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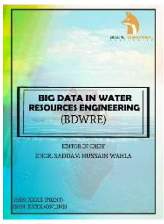

RESEARCH ARTICLE

TO ASSESS THE IMPACTS OF HYDRAULIC PARAMETERS OF WATER CHANNEL ON PRE AND POST LINING: A CASE STUDY IN FAISALABAD IRRIGATION ZONE

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ABSTRACT

Water distribution on earth is not constant in its both forms i.e. surface water and groundwater. In many areas, the groundwater availability is changing, making it less available to agriculture for irrigation purposes. Surface water has fresh quality and frequently used for irrigation practices by diverting water from rivers and stream into canals and watercourses. As this scare and valuable resource move into the irrigation structure, a certain part of that water is lost. The losses in the watercourses are much more than those in the main channels and distributaries. So farmer's face critical shortage of irrigation water issues. In addition to this groundwater pumping is also increasing that is decreasing groundwater table. The conveyance losses in the watercourses can be minimized by applying some lining techniques. To overcome this problem, there is a need to work out of the channel lining that ensures maximum water saving. A detail study has been carried out in the work to calculate the water losses using operational inflow and outflow approach. The losses from the pre and post lining of the canal have been calculated and assess the impacts of hydraulic parameters of the channel after lining the channel to investigate the hydraulic outlet's performance, seepage water losses from the channel. In this concern, a case study was conducted on channel lining of Faisalabad irrigation zone. The value of the hydraulic parameters (cross-sectional area, flow velocity, wetted perimeters, hydraulic radius, bed slope, and side slope) for the trapezoidal channel have been investigated in this study. For statistical analysis a generalized linear model (exponential) R-language were used in the study. The value of water losses in pre and post lining of three distributary Lagar Disty, Nasrana Disty and Sehti Wala Minor was 2.238, 1.805, 3.008 $m^3/s/10^6m^2$ and 0.385, 0.486, 0.644 $m^3/s/10^6m^2$ respectively. The lowest losses were found in lined channel of LCC (East) Lagar Disty and the highest losses were found in the LCC (West) of Sehti Wala Minor. In this investigation work, the saving of water through lining the channel is also authentic numerically evaluated and authenticated.

KEYWORDS

Lining of water channels, Seepage losses, Conveyance losses, Hydraulic parameters, Inflow-outflow method.

1. INTRODUCTION

Agriculture in Pakistan's is almost exclusively dependent on the irrigation and the irrigated land supplies more than 90 % of the agriculture production. Considerable investments in the irrigation contributed to the development of one of the largest Indus Basin Irrigation System (Jacoby et al., 2018). Water is an elementary input for crop production of the rising world. A large amount of irrigation water is carried over large distances by canals which may be completely unlined or partially lined. For a continuous supply of water to the land, it is essential that the canals prism should not only be hydraulically proficient of transmission the designed discharge but the banks should also be strong enough to ensure suitable supply to the fields. An exposed canal might be movable boundary (unlined) or rigid boundary (lined) segment. Through seepage, the substantial part of the usable water loses by unlined channel.

Leakage losses not only depleted resources of freshwater but also sources of groundwater contamination, water logging, and salinization. Seepage losses are slow down through canals lining. The perfect lining of the channels would avoid completely the seepage loss, but the lining of channels deteriorates with time. Weed growth in the canal, settlement of the subgrade, construction faults and use of lower quality lining materials, and weathering due to this crack somewhere on the perimeter in the lining may develop (Arsam et al., 2017). Seventy percent of the worldwide freshwater is used for the irrigation. In this figure is three times the amount is used for industry and ten times is the amount used for the domestic and for the urban use (Kinzli et al., 2010). Land and water are the two fundamental sources for agriculture. Water is most critical in the farming commitments, as the absolutely extraordinary increments happening might be practiced over the water. Pakistan is an outstanding country through water assets with the outcome is around 3/4 of its cultivable property is flooded.

