PERFORMANCE OF SUBSURFACE DRAINS IN MIRPUR KHAS AREA OF LBOD STAGE-1 PROJECT

Yawar Hamid[1], Irshad Ahmed Bohio[2]

ABSTRACT

Two tile drainage contracts i.e. T40.IB1 and T40.PC1 were implemented under LBOD Stage-1 Project in Mirpurkhas area during the period 1994-96. These contracts are in operation for the last 6 years. An attempt has been made to summarize the experiences gained from the design, construction, post construction monitoring results and views of the farmers for one of these contracts i.e. T40.IB1. Under this contract about 943,000 and 359,000 feet of lateral and collector drains, respectively, along with 16 pump stations were constructed at a cost of Rs. 243.29 million to drain an area of about 12,000 acres. The results of the study are:

(a) Better agricultural benefits were observed only at pump stations where the farmers take interest in the maintenance of the pump station. In most of the cases the farmers take interest in the maintenance.

(b) Lack of interest observed at some locations is due to conflicts between the land owners of a common pump station. If separate drainage systems and pump stations, for each land owner, are constructed then these conflicts will not appear in the maintenance of a pump station. This supports the idea of small drainage systems under private investment.

(c) A substantial percentage of abandoned land has been brought under cultivation. Abandoned lands not brought under cultivation may be due to shortage of irrigation water or lack of interest on the part of land owners.

(d) Due to the operation of the drainage system the farmers get benefits in the form of increased crop yield per acre, increased cropped area due to reclamation of abandoned land and increase in the value of land.

(e) Average yield per acre for sugarcane has increased from a range of 10-28 to 32-40 tons, of cotton from a range of 200-600 to 800-1,600 kg and of wheat from a range of 400-1,200 to 1,200 to 1,600 kg.

(f) Average cost per acre of land within the area has increased from a range of Rs. 4,000-20,000 to Rs. 50,000-100,000.

(g) The major complaints of the farmers are a lack of proper O&M of project works, unreliable electric supply and shortage of irrigation water to reclaim abandoned lands.

(h) For sustainable irrigated agriculture, a reliable drainage system is required to maintain the lands in good condition. If the O&M of the drainage system is not carried out properly then sustainable irrigated agriculture is not possible. Before the installation of the drainage system

1 General Manager in W&A Division of NESPAK and presently posted as Deputy Team Leader, Pakistan Drainage Consultants for National Drainage Programme, Lahore. Was responsible for the design of Mirpurkhas Tile Drainage and Interceptor Drain contracts.

2 Senior Engineer WAPDA and presently attached with Pakistan Drainage Consultants on the National Drainage Programme, Hyderabad. Was responsible for the implementation of Mirpurkhas Tile Drainage contracts.

about 50 % of area was out of production. With drainage, a substantial part of the abandoned land has been brought under cultivation and the reclamation process is in progress. However, the operation and maintenance of the project works is not of proper standard. If the O&M conditions remain as they are at present then the pumping equipment will wear out in a very short time resulting in a rise in watertable forcing lands out of production.

(i) There was over drainage in two pump station catchment areas during the canal water shortage period. This phenomenon was observed in high elevation lands. Farmers of one of the catchment areas have blocked some of the sub-surface drains to check over drainage.

(j) Uncertainty prevails, in that after the expiry of the current O&M Performance Contract funded by the World Bank, the availability of funding for continued O&M is in question.

1. INTRODUCTION

To lower watertable below the root zone of the crops, drainage tubewells as well as tile drains were installed in Mirpurkhas Component of LBOD Stage-1 Project. Tile drains were laid only in those areas where tubewells could not be installed due to the non-availability of aquifer required for the tubewells. The area selected for tile drains is located in the South of railway line connecting Mirpurkhas and Umerkot towns and between Mithrao and Jamrao canals. Total area selected for this purpose was about 60,000 acres (Figure-1). Two tile drainage contracts i.e. T40.IB1 and T40.PC1 were implemented on an area of about 32,300 acres during the period 1994-96. Tile drains on the remaining area of 27,700 acres could not be implemented due to a change in the investment policy of the Donors. The new policy demanded farmer's participation in the investment as well as in the operation and maintenance (O&M) of the drains. All the future tile drainage contracts will be implemented according to the new policy. Salient features of the implemented contracts are:

