STATISTICAL ANALYSIS FOR LINING THE WATERCOURSES

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ABSTRACT

Lining is an effective technique to improve the watercourse performance. The Directorate of On-farm Water Management (OFWM) normally lines 15-30 percent of the watercourse length whereas the farmers insist to line more than that. Present study was carried out during at watercourses 5486-R, 114626-R and 116928-R on Shahkot distributary and relevant data were collected to compute optimum length of lining based on channel usage time and trade off point. Statistical analysis predicted that it is economical feasible for lining the watercourses as 49 to 54 percent, earthen improvement as 21-29 percent and cleaning the watercourses as 11-13 percent of total length of watercourses. This technique is more reliable as conclusive results could be obtained through it as compared to graphical approach where there was biasness in scale measurement. On the other hand graphical approach is used to determine the quick representation and trend of the factors.

KEYWORDS: Lining; earthen improvement; water course; water management; trade off point;

INTRODUCTION

Pakistan lies in arid to semi-arid region where average annual rainfall is 254 to 356 mm against a potential demand (of water for maximum crop production) of 1778 mm (7). This gap between the demands and supplies is met through applying irrigation. Moreover, the country is facing threat of rapidly increasing population with the annual growth rate of 2.05 percent (2). It has been observed that water availability for agriculture is expected to decline globally to 62 percent by 2020 as was available (72%) in 1995 and from 87% to 73% in developing countries (8). Studies in Pakistan indicate that 13-18 cm of water is applied per irrigation on as average to a crop, which is considerably higher than the actual consumptive use of approximately 8 cm of water between two irrigations (5). On-farm irrigation efficiencies in Punjab range between 23 and 70 percent (3, 6). Rapidly increasing demands

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of household, industrial and environmental uses may put additional pressure on water resources in many river basins. Therefore, food security is challenged by food demand from ever increasing population in the coming decades (4, 15). Agriculture sector faces a challenge to produce more food with less water by increasing water productivity (9).

Pakistan has one of the most expensive and highly integrated irrigation water distribution systems in the world. The system comprises the Indus and its distributaries, three storage reservoirs, 19 barrages/headwork's, 44 canals and nearly 89,000 watercourses. Maximum length of water conveyance unit in the irrigation system is of watercourses and it has great impact on the equity of water distribution among the farmers. On an average 40% of water entering the watercourses is lost before reaching the field (1, 11) for the lined watercourses, the irrigation water losses ranged from 35 to 52% and for the unlined these were from 64 to 68%. Comparing the average water loss of 43.5% from lined to the average water loss of 66% from unlined watercourses. It was concluded that the lining reduced water loss by 22.5%.

This colossal loss of water can be saved by improving the watercourse i.e lining, earthen improvement and cleaning. The OFWM Directorate lined only about 15-30% length of community watercourses whereas, demand for increased length of lining by the farming community is increasing day by day. However, at some places additional lining is often provided without considering the relationship between net annual return and the investment (3, 10, 14). Thus at most of the places the lining does not prove to be economically feasible. Thus, there is a definite need to locate a trade off point (The point between lining and earthen improvement at which annual net return per unit length are equal) between lining and earthen improvement of watercourses, where the investment becomes cost effective. The optimum length of lining for a watercourse is the length which involves the minimum cost of improvement with the maximum benefits of water saving optimum length of lining for watercourses was determined by difference researchers using different approaches (12). The optimum length of lining for a watercourse was calculated by channel using time i.e. how much time a channel section is used. Malhotra (10) utilized the foot hours concept in a graphical optimum scheme for branched watercourses. He plotted foot hours as a function of length. In his scheme, maximum utilization of resources occurred, if the slope of foot hours versus foot curves were equal at the cut off point in all branches of watercourses. In the present study statistical analysis approach was used for determining the optimum length of watercourse lining. The objective of this study is to determine how much time a section should be used for a given technique for positive net return or a higher return as compared to other available improvement strategy.

