RESULTS

THE IMPACT OF LINING ON WATER DISTRIBUTION IN GHORDOUR AND LAGAR DISTRIBUTARIES

D. Hammond Murray-Rust[1]

Until recently the vast majority of lining of irrigation facilities in Pakistan has been restricted to watercourses under the auspices of the On-Farm Water Management Directorate of the Ministry of Agriculture. However, there is growing interest in extending lining programs into the main system in response to issues related to waterlogging and salinity, reducing conveyance losses, and decreasing the recurrent maintenance needs associated with unlined channels. This report assesses the experience of lining of the lower portions of two distributaries in Chuharkana Sub-Division of the Upper Gugera Canal system.

The two distributaries selected for lining were Ghordour and Lagar. These are adjacent distributaries on the Right Bank of Upper Gugera Branch Canal, with offtakes at RD 101000 and RD 118000. Main characteristics of the two distributaries are provided in Table 1.

Table 1. Comparison of Ghordour and Lagar Distributaries.

	Ghordour	Lagar
Length (ft)	67919	62218
Design Discharge (cfs)	50.0	38.0
Number of Watercourses	37	29
Total Discharge of Outlets (cfs)	39.91	32.67
Total Command Area (ac)	20965	16356
Length of Lined Section (ft)	19119	18218

Neither distributary has any control structure downstream of the distributary headgate. Flow into all watercourses served by the distributaries is controlled by the design of the watercourse outlet structure, or mogha; water surface elevation is entirely dependent on incoming discharge, cross-section, and slope of the channel. As a consequence, water availability at the tail end of the distributaries is largely governed by a combination of managerial inputs at the headgate and the current physical condition of the channel.

The lining activities did not modify this basic condition. Structural changes were limited to the lining of approximately the lower one-third of both distributaries, with no significant change to alignment and slope of the pre-lined channels. The cross-section of the lined portions was modified, however, to account for changed conditions of roughness. No additional control structures were installed, and no modifications made to the headgate. Nor were modifications made to locations and sizes of the moghas served by the lined portion of the distributaries. As a consequence it is possible to make a direct comparison of operating conditions before and after lining.

The two distributaries were lined during January and February 1985. This coincided with the period of annual closure of the Upper Gugera Canal system, although there was some subsequent disruption of irrigation deliveries during February 1985. The lined portion, therefore, has been in full operation for three complete irrigation seasons.

The lining consists of brick and mortar. In most places the lining is only one brick thick, resting on slightly compacted natural soil. The lack of readily available hardcore meant that provision of a proper base for the lining material could

Table 2. Average monthly inflow and tail stage.

	Ghordour Dy.			Lagar Dy.		
Zero Values Excluded						
	Before Lining	After Lining	% Change	Before Lining	After Lining	% Change
Inflow into Dy.						
Ave Discharge (cfs)	32.10	46.18	+43.8%	33.25	37.92	+14.0%
Ave Monthly C of V (%)	14.88	4.66	-68.7%	11.33	6.82	-39.8%
Tail Stage						
Ave Depth (ft)	0.66	0.71	+7.6%	0.56	0.60	+7.1%
Ave Monthly C of V (%)	21.25	14.38	-32.3%	24.83	14.52	-41.5%
Zero Values Included						
	Before Lining	After Lining	% Change	Before Lining	After Lining	% Change
Inflow into Dy.						
Ave Discharge (cfs)	28.44	41.45	+45.7%	30.82	34.51	+12.0%
Ave Monthly C of V (%)	42.11	27.71	-34.2%	33.06	27.79	-15.9%
Ave Depth (ft)	0.53	0.65	+22.6%	0.47	0.53	+12.8%
Ave Monthly C of V (%)	62.4	36.27	-41.9%	62.20	35.78	-42.5%

[1]Irrigation Engineer, IIMI-Pakistan

not be met without greatly increasing the cost of the entire project.

The cost of lining of the two distributaries was US$ 201,000 (Rs. 3.32 M), which was financed through the USAID/World Bank Irrigation Systems Rehabilitation Project. Actual costs were US$ 5.52 (Rs. 91.58) per linear foot for Ghordour and US$ 5.19 (Rs. 86.17) per linear foot for Lagar.

The evaluation is based largely on data provided by the Punjab Irrigation Department from the offices of the XEN Upper Gugera and SDO Chuharkana. Daily readings of water levels in Upper Gugera Branch, discharge into the two distributaries and tail water levels of both distributaries were used in the analysis.