Description	Name of Contract	
	T40.IB1	T40.PC1
Area covered (acres)	12,097	20,174
Length of lateral drains (ft)	942,871	1,625,731
Length of collector drains (ft)	359,299	631,165
Number of pump stations	16	21
Contract cost (Rs. Million)	218.15	365.69
Construction cost (Rs. Million)	243.29	437.65
Construction cost/acre (Rs. Million)	20,112	21,694
Total Drainage effluent (cusec)	36.02	58.92
Pumping into surface drains (cusec)	30.81	46.36
Pumping into canal (cusec)	5.21	12.56
Canal seepage interception (cusec)	2.86	6.83

The present study summarizes the experiences gained from the design, construction, post construction monitoring and views of the farmers after six years of operation of contract T40.IB1.

2 DESIGN

Tile drains installed in Mirpurkhas area fall under the command of Jamrao as well as Mithrao canals. A part of the area under Jamrao canal receives increased canal supplies due to canal remodelling while the entire area under Mithrao canal receives unchanged canal supply as the canal system is not remodelled. Areas drained by pump sumps SD-20, SD-23 and SD-25 receive supplies from Mithrao canal. However, the whole of the Jamrao canal command area, under Contract

T40IB1, receives increased canal supplies. Due to different rates of canal water supply, the volume of excess sub-surface water to be removed through the drainage system i.e. drainable surplus for the two areas are also different and is computed on the basis of steady state flow conditions.

Drainable surplus values used for the study area are:

Description of Area	Drainable Surplus	
	ft/day	mm/d
For areas with canal remodeling:		
Lateral drains	0.00732	2.23
Collector drains	0.00600	1.83
For areas without canal remodeling:		
Lateral drains	0.00415	1.26
Collector drains	0.00300	0.91

The average depth of the field drains is 7 feet and this is used for the drain spacing calculations. However, in practice, the depth varies from 6.3 to 7.5 feet. The depth of collector drains varies from 7.3 to 11.3 feet and maximum depth is at the outfall point into the sump. The drain spacing ranges from 450 to 650 feet for areas without canal remodelling and from 300 to 650 feet for areas with canal remodelling.

Apart from regular tile drains, interceptor drains were also installed along Mithrao canal to intercept the canal seepage. The tile drains and interceptor drains were integrated and the effluent was disposed into pump sumps SD-20 and SD-23. Interception rates are computed with the help of a computer model and are 0.0015 and 0.002 cusec/1000 ft of canal length, respectively, for pump station areas SD-20 and SD-23.

Un–plasticized, corrugated and perforated polyvinyl chloride (PVC) pipes have been used for the lateral as well as for the collector drains. The perforations (slots) were cut only in the valleys of the corrugations. The slots were 1.25 to 1.75 inches long and a maximum of 0.125 inch wide. The open area was at least one square inch per foot length of the pipe. Pipe stiffness was at least 30 psi at 5 percent deflection and 25 psi at 10 percent deflection. Elongation of the pipe, in the laboratory, was less than 5 percent and during laying, pipes were not allowed to be stretched more than 5 percent. Diameter of the lateral drains is 4 inches and collector drain diameter ranges from 6 to 15 inches. Hydraulic parameters used in the design of different diameter pipes are:

Pipe Diameter		Manning's	Minimum
Nominal (inches)	Inside (mm)	'N'	Pipe Gradient (%)
4	92	0.014	0.10
6	150	0.014	0.05
8	188	0.014	0.05
10	250	0.018	0.05
12	300	0.019	0.05
15	380	0.019	0.05

Natural gravel was used as an envelope material for the lateral drains. The designed grain size distribution of the gravel is:

- The maximum size shall be 12.5 mm;
- No more than 5 percent of the weight of a sample shall pass through 0.33 mm sieve;
- The D_{85} size shall be between 2.5 and 8.0 mm;
- The D_{60} size shall be between 1.0 and 3.0 mm;
- The D_{15} size shall be between 0.35 and 0.80 mm;
- The D_{10} size shall be between 0.30 and 0.70 mm;
- The coefficient of uniformity (CU) shall be greater than 4; and
- The coefficient of curvature (CC) shall be between 1 and 3.

