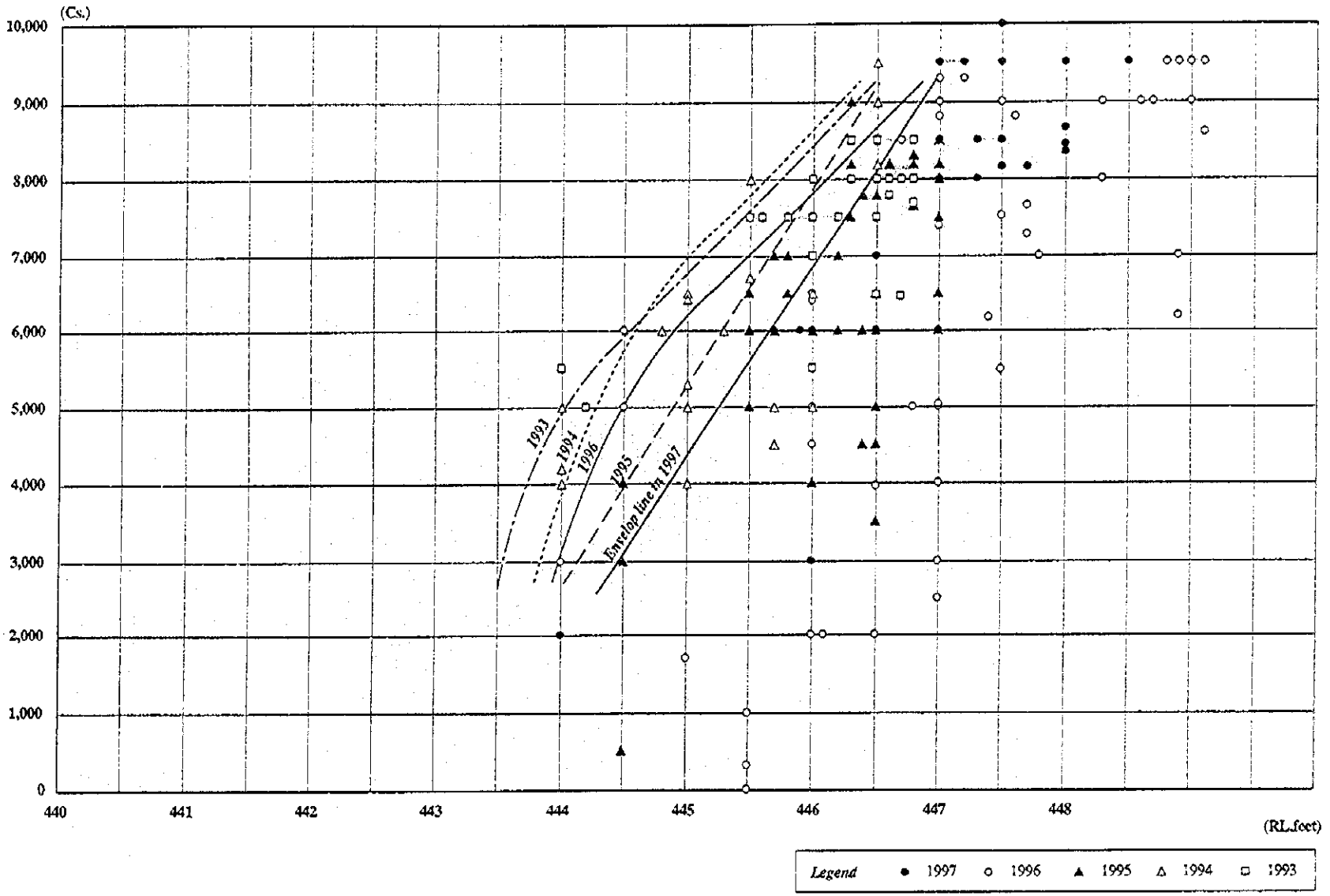


Fig. C2.2 Relation between Pond Level and Feeding Discharge of D.G.Khan Canal

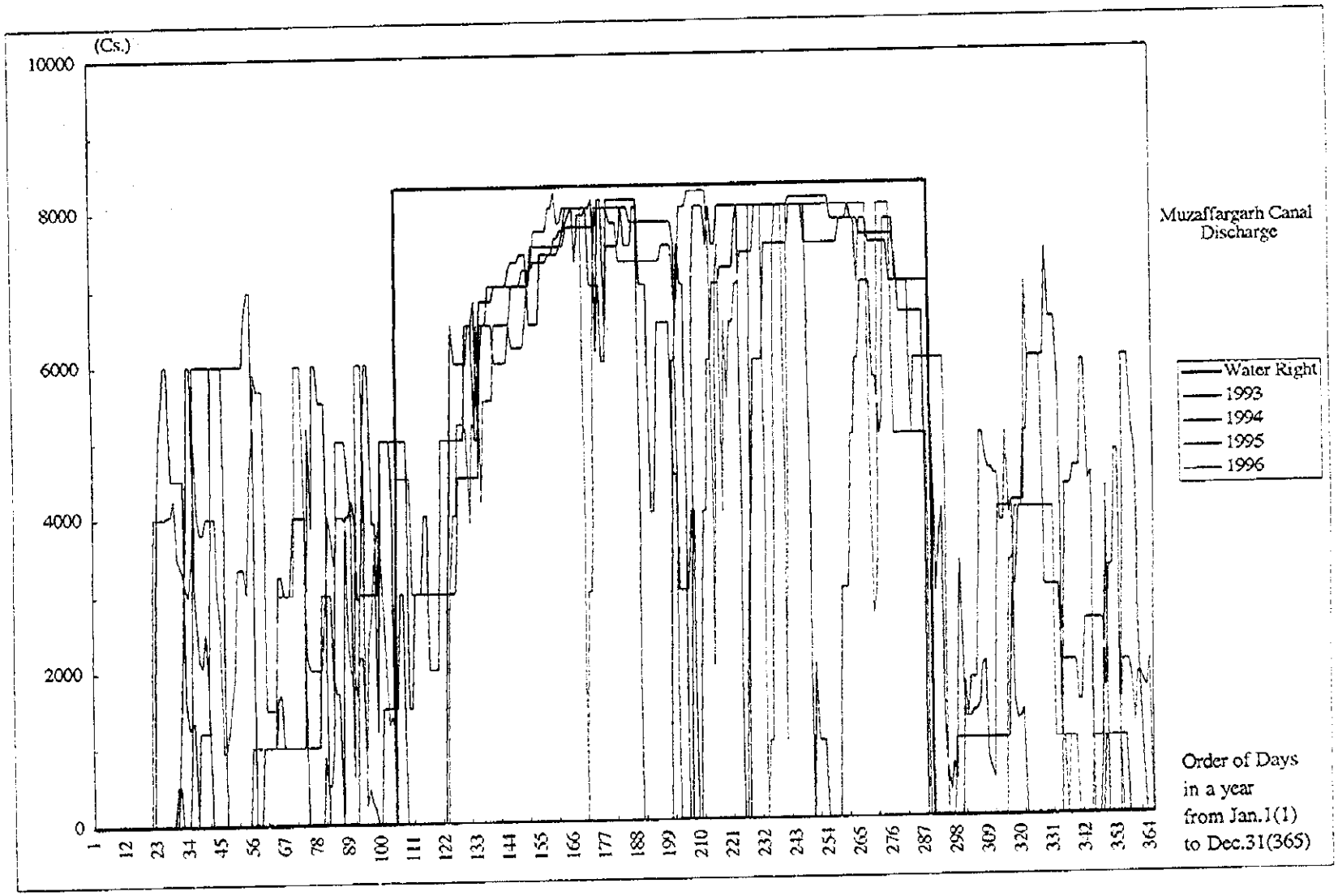


Fig.C3.1 Chronological Off-Taking Discharge of Muzaffargarh Canal

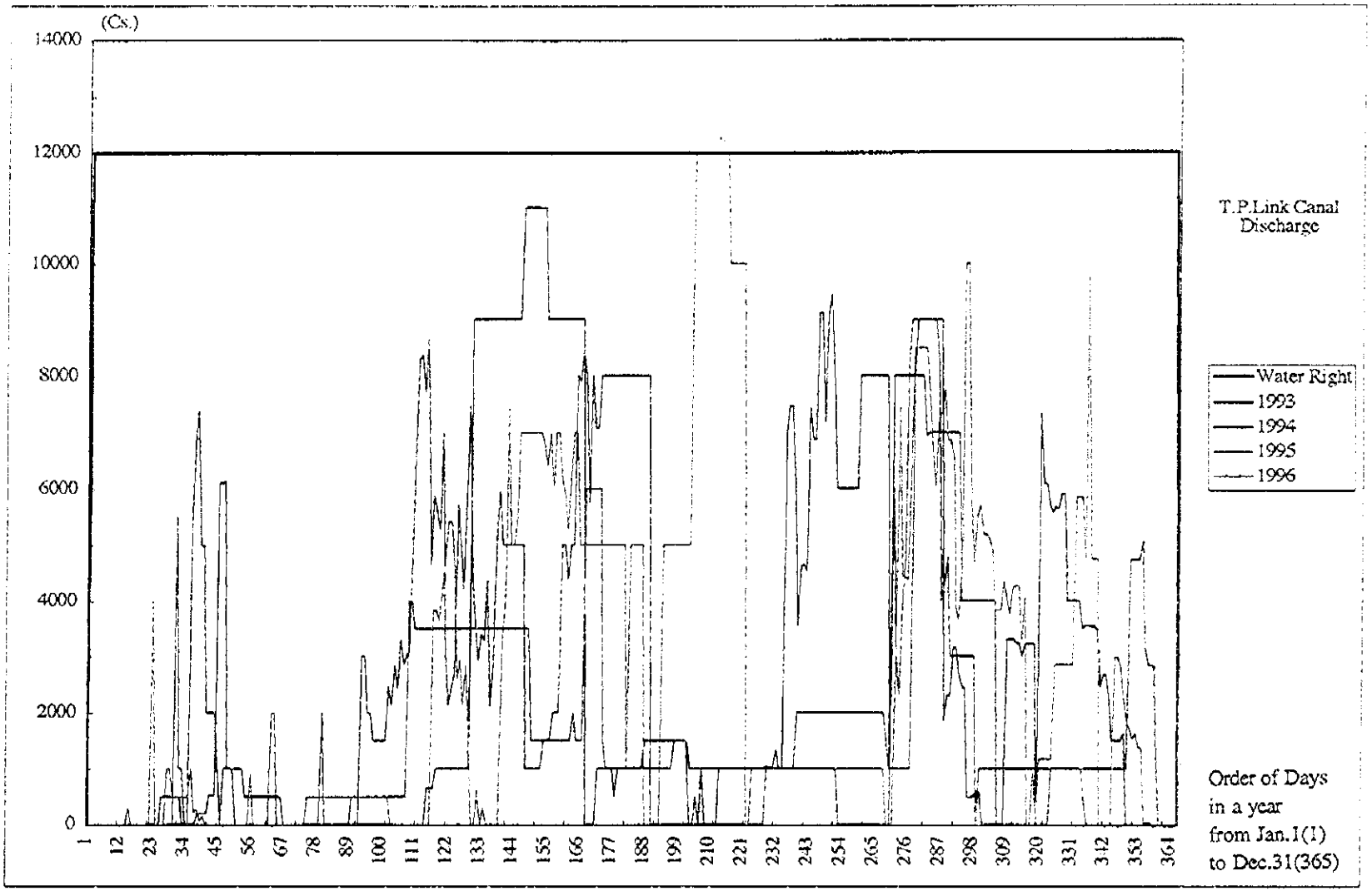


Fig.C4.1 Chronological Off-Taking Discharge of T.P.Link Canal

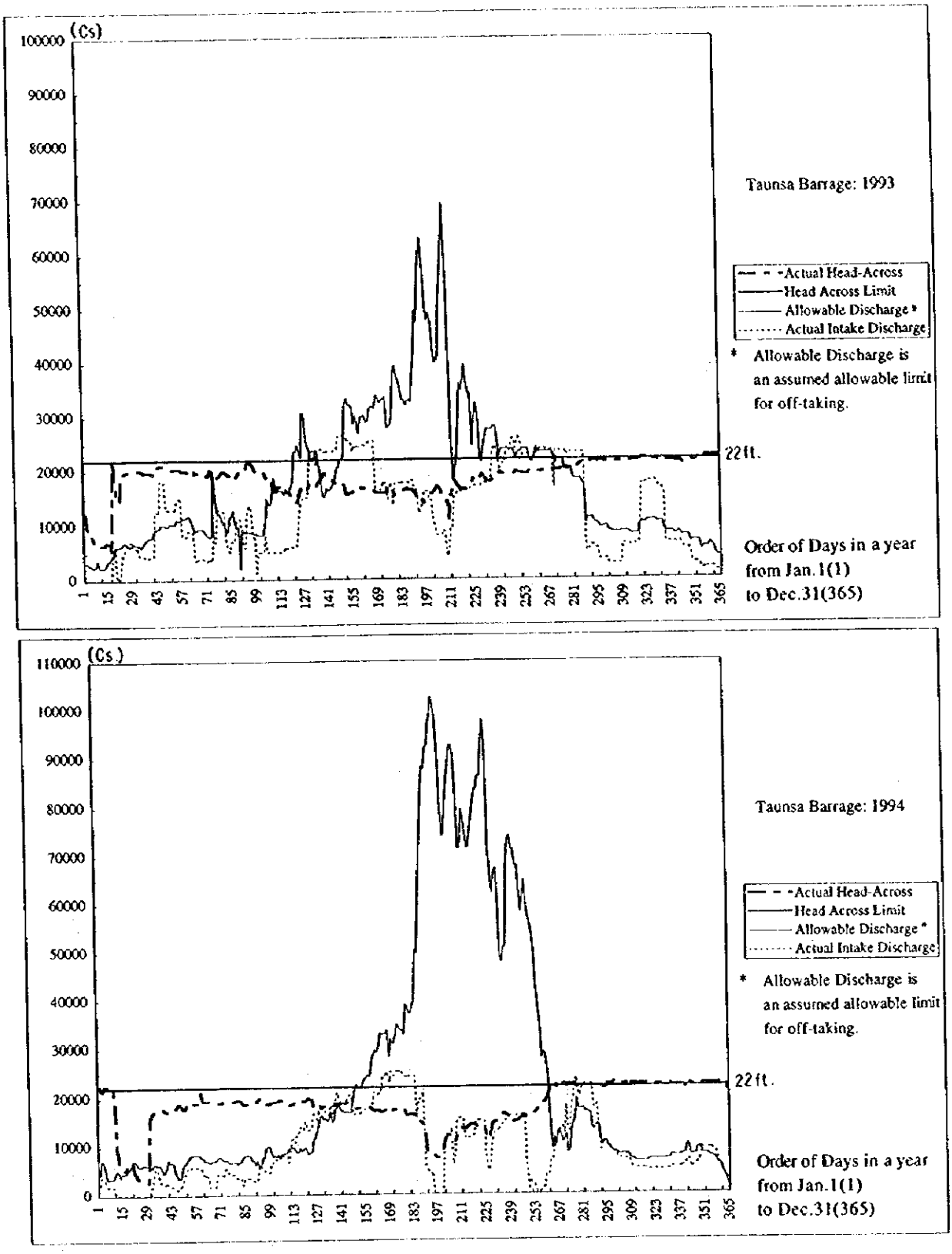


Fig.C5.1 Actual Head Across and Remaining Allowable River Water(1/2)