MATERIALS AND METHODS

The allocation of alternative improvement techniques to a rotational conveyance system, where different portions of the system are used for different period of time was done basically on economic grounds. In this analysis the technique giving a positive net return was considered economically desirable and that giving highest net return preferred.

Net returns (R)

Net returns vary with total water savings and thus with the period of time a channel section is utilized. by determining how much time a channel section is used. Net returns for a channel improvement, R (Rs/m/yr) was taken as the value of the saved water minus the costs of improvement, both of which are calculated on an annual basis.

Annual costs (C)

Annual costs included the initial costs spread evenly over the project life utilizing an appropriate discount rate, plus the annual cleaning, maintenance, repair and replacement costs. Annual costs were calculated on per unit channel length basis, C (Rs/m/yr).

The annual value of saved water (WS)

It is the unit value of the water V (Rs/m^3), times the volume saved in a year, W_S (m^3/yr). Thus:

$$R = VW_S - CL \qquad (1)$$

Where;

R = Net return per unit length of channel
V = Value of water comparing canal water with tubewell water
W_s = Volume of water saved
C = Cost of improvement
L = Loss rate from the watercourses

Water volume saved (WS)

Is equal to increase in the flow rate in a channel, times the period of time for which the channel is used, "t" (fraction of a year). The flow rate increase is represented as the initial flow loss (Q) (lps), times a fractional decrease in the loss as a result of improvement technique, F:

$$W_S = F\,Qt \quad \ldots\ldots\ldots\ldots\ldots\ (2)$$

Where;

W_s = Volume of water saved

F = Fractional decrease taking 0.9% for lining 0.5% for earthen improvement and 0.3% for cleaning.

Qt = Volume of water

Both losses and costs are most easily expressed on per unit channel length basis. When Eq. A.1. is converted to per unit length basis with W_S from Eq. A.2 inserted, the net return per unit length becomes:

$$R_L = \quad aVfQ_L \quad - C \ \ldots\ldots\ldots\ldots\ (3)$$

Where;

R_L = net annual return per unit length (Rs/m/yr)
Q_L = initial flow loss per unit length or the initial loss rate dL (lps/100m)
a = a volume and time conversion unit equal to 315 to convert from (lps/100m) to (m^3/m/yr).

Trade -off- point (T)

As stated, an improvement is economically desirable for a channel R_L is positive. If two techniques are being compared, the usage time trade-off point where a switch should be made from one improvement technique to another is that point where the net return of two techniques are equal. If we call R_L the higher cost net return and $R_{L1}$the lower cost return, the trade-off-point is;

$$R_{Lh} = R_{Li} \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Or when:

$$aVf_h o_L t \ \ - \ C_h = aVflQLt \quad - \ C_1 \ \ldots\ldots\ldots\ldots\ldots (5)$$

Solving this equation for usage time gives:

$$T = \frac{C_h - C_1}{315VQ_L\,(f_h - f_1)} \quad \ldots\ldots\ldots\ldots\ (6)$$

Where

t = fraction of a year a given section is full,
C_h = annualized unit costs of the higher cost alternative (Rs/m/yr).
C_1 = annualized unit cost of the lower cost alternative (Rs/m/yr),
f_1 = fractional water loss saved by the higher cost alternative, and
f_1 = fractional water loss saved by the lower cost alternative.

When an improvement alternative is being compared with no improvement C_l, and f_l are zero and Eq. 6 reduced to:

$$T = \frac{C_h}{315\ VQ_L f_h}$$

The value of 't' Would allow us to calculate the usage time required to justify the lower cost treatment over the higher cost treatment. The value of t obtained from this formula would be substituted in regression equation. Bythis procedure we can determine the optimum length of lining for watercourse improvement.

RESULTS AND DISCUSSION

Optimum usage time

The total average loss rate per 100m in watercourse of outlet No. 116928-R, 114626-R, and 5486-R was found 2.51, 3.08 and 1.91 (lps), respectively. The channel usage time per rotation period calculated was converted in to percent per year.