Where:

$CC = D_{60} / D_{10}$;

$CU = (D_{30} \times D_{30}) / (D_{10} \times D_{60})$

Synthetic geo-textile fabric, suitable for soils with D_{50} <= 0.075 mm, was used as an envelope material for the collector drains. All the collector drains were perforated. The D_{95} of the synthetic envelope was less than 0.149 mm.

Specifications adopted for the geo-textile fabric are:

Serial Number	Parameter	Specification
1	Fiber material	**Polyester, polypropylene knitted or woven**
2	Thickness	At least 0.9 mm under a pressure of 2.0 kPa (0.29 psi)
3	Weight	At least 200 grams/square meter
4	Permeability	At least 20 m/day
5	D_{95} of the fabric	Within a range of 0.100 to 0.149 mm
6	Tensile strength	At least 14 kN/m (80 lbs/inch)
7	Tear strength	At least 200 N (45 lbs)

A minimum number of manholes (about 2 to 7) were provided for any area drained by a single pump station, mostly at the junction point of two or more collectors or at the point of the change of collector alignment. Due to low ground surface slopes of the study area, the collector drains outfall into a sump before final disposal. There are a total of 16 sumps within the area. The area drained by the sumps varies from 492 to 1147 acres with an average area of 756 acres. The sumps are provided with vertical turbine pumps to dispose of the effluent into a surface drain or a canal. Effluent of two pump stations is discharged into Mithrao canal as the ground slopes towards the canal. Two standard pump sizes of 1.5 and 2.5 cusec have been used in the project area. The number and size of the pump(s) in a pump sump station depend upon the drain inflow rate and are selected in accordance with the following criteria:

Drain Inflow (cusec)	Number of Pumps	Pump Capacity (cusec)
Less than 1.75	1	1.5
1.75 – 2.75	1	2.5
2.75 – 3.30	2	1.5
3.30 – 5.50	2	2.5

Total design head of the pumps discharging into a surface drains is about 21 feet whereas for the pumps discharging into a canal it is 31 and 35 feet for 1.5 and 2.5 cusec pumps, respectively. Pumping equipment data and design inflow of the 16 pump stations is shown below:

Serial Number	Pump Station Number	Area Drained (acres)	Design Inflow (cusec)	Number of Pumps		Motor (HP)	Remarks
				1.5 cusec	2.5 cusec		
1	PS3L-17	1023.3	3.10	2		10	
2	PS3L-19	692.2	2.09		1	10	
3	PS3L-20	1078.1	3.26	2		10	
4	PS3L-21	1045.4	3.16	2		10	
5	PS3L-22A	758.1	2.30		1	10	
6	PS3L-22B	533.2	1.61	1		10	
7	PS3L-23	877.7	2.66		1	10	
8	PS3L-24	550.5	1.67	1		10	
9	PS3L-25	587.7	1.78		1	10	
10	PS3L-26	733.6	2.22		1	10	
11	PSSD-20	1146.9	3.04		2	20	Pumping into canal
12	PSSD-21A	491.7	1.49	1		10	
13	PSSD-22	447.9	2.26		1	10	
14	PSSD-23	406.3	2.17		1	20	Pumping into canal
15	PSSD-24	701.5	2.12		1	10	
16	PSSD-25	723.3	1.09	1		10	
Total		12097.4	36.02	10	10		

3. CONSTRUCTION

The contract was started in July 1994 and completed in two years (July 1996). The contractor was China Guangxi Corporation. Drains were installed with the help of Steenbergen, Hollanddrain trenchers BSS 4500 (one) and BSS 3500 (two) for collector and lateral drains, respectively.