Pakistan consumes one of the world's prime scale waterway stream water system framework The Indus Basin Irrigation System (IBIS) is a coordinated water system arrange on the planet usually covers relatively

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17.8 mha of land (Nawaz et al., 2016). In recent times, scarcity of water and conflicts of water are increasing due to the degradation of water environment and growing demand for the water (Yao et al., 2015). The well-organized operation and the managing of the irrigation system plays and significant role in the sustainability of irrigated agriculture (Unal et al., 2004). Water losses contain both vanishing and seepage losses. The dissipation losses as the function of the capacity of temperature, stickiness and wind speed. For all intents and purposes, dissipation losses can't be controlled however seepage losses can be controlled by giving impenetrable medium, for example, concrete, brick, geosynthetic material, and asphalt, etc. so forth between permeable soil and water streaming in the channel. Seepage losses in the waterways is a noteworthy reason behind water loss from the channel when contrasted with the other type of water losses (Saha, 2015).

2. MATERIAL AND METHODS

2.1 Description of the study area

The study area lies in the Rechna Doab, which is the interpluvial sedimentary basin between the Chenab and Ravi rivers. Rechna Doab lies between the Longitudes 71^{o} – $48^{/}$ to 75^{o} -$20^{/}$ East and Latitude 30^{o} – $31^{/}$ to 32^{o} – $51^{/}$ North of the Indus Basin of Punjab, Pakistan. To produce some substantial outcomes the specific selection of the site is an essential step that leads towards the collection of proper data and it's processing for meaningful results. The research plan required the assessment of the impact of hydraulic parameters to the lining of the water channel and its impact on conveyance losses. The investigation site is situated in the direction territory of Upper Gugera Branch (Lagar Disty) of Lower Chenab Canal (LCC East) and Jhang Branch Upper (Nasrana Disty & Sehti Wala Minor) LCC west water system framework in Faisalabad irrigation zone as shown in figure 1. These distributaries at head middle and tail are selected for the analysis of water losses on post lining and also for the analysis of the hydraulic parameters of the selected channels.

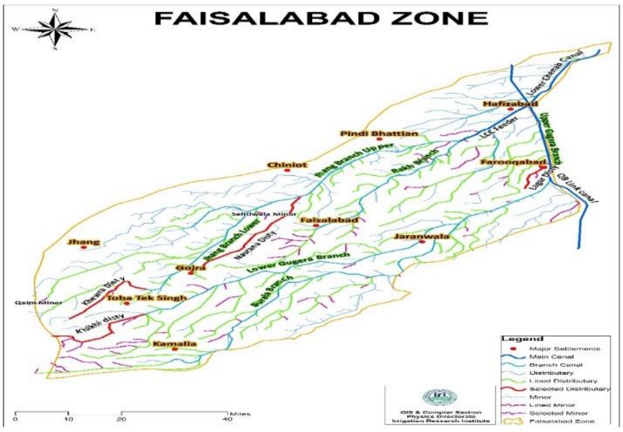

Figure 1: Study area showing the location of the selected irrigation canals

2.2 Data Collection

Canal water supplies and hydraulic parameters data for the research sites was determine as to check the surface water involvement in the seepage and the impact of hydraulic parameters on the canal lining. Canal water supplies that include Discharge (Q), inflow outflow data and total outlets discharge data of the selected distributaries were collected from the Punjab Irrigation Department (PID) Lahore. Additionally, at the outlets of the canal designed distributed discharge of watercourses and seepage data of pre lining of the channels were also collected from the Punjab Irrigation Department (PID) Lahore.

2.3 Evaluation of Hydraulic Parameters

2.3.1 Channel Cross-Sectional Parameters

In the hydraulic analysts of the stream and rivers various channel cross-sectional parameters are used. It is significant to quantity and use theses parameters reliably and precisely. A generalize cross section of a channel.

2.3.2 Flow Depth

The depth of flow is the distance amongst the channel bottom and the surface of the channel. For rectangular channels, the depth is the same across an entire cross section of the channel, but obviously differs in natural channels. Depth of the channel is frequently measured comparative to the lowest point of channel. Normal depth of the channel is the depth of water flow in the uniform channel for which the water surface is normal or parallel to the channel profile and energy grade (Zheng et al., 2018).