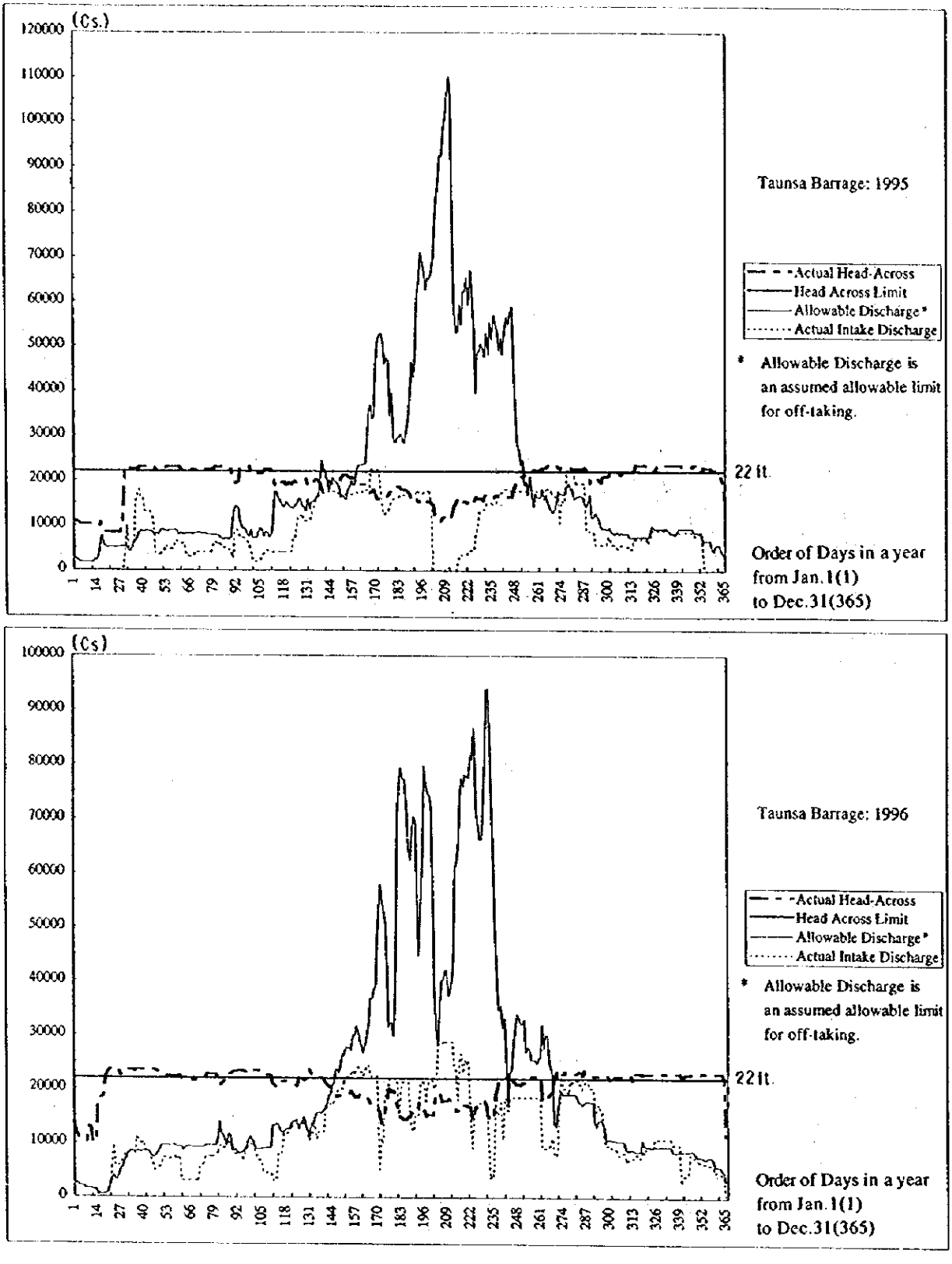
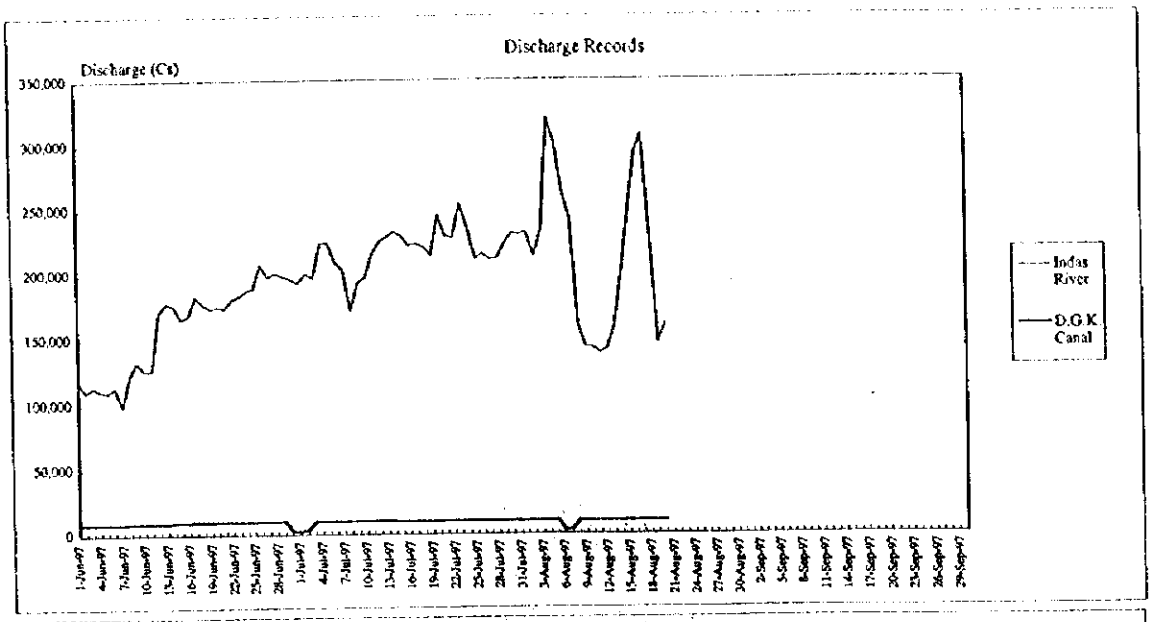
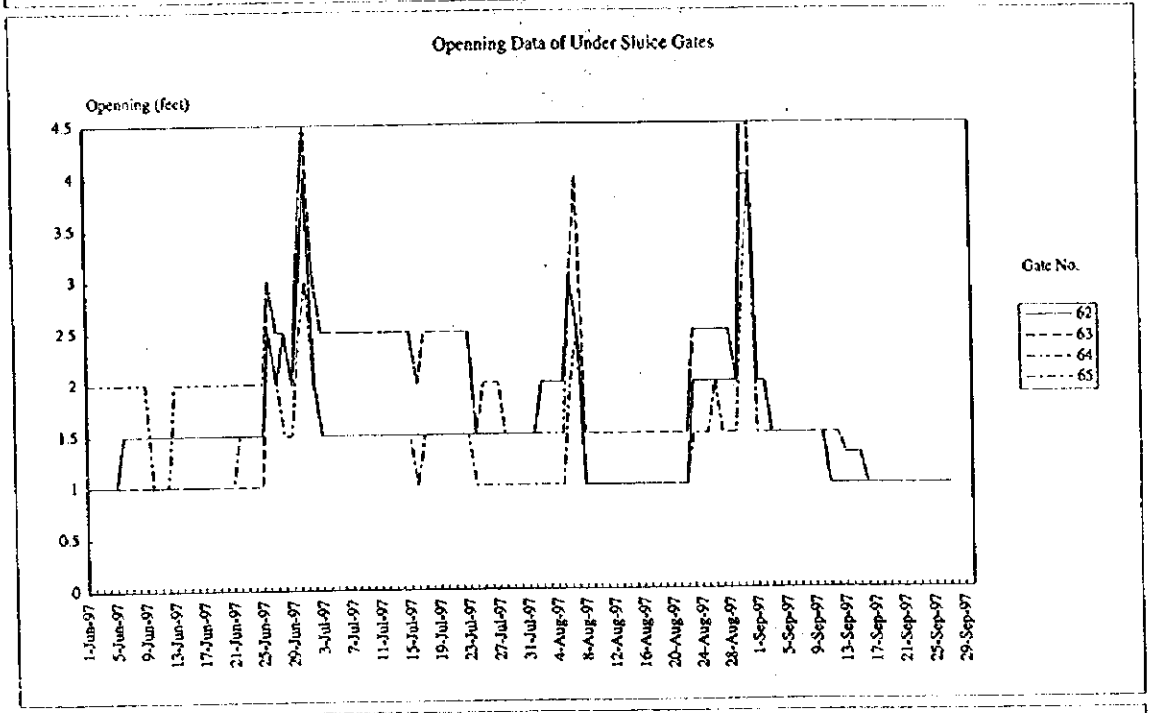


Fig.C5.1 Actual Head Across and Remaining Allowable River Water(2/2)





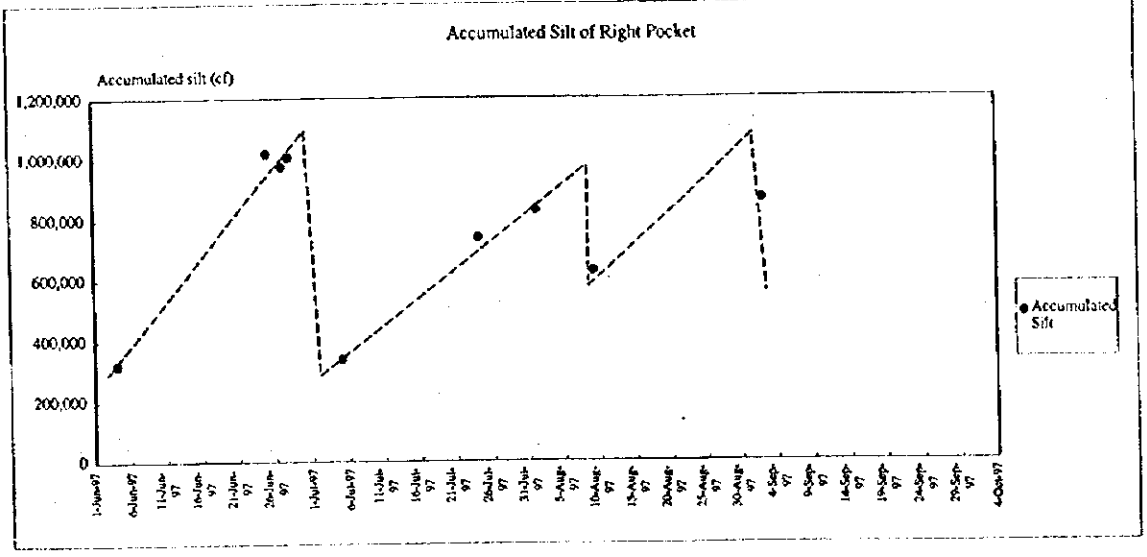


Fig.C6.1.1 Silt Observation in Right Pocket

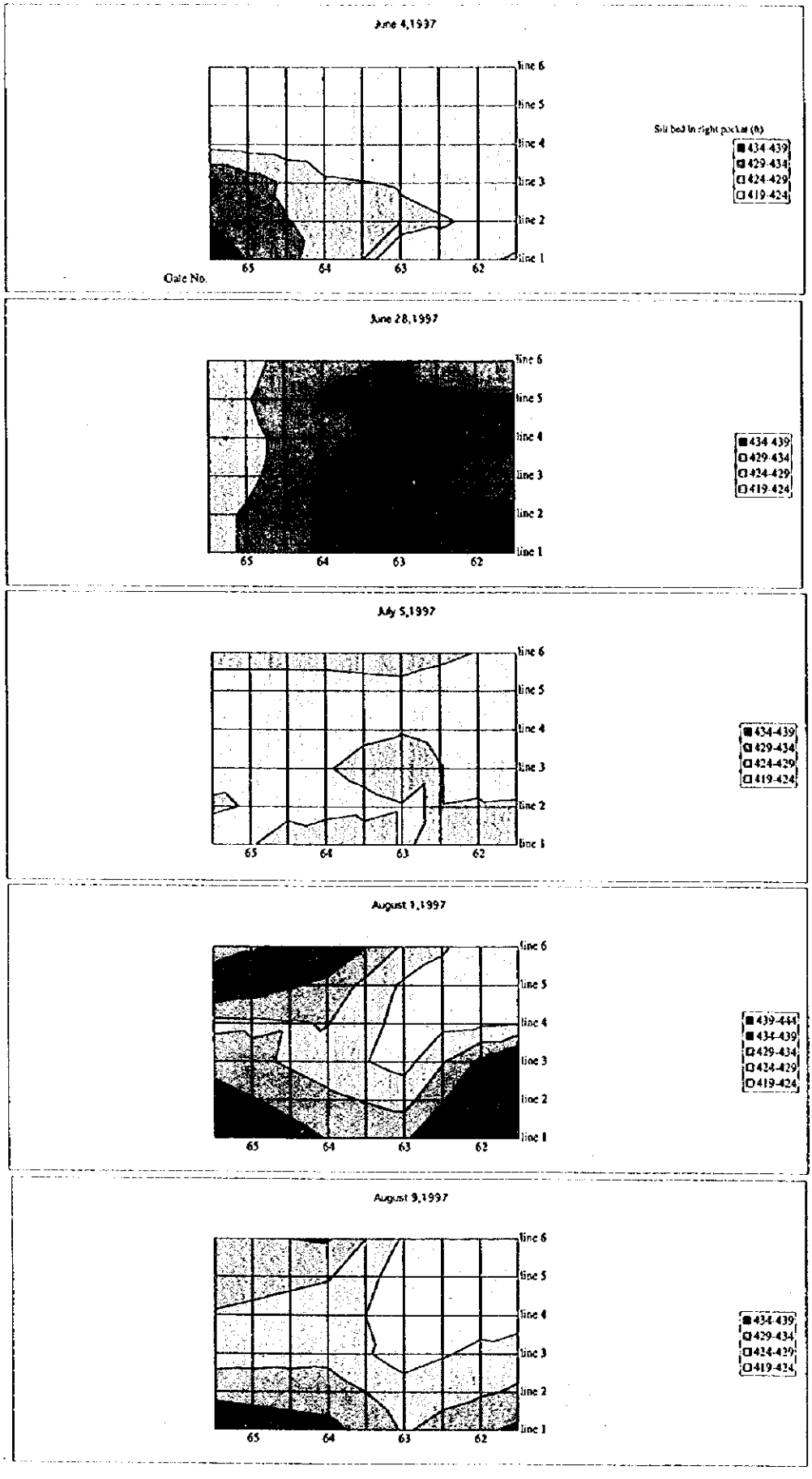


Fig.C6.1.2 Silt Distribution in Right Pocket

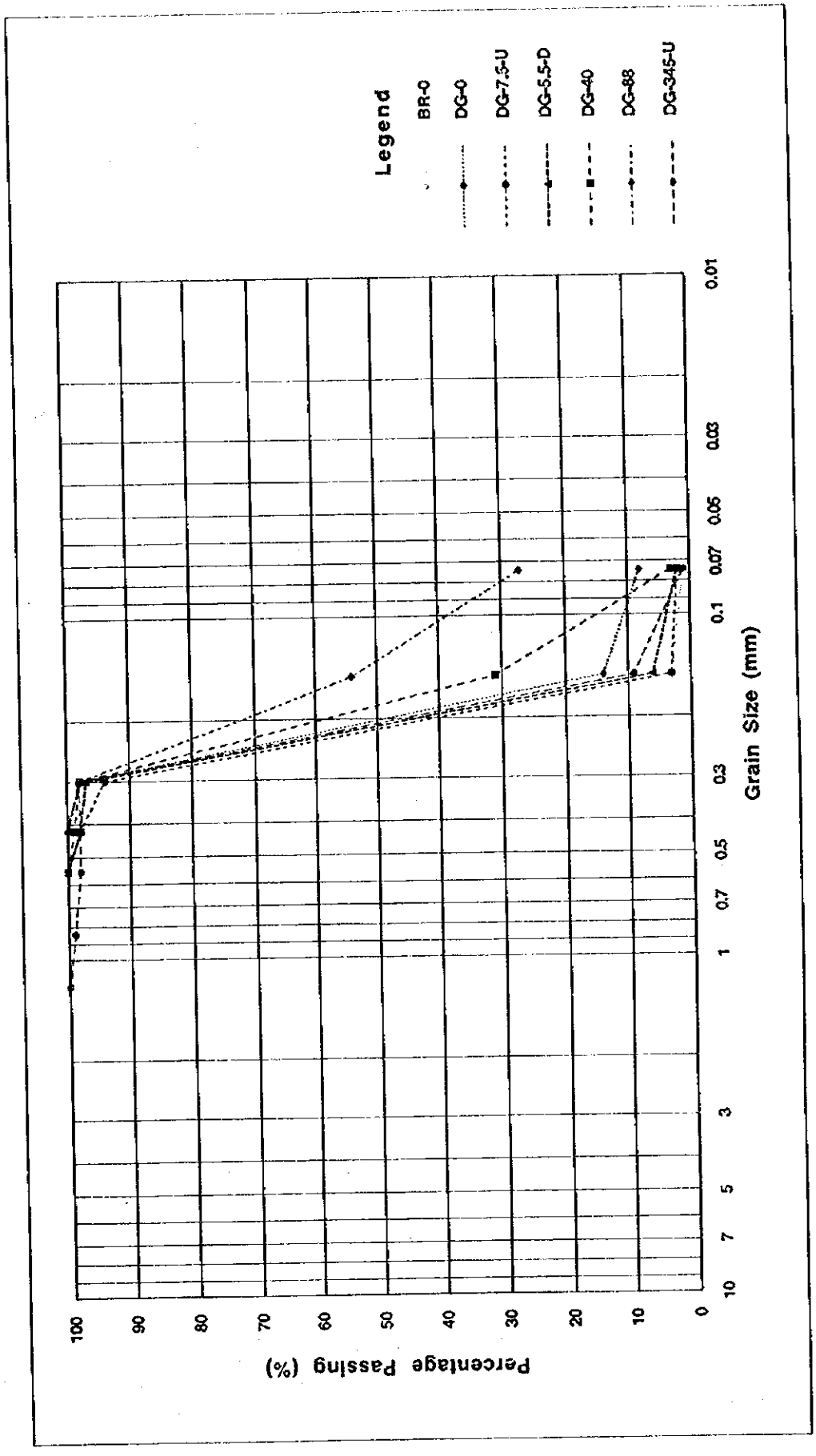
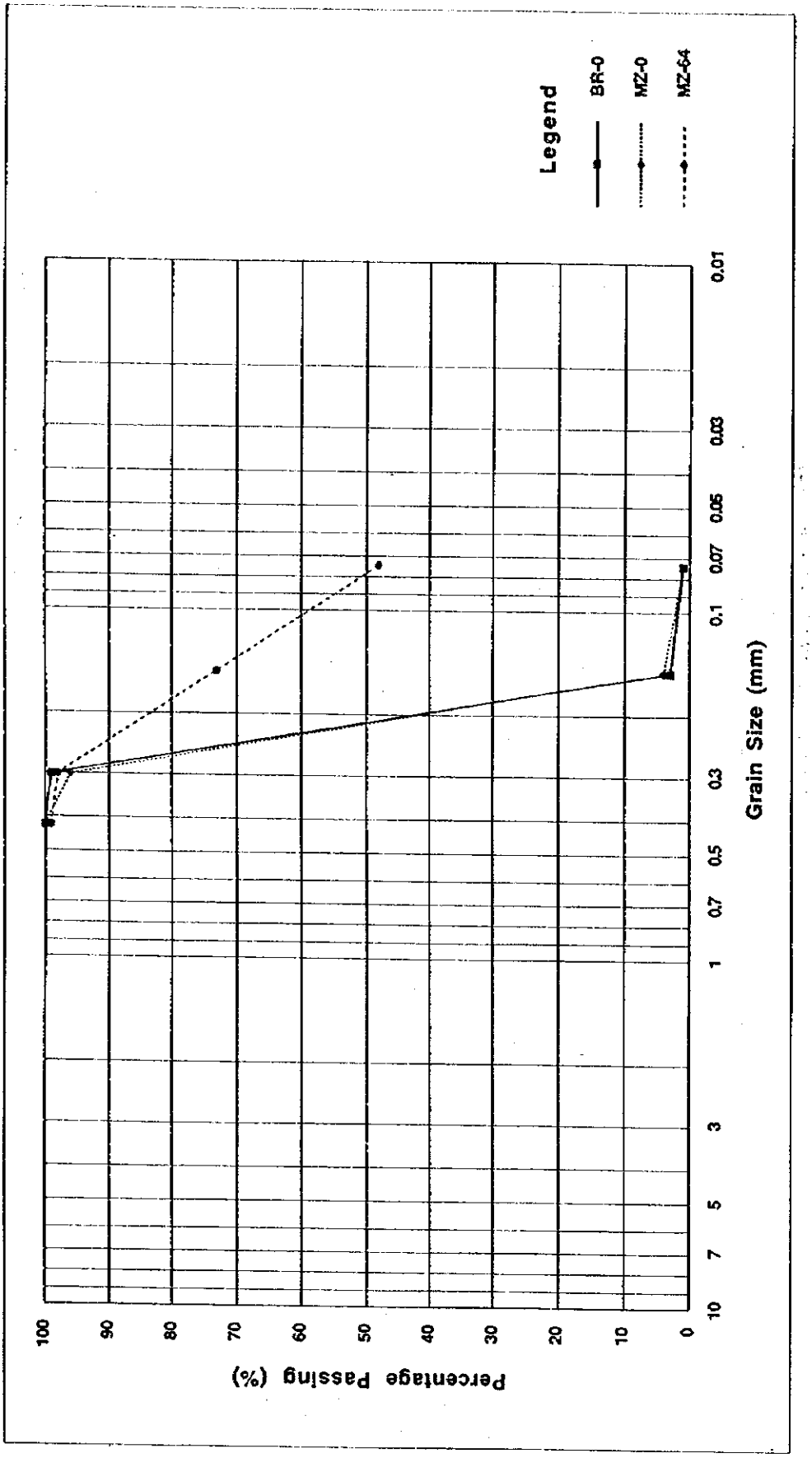


Fig. C6.2.1 Particle Size Distribution Curves (1/2)

Fig. C6.2.1 Particle Size Distribution Curves (2/2)