Annualized cost of improvement for higher cost alternative was found to be Rs. 40.6/m/Year. The value of canal water was taken as the value of tubewell water tubewell of one cusec running for one hour delivers one acre-inch of water. The prevailing cost of operation of tubewell water was Rs. 40/hr so the value of water for one acre-ft was 40 x 12 = Rs. 480 per hectare. The optimum usage time was determined as follow for watercourse No.114626-R, 5486-R and 1169628-R.

<u>Watercourse No. 114626-R</u>

(For lining and earthen improvement together)

$$\text{Optimum usage time (T)} = \frac{-\ 42.1\ \text{Rs/m/Year} - 12.6\ \text{Rs/m/Year}}{315(0.\ 388\ \text{Rs/m3})\ (3.08\ \text{lps/100m})\ (0.9 - 0.5)"} = 0.19$$

(For earthen and cleaning improvement together)

$$\text{Optimum usage time (T)} = \frac{12.6\ Rs/m/Year - 6.26\ Rs/m/Year}{315\ (0.388\ Rs/m^5)\ (3.08\ lps/100m)\ (0.5 - 0.3)} = 0.08$$

(For cleaning)

$$\text{Optimum usage time (T)} = \frac{6.26\ Rs/m/Year}{315\ (0.388\ Rs/m5)\ (3.08\ lps/100m)\ (0.3)} = 0.05$$

Watercourse no. 116928-R

(For lining and earthen improvement together)

$$\text{Optimum usage time (T)} = \frac{40.6\ Rs/m/Year - 12.1\ Rs/m/Year}{315\ (0.\ 388\ Rs/m^3)\ (2.51\ lps/100m)\ (0.9 - 0.5)} = 0.23$$

(For Earthen and cleaning improvement together)

$$\text{Optimum usage time (T)} = \frac{12.1\ Rs/m/Year - 6.06\ Rs/m/Year}{315\ (0.388\ Rs/m^3)\ (2.51\ lps/100m)\ (0.5 - 0.3)} = 0.09$$

(For cleaning)

$$\text{Optimum usage time (T)} = \frac{6.06\ Rs/m/Year}{315\ (0.388\ Rs/\ m^3)\ (2.51\ lps/100m)\ (0.3)} = 0.06$$

Watercourse no. 5486-R

(For lining and earthen improvement together)

$$\text{Optimum usage time (T)} = \frac{36.7\ Rs/m/Year - 11\ Rs/m/Year}{315\ (0.\ 388\ Rs/m^3)\ (1.91\ lps/100m)\ (0.9 - 0.5)} = 0.27$$

(For Earthen and cleaning improvement together)

$$\text{Optimum usage time (T)} = \frac{11\ Rs/m/Year - 5.4\ Rs/m/Year}{315\ (0.388\ Rs/m^3)\ (1.91\ lps/100m)\ (0.5 - 0.3)} = 0.11$$

(For cleaning)

$$\text{Optimum usage time (T)} = \frac{5.4\ Rs/m/Year}{315\ (0.388\ Rs/\ m^3)\ (1.91\ lps/100m)\ (0.3)} = 0.07$$

The regression equation was developed to examine the relationship between channel usage time and channel length. Length of the channel was considered as dependent variable while channel usage time as independent variable. It was noted that increasing the optimum usage time for a given channel the optimum length of lining for watercourse improvement decreases the equation was developed using linear regression analysis for the watercourse

Regression equation

Optimum length of lining for watercourse No. 116928-R

Optimum length of lining = 3685 - 780 × ln (23)	=	1239.3 m
Optimum length of earthen improvement = 3685 - 780 x ln (9)	=	1971.1 m
Optimum length of cleaning the watercourse = 3685 - 780× ln (6)	=	2287.4 m
Optimum length to be lined	=	1239.3 m
Net optimum length to be earthen improved = 1971.1-1239.3	=	731.8 m
Net optimum length to be cleaned only = 2287.4-1971.1	=	316.3 m