Specifications of trenching machine Steenbergen Holland Drain BSS 4500 are:

Power 389 HP

Digging speed 0-5100 m/hr

Track width 3900 mm

Digging depth 3.5 m

Digging width 65 cm

Laser Automatic Depth Control

Machine weight 45 tons

Specifications of trenching machine Steenbergen Holland Drain BSS 3500 are:

Power 325 HP

Track width 70 cm

Digging depth up to 2.5 m

Digging width up to 36 cm

Laser automatic depth Control

Machine weight 23 Tons

Holland Drain gravel trailer 3 Nr. for each trencher:

Hopper with 4 m contents

Conveyor belt hydraulic driven

Gravel door hydraulic driven

Trailer to be tractor pulled

Drain flushing machine for drain cleaning purposes.

Materials:

PVC pipe provided by M/s Nowshera PVC Company (Pvt) Ltd. and Shama Wire and Cable Industries (Pvt) Ltd., Paksitan.

Geo-textile fabric as an envelope material around collector drains from M/s Polyfelt Australia.

Gravel and sand from Bholari, Hyderabad after screening and grading.

Construction Sequence:

The construction work was carried out in the following sequence:

Layout of the sub-surface drains, location of sumps and allied manholes was carried out at site with the help of survey work by using Northing and Easting coordinates.

Pre-cast manhole pieces varying from 2 to 4 feet height were fabricated at the contractor's camp and carried to the site for installation. All the manholes were covered with a slab and a locking arrangement was provided for safety purposes. Diameter of the manholes is 3 feet. A total of 63 manholes were provided for the entire area.

All the sumps were constructed at site. It involved the excavation of a circular pit 3 to 4 feet in depth for the first pour of concrete. The constructed part was lowered down by the well sinking method. In this way the whole depth of the sump was completed in parts. This method was very successful in areas where the water table was relatively deeper. Dewatering was also involved at some locations where the water table was shallow. In the end the sump was plugged with a concrete slab. A baffle wall was also constructed within the sump to avoid turbulence around the pump suction pipe. All the sumps were circular having diameters of 7 and 10 feet for one or two pumps, respectively.

The laying of collector drains was started from the sump by installing corrugated blind PVC pipe sleeves in the sump as per the required number of collector lines coming towards the sump. The installation of the manhole was also carried out during the installation of collector drains. Installation of drains and backfilling and compaction were carried out simultaneously. The progress of collector drain laying was 3,000 to 5,000 feet per day. Drain markers were provided along the alignment of the collectors so that exact position of the drain is known during the post construction period.

After the installation of collector drains the laying of lateral drains commenced. Natural gravel, used as an envelope material around the pipe, was gravity fed through the pipe box using the gravel hoppers hauled by farm tractors. Connections of the lateral pipes were made with the help of tee joints and couplings. All the laterals were connected at right angles to the collector lines. The progress of lateral drain laying was 10,000 to 12,000 feet per day.

After the completion of backfilling and compaction of the trench the testing of the drains was carried out in order to check any damage occurrence to the collector as well as lateral drains during installation. During the laying of the drains, ropes were provided inside the drains and were fastened to a steel rod in the sump. A special type of steel mandrel of diameter of 20% less than the inner diameter of the pipe, which was to be tested, was fastened to the rope at the other end and pulled inside the pipe through its entire length. If it passed without any obstruction then this confirmed that the line was clear and indicated no damage to the pipe due to breakage, collapse or sediments. All the damaged portions of pipe were rectified on the spot.

When the installation and testing of the drains was complete then the construction of the pump house was started. The pump house was a 10 feet diameter brick masonry structure with galvanized iron roof.

After pump house construction the installation of pumps, motors, motor control units, water level sensors and delivery pipes was accomplished. After installation the pumping equipment was tested for its performance. The electric supply to the pump stations was carried out through a separate contract, which was also carried out simultaneously.