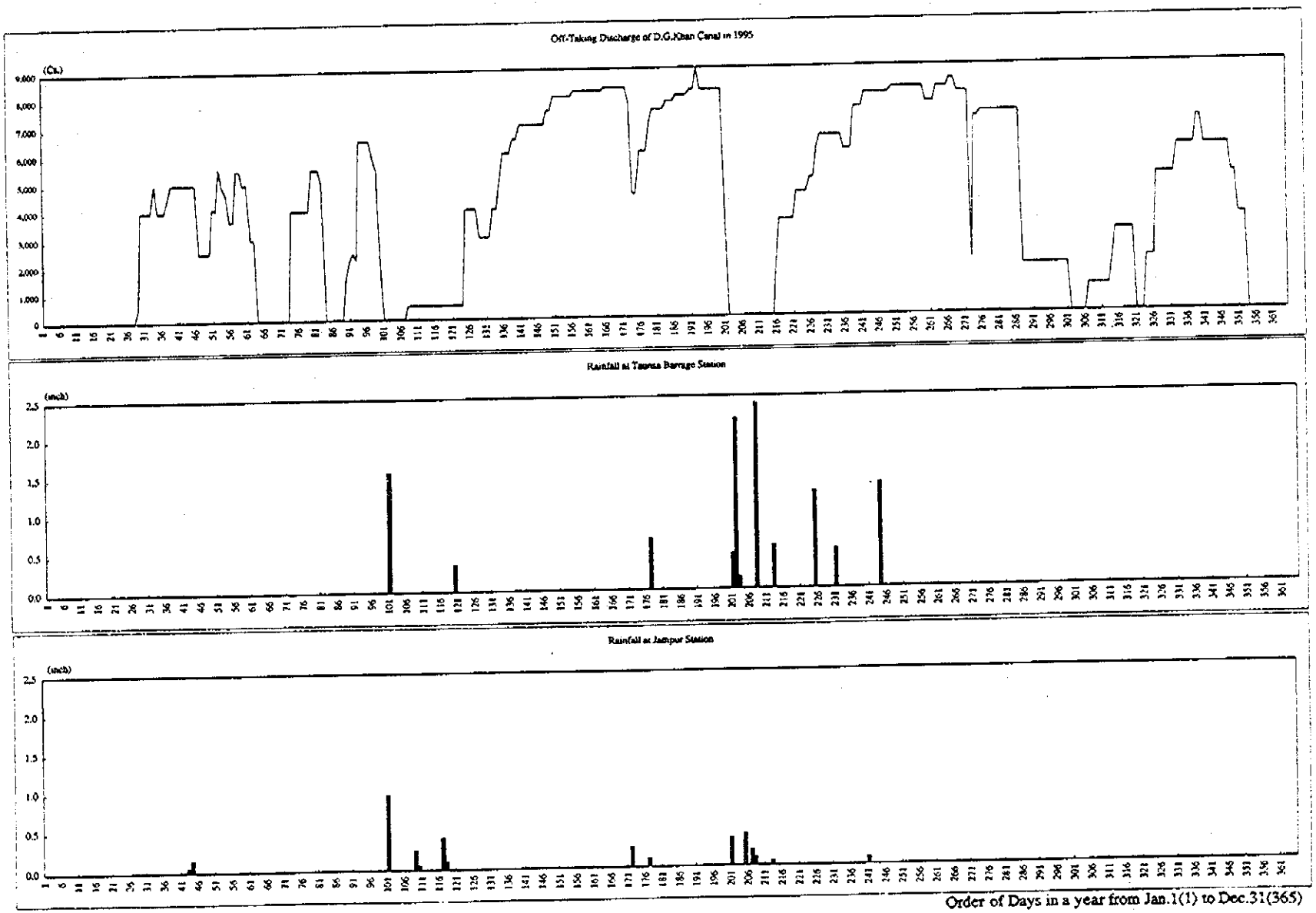


Fig.C7.1.1 Relation between Off-Taking Canal Discharge and Actual Rainfall in the Irrigation Area

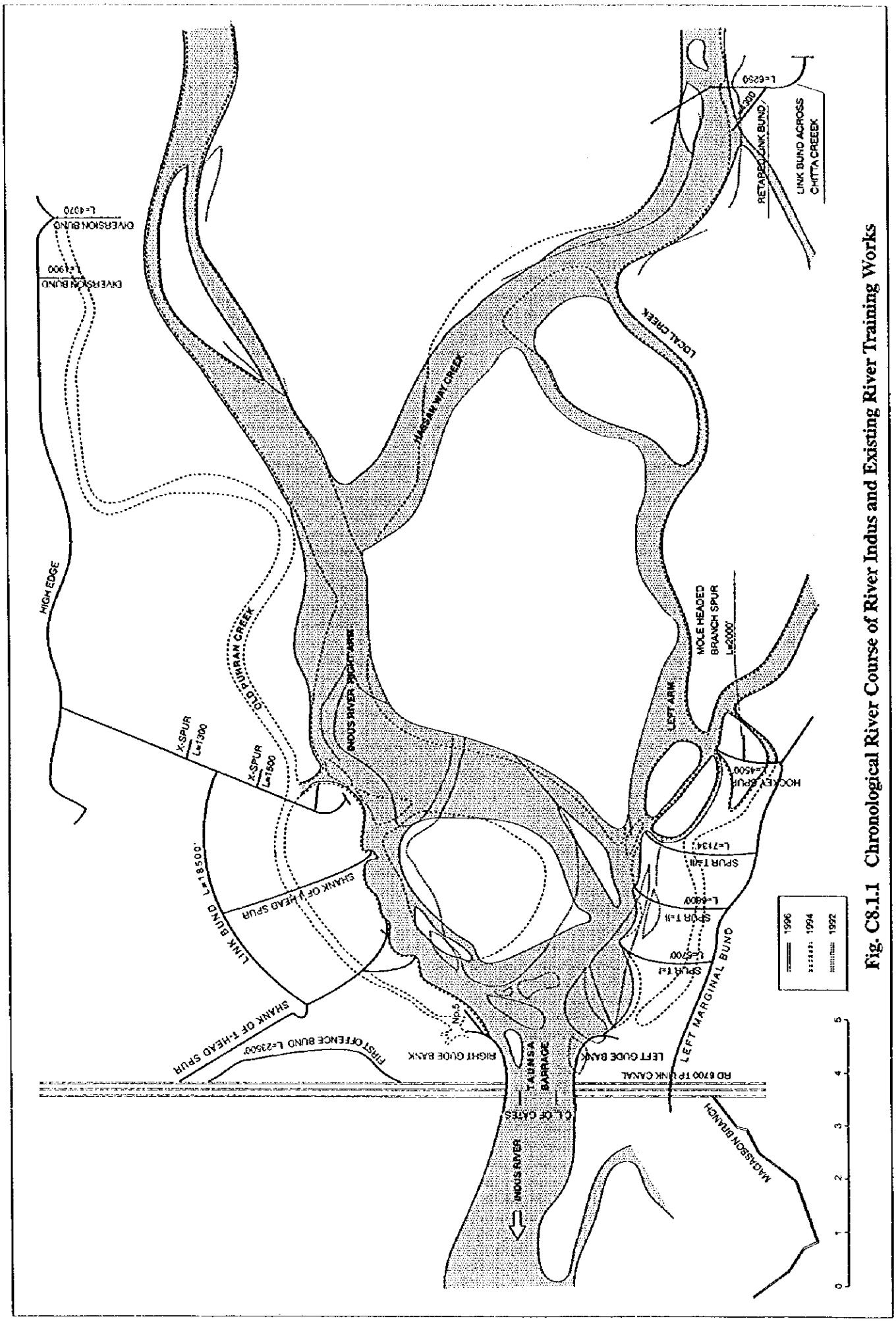


Fig. C8.1.1 Chronological River Course of River Indus and Existing River Training Works

Annex D

Irrigation System

ANNEX D IRRIGATION SYSTEM

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D.1. Deterioration and Damage of Gate Structures

Deterioration and damage of gate installed facilities such as silt ejector, escape and regulator on the canal systems were inspected. Around 40 facilities were sampled from representative ones and ocular survey was made on agate mechanics and civil engineering works aspects.

(1) Gate Mechanics

- Gate leaf and iron groove have been deteriorating depend on the age. Some ill-fitted gate and leakage were, however, observed, they are generally tolerable or repairable by routine O&M supported by Irrigation Workshop. Gate mechanics of silt ejector and escape are considerably deteriorated due to heavy operation, and some of them are severely damaged.

- Many reducer (worm gear/bevel gear) and spindle are damaged by supposedly superhuman strength at the time of gate closing difficulty caused by some jamming obstacle. Removal of the obstacle or repeated opening and closing of the gate with designed operation strength will avoid the damage such as beaking of the gear cog or bending of the spindle. Training of regulation belder is very important to establish both sustainable O&M of canal regulator and rational water distribution.

- Gate mechanics on canal regulators could be rehabilitated/replaced gate by gate without serious risks, at the damaged time. On the contrary, escape and silt ejector should be always well-conditioned to prepare for all emergencies.

(2) Civil Engineering Works

- many piers and superstructures are also damaged in the form of beaking or lifting by the reaction from above mentioned gate closing by superhuman strength. The damage could be repaired by routine O&M and other damages will be prevented by the training of regulation belders.

- Scouring of immediate D/S canal dikes was commonly observed, which menaces dikes with collapse and disturbs canal patrol. Stone pitching revetment on the dike inside slope will be effective. The revetment of immediate D/S of head regulator RD 59,000 Link No. I is successful and instructive for other rehabilitation works.

D.2. Irrigation Water Requirement

(1) Eto Estimation

Reference evapotranspiration (Eto) which is a substantial factor for calculation of irrigation water requirement, is estimated by Modified Penman method. The result having annual evapotranspiration of 1,876 mm is shown in Table D2.1. in which results of Eto calculation applying other routines of the estimation method by observed Etpan and the Blaney-Criddle method are attached as reference. Insignificant difference is found between the results obtained by Modified Penman method and by others.

On the estimation of Eto, available climate data of the stations within and adjacent of the Study Area collected during Phase I are used. The result of Eto may be re-estimated in Phase II if more reliable climate data is obtained.

(2) Calculation of Irrigation Water Requirement

Irrigation water requirement is calculated on the basis of Eto as estimated above applying present cropping pattern in the Study Area. Crop water requirements for each concerned crop in the Study Area are calculated as shown in Table 2.2. Calculation of Crop water requirement is dune in 10 daily basis under the following conditions and assumptions:

- Crop coefficient (Kc) is referred values in the F.A.O Technical Paper
- Effective rainfall is estimated as 90% of actual rainfall of Taunsa Barrage station when 10 days' amount is less than 16.7 mm, 85% when more than.
- For the irrigation water requirement calculation of rice, land sorking water of 80 mm is considered in the initial stage. Percolation of 2 mm par day is required during whole cultivation stage.

Irrigation water requirements for each canal circle are calculated in consideration with those present cropping patterns as shown in Table D2.3 and Table D2.4.

(3) Adequacy of Present Value of Water Allowance

Peak irrigation water net requirement calculated by theoretical method of D.G. Khan Canal and Muzaffargh Canal are obtained at 4.638 and 4.667 Cs. per thousand acre, respectively.

Considering field application efficiency of 0.60 which is normal value for these zone, unit irrigation discharges are calculated at 6.184 and 6.236 Cs. per thousand acre, respectively. In

comparison with these results, present values of authorized water allowance of 6.36 Cs. per thousand acre in D.G.Khan Canal Area, and 8.57 Cs. per thousand acre in Muzaffargh Canal Area could be judged as reasonable.

D.3. Hill Torrent Crossing Structures

The run-off of the hill torrent (H/T) is really torrent and the course and discharge are quite changeable, and the design of the H/T crossing facilities are greatly significant. The designed H/T discharges vary from 200 cs up to 40,000 cs. Although the ideal H/T crossing types are Aqueduct (A) or Super Passage (SP), Siphon Super Passage (SSP) or Siphon Aqueduct (SA) is obliged due to the topography and the canal water head. Sixteen SSPs and one SA are troublesome siphon type H/T crossings amongst twenty.

The troubles of H/T crossing are mainly caused by the sedimentation of both on H/T aqueduct and canal siphon under H/T aqueduct as shown in Table . The sedimentation on the H/T aqueduct decreases H/T flow capacity and causes spill over the flow into the canal. The canal siphon continuously catches bed load and suspended load in low flow season, and results raising back water and overtopping at the upstream of the canal.

Fundamental measure of the sedimentation is to reduce the bed load from the Taunsa barrage head regulator into the canal, and removal of the sediment deposit including some extent of U/S and D/S reaches of the H/T and canal. Heightening of U/S canal dikes by the removed sediment is one of the alternative measures to allow raising of the canal U/S water head to obtain sufficient flow velocity under the H/T aqueduct. H/T crossing R/D 185,500 on D.G.Khan canal is one of successful and instructive ones for future improvement.

Table D1.1 Damage Scoring Summary of Gate Structure

Facilities	Nos of inspected facilities	Gate Damage			
		Gate Leaf	Groove	Reducer	Spindle
Silt Ejector	3	2.50	2.50	3.30	3.00
Escape	2	1.30	1.30	2.00	2.70
Head Regulator	15	1.20	0.80	1.60	1.40
Regulator	20	1.50	1.10	1.70	1.20
Total	40	1.45	1.10	1.80	1.49

Facilities	Nos of inspected facilities	Civil Engineering Work Damage				
		Pier	Super-structure	U/S Guide Wall	D/S Guide Wall	Canal
Silt Ejector	3	1.30	1.00	1.00	1.30	2.70
Escape	3	1.00	1.00	1.70	1.00	1.00
Head Regulator	16	1.10	0.90	1.00	1.30	2.50
Regulator	15	1.30	1.60	0.90	0.80	2.10
Total	37	1.19	1.20	1.02	1.07	2.23

Remarks: Magnitude of damage (scored by ocular survey)
0: No damage
1: Slightly damaged (to be reconditioned)
2: Partly damaged (to be repaired)
3: Severely damaged (to be replaced)
4: Uncontrolable (to be reconstructed)

T.P. Link Canal system is excluded.

Table D1.2 Gate Condition on Canal Regulating Facilities

Facilities	Location		Gate				Deterioration			Leakage	Remarks
	RD	Type	Width (m)	Height (m)	Nos.	Gate Leaf	Groove	Reducer	Spindle		
D.G. Khan Canal System											
D.G. Khan Canal											
Silt Ejector	7,500	Slide	2.70	-	3	3	3	3	3	-	
Silt Ejector	20,800	Slide	2.42	-	2	-	-	U/S 4 D/S 3	-	-	
Regulator	88,500	Roller	4.55	2.10	11	1	1	1	1	-	
Link No. I	88,500	Roller	4.55	2.10	4	1	1	1	1	-	
Escape	88,500	Roller	4.55	2.10	6	-	-	3	3	Very much	
Lower Hot	88,500	Slide	3.05	-	1	1	1	2	2	-	
Link No. I											
Head Regulator	59,000	Slide	3.20	1.70	5	0	1	0	0	-	
1-L Disty	59,000	Slide			1						
Regulator	92,330	Slide	2.40	1.75	5	1	1	0	0	0	
Fall	138,872	None			2						
Escape	138,872	Slide	4.56	1.75	2	0	0	0	2	0	
Tail Regulator	203,400	Slide	3.00	1.60	2	0	0	2	1	-	Sahiban Disty
Jhok Disty	203,400	Slide	0.43	1.22	1	0	0	0	0	-	
Banuhan Disty	203,400	Slide	0.83	1.22	1	0	0	0	0	-	
DG Khan Canal	345,230	Slide	4.80	2.10	7	1	1	1 & 4	2 & 4	-	No 7 gate uncontrolable
Link No. III	345,230	Slide	4.80	2.10	6	1	1	2 & 4	1 & 4	-	No 2 gate uncontrolable
Mianwaka	345,230	Slide	2.25		1	1	1	3	1	0	
Shaheena	345,230	Slide	1.65		1	1	1	1	1	0	
Tail Dajal B.	190,000	Slide	2.40	1.60	3	2	1	3	2	-	
Fatehpur D.	190,000	Slide	1.80	1.80	1	2	3	3	2	-	
Link No. III	142,100	Slide	4.50	1.40	4						
Dhundi Kutab C.	142,100	Slide	4.50	1.40	2						
Talai	142,100	Slide	1.00	-	1						
Tail Link No. III	227,820	Slide	4.50	3.00	3	1	1	1	1		Rehabilitation in 1996
Escape	227,820	Slide	2.10	3.00	5	1	1	1	3		Rehabilitation in 1996
Muzaffargarh Canal System											
Muzaffargarh Canal											
Silt Ejector	4,148	Slide	2.25	2.30	2	2	2	3	3	bearable	
Maggason B.	5,785	Slide	3.05	2.60	5	2	2	3	3	bearable	
Head Regulator	19,500	Slide	3.05	2.30	13	2	2	3	3	-	
Kot Sultan D.	19,500	Slide	3.05	2.30	1	2	2	3	3	-	
Pattal D.	39,576	Slide	1.50	1.50	1	2	2	2	2	-	
Head Regulator	64,357	Slide	3.05	-	11	1	1	3	2	-	
Thal B.	64,357	Slide	3.05	-	4	1	1	3	2	-	
Rafique D.	64,357	Slide	0.91	-	1	1	1	2	2	-	
Regulator	246,800	Slide	3.00	1.80	10	1	0	1	1	-	
Escape	246,000	Slide	3.00	2.40	7	-	-	-	-	-	
Ghuttu Left D.	246,800	Slide	0.80	1.00	1	1	0	1	1		
Ghuttu Right D.	246,800	Slide	1.30	1.00	1	1	0	1	1		
Regulator	290,300	Slide	3.00	1.65	9	1	0	0	1	-	
Adil Wah D.	290,300	Slide	3.00	1.20	3	1	1	1	1	-	
Qaimshah	290,300	Slide	-	-	-	3	2	1	2		
Regulator	329,112	Slide	3.00	2.00	7	-	0	2			
Shujra D.	329,112	Slide	1.10	1.35	1	1	1	1	0		
Damber Wala D.	329,112	Slide	3.00	1.35	2	2	2	2	0		
Harman D.	329,112	Slide	1.50	-	1						
Tail Regulator	370,700	Slide	2.15	1.60	7	2	1	2	1	-	Ali Pur B.
Kaure Khan D.	370,700	Slide	1.75	0.80	1	3	1	2	1		
Surab D.	370,700	Slide	3.00	1.25	2	2	1	2	1		
Jatoi B.	370,700	Slide	3.00	1.25	3	2	1	2	1		
Soni D.	370,700	Slide	3.00	1.25	3*	2	1	2	1		No 1 gate missing
T.P. Link Canal System											
Tail Regulator	193,000	Roller	7.20	2.20	8	0	0	0	0		Perfect
Rangpur C.	612,000	Slide	1.80	1.80	4	0	0	0	0		Perfect

Remarks: Magnitude of damage (scored by ocular survey)
0: No damage
1: Slightly damaged (to be reconditioned)
2: Partly damaged (to be repaired)
3: Severely damaged (to be replaced)
4: Uncontrolable (to be reconstructed)
-: Not inspected

Table D.1.3 Civil Engineering Works Condition of Canal Regulating Facilities

Facilities	Location RD	Gate Pier	Gate Super-structure	U/S Guide Wall	Down Stream Guide Wall	Down Stream Immediate Canal	Remarks
D.G. Khan Canal System							
D.G. Khan Canal							
Silt Ejector	7,500	1	1	1	1	3	Gates are completely buried caused by heavy D/S canal sediment
Silt Ejector	20,800	1	1	1	1	3	
Regulator	88,500	1	1	1	3	2	
Link No. I	88,500	1	1	1	1	2	
Escape	88,500	1	2	1	2		
Lower Hot	88,500						
Link No. I							
Regulator	59,000	1	1	0	1	0	D/S immediate canal side is well furnished with revetment
Regulator	92,330	2	1	0	0	1	Pier is jacked up by spindle
Fall	138,872	0	0	0	0	0	
Escape	138,872	1	0	0	0	0	Spindles are bent
Fall	186,500	1	None	0	1	3	
Tail Regulator	203,400	0	0	1	1	2	Equips 3 m fall foundation
DG Khan Canal	345,230	1	1	1	1	3	
Link No. III	345,230	1	1	1	1	3	
Mianwaka	345,230	1	1	1	1	3	
Shaheena	345,230	1	1	1	1	2	
Tail Dajal Br.	190,000	3	2	2	-	-	
Link No. III	142,100	1	1	1	1	3	
Dhundi Kutab C.	142,100	1	1	1	1	2	
Talai	142,100	1	3	-	-	3	
Hazratwah	142,100	2	None	1	1		
Tail Link No. III	227,820	0	0	1	0	3	Inheritated from inundation canal constructed in 1913. Rehabilitated 1996.
Escape	227,820	0	1	1	3	3	
Muzaffargarh Canal System							
Muzaffargarh Canal							
Silt Ejector	4,148	2	1	1	2	2	Groove concrete is damaged
Maggason B.	5,785	1	1	1	2	2	
Regulator	19,500	1	1	1			
Kot Sultan D.	19,500						
Regulator	39,576	1	1	1	1	2	Gates are removed, then no operation
Pattal D.	39,576						
Regulator	64,357	1	2	1	2	3	Right side D/S glacis is damaged
Thal B.	64,357	1	1	1	-	-	
Rafique D.	64,357	1	1	1	-	-	
Regulator	246,800	1	0	2	1	4	
Escape	246,000	1	1	4	-	-	
Regulator	290,300	1	1	1	2	4	
Adil Wah D.	290,300	1	1	1	2	4	
Qaimshah	290,300	-	-	-	-	-	
Regulator	329,112	1	1	1	2	4	
Shujra D.	329,112	2	4	1	0	1	
Damber Wala D.	329,112	2	2	1	0	1	
Harnnan D.	329,112	2	4	1	0	1	
Tail Regulator	370,700	2	1	1	2	2	
Kaure Khan D.	370,700	1	1	1	1	-	
Surab D.	370,700	1	1	1	1	-	
Jatoi B.	370,700	1	1	1	1	-	
Soni D.	370,700	1	1	0	1	-	
T.P. Link Canal System							
Tail Regulator	183,000	0	0	0	0	0	Perfect
Rangpur C.	612,000	0	0	0	0	0	Perfect