Similarly, the optimum length of lining, length of earthen improved as well as simply cleaned sections of watercourse No. 114626-R and 5486-R were also calculated. The results showed that on watercourse No. 114626-R the length of lining should be 54 percent, length of earthen improvement be 21 percent and the length of cleaning should be 11 percent. On watercourse No. 116928-R the length of lining be 50 percent, length of earthen improvement 29 percent and length of cleaning be 12 percent. Similarly on watercourse No.5486-R the length of lining should be 49 percent, length of earthen improvement be 26 percent and length of cleaning was 13 percent.

Optimum length of lining for watercourse No. 114626-R

Optimum length of lining = 2962 - 571 x ln (19)	=	1280 m
Optimum length of earthen improvement = 2962 - 571x ln (8)	=	1774.6 m
Optimum length of cleaning the watercourse = 2962 - 571 x ln (5)	=	2043 m
Optimum length to be lined	=	1280 m
Net optimum length to be earthen improved = 1774.6-1280	=	494.6 m
Net optimum length to be cleaned = 2043 - 1774.6	=	268.4 m

Optimum length of lining for watercourse No. 5486-R

Optimum length of lining = 1876 - 375 x ln (27)	=	640 m
Optimum length of earthen improvement = 1876 - 375 x ln (11)	=	976 m.
Optimum length cleaning the watercourse = 1876 - 375 x ln (7)	=	1146.2m.
Optimum length to be lined	=	640 m
Net optimum length to be earthen improved = 976-640	=	336 m
Net optimum length to be cleaned = 1146.2 – 976	=	170.2 m

The purpose of field data collection was to enable determination of optimum length of lining for the watercourse improvement. The variation in the collected field data stressed the need to use statistical techniques for determining the optimum distance, this is function of optimum usage time. Initially linear regression equation was used to relate these variables. The graphical investigations indicated a curvilinear relationship, one or both of the variables were transformed using logrithum and data was gain linearly regressed so that linear and logrithemic models could be evaluated. The coefficient of determination (R^2) was obtained to compare the fitness of models to the data. The coefficient of determination criterion was used to determine that relationship was meaning full or not, also the significance of relationship was considered. It was significant if probability of accepting the null hypothesis was less than 0.05 (termed as being significant at the 90% probability level.) in all cases probability level was specifically obtained by analyzing the data by using minitab package. The data strongly support the hypothesis that the channel length is linearly and logrithemically related to the channel usage time. The relationship between channel length (m) and channel usage time (% hours) fitted logrithemically with a high coefficient of determination as compared to that of linearly relationship. To estimate the optimum usage time length is taken as depended variable and time as an independent variable and there was inverse relationship and was highly significant because coefficient of determination was very high and standard was low and in the regression equation ($Y = a+bx$) "b" was the derived coefficient and was the rate of change of length with respect to usage time it can be used to indicate the sign of relationship between the time usage and channel length. The regression analysis was shown in the form of regression equations, coefficient of determination and standard error of Y estimate in the table. The optimum length of lining determined through statistical technique was found to be 54, 50 and 49 percent for water course No. 114626-R, 1166928-R and 5486-R, respectively. This technique is more reliable and conclusive results could be obtained through this technique as compared to graphical approach where there was biasness in scale measurement. On the other hand graphical approach is used to determine the quick representation and the trend of the factors.

CONCLUSIONS

It is recommended that OFWM department may increase the length of lining up to 50 percent, rather than 15 to 30 percent in saline areas where net returns are positive. It is also recommended that more data may be collected on additional watercourses for developing a linear programming model for determining the optimum length of lining for watercourse. The model may be provided to all field team WFWM projects in the country. This would facilitate and ensure economical utilization of financial resources of the country.

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