Structures:

The following structures were also provided in the drainage system apart from the collector and lateral drains:

a) End riser: a blank pipe piece, with a plug, at the upstream end of each lateral drain;
b) Intermediate riser: similar to end risers but provided at collector pipes at intermediate points;
c) Manhole: provided at the junction point of two or more collectors or at the point of the change of collector alignment;
d) Drain marker: concrete post provided at several points along the collector alignment;
e) Watercourse crossing: blank pipe at the crossing point of a main watercourse;
f) Pump sump: open well where some collectors outfall through gravity;
g) Pumping equipment: to lift of the drainage effluent of the sump at a higher elevation;
h) Discharge box: open concrete box where effluent from a pump station is discharged;
i) Disposal channel: a small lined or unlined channel connecting the discharge box and a surface drain;
j) Surface drain: open channels of the main surface drainage system;
k) Disposal drain crossing: blank pipe at the crossing point of a disposal channel; and
l) Surface drain crossing: blank pipe at the crossing point of a small surface drain.

Problems during the Construction Work:

a) Excessive dewatering was required, during sump construction, at places where the water table was shallow.
b) Drain laying was delayed due to the watering of fields by the farmers.

c) Obstructions were made by the farmers to avoid crop damage although crop compensation was paid by the Implementing Agency.

d) Work was delayed due to short supply of PVC pipes from the factory.

e) Break downs of machinery and delays in the supply of spare parts.

4. POST CONSTRUCTION MONITORING

The LBOD Stage-1 Project is being monitored by SCARPS Monitoring Organisation (SMO) and regular publications are issued by the agency. The following are the monitoring results related to the study area of contract T40IB1:

(a) SCARPS Monitoring Organisation (SMO), within the tile drainage areas of T40IB1 and T40PC1, has installed seventeen piezometers. Water level observations are made during the months of April and October, which are pre and post monsoon rainfall periods. Observation data for the years from 1994 to 2000 are available and are presented here in **Table 1**. Data shows that appreciable lowering of the watertable has occurred. During April 1998 the depth to watertable was more than 5 feet at 6 locations, whereas, during April 2000 the depth to watertable was more than 5 feet at 11 locations. The lowering of watertable is a combined effect of tile drainage, low precipitation during the last few years and reduced canal deliveries.

TABLE 1: DEPTH TO WATERTABLE OBSERVATIONS IN STUDY AREA

Serial No.	Piezometer No.	Depth to Watertable Below Ground Surface (ft)					
		Apr–98	Oct–98	Apr–99	Oct–99	Apr–2000	Oct–2000
1	MC–42	4.27	4.46	3.28	4.66	8.27	4.33
2	MC–43	3.12	3.22	5.41	3.48	4.69	2.56
3	MC–45	5.71	4.53	4.43	4.79	5.25	3.02
4	MC–55	4.30	4.13	7.84	5.05	4.43	4.43
5	MC–56	8.14	6.33	8.20	5.05	6.40	4.30
6	MC–57		4.17				
7	MC–58	2.66		6.40	7.09	6.07	
8	MC–59	4.40				5.97	6.40
9	MC–67				4.17	5.35	7.22
10	MC–68	8.07	7.09	10.83	12.30	12.76	10.01
11	MC–69		6.07		9.84	10.33	10.79
12	MC–70	7.12			10.63		10.30
13	MC–81	2.85			4.76	4.99	3.90
14	MC–82	1.67	1.74	4.43	1.84	5.18	4.04
15	MC–83	3.44			3.38	4.23	5.05
16	MC–84	6.36	7.64	3.12	1.18	4.02	5.31
17	MC–85	2.53	4.17	7.45	3.87	8.60	3.90

(b) The pump stations of the study area are regularly tested by SMO for chemical quality of the drainage effluent. A comparison is presented in **Table 2** between the chemical quality of

drainage water at the time of final testing after drain installation and post construction observations made by SMO. Except for a few pump stations, generally the EC of drainage effluent has increased over the time. This is due to the reason that reclamation of abandoned lands is in progress.

(c) As shown in **Table 2**, discharge of six sumps is low as compared to the designed rate. This can be due to the shortage of irrigation supplies in March 2000. As a comparison, during acceptance tests in 1996, discharge of only 2 sumps i.e. 3L-22B and 3L-25A was found to be less than the designed rate. Operation time of the pumps, as observed also during March 2000, ranged from 1072 to 7972 hours. Operation times of the sumps 3L-22B and SD-23 are very low.