Remarks: Magnitude of damage (scored by ocular survey)
0: No damage
1: Slightly damaged (to be reconditioned)
2: Partly damaged (to be repaired)
3: Severely damaged (to be replaced)
4: Uncontrolable (to be reconstructed)
-: Not inspected

Table D2.1 Estimated Referance Evapo-Transpiration (ETo) in the Study Area

Evapotranspiration Estimated by Ovserved Pan Evaporation (for reference)

Station:Multan

Items	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Epan (Monthly)**	80.4	99.3	168.6	258.3	325.0	348.6	296.1	268.2	220.7	169.6	111.2	82.7	2,428.7
Epan (Daily)	2.59	3.55	5.44	8.61	10.48	11.62	9.55	8.65	7.36	5.47	3.71	2.67	
RHmean (%)*	62.0	55.7	51.8	42.4	36.0	40.8	56.7	61.0	58.7	54.2	62.8	67.1	
Wind verosity*(Km/day	68.6	91.4	121.8	125.6	141.0	215.4	189.5	179.0	152.2	79.7	46.6	47.6	
Kp	0.8	0.8	0.8	0.7	0.7	0.7	0.75	0.75	0.8	0.8	0.8	0.8	
ETo (Daily)	2.07	2.84	4.35	6.03	7.34	8.13	7.16	6.49	5.89	4.38	2.97	2.13	
ETo (Monthly)	64.3	79.4	134.9	180.8	227.5	244.0	222.1	201.2	176.6	135.7	89.0	66.2	1821.6

Evapotranspiration Estimated by FAO's Blaney-Criddle Method (for reference)

Station: Multan

Items	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Temperature*	12.6	15.4	21.0	27.2	32.4	34.7	34.1	33.0	31.1	26.4	19.6	14.3	
P	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23	
P(0.46T+8.13)(=F)	3.34	3.81	4.80	5.99	7.14	7.72	7.38	7.00	6.28	5.27	4.12	3.38	
Monthly Total(F)	103.7	106.6	148.8	179.6	221.3	231.5	228.7	217.0	188.4	163.4	123.6	104.8	2017.2
RHmin*	40.5	34.4	32.2	24.2	21.2	26.5	43.6	47.9	42.7	35.3	43.3	48.0	
n*	7.1	7.3	7.6	9.2	9.4	8.6	8.0	9.1	9.1	8.3	8.0	6.9	
N	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2	
n/N	0.68	0.66	0.63	0.71	0.69	0.61	0.58	0.69	0.73	0.72	0.75	0.68	
Wind verosity* (m/sec)	0.79	1.06	1.41	1.45	1.63	2.49	2.19	2.07	1.76	0.92	0.54	0.55	
ETo (Daily)	2.20	2.85	4.00	5.50	6.95	8.60	8.35	8.00	6.02	4.75	3.26	2.15	
ETo (Manthly)	68.2	79.8	124.0	165.0	215.5	258.0	258.9	248.0	180.6	147.3	97.8	66.7	1909.6

Evapotranspiration Estimated by Modify PENMAN Method

Station: Multan

Items	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
ea	14.60	17.48	24.90	36.12	48.68	55.30	53.50	50.30	45.17	34.44	22.84	16.37	
ed	9.06	9.74	12.91	15.33	17.53	22.58	30.34	30.68	26.51	18.68	14.35	10.98	
(ea-ed)	5.54	7.74	11.99	20.79	31.15	32.72	23.16	19.62	18.66	15.76	8.49	5.39	
Wind verosity*(Km/da	68.6	91.4	121.8	125.6	141.0	215.4	189.5	179.0	152.2	79.7	46.6	47.6	
f(Wind verosity)	0.46	0.52	0.60	0.61	0.65	0.85	0.78	0.75	0.68	0.49	0.40	0.40	
(1-W)	0.41	0.37	0.31	0.24	0.20	0.18	0.19	0.20	0.21	0.25	0.32	0.39	
(1-W)f( )(ea-ed)	1.04	1.48	2.19	3.04	4.05	5.01	3.44	2.88	2.67	1.91	1.08	0.84	
Ra	8.80	10.70	13.10	15.20	16.50	17.00	16.80	15.70	13.90	11.60	9.50	8.30	
n	7.1	7.3	7.6	9.2	9.4	8.6	8.0	9.1	9.1	8.3	8.0	6.9	
N	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2	
n/N	0.68	0.66	0.63	0.71	0.69	0.61	0.58	0.69	0.73	0.72	0.75	0.68	
(1-a)(0.25+0.5n/N)	0.44	0.43	0.43	0.45	0.45	0.42	0.40	0.45	0.46	0.46	0.47	0.44	
Ra(1-a)(0.25+0.5n/N)	3.90	4.65	5.57	6.92	7.37	7.10	6.78	7.00	6.43	5.31	4.47	3.66	
f(t)	13.22	13.31	14.80	16.14	17.30	17.84	17.70	17.45	16.95	15.98	14.52	13.55	
f(ed)	0.22	0.22	0.20	0.18	0.17	0.15	0.12	0.12	0.13	0.17	0.19	0.21	
f(n/N)	0.71	0.69	0.67	0.74	0.72	0.65	0.62	0.72	0.76	0.75	0.78	0.71	
f(t)f(ed)f(n/N)	2.07	1.98	1.95	2.20	2.16	1.75	1.31	1.49	1.73	2.00	2.13	1.99	
W( )	1.08	1.68	2.52	3.59	4.17	4.39	4.43	4.44	3.72	2.48	1.59	1.02	
ETo (Daily)	2.01	3.00	4.47	6.30	7.82	8.94	7.47	6.95	6.07	4.18	2.53	1.76	
ETo (Manthly)	62.2	84.0	138.6	188.9	242.3	268.1	231.7	215.6	182.0	129.5	75.9	54.7	1,873.5

Note : Adjustment coefficient C is applyed at 0.95.

* : Observed data of Multan Meteorological Station

** : Observed data of Muzaffargh Station

Table D2.2 Crop Water Requirement in Taunsa Barrage Irrigation System (1/2)

Wheat;

Month	Nov.			Dec.			Jan.			Feb.			Mar.			Apr.			May		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	0.84	0.85	0.84	0.82	0.81	0.80	0.80	0.79	1.16	1.35	1.34	1.19	1.01	0.80	0.37						
		0.84	0.85	0.84	0.82	0.81	0.80	0.80	0.79	1.16	1.35	1.34	1.19	1.01	0.80	0.37					
			0.84	0.85	0.84	0.82	0.81	0.80	0.80	0.79	1.16	1.35	1.34	1.19	1.01	0.80	0.37				
				0.84	0.85	0.84	0.82	0.81	0.80	0.80	0.79	1.16	1.35	1.34	1.19	1.01	0.80	0.37			
					0.84	0.85	0.84	0.82	0.81	0.80	0.80	0.79	1.16	1.35	1.34	1.19	1.01	0.80	0.37		
						0.84	0.85	0.84	0.82	0.81	0.80	0.80	0.79	1.16	1.35	1.34	1.19	1.01	0.80	0.37	
Kc(10days)	0.84	0.85	0.84	0.84	0.83	0.83	0.82	0.81	0.86	0.95	1.04	1.10	1.14	1.14	1.01	0.94	0.84	0.72	0.58	0.37	0.00
Kc		0.84			0.83			0.83			1.03			1.10			0.83			0.32	
Area %(10days	0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17	0.00
Area %		0.33			1.00			1.00			1.00			1.00			0.67			0.17	
ETo		75.9			54.7			62.2			84.0			138.6			188.9			242.3	
Req.(1)		11.4			45.6			51.7			86.7			151.9			105.1			12.8	
Effective rain		0.8			2.0			3.6			6.3			31.3			22.8			9.7	
Waterreq.(mm)		20.6			43.6			48.1			80.4			120.6			82.4			3.1	

Total 398.6 mm

Rabi fodder;

Month	Nov.			Dec.			Jan.			Feb.			Mar.			Apr.			May		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	0.78	0.83	0.91	0.99	0.98	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.87	0.77			
		0.78	0.83	0.91	0.99	0.98	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.87	0.77		
			0.78	0.83	0.91	0.99	0.98	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.87	0.77	
				0.78	0.83	0.91	0.99	0.98	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.87	0.77
Kc(10days)	0.78	0.81	0.84	0.88	0.93	0.96	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.94	0.92	0.88	0.85	0.82	0.77
Kc		0.81			0.92			0.96			0.95			0.95			0.91			0.81	
Area %(10days	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25
Area %		0.40			1.00			1.00			1.00			1.00			1.00			0.40	
ETo		75.9			54.7			62.2			84.0			138.6			188.9			242.3	
Req.(1)		24.7			50.4			59.6			79.8			131.6			172.5			78.9	
Effective rain		0.8			2.0			3.6			6.3			31.3			22.8			9.7	
Waterreq.(mm)		23.9			48.4			56.0			73.5			100.3			149.8			69.2	

Total 521.0 mm

Oilseeds;

Month	Sep.			Oct.			Nov.			Dec.			Jan.			Feb.			Mar.			Apr.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
		0.49	0.48	0.51	0.56	0.64	0.73	0.79	0.84	0.88	0.90	0.90	0.91	0.92	0.94	0.96	0.92	0.86	0.72					
			0.49	0.48	0.51	0.56	0.64	0.73	0.79	0.84	0.88	0.90	0.90	0.91	0.92	0.94	0.96	0.92	0.86	0.72				
				0.49	0.48	0.51	0.56	0.64	0.73	0.79	0.84	0.88	0.90	0.90	0.91	0.92	0.94	0.96	0.92	0.86	0.72			
					0.49	0.48	0.51	0.56	0.64	0.73	0.79	0.84	0.88	0.90	0.90	0.91	0.92	0.94	0.96	0.92	0.86	0.72		
Kc(10days)	0	0.49	0.49	0.50	0.51	0.55	0.61	0.68	0.75	0.81	0.85	0.88	0.90	0.91	0.92	0.93	0.93	0.92	0.86	0.83	0.79	0.72	0.00	0.00
Kc		0.33			0.52			0.68			0.85			0.91			0.93			0.83			0.24	
Area %(10days	0	0.25	0.5	0.75	1	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25	0.00	0.00
Area %		0.25			0.92			1.00			1.00			1.00			1.00			1.00			0.08	
ETo		182			130			75.9			54.7			62.2			84.0			138.6			188.9	
Req.(1)		14.9			61.9			51.7			46.3			56.4			78.0			114.9			3.8	
Effective rain		15.3			0.54			0.8			2.0			3.6			6.3			31.3			22.8	
Waterreq.(mm)		0.0			61.4			50.9			44.4			52.8			71.7			83.6			0.0	

Total 303.3 mm

Sugarcane;

Month	Jan.			Feb.			Mar.			Apr.			May			Jun.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	0.71	0.7	0.69	0.68	0.65	0.62	0.59	0.57	0.59	0.61	0.62	0.67	0.74	0.80	0.87	0.92	0.97	1.02
Kc(10days)	0.71	0.70	0.69	0.68	0.65	0.62	0.59	0.57	0.59	0.61	0.62	0.67	0.74	0.80	0.87	0.92	0.97	1.02
Kc		0.70			0.65			0.59			0.64			0.80			0.97	
Area %(10days	1	1	1	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Area %		1.00			1.00			1.00			1.00			1.00			1.00	
ETo		62.2			84			138.6			188.9			242.3			268.1	
Req.(1)		43.7			54.8			81.2			120.1			194.4			260.3	
Effective rain		3.6			6.3			31.3			22.8			9.7			19.1	
Waterreq.(mm)		40.1			48.5			49.9			97.4			184.6			241.2	

Month	Jul.			Aug.			Sep			Oct.			Nov.			Dec.		
10days	1	2	3	1	2	3	1	2	3							1	2	3
	1.06	1.09	1.12	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.11	1.06	1.01	0.95	0.90	0.85	0.80
Kc(10days)	1.06	1.09	1.12	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.11	1.06	1.01	0.95	0.90	0.85	0.80
Kc		1.09			1.15			1.15			1.14			1.01			0.85	
Area %(10days	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Area %		1.00			1.00			1.00			1.00			1.00			1.00	
ETo		231.7			215.6			182.0			129.5			75.9			54.7	
Req.(1)		252.9			247.7			209.3			147.3			76.5			46.4	
Effective rain		55.3			44.5			15.3			0.5			0.8			2.0	
Waterreq.(mm)		197.7			203.3			194.0			146.8			75.7			44.5	

Total 1523.6 mm

Table D2.2 Crop Water Requirement in Taunsa Barrage Irrigation System (2/2)

Orchard;

Month	Jan.			Feb.			Mar.			Apr.			May			Jun.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	0.6	0.6	0.61	0.61	0.61	0.62	0.63	0.63	0.65	0.66	0.68	0.70	0.72	0.74	0.76	0.77	0.78	0.79
Kc(10days)	0.60	0.60	0.61	0.61	0.61	0.62	0.63	0.63	0.65	0.66	0.68	0.70	0.72	0.74	0.76	0.77	0.78	0.79
Kc		0.60			0.62			0.64			0.68			0.74			0.78	
Area %(10days)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Area %		1.00			1.00			1.00			1.00			1.00			1.00	
ETo		62.2			84			138.6			188.9			242.3			268.1	
Req.(1)		37.6			51.7			88.2			128.0			179.2			210.0	
Effective rain		3.6			6.3			31.3			22.8			9.7			19.1	
Waterreq.(mm)		34.0			45.4			56.9			105.3			169.5			190.9	

Month	Jul.			Aug.			Sep			Oct.			Nov.			Dec.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.78	0.76	0.73	0.71	0.67	0.64	0.60	0.57	0.52	0.47	0.42
Kc(10days)	0.80	0.80	0.80	0.80	0.80	0.79	0.79	0.78	0.76	0.73	0.71	0.67	0.64	0.60	0.57	0.52	0.47	0.42
Kc		0.80			0.80			0.78			0.70			0.60			0.47	
Area %(10days)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Area %		1.00			1.00			1.00			1.00			1.00			1.00	
ETo		231.7			215.6			182.0			129.5			75.9			54.7	
Req.(1)		185.4			171.9			141.5			91.3			45.7			25.8	
Effective rain		55.3			44.5			15.3			0.5			0.8			2.0	
Waterreq.(mm)		130.1			127.5			126.2			90.7			44.9			23.8	

Total 1145.1 mm

Cotton;

Month	May			June			July			Aug.			Sep.			Oct.			Nov.			Dec.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
		0.40	0.42	0.42	0.46	0.55	0.66	0.77	0.86	0.87	0.89	0.92	0.69	0.51	0.40	0.33								
			0.40	0.42	0.42	0.46	0.55	0.66	0.77	0.86	0.87	0.89	0.92	0.69	0.51	0.40	0.33							
				0.40	0.42	0.42	0.46	0.55	0.66	0.77	0.86	0.87	0.89	0.92	0.69	0.51	0.40	0.33						
					0.40	0.42	0.42	0.46	0.55	0.66	0.77	0.86	0.87	0.89	0.92	0.69	0.51	0.40	0.33					
						0.40	0.42	0.42	0.46	0.55	0.66	0.77	0.86	0.87	0.89	0.92	0.69	0.51	0.40	0.33				
							0.40	0.42	0.42	0.46	0.55	0.66	0.77	0.86	0.87	0.89	0.92	0.69	0.51	0.40	0.33			
Kc(10days)	0.00	0.40	0.41	0.41	0.43	0.45	0.49	0.55	0.62	0.69	0.77	0.83	0.83	0.79	0.71	0.62	0.57	0.48	0.42	0.37	0.33	0.00	0.00	0.00
Kc		0.27			0.43			0.55			0.76			0.78			0.56			0.37			0.00	
Area %(10days)	0.00	0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17	0.00	0.00	0.00
Area %		0.40			0.67			1.00			1.00			1.00			1.00			0.33			0.40	
ETo		242.3			268.1			231.7			215.6			182.0			129.5			75.9			54.7	
Req.(1)		26.2			76.7			127.7			164.4			141.5			72.4			9.4			0.0	
Effective rain		9.7			19.1			55.3			44.5			15.3			0.5			0.8			2.2	
Waterreq.(mm)		16.4			57.7			72.5			120.0			126.2			71.9			8.6			0.0	

Total 473.2 mm

Khrif fodder;

Month	June			July			Aug.			Sep.			Oct.			Nov.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
		0.80	0.90	0.99	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.80						
			0.80	0.90	0.99	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.80					
				0.80	0.90	0.99	0.95	0.95	0.95	0.95	0.95	0.95	0.92	0.80				
					0.80	0.90	0.99	0.95	0.95	0.95	0.95	0.95	0.92	0.80	0.80			
Kc(10days)	0.00	0.80	0.85	0.90	0.91	0.95	0.96	0.95	0.95	0.95	0.94	0.90	0.89	0.86	0.80	0.00	0.00	0.00
Kc		0.55			0.92			0.95			0.93			0.85			0.00	
Area %(10days)	0.00	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Area %		0.40			0.92			1.00			1.00			1.00			0.00	
ETo		268.1			231.7			215.6			182.0			129.5			75.9	
Req.(1)		59.1			195.1			205.5			169.7			110.2			0.0	
Effective rain		19.1			55.3			44.5			15.3			0.5			0.8	
Waterreq.(mm)		40.0			139.8			161.0			154.4			109.6			0.0	

Total 604.9 mm

Rice;

Month	Apr.			May			June			July			Aug.			Sep.			Oct.			Nov.		
10days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
				0.83	0.88	0.95	1.01	1.08	1.13	1.17	1.20	1.21	1.20	1.18	1.15	1.10	1.02	0.99						
					0.83	0.88	0.95	1.01	1.08	1.13	1.17	1.20	1.21	1.20	1.18	1.15	1.10	1.02	0.99					
						0.83	0.88	0.95	1.01	1.08	1.13	1.17	1.20	1.21	1.20	1.18	1.15	1.10	1.02	0.99				
							0.83	0.88	0.95	1.01	1.08	1.13	1.17	1.20	1.21	1.20	1.18	1.15	1.10	1.02	0.99			
Kc(10days)	0.00	0.00	0.00	0.83	0.85	0.88	0.92	0.98	1.04	1.10	1.14	1.17	1.19	1.20	1.19	1.16	1.11	1.06	1.04	1.00	0.99	0.00	0.00	0.00
Kc		0.00			0.85			0.98			1.14			1.19			1.11			1.01			0.00	
Area %(10days)	0.00	0.00	0.00	0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25	0.00	0.00	0.00
Area %		0.00			0.40			1.00			1.00			1.00			1.00			1.00			0.00	
ETo		188.9			242.3			268.1			231.7			215.6			182.0			129.5			75.9	
Req.(1)		0.0			82.8			262.6			263.8			256.9			202.4			130.6			0.0	
Land soaking			20.0	20.0	20.0	20.0																		
Percolation				5.0	10.0	15.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	15.0	10.0	5.0			
Sub-total			20.0	25.0	30.0	35.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	15.0	10.0	5.0			
Req.(2)		20.0			172.8			322.6			323.8			316.9			262.4			160.6			0.0	
Effective rain		22.8			9.7			19.1			55.3			44.5			15.3			0.5			0.8	
Waterreq.(mm)		0.0			163.1			303.5			268.5			272.5			247.1			160.1			0.0	