Data were compiled over a four year period, 1 October 1982 to 30 September 1986. covering eight full irrigation seasons: four seasons of the pre-lining condition, one season during which lining actually occurred, and the three full seasons after lining.

The analysis was undertaken in two parts. In the first stage all zero readings were removed from the data base in order to assess the hydraulic changes that occurred along the distributaries since lining. However, this approach does not truly reflect the actual nature of water deliveries received by farmers at the mogha because farmers normally do not know when breaks will occur in water deliveries. The second stage therefore included all zero readings except for those associated with the annual closures during January and February.

In both stages of the analysis two primary measures of the impact of the lining program have been adopted. The first is a straight comparison of averages of discharges and water levels. The second is a comparison of the degree of variability of the averages, a truer representation of what farmers can expect to receive. When managing water along a watercourse or on his own fields, a farmer works with a range of water delivery conditions rather than a simple average. This range represents the variability of inflow into the channel itself, and the variability caused by diffusion of flow conditions along the channel. Because both distributaries are several kilometers in length, it is unreasonable to expect that variability at the tail will be identical to that at the head. Rather, there is some increase. However, a hydraulically efficient channel should have a smaller increase in variability between head and tail than one which is hydraulically inefficient.

All data have been presented on a monthly basis using the daily water readings.

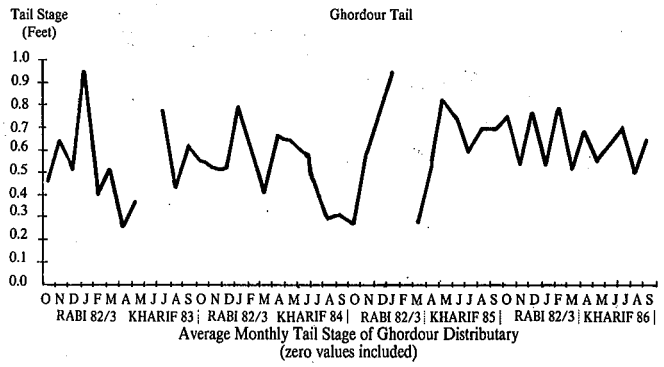
RESULTS

Average Data

Tail water levels. A comparison of the tail water conditions in both distributaries (Figures 1 and 2) indicates some degree of improvement since lining occurred (Table 2) with both channels showing an increase of approximately 15mm in the depth of water at the tail end. There is no statistically significant difference between the pre-and post-lining values for either distributary (Figures 3 and 4). The designed tail water depth is 0.21m (0.7 feet) for both channels.

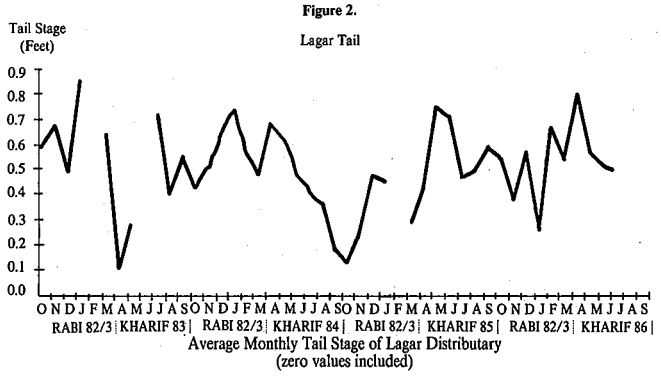
Analysis of the data when zero values are included indicate a similar picture. The data show a greater improvement in Ghordour than in Lagar.

Figure 1.



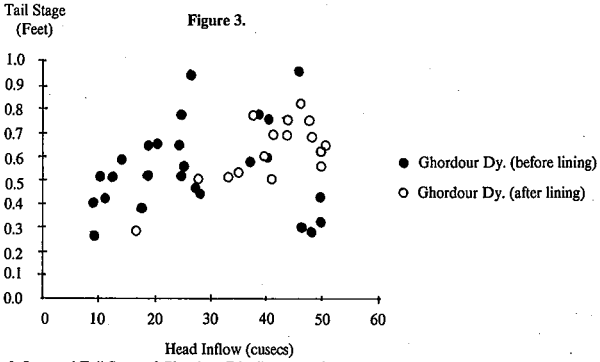
Average Monthly Tail Stage of Ghordour Distributary
(zero values included)

Figure 2.



Average Monthly Tail Stage of Lagar Distributary
(zero values included)

Figure 3.