TABLE 2: DRAIN PERFORMANCE DATA

Serial No.	Sump No.	EC of Drain Water on Dates			Discharge		Working Hours on Mar-2000
		Nov 1995 Jan. 1996	Mar 2000	Nov–Dec 2000	Design	On Mar-2000	
1	3L–17	13.90	11.26	10.65	3.10	0.75	3250
2	3L–19	6.40		9.32	2.09		
3	3L–20	16.25	20.50	12.79	3.26	0.54	2834
4	3L–21	15.50		22.60	3.16		
5	3L–22A	6.25	9.92	11.78	2.30	1.46	2216
6	3L–22B	1.90	6.00		1.61	2.12	1318
7	3L–23	2.40	3.65		2.66	1.87	7094
8	3L–24	3.80	5.46		1.67	1.24	5145
9	3L–25A	5.10	3.31		1.78	1.69	6574
10	3L–26	7.80	7.60		2.22	2.38	5998
11	SD–20	3.35	6.88	7.66	3.04		7972
12	SD–21A	16.80	24.10		1.49	0.75	7586
13	SD–22	20.70	13.58		2.26	2.12	5565
14	SD–23	0.65	1.37	0.43	2.17		1072
15	SD–24	4.15	2.61		2.12	2.00	6796
16	SD–25	6.50	5.60		1.09	1.52	3385

5. SOME FACTS FROM SITE VISITS AND FARMER'S INTERVIEWS

Farmers were interviewed during site visits and their views were collected. The following are the farmer's views about the drainage system and facts observed during the visit.

Pump Station 3L-17: Pumps are not in operation. One pump has been dismantled. Crops are cotton and sugarcane. Condition of the land around the pump station has improved. Departmental maintenance is poor.

Pump Station 3L-19: Pump is in operation. Watertable is appreciably lowered. Abandoned land, which was about 50 % of the total, has been brought under cultivation. Crops are cotton and

sugarcane. Average yield per acre of sugarcane has increased from 20 to 36 tons and for cotton from 400 to 1000 kg. Average cost per acre of land has increased from Rs. 10,000 to 70,000.

Pump Station 3L-20: Pumps are not in operation. One pump has been dismantled. Departmental maintenance is poor. Land reclamation process is not visible.

Pump Station 3L-21: Pumps are not working. Departmental maintenance is poor. Land has improved. Crops are sugarcane and onions. Farms of Eucalyptus have been grown.

Pump Station 3L-22A: Pump is not in operation. Departmental maintenance is poor. Operation of the pumps is not continuous. Land has improved. Crops are sugarcane and cotton. Average yield per acre for sugarcane has increased from 10 to 36 tons and for cotton from 200 to 1000 kg. Cultivated land of a farmer, before the operation of the drainage system, was only 15 acres out of a total of 50 acres. Now the entire land is under cultivation. Average cost of land per acre has increased from Rs. 15,000 to 50,000.

Pump Station 3L-22B: Pump is in operation. Water level sensor is not working. Departmental maintenance is poor. A large tract of land is out of cultivation because of topography or shortage of irrigation water

Pump Station 3L-23: Pump is in operation. Pump head is corroded. Sound in top shaft bearing. The farmers take interest in the maintenance of the pump station. Departmental maintenance is poor. The farmers used the drainage effluent for irrigation purposes during the last crop season. A substantial percentage of abandoned land has been brought under cultivation. Cultivated land of a farmer, before the operation of the drainage system, was only 5 acres out of a total of 30 acres. Now the entire area is under cultivation. Average yield per acre of sugarcane has increased from 8 to 40 tons, of cotton from 200 to 1,200 kg and of wheat from 400 to 1,20 kg. Average Cost of land has increased from Rs. 4,000 to 50,000.