Total 1414.8 mm

Table D2.3 Present Unit Water Requirement in D.G.Khan Canal Area

(Unit:mm)

	Wheat	Rabi.fodder	Oilseeds	Sugarcane	Orchard	Cotton	Khrif.fodder	Rice
Jan.	48.1	56.0	52.8	40.1	34.0	0.0	0.0	0.0
Feb.	80.4	73.5	71.7	48.5	45.4	0.0	0.0	0.0
Mar.	120.6	100.3	83.6	49.9	56.9	0.0	0.0	0.0
Apr.	82.4	149.8	0.0	97.4	105.3	0.0	0.0	0.0
May	3.1	69.2	0.0	184.6	169.5	16.4	0.0	163.1
Jun.	0.0	0.0	0.0	241.2	190.9	57.7	40.0	303.5
Jul.	0.0	0.0	0.0	197.7	130.1	72.5	139.8	268.5
Aug.	0.0	0.0	0.0	203.3	127.5	120.0	161.0	272.5
Sep.	0.0	0.0	0.0	194.0	126.2	126.2	154.4	247.1
Oct.	0.0	0.0	61.4	146.8	90.7	71.9	109.6	160.1
Nov.	20.6	23.9	50.9	75.7	44.9	8.6	0.0	0.0
Dec.	43.6	48.4	44.4	44.5	23.8	0.0	0.0	0.0
	398.6	521.0	364.7	1523.6	1145.1	473.2	604.9	1414.8

Irrigation Water Requirement in D.G.Khan Canal Area

Total Crop Intensity: 102.0 %

Crops	Wheat	Rabi.fodder	Oilseeds	Sugarcane	Orchard	Cotton	Khrif.fodder	Rice	Total	Total (Cs./1,000 acre)
Areal Parcentage	35.00	5.70	2.10	0.60	1.10	43.30	8.80	5.40	(mm)	
Jan.	16.84	3.19	1.11	0.24	0.37	0.00	0.00	0.00	21.75	1.161
Feb.	28.13	4.19	1.51	0.29	0.50	0.00	0.00	0.00	34.62	2.045
Mar.	42.20	5.72	1.76	0.30	0.63	0.00	0.00	0.00	50.60	2.700
Apr.	28.83	8.54	0.00	0.58	1.16	0.00	0.00	0.00	39.11	2.156
May	1.07	3.94	0.00	1.11	1.86	7.12	0.00	8.81	23.92	1.276
Jun.	0.00	0.00	0.00	1.45	2.10	24.96	3.52	16.39	48.42	2.670
Jul.	0.00	0.00	0.00	1.19	1.43	31.39	12.30	14.50	60.81	3.244
Aug.	0.00	0.00	0.00	1.22	1.40	51.94	14.17	14.71	83.44	4.452
Sep.	0.00	0.00	0.00	1.16	1.39	54.64	13.59	13.34	84.12	4.638
Oct.	0.00	0.00	1.29	0.88	1.00	31.12	9.65	8.64	52.57	2.805
Nov.	7.19	1.36	1.07	0.45	0.49	3.72	0.00	0.00	14.29	0.788
Dec.	15.25	2.76	0.93	0.27	0.26	0.00	0.00	0.00	19.47	1.039
	139.52	29.70	7.66	9.14	12.60	204.89	53.23	76.40	533.14	

Table D2.4 Present Unit Water Requirement in Muzaffargarh Canal Area

(Unit:mm)

	Wheat	Rabi.fodder	Oilseeds	Sugarcane	Orchard	Cotton	Khrif.fodder	Rice
Jan.	48.1	56.0	52.8	40.1	34.0	0.0	0.0	0.0
Feb.	80.4	73.5	71.7	48.5	45.4	0.0	0.0	0.0
Mar.	120.6	100.3	83.6	49.9	56.9	0.0	0.0	0.0
Apr.	82.4	149.8	0.0	97.4	105.3	0.0	0.0	0.0
May	3.1	69.2	0.0	184.6	169.5	16.4	0.0	163.1
Jun.	0.0	0.0	0.0	241.2	190.9	57.7	40.0	303.5
Jul.	0.0	0.0	0.0	197.7	130.1	72.5	139.8	268.5
Aug.	0.0	0.0	0.0	203.3	127.5	120.0	161.0	272.5
Sep.	0.0	0.0	0.0	194.0	126.2	126.2	154.4	247.1
Oct.	0.0	0.0	61.4	146.8	90.7	71.9	109.6	160.1
Nov.	20.6	23.9	50.9	75.7	44.9	8.6	0.0	0.0
Dec.	43.6	48.4	44.4	44.5	23.8	0.0	0.0	0.0
	398.6	521.0	364.7	1523.6	1145.1	473.2	604.9	1414.8

Irrigation Water Requirement in Muzaffargarh Area

Total Crop Intensity: 100.5 %

Crops	Wheat	Rabi.fodder	Oilseeds	Sugarcane	Orchard	Cotton	Khrif.fodder	Rice	Total	Total (Cs./1,000 acre)
Areal Parcentage	34.00	7.60	0.50	2.20	5.60	28.20	18.80	3.60	(mm)	
Jan.	16.36	4.25	0.26	0.88	1.90	0.00	0.00	0.00	23.66	1.263
Feb.	27.33	5.59	0.36	1.07	2.54	0.00	0.00	0.00	36.88	2.178
Mar.	40.99	7.63	0.42	1.10	3.18	0.00	0.00	0.00	53.32	2.845
Apr.	28.01	11.38	0.00	2.14	5.89	0.00	0.00	0.00	47.43	2.615
May	1.04	5.26	0.00	4.06	9.49	4.64	0.00	5.87	30.37	1.620
Jun.	0.00	0.00	0.00	5.31	10.69	16.26	7.53	10.93	50.71	2.796
Jul.	0.00	0.00	0.00	4.35	7.29	20.44	26.29	9.67	68.03	3.630
Aug.	0.00	0.00	0.00	4.47	7.14	33.83	30.27	9.81	85.52	4.563
Sep.	0.00	0.00	0.00	4.27	7.07	35.59	29.02	8.90	84.84	4.677
Oct.	0.00	0.00	0.31	3.23	5.08	20.27	20.61	5.76	55.25	2.948
Nov.	6.99	1.81	0.25	1.66	2.51	2.42	0.00	0.00	15.66	0.863
Dec.	14.82	3.68	0.22	0.98	1.33	0.00	0.00	0.00	21.03	1.122
	135.54	39.60	1.82	33.52	64.12	133.44	113.72	50.93	572.69	

Table D3.1 Hill Torrent Crossing and Sedimentation

No	Hill Torrent	Canal RD (ft)	H/T Discharge (cs)	Crossing Type	Sedimentation* on H/T Aqueduct	Sedimentation* on Canal at H/T Crossing
D.G. Khan Canal						
1	Kaura	51,000	5,000	SSP	±50% depth	Moderate
2	Sori Lund	69,100	28,000 -40,000	SSP	±30% depth	Moderate
3	Sori Lund	83,500	500	SSP	±20% depth	Moderate
4	Sori Lund	108,857	2,000	SSP	±15% depth	Moderate
5	Sori Lund	144,000	1,500	SSP	±50% depth	Heavy
6	Vidore	156,750	1,000	SSP	±15% depth	Moderate Heavy Trash
7	Vidore	185,500	2,000	SSP	±10% depth	Moderate
8	Sakhi Sarwar	242,215	15,000	SSP	±25% depth	Moderate
9	Sakhi Sarwar	279,320	2,000	SSP	±50% depth	Moderate
10	Mithawan	316,430	2,000	SSP	±0% depth	Moderate
Dajal Branch Canal						
11	Mithawan	19,213	1,400	SSP	±0% depth	Heavy
12	Mithawan	32,166	6,000	SA	Some in siphon	Moderate
13	Kaha	79,500	10,000	SSP	±0% depth	Very Heavy
14	Kaha	95,280	200	SSP	±0% depth	Heavy
15	Kaha	109,768	1,000	SP	±0% depth	Moderate
16	Kaha	123,850	5,000	SSP	±0% depth	Very Heavy
17	Kaha	145,760	7,000	SSP	±0% depth (D/S H. damaged)	Very Heavy
18	Chachar	165,970	2,000	SSP	-	-
19	Chachar	177,300	2,000	SP	-	-
20	Chachar	196,100	10,000	SP	-	-

Remarks: -; Not Inspected
*; Ocular Survey

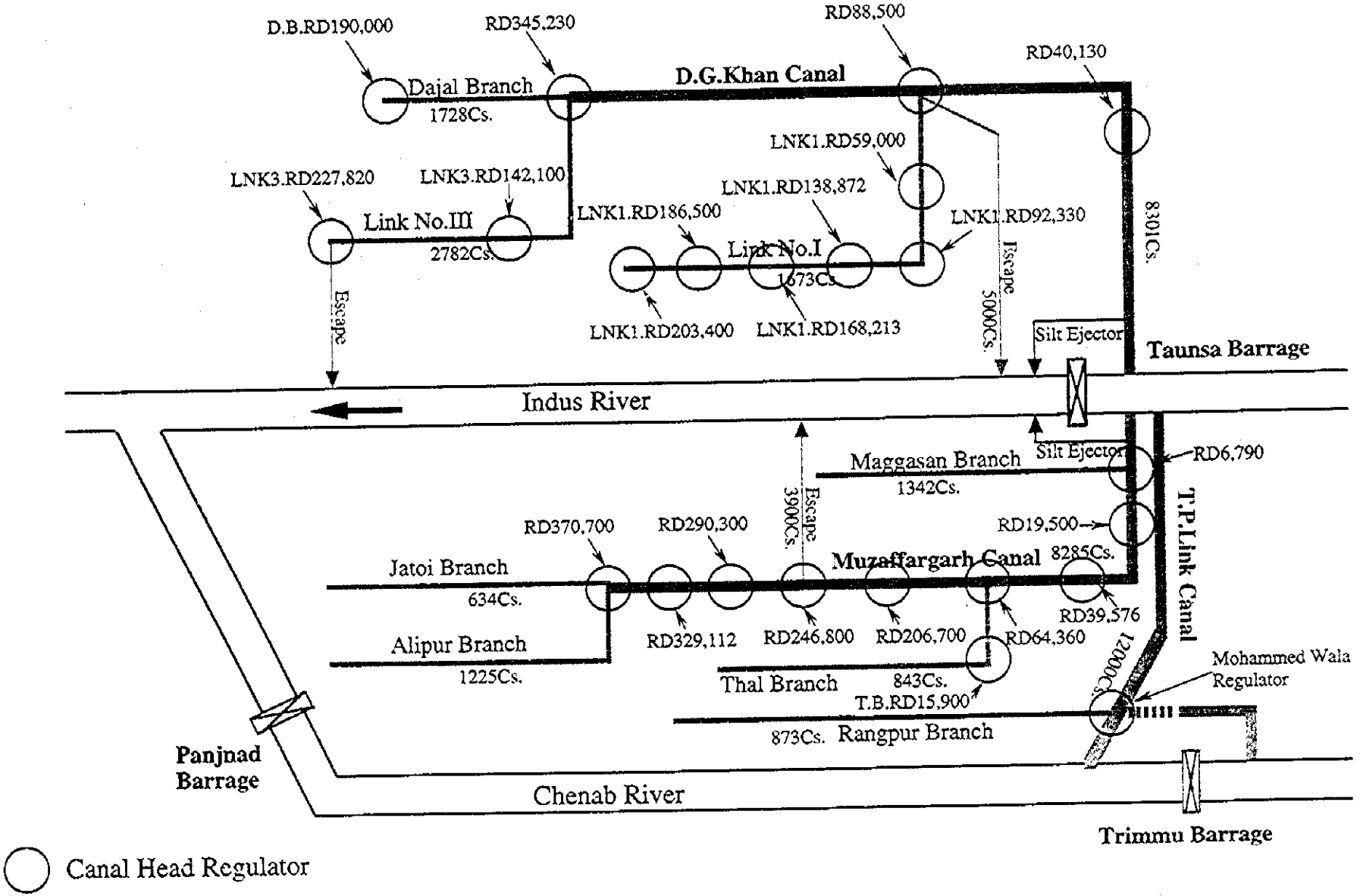

Fig. D1.1 Locations of Major Regulating Canal Facilities

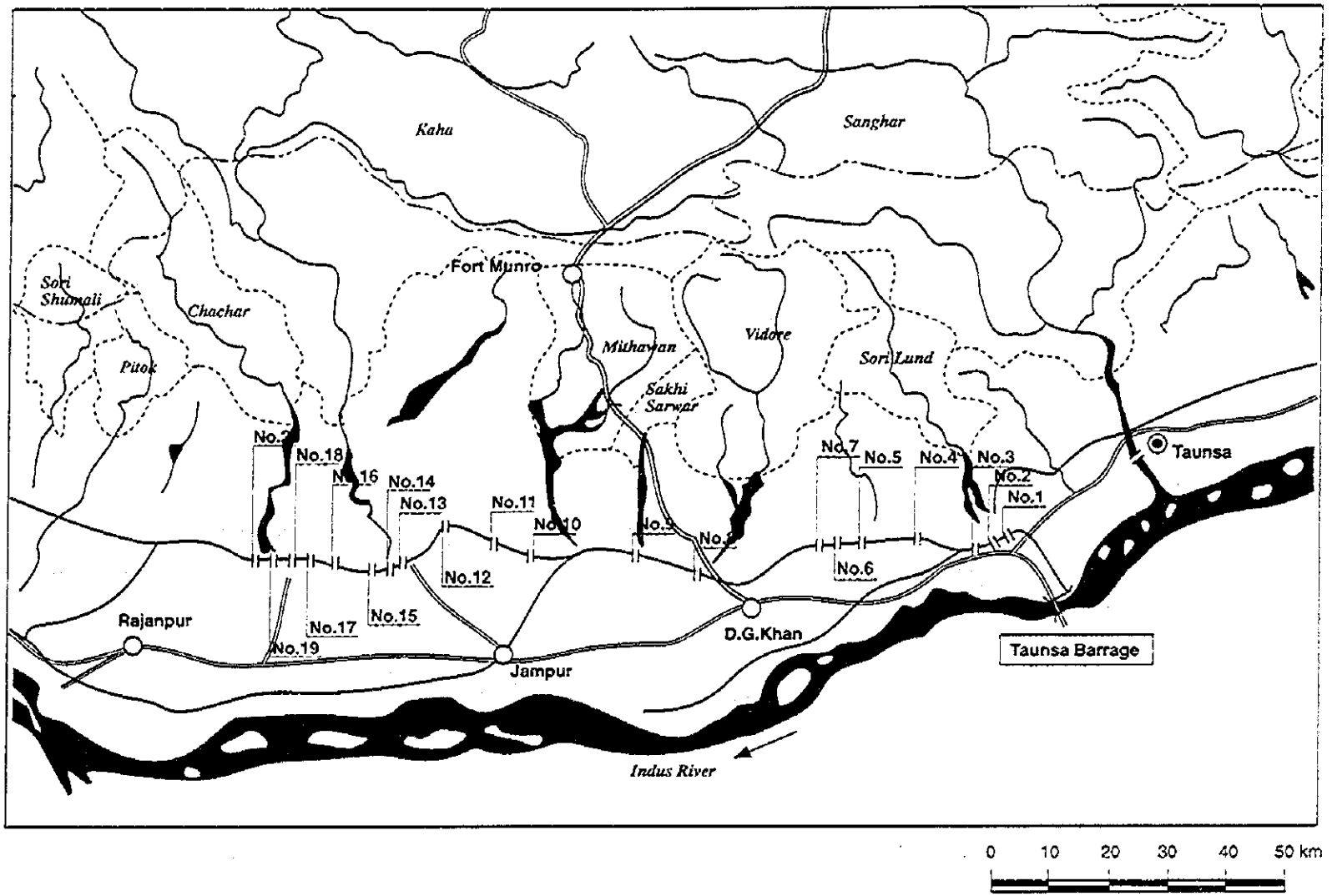

Fig.D3.1 Location Map of Hill Torrent Crossing on D.G. Khan Canal System

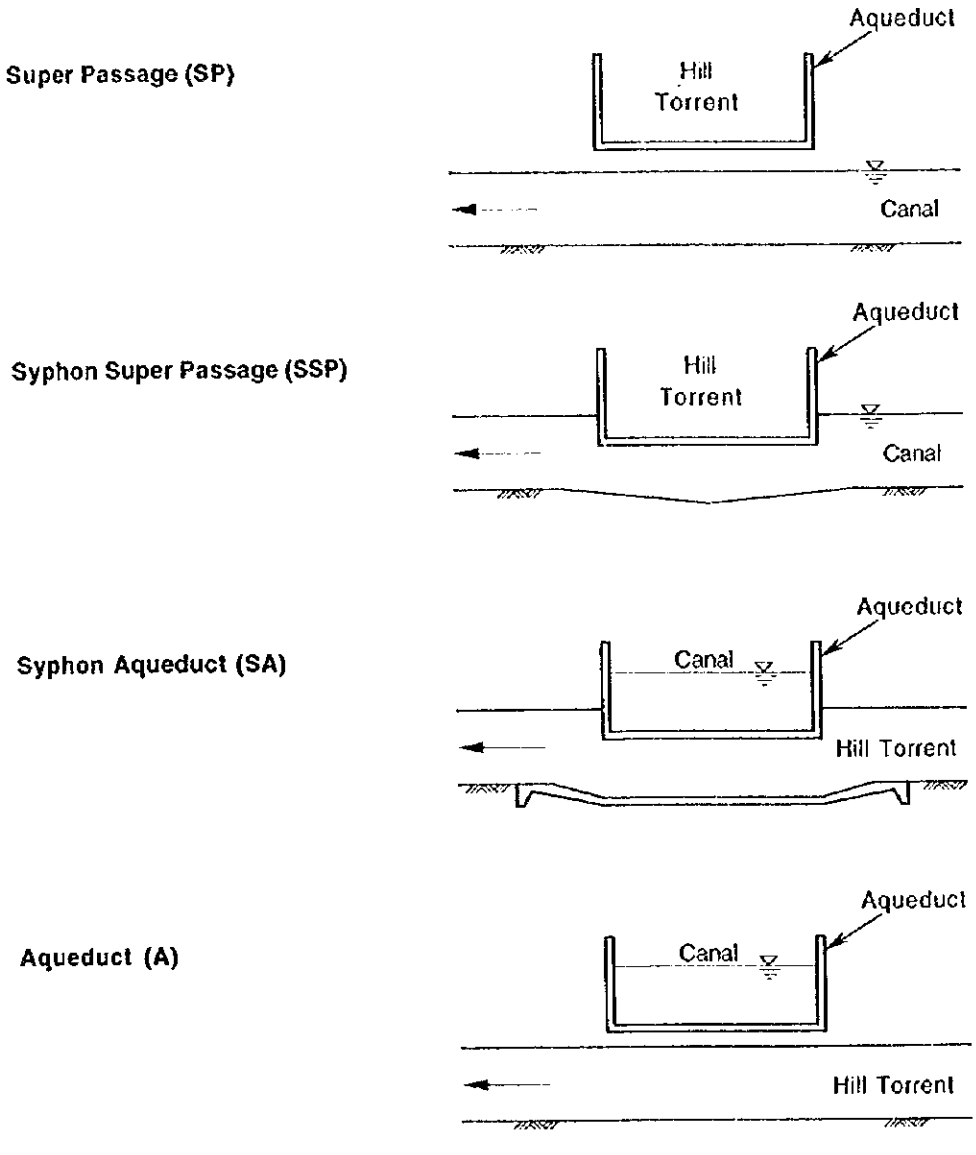

Fig. D3.2 Various Types of Hill Torrent Crossing

Annex E

Agriculture and Agro-economy

ANNEX E AGRICULTURE AND AGRO-ECONOMY

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E.1 SOCIO-ECONOMIC CONDITION

The Taunsa Barrage Irrigation System is located in the southwestern part of the Punjab. The all areas of D.G. Khan and Muzaffargarh canal command area lie within the three districts of D.G. Khan, Rajanpur and Muzaffargarh of D.G. Khan division. The number of tehsils is 11 in the districts, but four of those do not or less 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.