Inflow and Tail Stage of Ghordour Distributary Before and After Lining
(zero values included)

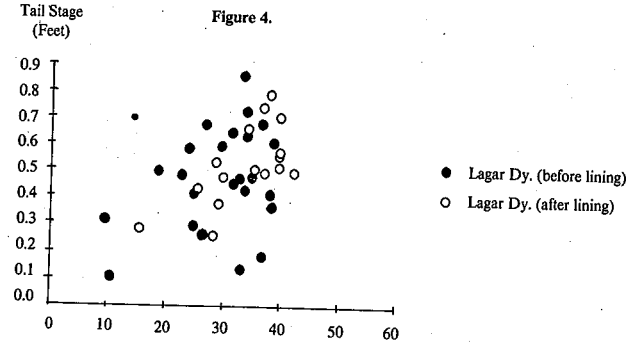


Figure 4.

Inflow and Tail Stage of Lagar Distributary Before and After Lining
(zero values included)

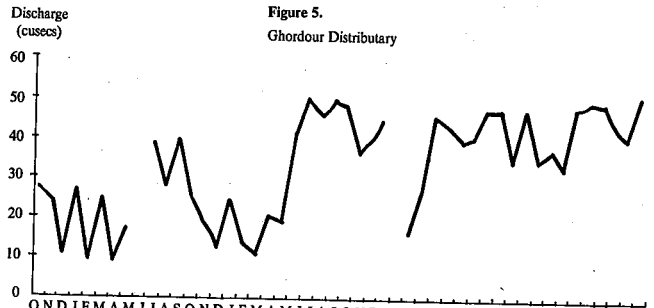


Figure 5.
Ghordour Distributary

Average Monthly Discharge into Ghordour Distributary
(zero values included)

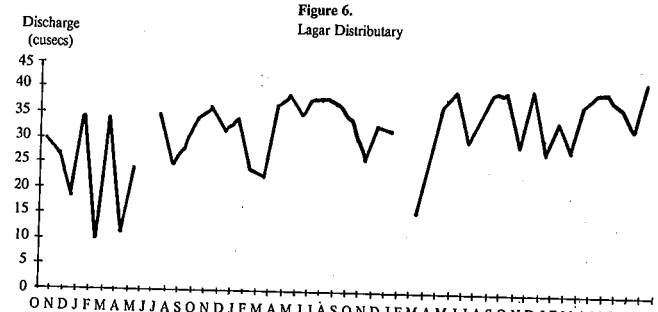


Figure 6.
Lagar Distributary

Average Monthly Discharge into Lagar Distributary
(zero values included)

The reason for the larger increase in tail water levels in Ghordour Distributary can be attributed to long periods before lining when there was no water present at the tail, particularly during the first two seasons of the study. Lagar Distributary shows fewer zero readings before or after lining. Again, these differences are not statistically significant.

However, to make meaningful comparisons of the average tail water conditions it is necessary to ensure that inflow conditions were essentially the same before and after lining. The next analysis shows that this was not the case.

Inflow analysis. Average monthly discharges into the two distributaries are presented in Figures 5 and 6. The data show that there have been considerable increases in inflow into Ghordour Distributary since lining occurred. Before lining the average monthly inflow into Ghordour using non-zero data, was 32.10 cusecs, or 64.2 percent of design capacity. After lining occurred, this increased to 46.18 cusecs, an increase of 43.9 percent. A similar, but less marked pattern occurred in Lagar, where average monthly inflow averaged 33.25 cusecs before lining and 37.92 cusecs after lining, an increase of 14 percent.

When zero data are included, the same trend is observed. Ghordour inflows averaged 28.44 cusecs before lining and 41.45 cusecs after lining, while Lagar averaged 30.82 cusecs before lining and 34.51 cusecs after lining.

The increases in inflow since lining occurred make it difficult to determine the exact causes of improvement in tail water conditions. It would be possible to attribute all improvements to lining, but they could also be attributed to increased discharge into the channels themselves. In Ghordour the percentage increase in inflow was much greater than the percentage increase in water depth at the tail. This may be because the tail stage readings are close to or above design level, and further increases are impossible without overtopping the channel. This argument is less convincing in the case of Lagar.

However, there is one important indication that lining has been a major contributor to improved tail water conditions. In the eight months before lining (June 1984 to January 1985) monthly discharge into Ghordour Distributary averaged 47.53 cusecs (zeros excluded) and 44.43 cusecs (zeros included),

essentially the same as in the post-lining period. During this eight month period, however, the tail water conditions were lower than during the rest of the pre-lining period.