Pump Station 3L-24: Pump is in operation. The farmers take interest in the maintenance of the pump station. A burnt motor was re-wound with the help of farmers. Departmental maintenance is poor. The farmers are sometimes using the drainage effluent for drinking purposes. A substantial percentage of abandoned land has been brought under cultivation. Cultivated land of a farmer, before the operation of the drainage system, was only 40 acres out of a total of 150 acres. Now the entire land is under cultivation. Average yield per acre of sugarcane has increased from 12 to 32 tons and of cotton from 160 to 800 kg. Average cost of land has increased from Rs. 6,000 to 100,000.

Pump Station 3L-25: Pump is in operation. The farmers take interest in the maintenance of the pump station. Departmental maintenance is poor. Pumps remain stopped for months due to non-availability of electric power. The reclamation process is stopped due to the shortage of canal water. There was over drainage in a part of the catchment area during the canal water shortage period. Due to over drainage the lands became dry and irrigation requirements were increased. This phenomenon was observed in high elevation lands. Cultivated land of a farmer, before the operation of the drainage system, was only 40 acres out of a total of 70 acres. Now 63 acres of land is under cultivation. Average yield per acre of sugarcane has increased from 28 to 36 tons, of cotton from 600 to 800 kg and of wheat 1,200 to 1,600 kg. Average cost of land has increased from Rs. 10,000 to 40,000.

Pump Station 3L-26: The pump house is not properly maintained. Farmers do not take interest in the maintenance of the pump station. Pump pedestal is broken. Pump head is corroded. The pumps are not working for the last 6 months. When the pumps were in operation the water table

fell and benefits to the crops were observed. Presently the water table is at shallow depth, which is visible in the fields. Abandoned land was previously reclaimed but now the progress is negligible due to the shortage of irrigation water and lack of operation of the pumps.

Pump Station SD-20A: Pumps are in operation. . Farmers take interest in the maintenance of pump station. At the time of visit the discharge pipe leading the drainage effluent to Mithrao canal was open. Drainage effluent is of good quality and is being used for irrigation purposes also. One farmer has constructed fish ponds and is using the effluent for the ponds. A substantial percentage of abandoned land has been brought under cultivation. There was over drainage in a part of the catchment area during the canal water shortage period. This phenomenon was observed in high elevation lands. Farmers in high elevation areas have blocked some of the sub-surface drains to check over drainage. Due to topography, even if the pump station is not in operation, the high elevation areas are drained and the areas near the pump station are submerged. This problem, in future designs, can be avoided by splitting the catchment area in to two parts and providing independent pump station for high and low lying areas.

One farmer stated that about 50 percent of his land was out of cultivation before the installation of the drainage system. Now the entire area is under cultivation. Average yield of sugarcane has increased from 16 to 40 tons and of cotton from 200 to 1,200 kg.

Pump Station SD-21A: Pump is in operation. Farmers take interest in the maintenance of the pump station. A substantial percentage of abandoned land has been brought under cultivation. One farmer stated that, before the installation of drainage system, out of 150 acres of his land about 70 acres were under cultivation. Now the entire land is cropped. Average yield per acre of sugarcane has increased from 20 to 40 tons, of cotton 600 to 1,200 kg and of wheat 800 to 1,600 kg. Banana trees have also been planted in the area. Average cost of land has increased from Rs. 20,000 to 50,000.

Pump Station SD-22: Pump is in operation. A substantial percentage of abandoned land has been brought under cultivation. Crops are sugarcane and cotton.

Pump Station SD-23: Pump is not in operation. Land around the pump station is not developed. The farmers do not take interest in land development.

Pump Station SD-24: Pump is in operation. Farmers take interest in the maintenance of pump station. A substantial percentage of abandoned land has been brought under cultivation. Crops are sugarcane, cotton and date palm orchards. There was over drainage in a part of the catchment area during canal water shortage period. Due to over drainage the lands became dry and irrigation requirements were increased. This phenomenon was observed in high elevation lands. Farmers in high elevation areas have blocked some of the sub-surface drains to check over drainage. Due to topography, even if the pump station is not in operation, high elevation areas are drained and the areas near the pump station are submerged. The farmers indicated that due to operation of the drainage system they get benefits in the form of increased crop yield, increased cropped area, reclamation of abandoned land and increase in the cost of land.