Area and Population by Tehsil in the Distiets 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 lives in 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 %.

E.2 AGRICULTURE

E.2.1 General

The Punjab province has a total area of 20.6 million ha of which about 12.7 million ha (62 %) is irrigated mainly by gravity canals and tubewells. The total irrigated area in Punjab corresponds to about 75 % of the total area irrigated (17 million ha) in Pakistan. The total irrigated area in D.G. Khan division is 1.5 million ha which is about 12 % of the irrigated area in Punjab. The Gross Command Area (GCA) in the Study area is estimated about 0.82 million ha and the Cultivable Command Area (CCA) is estimated about 0.75 million ha or about 50 % of the total irrigated area in D.G. Khan division.

The Indus Basin Irrigation System is divided into 9 agro-climatic zones according to the Revised Action Program for Irrigated Agriculture. There are 4 zones in Punjab province, namely, Mixed-Wheat (Thal Doab), Rice-Wheat, Sugarcane-Wheat (Punjab Mixed Crop) and Cotton-Wheat. The greater part of the Study area belongs to the Cotton-Wheat zone.

There are two seasons for cropping, namely, Kharif in summer (April to October) and Rabi in winter (October to April). Cotton is the major Kharif crop and wheat which is the main subsistence crop is the major Rabi crop in the Study area. The Study area consists of the important part of the so-called Cotton Belt which is comprising Vehari, Multan, Bahawalpur and Rahimyar Khan districts.

E.2.2 Land Use and Cropping Pattern

E.2.2.1 Soil and Land Use

(1) Physiography

Most of the Study area is situated on the active flood plains on both sides of the Indus river. A part of the Study area on the right bank is situated on the piedmont plains extended from Sulaiman mountains. This piedmont plains are dominated by the alluvial fans developed along the rivers flowing eastward down the mountains. On the contrary, the northern part of the left bank is mostly covered with rolling sand plains/dunes and interdunal depressions. The considerable part of such sandy area is currently under cultivation.

(2) General Characteristics of Soils

The flood plain soils are calcareous and contain variable amount of lime (3 to 16 %). The electrical conductivity of saturation extract (ECe) of normal soils ranges from 0.4 to 3.9 mS/cm and for saline soils from 4.1 to 220 mS/cm. The pH of normal soils ranges from 7.9 to 8.4 and that of saline/sodic soils can be as high as 9.1. The soils are deficient in available phosphorus and organic matter.

Most of the soils of the piedmont plains are clayey of an expanding type of which form deep and wide cracks on drying. All piedmont soils are moderately to strongly calcareous. The ECe of normal soils ranges from 0.9 to 3.4 mS/cm and for saline soils 4.6 to 300 mS/cm. The pH of normal soils ranges from 7.4 to 8.1 and for saline soils 7.2 to 8.0.

(3) Hill Torrents

There are several hill torrents located to the west of the D.G. Khan and Dajal Branch (including proposed extension) canals which encroach upon the command areas of these canals. The major hill torrents are from north Sori Lund, Vidore, Sakhi Sarwar, Mithawan, Kaha, Chachar, Pitok, Sori Shumali and Zangi.

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. Damage is also caused by flood water running parallel to the bund of these canals and this has also led to the breaching of canal banks.

Floods that cross into the command area cause extensive damage to crops and infrastructure and contribute to the waterlogging in the area. The area severely smashed by the flood of Kaha hill torrent was observed at the north of Rajanpur. These floods from hill torrents are, therefore, considered to be the main constraints for the development of agriculture in the area.

(4) Present Land Use

Remote Sensing Data of the Study Area was obtained through Remote Sensing Technology Center of Japan and the detailed information about the data is as follows;

- Kind of data: Landsat TM data (band number 1, 2, 3, 4, 5, 6, 7),
- Number of scenes: 151-39 (northern part) and 151-40 (southern part), and

- Date of scanning: 8 August 1991.

Data analysis by the image processing was carried out in the following manner;

- False Color Composite (Fig. E.1) was created by applying the RGB color on bands 4, 3 and 2 respectively with the application software of Photoshop version 3.0,
- In order to analyze the vegetation cover, NDVI Composite was then created as one of the Vegetation Index by using bands 3 and 4 with the VEGINDEX modules of the IDRISI, and
- By applying the TASSCAP modules of the IDRISI, Soil Brightness Index, Green Vegetation Index and Moisture Index were also created by using Bands 1, 2, 3, 4, 5 and 7.

Field reconnaissance survey was then carried out for the ground trace of the Study area and also for confirming the above mentioned indices. Special attention was paid to locate the forest, swamp vegetation and saline area. The land use maps attached to the reconnaissance soil survey report for D.G. Khan, Muzaffargarh and Thal South issued by Soil Survey of Pakistan were referred to determine the map legend.

Based on the information obtained during the ground truth, each land use element was incorporated in to false color composite and the present land use map (Fig. E.2) was created through level slice method. 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 swamp area is distributed along the Indus river and also along the main canals. The reserved forests are distributed in both sides of Indus river but the orchards are distributed within the cultivated area. Saline area, sand dune and other barren land occupies about 9 % of the gross area.

Present Land Use of the 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

E.2.2.2 Land Holding

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.

Number and Area of Private Farms by Farm Size in the Study Area

Farm Size (acre)	<5.0	5.0 -12.5	12.5 -25.0	25.0 -50.0	>50.0	Total
Study Area *						
Number of farms ('000)	133.8	82.7	35.0	18.4	8.4	278.4
Number of farms (%)	48.1	29.7	12.6	6.6	3.0	100.0
Farm area ('000 acre)	260.1	647.6	577.0	568.3	913.7	2,966.7
Farm area (%)	8.8	21.8	19.45	19.2	30.8	100.0
D.G. Khan District						
Number of farms ('000)	37.3	22.1	8.7	4.1	2.2	74.5
Number of farms (%)	50.1	29.7	11.7	5.5	3.0	100.0
Farm area ('000 acre)	77.0	171.1	145.1	128.7	272.4	794.4
Farm area (%)	9.7	21.5	18.3	16.2	34.3	100.0
Muzaffargarh District						
Number of farms ('000)	76.9	41.0	16.8	8.4	3.5	146.6
Number of farms (%)	52.5	28.0	11.4	5.8	2.4	100.0
Farm area ('000 acre)	137.1	317.0	277.3	262.2	376.9	1,370.5
Farm area (%)	10.0	23.1	20.2	19.1	27.5	100.0
Rajanpur District						
Number of farms ('000)	19.6	19.6	9.6	5.9	2.7	57.4
Number of farms (%)	34.1	34.1	16.7	10.3	4.8	100.0
Farm area ('000 acre)	45.9	159.5	154.6	177.4	264.4	801.8
Farm area (%)	5.7	19.9	19.3	22.1	33.0	100.0

Notes: The Study area means D.G. Khan, Muzaffargarh and Rajanpur district area excluding tribal areas in the table.
Source: Census of Agriculture 1990

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.

Number and Area of Private Farms by Land Ownership and District

(Unit: %)

Description	Study Area	D.G. Khan District	Muzaffargarh District	Rajanpur District
Number of Farms				
Owner Farms	72.1	77.5	75.7	55.8
Owner-Cum-Tenant Farms	16.1	14.4	15.7	19.4
Tenant Farms	11.8	8.1	8.6	24.8
Farm Area				
Owner Farms	62.8	70.2	64.4	52.8
Owner-Cum-Tenant Farms	26.7	23.2	27.8	28.3
Owned Self Operated	*12.5*	*10.3*	*13.9*	*12.5*
Share Cropped	*9.9*	*11.3*	*8.7*	*10.4*
Leased	*3.7*	*1.5*	*4.8*	*3.9*
Others	*0.6*	*0.1*	*0.4*	*1.6*
Tenant Farms	10.5	6.6	7.8	18.9
Share Cropped	*6.1*	*5.3*	*4.8*	*9.0*
Leased	*3.8*	*1.3*	*2.7*	*8.2*
Others	*0.6*	*0.0*	*0.3*	*1.7*

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

Source: Census of Agriculture 1990

E.2.2.3 Salinity and Waterlogging in 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 Integrated Drainage and Irrigation Project. NESPAK has carried out the similar survey for the Muzaffargarh canal command as a part of 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.

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

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 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. As for the left bank, the permanent swamps and shallow water tables are observed along the Muzaffargarh main canal. The area with a depth to groundwater less than 150 cm occupies 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 shows strongly saline occupying about 9 % of the area.

E.2.2.4 Cropping Pattern

The existing cropping pattern and intensities in the Study area, collected from the revenue offices of the canal division, is given in the table below and in Fig. E.3. 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 shown in Table E.2, the percentage of cotton is high in D.G. Khan canal command area specially in Rajanpur division. Sugarcane is remarkable in Kot Addu 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.

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

Since the data have been collected from the revenue offices of the canal division, as mentioned above, this results only indicate the situation of the area irrigated by the canal network. An extra area is irrigated by the tubewell 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 %.

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

E.2.3 Farming Practice and Agricultural Production

E.2.3.1 Farming Practices

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

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 irrigations 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

Among the major crops, cotton is the most important cash crop in the Study area. The department of agriculture is insisting that the early matured variety is needed because of successive wheat sowing in the same field. According to the observation of cotton field during the reconnaissance survey in the Study area, uneven growth of cotton within and between

fields were noticed compared to the main cotton producing area in Multan. In spite of the sandy characteristic of the soil, in some area, the unit basin for irrigation seems too wide to distribute water evenly. Although the main reasons can be attributed to such uneven water distribution due to inappropriate irrigation practice, many other reasons such as soil salinization, poor seed quality and the damage by cotton leaf curl virus and white fly are also conceivable.

Wheat is the major Rabi crop in the Study area and the varieties cultivated are all bread wheat. According to the department of agriculture, approximately 70 % of the cotton field is utilized for the successive cultivation of wheat and therefore 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. The average yield of the rice in the Study area is lower than the standard yield of IRRI-varieties in Pakistan. Although transplanting method is recommended by the department, about 50 % of farmers are practicing direct seeding with an inappropriate seed rate.

The area under sugarcane increases rapidly in last 40 years in Pakistan and the yield per unit area have also been improved. But a much greater increase is possible compared to the world standard. In the Study area, sugarcane is usually planted in January/February and is harvested in November/March with same standing for 2 to 3 years. But the plantation in September gives 20 to 30 % more yield and 10 % more sugar content.

The Rabi fodder such as berseem and lucerne are usually sown in October/November and give 4 or 5 cuttings in a season. The Kharif fodder such as sorghum and millet can be grown in poor soils and are relatively resistant to drought. But their acreage and production are on the decline in general. Berseem as Rabi fodder and Jantar as Kharif fodder are sometimes utilized as green manure. Jantar has also soil improvement effect because of deep rooting system.

E.2.3.2 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 per unit area.

Main Crops Cultivated in D.G. Khan Division

Kharif Crop	Cotton acre	tons	kg/acre	Rice acre	tons	kg/acre	Sugarcane 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 Crop	Wheat acre	tons	kg/acre	Gram acre	tons	kg/acre	Oilseeds 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)

E.2.4 Animal Husbandry

The department of livestock and dairy development is playing an important role for the animal husbandry in the Study area. There is a network of veterinary hospitals, dispensaries and centers to provide necessary veterinary services to all classes of livestock in the area (Fig. E.4). The main functions of the department are as follows;

- Prophylactic vaccination against contagious/infectious diseases,
- Provision of veterinary aid to sick and injured animals,
- Control and treatment of ecto- and endo-parasites,
- Elimination of scrub males through castration,
- Propaganda and publicity through pamphlets, booklets, brochures etc. and radio, TV-talks for better management, breeding and feeding of livestock, and
- Arrangement for short term training courses for educating farmers and livestock/poultry breeders at various veterinary hospitals by providing technical know-how and expert services.

The number of livestock in the Study area is given in the table below. It shows that the number of large animals such as cattle and buffaloes are decreasing and the number of small animals such as sheep and goats are contrary increasing in the area. According to the district wise

results shown in Table E.3, the percentage of small animals in D.G. Khan and Rajanpur districts is higher than that of Muzaffargarh district.

Number of Livestock in the Study Area

Livestock	1986		1990	
	head	(%)	head	(%)
Cattle	1,131,488	30.3	953,594	21.4
Buffaloes	494,331	13.2	477,277	10.7
Sheep	1,089,011	29.1	1,564,349	35.0
Goats	1,023,621	27.4	1,469,952	32.9
Total	3,738,451	100.0	4,465,172	100.0

Source : Pakistan Census of Livestock 1986 and Census of Agriculture 1990

E.2.5 Agricultural Supporting Services

E.2.5.1 Agricultural Research

The agricultural research has its own organization under Director General Research. The main research center is in Faisalabad and the regional research center and sub-stations are distributed in various locations. Each center and sub-station is dealing with the particular crop suitable for each location. The recommendations will be prepared based on the results obtained through various experiment carried out in such stations. The adaptive research component is re-checking thus established recommendations at the local level. The research center organizes refresher courses at the beginning of Rabi and Kharif season for the training of extension staff.

E.2.5.2 Agricultural Extension

Agricultural Extension System operates independently in the Punjab province. This has a organization from the Director General Agriculture (Extension and Adaptive Research) to the Field Assistant (FA) as shown in Fig.E.5.

The main objectives of the extension services are (i) to transfer the latest modern crop production technology to the farmers and (ii) to work as a bridge between farmers and research experts and other related agricultural engineers.

The extension activities are being carried out according to the Training and Visit System (T-V System) proposed by the World Bank. The training system based on the periodical training courses organized each fortnight by the training component for Agricultural Officers (AOs) and

FAs. The agricultural messages including the seasonal topics are distributed to the participants as the extension material. Furthermore, audio-visual equipment such as OHP, slide and video programs are used for the effective training. AOs and FAs will hold meeting after one week at the Markaz or Union Council level for the progressive farmers in his area by using the same agricultural messages. T-V System is thus continued in fortnight cycle all the year around.

E.2.5.3 Seed Supply

Punjab Seed Corporation (PSC) carries out the seed multiplication activities. The head quarter of PSC is in Lahore and three seed cleaning plants are operational in Pirowal, Sahiwal and Rahimyar Khan. PSC is operating seed multiplication farm of 6,000 ha mainly for cotton and wheat seed production. Since the production from this farm is insufficient, PSC supply the seeds to the registered growers and purchase the products with incentives according to the quality of the product. In these days, the private companies are supplying more amount of seeds to the growers and also many kind of foreign seeds are imported by small shop holders.

E.2.5.4 Cooperative

The registered cooperative societies sum into 46,100 in the Punjab province. The statistical facts on the cooperatives are summarized in the following table.

Working of Coopertive Societies in the Punjab (1993-94)

(Unit: Rs. million)

Item	Total	Provincial Cooperative Bank	Central Non-Credit Societies	Agricultural Cooperative Societies		Non-Agri. Cooperative Societies	
				Credit	Others	Credit	Others
Number (Nos)	46,101	1	232	33,666	7,686	1,109	3,387
Membership ('000)	2,439	36	44	1,572	224	107	456
Share Capital	402	59	25	108	31	9	170
Reserve Fund	493	217	12	227	10	3	24
Other Fund	595	427	19	4	8	1	136
Deposits	9,964	1,137	14	32	110	23	8,648
Loans	4,774	2,578	28	1,925	108	8	127
Working Capital	16,228	4,418	4	9	1	-	46
Profit & Loss	125	65	4	9	1	-	46
Cost of Management	1,075	290	15	35	370	240	125
Loans Advanced							
Individuals	2,594	-	-	2,384	-	210	-
Societies	2,384	2,384	-	-	-	-	-
Receipt from Loans Paid							
Individuals	1,373	-	-	1,283	-	90	-
Societies	1,283	1,283	-	-	-	-	-
Percentage of Recovery of Loans (%)							
Individuals	53	-	-	54	-	43	-
Societies	54	54	-	-	-	-	-

Source: 1995 Punjab Development Statistics

In the three districts covering the Study area, there exist 2,729 cooperative societies, in which 91,000 members are involved. However, their activities are quite low except borrowing advantageous public loans.

Coopertive Societies by District (1994-95)

District	Number (Nos)	Membership ('000)	Share Capital (Rs. million)	Working Capital (Rs. million)
D.G. Khan	1,057	37	5	48
Rajanpur	611	22	3	39
Muzaffargarh	1,061	32	4	46
Total	2,729	91	12	133

Source: 1996 Statistical Pocket Book of the Punjab

E.2.5.5 Rural Credit

Financial supports for the farmers are crucial to maintein 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 Revenue Department has also provided Taccavi loan which is a direct state credit, but it is no longer operative.

The total disburcement of the institutional agricultural credit was Rs. 16,069 million in the Punjab during 1994-95. This loan amount was interpreted as about Rs. 1,100 every ha of cropped area in average. The ADBP had largest share of 63 %, followed by coopertative societies of 25 % and commercial banks of 12 %. Main purposes of the borrowings are to prchase agricultural machinery as well as to purchase fertilizer and seeds.

Agricultural Loans Advanced in the Punjab (1994-95)

	Total	ADBP	Commercial Bank	Agricultural Cooperative Societies	Taccavi Loans
Total Loans Advanced	16,069	10,050	1,968	4,044	7
By Type					
Long Term		4,142			
Medium Term		706			
Short Term		5,167			
By Purpose					
Seed/Seedlings		730			
Ferlizers		1,970			
Tractors, Tillers, etc.		4,568			
Tubewells, Pumps, Engines		269			
Draught Animal		0			
Livestock		696			
Fisheries		4			
Cold Storage/Godown		0			
Others		1,778			

Source: 1996 Statistical Pocket Book of the Punjab

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, neighbourer, 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.

Debt and Investment of Farmers by District

Description	D.G. Khan	Muzaffargarh	Rajanpur	Total
Households under debt				
Number (nos)	11,496	45,283	12,801	69,580
Percentage to total households (%)	8	18	13	14
Amount of outstanding debt (Rs. million)				
Total	210	884	214	1,308
Institutional sources	133	462	99	694
Non-institutional sources	77	422	115	614
Households made investment				
Number (nos)	48,477	100,662	35,890	185,119
Percentage to total households (%)	33	41	38	38
Amount of investment (Rs. million)				
Total	429	1,556	469	2,454
Own resources	290	877	313	1,480
Borrowing	139	679	156	974

Notes: Excluding tribal areas.
Source: 1990 Census of Agriculture

E.2.6 Marketing and Prices

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 the 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 prducts 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 marchants. Their selling rates are usually controled by the middlemen at given rates lower than fixed rate.

As to input supply, Punjab Seed Corporation (PSC) under Agriculture Department produces and markets 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 anounced 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.