This indicates that despite substantial improvements in the discharge into Ghordour Distributary, the benefits were not felt at the tail end. Only after lining occurred were conditions significantly improved at the tail, and these benefits were achieved without further modifications to inflow into the distributary.

There are no comparable data for Lagar Distributary because inflow conditions have remained much more uniform throughout the eight seasons of analysis.

Variability

Analysis of the variability of the data indicates additional benefits from the lining program. Both distributaries show a healthy reduction in the coefficient of variation of tail water levels since lining, from which one can assume that farmers are more able to assess the likely availability of water when their next irrigation turn is due.

However, inflow data also show a large decrease in the coefficient of variation of inflows into both distributaries. For both distributaries, using the non-zero data set, the decrease in variability was greater for inflow than for tail water stage, making it difficult to isolate the impact of inflow changes from the impact of lining.

The non-zero data set shows a less convincing pattern. While the decrease at the tail of Lagar was 41.5 percent, compared to a decrease at the head of 39.8 percent, the decrease in average monthly coefficients of variation at the tail of Ghordour was only 32.3 percent compared to a 68.7 percent decrease at the head.

A more detailed analysis was made of those periods when inflow conditions before and after lining were essentially the same (Table 3). This gives an opportunity to better assess the impact of lining.

In Ghordour Distributary, there is evidence that the variability of tail stage data is higher during the eight months prior to lining than the variability of the tail stage data after lining, even though the variability of the inflow in both periods was essentially the same. The same is true in Lagar Distributary although the results are less dramatic.

DISCUSSION AND CONCLUSIONS

The data show some evidence that lining has improved the situation in both Ghordour and Lagar Distributaries but that it is hard to disaggregate changes that have occurred due to changes in inflows into the two channels. The most important issue to be resolved, therefore, is the extent to which lining has permitted greater discharges to be delivered.

The condition of the channels themselves becomes a factor if there are breaches and other physical problems that require closure of the distributary or reduction of discharge. It is probable that there have been fewer breaches in the lined sections, and therefore fewer overall closures of the distributaries. This is one cause of improved reliability.

Because the distributaries have only been operational for three full seasons since lining it is impossible to determine the long-term impact of lining. It is reasonable to expect efficient conditions in the period immediately following lining, with an inevitable deterioration in efficiency over several seasons.

It is clear that lining only the lower portion of a distributary ought to be accompanied by some measures in the upstream, unlined section in order to gain full benefit. In both Ghordour and Lagar there are continuing instances of breaching in the upstream, unlined sections, either due to weakness of the berm or deliberate activities by farmers, which affect the reliability of water deliveries throughout the entire length of the distributaries.

An alternative strategy that should be considered is one of lining of those sections where berm conditions are most deteriorated. This approach has the disadvantage of requiring more survey prior to rehabilitation but, in the long run, can be more cost effective as it focusses on the weakest points in the system.

It is possible to postulate that farmers have benefitted from the lining program because water supplies are much more reliable than in the past. However a parallel field study should be undertaken that examines the farmers' perceptions of the benefits, if any, of the lining program.

Further evaluation of the relative benefits of lining versus upgraded maintenance should also be undertaken. Although clearly beneficial, lining in both Lagar and Ghordour has been comparatively expensive. Alternative strategies such as partial lining or restoration or channel berms and cross-sections should be tested before embarking on a large scale program of lining minor and distributary canals. □

Table 3. Average monthly coefficients of variation of inflow and tail stage for periods immediately before and after lining. (All figures are percentages.)

	Zero Values Excluded					
	Ghordour Dy.			Lagar Dy.		
	8 Months Before Lining	19 months After Lining	% Change	19 months Before Lining	19 months After Lining	% Change
Inflow into Dy. Ave.	6.62	4.66	-29.6%	10.93	6.82	-37.6%
Tail Stage Ave.	23.80	14.38	-39.6%	23.93	14.52	-39.3%
	Zero Values Included					
	Ghordour Dy.			Lagar Dy.		
	8 Months Before Lining	19 months After Lining	% Change	19 months Before Lining	19 months After Lining	% Change
Inflow into Dy. Ave.	19.11	27.71	+45.0%	25.45	27.79	+9.2%
Tail Stage Ave.	47.02	36.27	-22.9%	46.50	35.78	-23.1%