Pump Station SD-25: Pump is in operation. Farmers take interest in the maintenance of pump station. A substantial percentage of abandoned land has been brought under cultivation. Crops are sugarcane and cotton. All the depressions, which were previously abandoned, are under cultivation. One farmer stated that, before the installation of the drainage system, out of 300 acres of

his land, about 50 acres were under cultivation. Now the entire land is under crops. Average yield per acre of sugarcane has increased from 12 to 40 tons, of cotton from 200 to 1,600 kg and of wheat from 400 to 1,600 kg. Average cost of land has increased from Rs. 10,000 to 50,000.

6. COMMENTS AND RECOMMENDATIONS

To increase the life of the project the following actions are of prime importance:

a) If the designed agricultural benefits are the objectives of the installed drainage system then electric supply should be reliable and continuous. Unreliable electric supply is one of the major complaints of the farmers.

b) Social mobilization is required so that the farmers take maximum interest in the operation and maintenance of the drainage system. Without farmer's interest, the project objectives will not be achieved.

c) Additional canal supplies are required to reclaim the abandoned soils.

d) Monitoring scope needs to be extended. Monitoring should also include:

- study of the behaviour of tile drains;
- determination of actual drainable surplus;
- determination of canal seepage interception rates along Mithrao canal;
- in depth study at sumps where drainage inflow is lower than the design rate; and
- economics of the drain installation.

e) Areas to be delineated where over drainage is being experienced and provide site specific solutions. One of the solutions may be the construction of manholes with sliding gates so that the water flow can be stopped to control the depth to watertable. This problem, in future designs, can be avoided by splitting the catchment area in to two parts and providing independent pump station for high and low lying areas.

f) At some locations the pumping equipment is not suited to the incoming drainage effluent. At the time of pump replacement this factor should be taken into consideration.

7. CONCLUSIONS

The following conclusions can be drawn from the study:

a) Better agricultural benefits are observed only at pump stations where the farmers take interest in the maintenance of the pump station. In most of the cases the farmers take interest in such maintenance.

b) Lack of interest observed at some locations is due to the conflicts between the land owners of a common pump station. If separate drainage systems and pump stations, for each the land owner, are constructed then these conflicts will not appear in the maintenance of a pump station. This supports the idea of small drainage systems under private investment.

c) A substantial percentage of abandoned land has been brought under cultivation. Abandoned lands not brought under cultivation may be due to shortage of irrigation water or lack of interest on the part of land owners.

d) Due to the operation of the drainage system the farmers get benefits in the form of increased crop yield per acre, increased cropped area due to reclamation of abandoned land and increase in the cost of land.

e) Average yield per acre of sugarcane crop has increased from a range of 10-28 to 32-40 tons, of cotton crop from a range of 200-600 to 800-1,600 kg and of wheat crop from a range of 400-1,200 to 1,200-1,600 kg.

f) Average cost of land per acre has increased from a range of Rs. 4,000-20,000 to 50,000-100,000.

g) Major complaints of the farmers are lack of proper O&M of project works, unreliable electric supply and shortage of irrigation water to reclaim abandoned lands.

h) For sustainable irrigated agriculture, a reliable drainage system is required to maintain the lands in good condition. If the O&M of the drainage system is not carried out properly then sustainable irrigated agriculture is not possible. Before the installation of the drainage system about 50 % of area was out of production. With drainage, a substantial part of abandoned land has been brought under cultivation and the reclamation process is in progress. However, the operation and maintenance of the project works is not to a proper standard. If the O&M conditions remain as they are at present then the pumping equipment will wear out in a very short time resulting in a rise of watertable and forcing lands out of production.

i) There was over drainage in two pump station catchment areas during the canal water shortage period. This phenomena was observed in high elevation lands. Farmers of one of the catchment area have blocked some of the sub-surface drains to check over drainage.

j) Uncertainty prevails, in that after the expiry of the current O&M Performance Contract funded by the World Bank, the availability of funding for continued O&M is in question. One solution to the problem is that the farmers may be motivated to take over the O&M of the project.

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