E.2.7 Farm Economy

E.2.7.1 Farm Operation

The farm operation in the area is analized using the 1990 Agriculture Census. The farmers can be grouped by land holding type; owner (72.1 % of all farmers), owner-cum-tenant (16.1 %) and tenant farmers (11.8 %), and by farm size; less than 5 acre (48.1 % of all farmers), 5 to 12.5 acre (29.7 %), 12.5 to 25 acre (12.6 %), 25 to 50 acre (6.6 %) and more than 50 acre (3.0 %). In terms of average of the all farmers group, farm area is 10.7 acre and cultivated area is 8.3 acre. However, nearly half farmers operate less than 5 acre, and their average farm area and cultivated area are 1.9 acre and 1.8 acre, respectively. And about 30 % of farmers operate 7.8 acre of farm land and cultivate 7.0 acre.

Land Tenure and Farm Size in the Study Area

(Unit: %, acre)

Farm Size (acre)	<5.0	5.0 -12.5	12.5 -25.0	25.0 -50.0	>50.0	Total/ Average
All Farmers						
Number of farmers (%)	48.1	29.7	12.6	6.6	3.0	100.0
Average Farm Area (acre)	1.9	7.8	16.5	30.8	108.6	10.7
Average Cultivated area (acre)	1.8	7.0	13.8	23.7	66.4	8.3
Owner Farmers (72.1 %)						
Number of farmers (%)	56.2	25.8	9.9	5.3	2.8	100.0
Average Farm Area (acre)	1.8	7.7	16.4	30.5	107.0	9.3
Average Cultivated area (acre)	1.7	6.8	13.3	22.7	68.3	7.1
Owner-Cum-Tenant Farmers (16.1 %)						
Number of farmers (%)	20.2	40.1	22.8	11.9	5.0	100.0
Average Farm Area (acre)	3.0	8.1	17.2	32.5	119.3	17.7
Average Cultivated area (acre)	2.8	7.4	14.9	25.3	65.4	13.2
Tenant Farmers (11.8 %)						
Number of farmers (%)	36.5	39.4	14.9	7.8	1.3	100.0
Average Farm Area (acre)	2.3	7.9	15.3	28.4	75.4	9.5
Average Cultivated area (acre)	2.2	7.4	13.8	24.6	48.1	8.3

Notes: The Study area is the three districts excluding tribal areas.
Source: 1990 Census of Agriculture

The uneven distribution of farm operation size is clearly illustrated in Fig. E.6, where the Lorenz Curve bends down significantly. The magnitude of the unevenness of the Study area is stronger than it of the total Punjab province. Such accumulation of farm land to large-scale

farmers causes lower land use efficiency (= cultivated area/farm land), because the efficiency of the smaller farmers is much higher than the larger farmers. In other words, the existence of huge fallow land of the large-scale farmers makes substantial economic losses in agriculture sector.

E.2.7.2 Farm Household Economy

According to the farm survey in "the Study on the Lining of Distributaries and Minors in Punjab; JICA; July 1997", the tyoical farm budgets for the canal irrigation area in the Punjab are summarized as shown in the following table. Marginal and some small farmers can not afford their daily life on farm and non-farm income. On the contraly, the large farmers can reserve more than Rs. 100,000 a year. The farm income per farm size ranges from Rs. 13,000 to Rs. 25,000 per ha.

Typical Farm Household Economy in the Selected Area of the Punjab

(Unit: Rs./year)

Farm Size	Marginal	Small	Medium	Large
Lower Jhelum Canal System				
Farm Size (acre)	*3.85*	*8.62*	*15.72*	*40.65*
1. Income	51,900	73,200	119,900	325,100
Net Farm Income	33,200	50,600	100,700	218,500
Off-Farm Income	18,700	22,700	19,200	106,600
2. Expenditure	54,600	79,200	88,600	201,600
3. Net Reserve	-2,700	-6,000	31,300	123,500
Lower Chenab Canal System				
Farm Size (acre)	*3.76*	*9.14*	*16.85*	*34.57*
1. Income	98,700	115,900	155,300	298,000
Net Farm Income	30,700	80,500	130,000	255,800
Off-Farm Income	68,000	35,400	25,300	42,300
2. Expenditure	101,700	97,000	122,400	179,600
3. Net Reserve	-3,000	18,900	32,900	118,400
Central Bari Doab Canal System				
Farm Size (acre)	*3.66*	*8.57*	*15.72*	*39.56*
1. Income	56,000	98,200	204,200	290,300
Net Farm Income	21,000	66,600	157,900	258,300
Off-Farm Income	35,000	31,700	46,300	32,000
2. Expenditure	43,700	60,400	78,900	157,500
3. Net Reserve	12,300	37,800	125,300	132,800

Source: Study on the Lining of Distributaries and Minors in Punjab; JICA; July 1997

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.

Typical Crop Budget in the Punjab

(Unit: Rs./acre)

Crop	Gross Income	Production Cost	Net Return
Sugarcane	10,200	4,800	5,400
Cotton	10,900	3,900	6,900
Rice (Basmati)	2,800	2,200	600
Vegetable	20,200	5,500	14,700
Maize	3,800	3,000	900
Fodder	4,400	3,200	1,100
Mung Bean	2,700	900	1,900
Wheat	4,700	2,900	1,800
Fodder (Berseem)	7,100	4,200	2,900
Oilseeds	6,600	1,500	5,200
Fruit (Citrus)	17,300	3,200	14,100

Source: Study on the Lining of Distributaries and Minors in Punjab; JICA; July 1997

E.3 AGRICULTURAL IMPROVEMENT PLAN

E.3.1 Present Agricultural Constraints

The main agricultural constraints prevailing in the Study area are as follows;

- Damage by the flood of hill torrent,
- Sand dune encroachment,
- Waterlogging and soil salinity,
- Shortage of water at the tail of distributery,
- Fragmentation of farm land,
- Unfair farm land distribution,
- High cost for input and low return from output, and
- Improper utilization of capital and credit.

E.3.2 Land Use and Cropping Pattern

(1) Hill Torrent

Watershed management project should be promoted in the hilly area in order to minimize the damage by the flood of hill torrent. By applying the water harvesting facilities in the hilly area, the agricultural production and the vegetation in the area can be improved and thus the function of soil and water conservation can be improved in general.

(2) Sand Dune Fixation

The sand dune distributed in the Study area should be fixed by the active afforestation activities.

(3) Effective Utilization of Waterlogged and Saline Area

Waterlogged and/or saline area should be improved by providing adequate drainage system with effective and regular maintenance system. Further, the activities already implemented and planned such as SCARP and National Drainage Program should be promoted. Salt tolerant and other promising crops should be introduced for the effective utilization of waterlogged and saline area.

(4) Soil Management

The soil fertility should be improved through adopting an appropriate crop rotation system by introducing more nitrogen fixing crops such as leguminous fodder.

(5) Land Distribution

Proper farm land distribution may promote higher cropping intensity. The significant land accumulation to few large-scale land lord is expected to be solved by means of some agrarian reform program.

E.3.3 Proposed Farming Practices

(1) On Farm Water Management

On farm water management should be improved in order to be able to irrigate according to the crop water requirement. The lining of water courses currently carried out under the on-farm water management project should be activated. Proper land leveling should also be promoted.

Further, the ET crop data to be calculated according to the various meteorological factors should be applied to the actual irrigation.

(2) Crop Rotation

Although it is difficult to secure the fallow land due to the fragmentation of the farm land, the maximum effort should be paid to introduce the improved crop rotation system in order (i) to avoid the conflict in the cotton-wheat, rice-wheat cropping pattern, (ii) to maintain soil moisture and fertility and (iii) to control insect pests, diseases and weeds effectively.

(3) Animal Husbandry

Since the livestock is taking an important part of the income for ordinary farmers, the appropriate combination between agriculture and livestock should be promoted. For example, weeds and agricultural by-products can effectively be used for the feeding material of livestock. Further, the farmyard manure can be applied to the field in order to improve the physico-chemical condition of the soil.

(4) Agroforestry

The concept of agroforestry should properly be introduced to the growers in order to utilize the various kind of trees purposely. Some of the trees can be effected as windbreaks, shade, soil and water conservation purposes. Further, the forestry products can be utilized as fodder, fuelwood, compost and many other materials.

E.3.4 Agricultural Supporting System Improvement Plan

(1) Agricultural Extension

- The qualification of Field Assistant is currently 2 years diploma in agriculture and their level is not sufficient to give proper suggestions to the farmers.
- It might be more effective to strengthen the role of agriculture graduate and subject matter specialist with the provision of effective facilities including diagnostic equipment and transportation. Supervisory staff should also be provided with proper transportation facilities.
- Audio visual equipment with proper transportation facilities should be provided in order to implement the effective extension activities including mass education and training.

- Agricultural Research Institute, Adaptive Research Unit, Extension Wing of Agriculture and other related organizations should launch an extension enhancement program to create integrated agricultural service for the agricultural extension.

(2) Institutional Support to Farm Economy

- The government support or control prices of farm inputs and outputs should be rearranged to support farm economy. The nation's price system is distorted in comparison with international prices.

- The easy access to the institutional credit service will improve farm economy, because the ignorant rural farmers use only high-interest non-institutional credit today. The public loan should advance to the poorest small farmers with high priority.

Table E.1 Number and Area of Farms by Size of Farm for Irrigated Area

Size of Farm (acre)		Number of Farms	Number of Farms (%)	Farm Area (acre)	Farm Area (%)	Average Farm Size (acre)
Area Total		278,390	100.0	2,966,713	100.0	10.7
To under	1.0	31,443	11.3	13,564	0.5	0.4
1.0 To under	2.5	54,589	19.6	84,485	2.8	1.5
2.5 To under	5.0	47,796	17.2	162,022	5.5	3.4
5.0 To under	7.5	39,640	14.2	230,485	7.8	5.8
7.5 To under	12.5	43,011	15.4	417,127	14.1	9.7
12.5 To under	25.0	35,053	12.6	577,030	19.5	16.5
25.0 To under	50.0	18,446	6.6	568,252	19.2	30.8
50.0 To under	150.0	7,184	2.6	506,062	17.1	70.4
150.0 and Above		1,228	0.4	407,686	13.7	332.0
D.G.Khan		74,460	100.0	794,406	100.0	10.7
To under	1.0	6,262	8.4	2,970	0.4	0.5
1.0 To under	2.5	17,180	23.1	26,371	3.3	1.5
2.5 To under	5.0	13,893	18.7	47,691	6.0	3.4
5.0 To under	7.5	11,026	14.8	64,392	8.1	5.8
7.5 To under	12.5	11,083	14.9	106,732	13.4	9.6
12.5 To under	25.0	8,699	11.7	145,129	18.3	16.7
25.0 To under	50.0	4,113	5.5	128,704	16.2	31.3
50.0 To under	150.0	1,728	2.3	116,223	14.6	67.3
150.0 and Above		476	0.6	156,194	19.7	328.1
Muzaffargarh		146,562	100.0	1,370,510	100.0	9.4
To under	1.0	22,401	15.3	9,290	0.7	0.4
1.0 To under	2.5	30,624	20.9	47,417	3.5	1.5
2.5 To under	5.0	23,911	16.3	80,390	5.9	3.4
5.0 To under	7.5	20,358	13.9	118,284	8.6	5.8
7.5 To under	12.5	20,616	14.1	198,714	14.5	9.6
12.5 To under	25.0	16,767	11.4	277,298	20.2	16.5
25.0 To under	50.0	8,426	5.7	262,193	19.1	31.1
50.0 To under	150.0	2,975	2.0	210,076	15.3	70.6
150.0 and Above		484	0.3	166,848	12.2	344.7
Rajanpur		57,368	100.0	801,797	100.0	14.0
To under	1.0	2,780	4.8	1,304	0.2	0.5
1.0 To under	2.5	6,785	11.8	10,697	1.3	1.6
2.5 To under	5.0	9,992	17.4	33,941	4.2	3.4
5.0 To under	7.5	8,256	14.4	47,809	6.0	5.8
7.5 To under	12.5	11,312	19.7	111,681	13.9	9.9
12.5 To under	25.0	9,587	16.7	154,603	19.3	16.1
25.0 To under	50.0	5,907	10.3	177,355	22.1	30.0
50.0 To under	150.0	2,481	4.3	179,763	22.4	72.5
150.0 and Above		268	0.5	84,644	10.6	315.8

Source: Census of Agriculture 1990

Table E.2 Present Cropping Pattern in the Study Area

Intensity=Percent of CCA

Canal Division	D.G.Khan Canal						Muzaffargarh Canal						Rangpur Canal		Grand Total	
	D.G. Khan Canal Division		Rajanpur Canal Division		Total		Kot Adu Canal Division		Muzaffargarh Canal Division		Total		Muzaffargarh Canal Division		Total	
	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)	(Acre)	(%)
GCA	507,281		494,540		1,001,821		421,970		485,201		907,171		126,200		2,035,192	
CCA	473,520		476,852		950,372		323,633		453,462		777,095		119,584		1,847,051	
Kharif	267,996	56.6	293,123	61.5	561,119	59.0	184,545	57.0	228,236	50.3	412,781	53.1	57,721	48.3	1,031,621	55.9
Cotton	177,793	37.5	233,529	49.0	411,322	43.3	84,060	26.0	135,427	29.9	219,487	28.2	14,793	12.4	645,602	35.0
Rice	32,014	6.8	19,450	4.1	51,464	5.4	17,632	5.4	10,248	2.3	27,880	3.6	5,864	4.9	85,208	4.6
Sugarcane	2,992	0.6	2,703	0.6	5,695	0.6	15,939	4.9	1,239	0.3	17,178	2.2	449	0.4	23,322	1.3
Oilseeds	32	0.0		0.0	32	0.0	3,154	1.0	79	0.0	3,233	0.4	11	0.0	3,276	0.2
Corn	6,499	1.4	1,047	0.2	7,546	0.8	2,707	0.8	10,299	2.3	13,006	1.7	1,475	1.2	22,027	1.2
Sorghum	18,925	4.0		0.0	18,925	2.0		0.0	33,241	7.3	33,241	4.3	14,022	11.7	66,188	3.6
Millet	604	0.1	401	0.1	1,005	0.1	1,308	0.4	878	0.2	2,186	0.3	44	0.0	3,235	0.2
Jantar	13,598	2.9		0.0	13,598	1.4	9,745	3.0	12,323	2.7	22,068	2.8	4,872	4.1	40,538	2.2
Fodder	6,957	1.5	26,915	5.6	33,872	3.6	32,303	10.0		0.0	32,303	4.2		0.0	66,175	3.6
Tobacco	2,046	0.4		0.0	2,046	0.2		0.0		0.0	0	0.0		0.0	2,046	0.1
Vegetables	2,267	0.5	430	0.1	2,697	0.3	301	0.1	295	0.1	596	0.1	14,945	12.5	18,238	1.0
Orchard, forest,etc.	4,269	0.9	8,648	1.8	12,917	1.4	17,396	5.4	24,207	5.3	41,603	5.4	1,246	1.0	55,766	3.0
Rabi	217,915	46.0	197,434	41.4	415,349	43.7	158,282	48.9	210,090	46.3	368,372	47.4	61,502	51.4	845,223	45.8
Wheat	171,177	36.1	160,433	33.6	331,610	34.9	116,183	35.9	147,242	32.5	263,425	33.9	28,227	23.6	623,262	33.7
Barseem	32,091	6.8		0.0	32,091	3.4	23,038	7.1		0.0	23,038	3.0		0.0	55,129	3.0
Gram	7,744	1.6	5,103	1.1	12,847	1.4		0.0		0.0	0	0.0		0.0	12,847	0.7
Oilseeds		0.0	19,133	4.0	19,133	2.0	253	0.1		0.0	253	0.0		0.0	19,386	1.0
Fodder		0.0	9,691	2.0	9,691	1.0		0.0	35,790	7.9	35,790	4.6	14,645	12.2	60,126	3.3
Vegetables		0.0	769	0.2	769	0.1	94	0.0	316	0.1	410	0.1	310	0.3	1,489	0.1
Orchard, Forest, etc.	6,903	1.5	2,305	0.5	9,208	1.0	18,714	5.8	26,742	5.9	45,456	5.8	18,320	15.3	72,984	4.0
Annual		102.6		102.9		102.7		105.9		96.7		100.5		99.7		101.6

Source: PID Canal Division

Table E.3 Number of Livestock in the Study Area

	1986		1990	
	head	(%)	head	(%)
Area Total				
Cattle	1,131,488	30.3	953,594	21.4
Buffaloes	494,331	13.2	477,277	10.7
Sheep	1,089,011	29.1	1,564,349	35.0
Goats	1,023,621	27.4	1,469,952	32.9
Total	3,738,451	100.0	4,465,172	100.0
D.G.Khan District				
Cattle	287,380	26.1	286,977	18.2
Buffaloes	115,161	10.5	101,100	6.4
Sheep	409,100	37.2	591,576	37.5
Goats	288,522	26.2	597,179	37.9
Total	1,100,163	100.0	1,576,832	100.0
Muzaffargarh District				
Cattle	562,993	37.5	465,820	26.4
Buffaloes	258,811	17.2	278,873	15.8
Sheep	302,526	20.1	483,809	27.4
Goats	377,051	25.1	535,352	30.4
Total	1,501,381	100.0	1,763,854	100.0
Rajanpur District				
Cattle	281,115	24.7	200,797	17.9
Buffaloes	120,359	10.6	97,304	8.7
Sheep	377,385	33.2	488,964	43.5
Goats	358,048	31.5	337,421	30.0
Total	1,136,907	100.0	1,124,486	100.0

Source : Pakistan Census of Livestock 1986 and Census of Agriculture 1990

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Fig. E.1 False Color Image of the Study Area

151-39/151-40
8 August 1991

PRESENT LAND USE MAP OF THE STUDY AREA

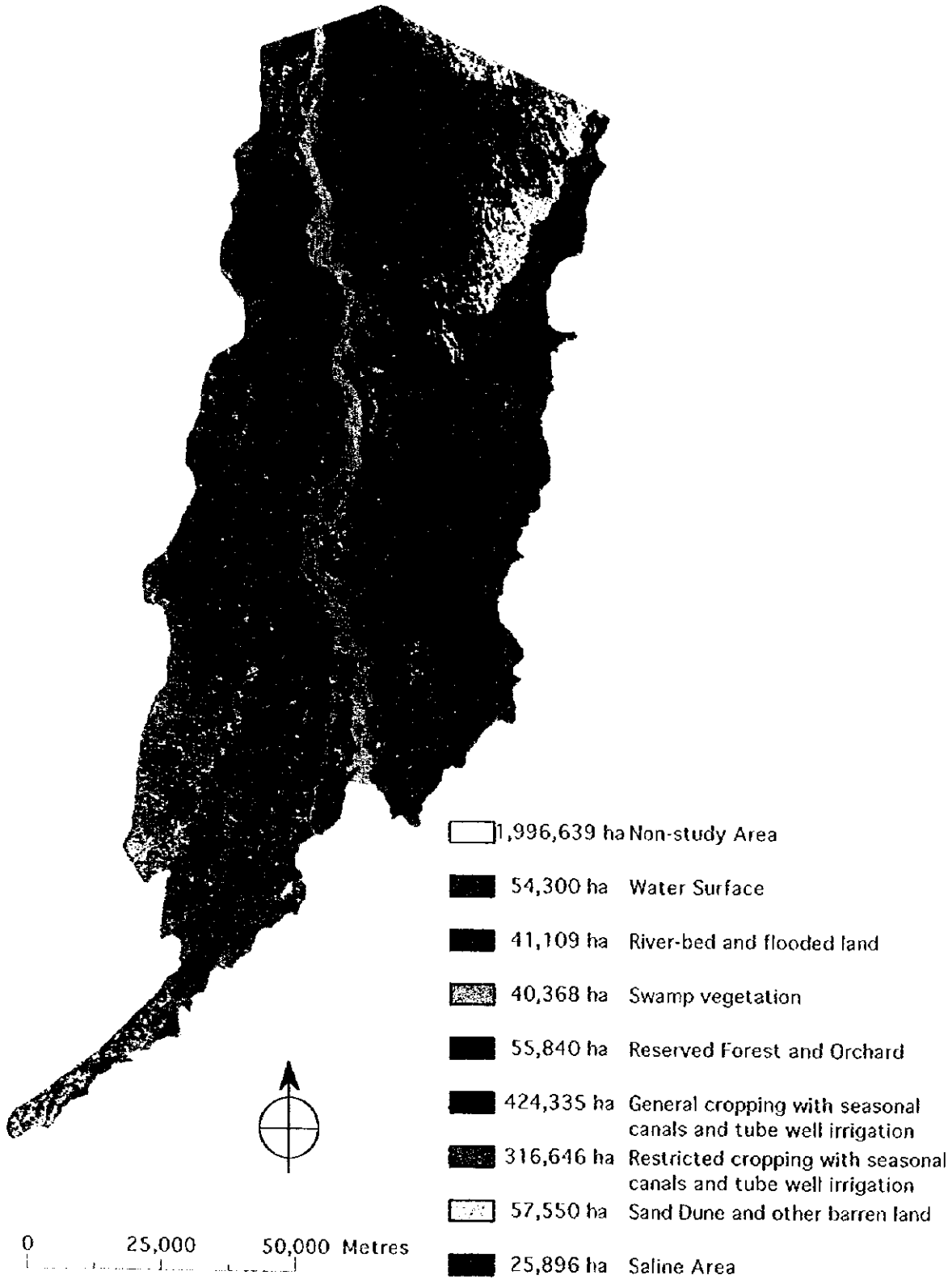
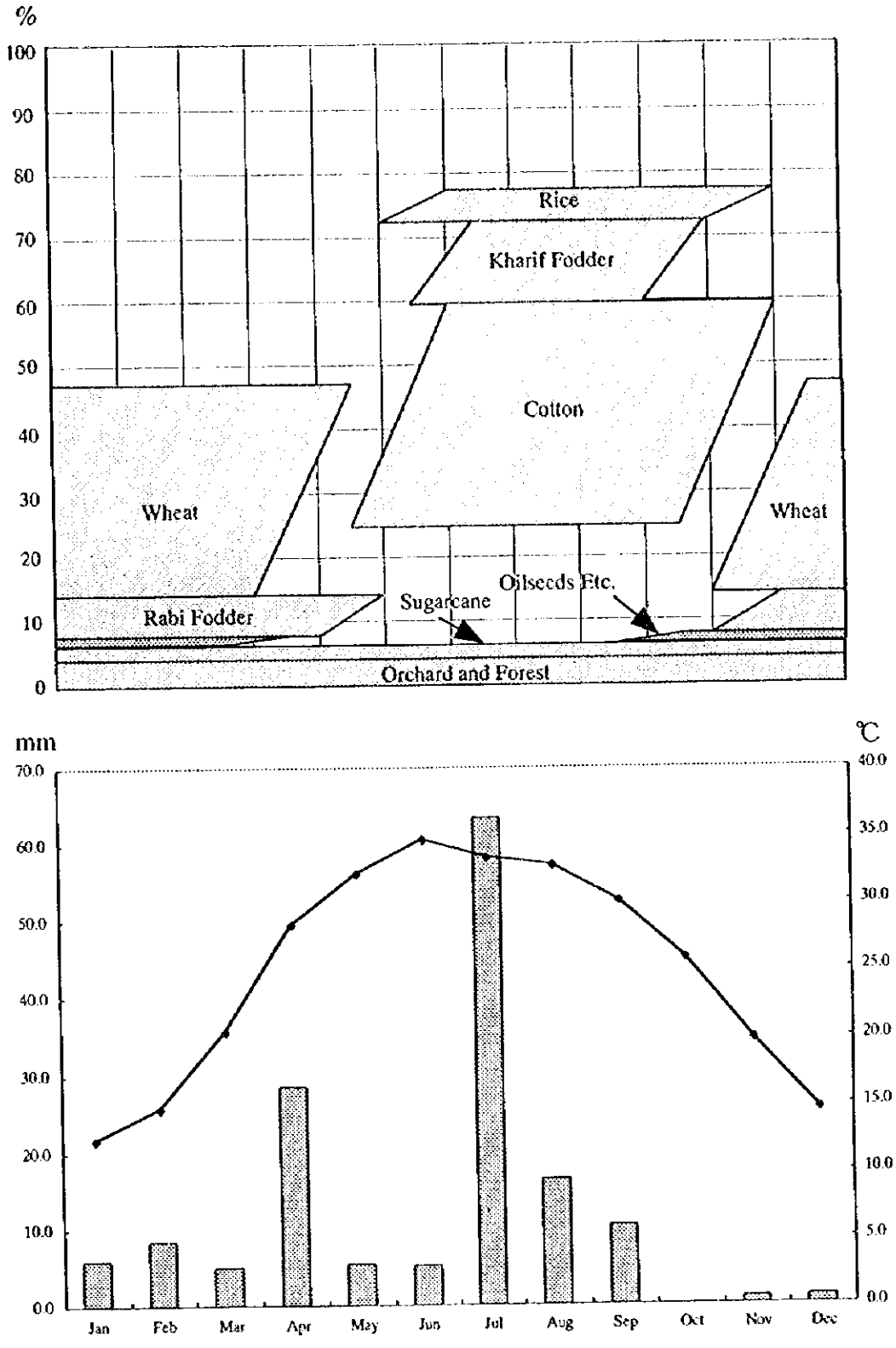


Fig. E.2 Present Land Use Map of the Study Area



Data: Temperature; Muzaffargarh Station (WAPDA) 1970-1980 Average
Rainfall; D.G.Khan Station (Agriculture Dept.) 1994-1996 Average

Fig. E.3 Present Cropping Pattern in the Study Area

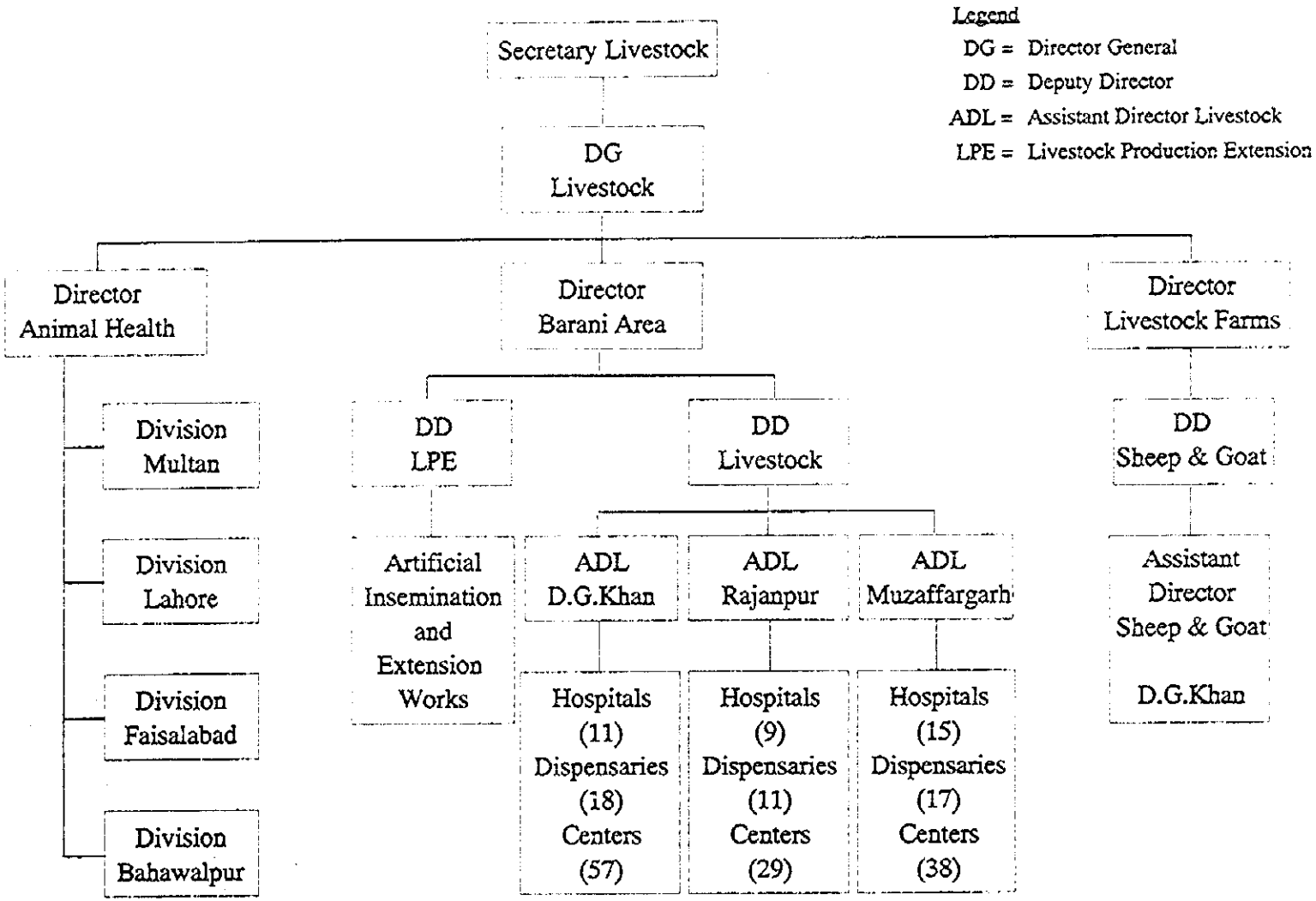


Fig. E.4 Major Sections of Livestock and Dairy Development related to the Study Area

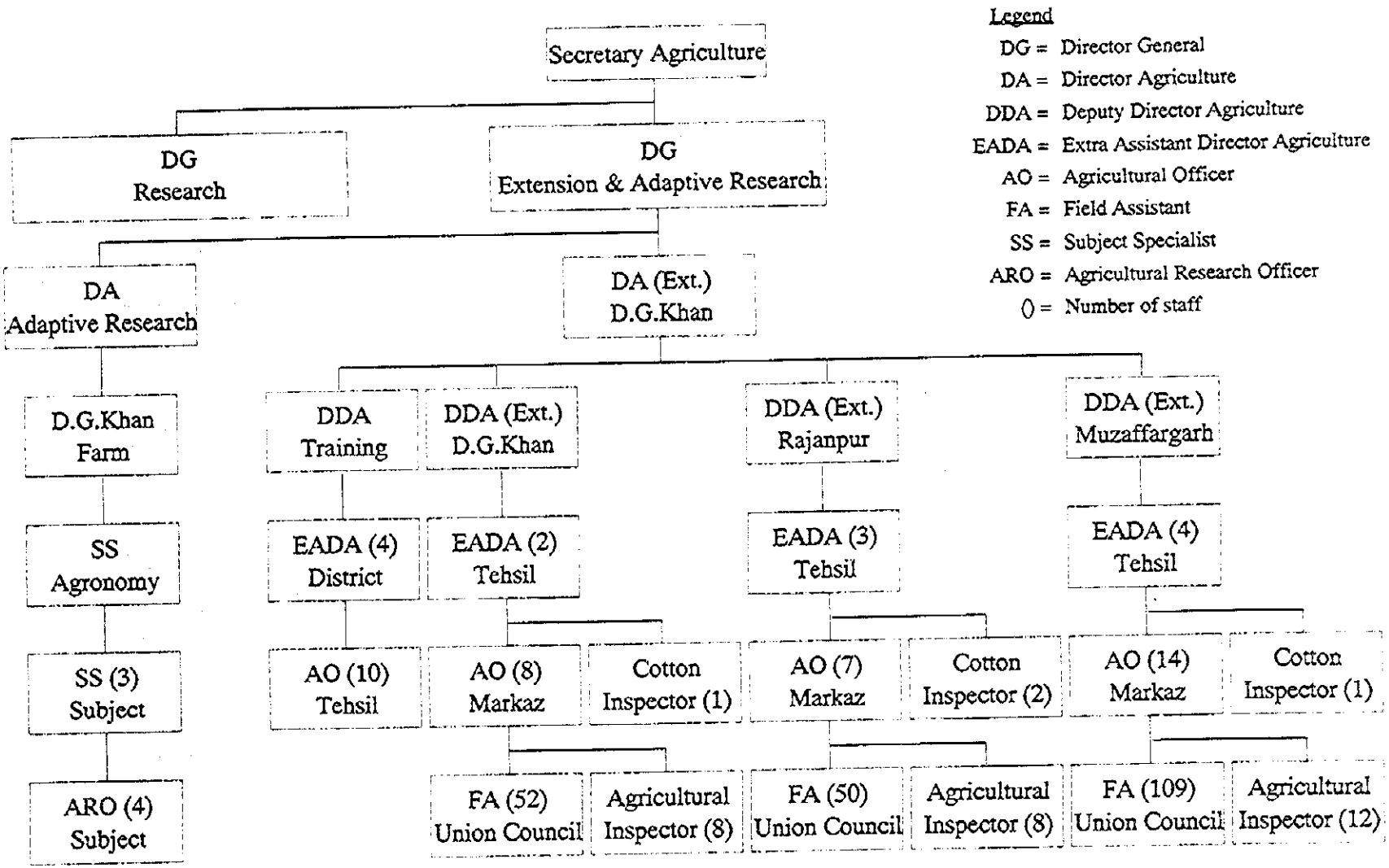
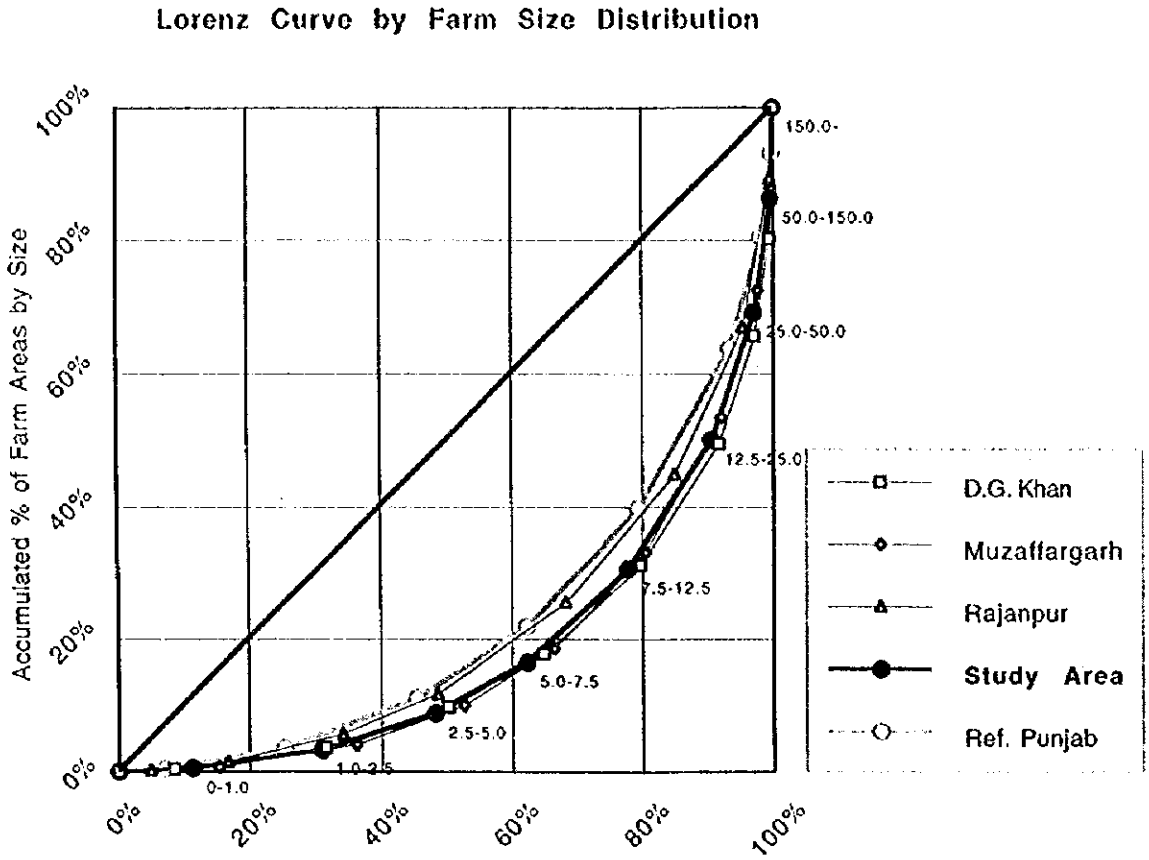
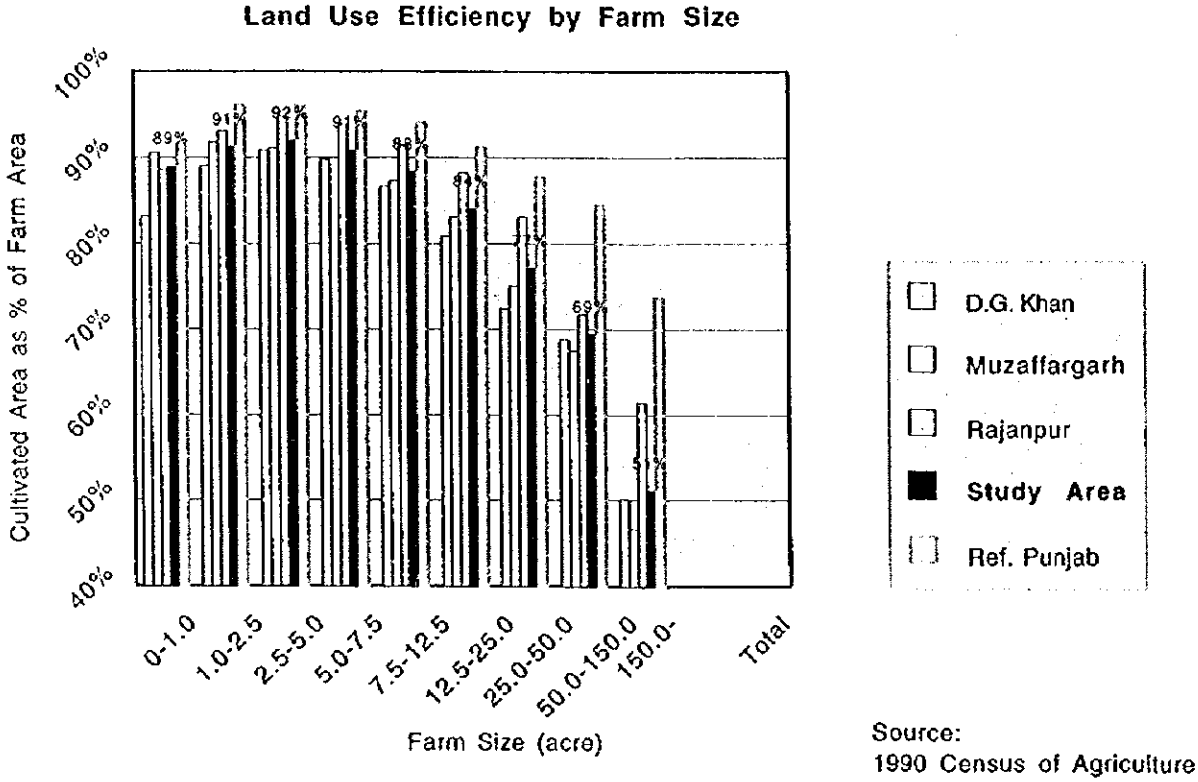


Fig. E.5 Major Sections of Agricultural Extension and Agricultural Research related to the Study Area





Source:
1990 Census of Agriculture

Fig. E.6 Farm Distribution and Land Use Efficiency in the Study Area