2.3.3 Flow Area

For the cross section ranged so that streamlines of the flow are perpendicular, the area of the flow of the cross section amongst bed level and banks and surface of the water. For the channel of rectangular shape, flow area is the depth multiplied by the top width. For the cross section of the natural channel, the area might be approached with the sum of the trapezoidal areas amongst points of cross sectional. The top width of the cannel cross section at water surface, typically as T, is a factor in the hydraulic depth of the channel (Neal et al., 2015).

2.3.4 Hydraulic Depth

Hydraulic depth is the ratio of cross-sectional area of the flow to surface of the water or top width. The hydraulic depth, d, is generally used either in computing the Froude number or in computing the channel section factor for the critical depth. Since for the given discharge in a channel only one critical depth is possible. The suction factor, Z, can be used easily to determine it (Dingman, 2007).

$$Z = \frac{A}{\sqrt{d}} \tag{1}$$

$$Q\text{critical} = Z\sqrt{g} \tag{2}$$

For the cross section which is normal to the direction of the flow, the wetted perimeter (typically design P) is the length of the boundary of the cross section between the water and bed and banks of the channel.

2.3.5 Hydraulic Radius

Hydraulic radius is the ratio of the cross-sectional area of the flow to the wetted perimeter or the flow boundary. The hydraulic radius is used in Manning's equation for the calculation of the normal depth discharge and as well as for the calculation of the shear velocity (Fang, 2019). The value of hydraulic radius for the trapezoidal channels were computed by the given Eq. 3.3.

$$R = A/P \tag{3}$$

Where,

R= Hydraulic range,
A= Cross-sectional zone,
P= Wetted edge.

The more the hydraulic radius range, the more the channel effectiveness and the less likely outlandish the channel into a flood.

2.3.6 Flow Velocity

Various extraordinary and fluctuated strategies have been developed to quantify the flow of water in open channels. Open channels are those common and man-made structures through which water streams with a free surface. Flow velocity is states is to the areal range of the flow in the cross section for which the velocity is identified. For illustration, a normal velocity that applies to a whole cross-sectional area may be calculated from V = Q/A or if discharge is unknown, a uniform velocity might be determined from Manning's equation (Ahmad et al., 2018).

$$V = (1/n)\, R\hat{}\,(2/3)*S\hat{}\,(1/2) \tag{4}$$

Where,

V = Velocity of the stream
n = Roughness coefficient

S = Slope of the water surface as same as bed slant, Here R = A/P
A = cross sectional-area of the stream in m^2
P = Wetted perimeter
R = Hydraulic radius Velocity with in average value of 1.5 feet per second for this study.

Selected lined channels range from 1.01 to 2.03 feet per second.

2.3.7 Manning's Roughness Coefficient

The Manning's roughness coefficient is used in the Manning's formula to calculate the flow in the open channels (Ye et al., 2018). Roughness coefficient for some commonly used surface materials are given in below table 3.3. The design of lined channel selected for this study 'n' is 0.016.

2.3.8 Cross Sectional Area

An open channel that passing on water may have a normal or unpredictably shaped cross-segment. Standardly structured cross sections having stationary shape and estimation are commonly discovered Sin lined channels while unlined channels take unpredictable segments since they are responsible for transition due to forces causing disintegration and deposition.

2.3.9 Wetted Perimeter

It is characterized as the surface of the channel base and sides in direct contact with the water body. Friction losses regularly increment with an expending wetted perimeter, bringing about a decline in head. It is the border of the cross-sectional zone that is utilized in open channel streams. One is gauging the wetted perimeter with a measuring tape weighted down to the stream bed to get a progressively exact estimation (Knight et al., 2018).

3. METHODS OF SEEPAGE LOSSES

The seepage losses through the selected canals were calculated by the measuring of difference between inflow, outlet discharge and the outflow in the canal section. The dimensions of the canal (wetted surface) and field channel were measured by the measuring tape. Current meter was used for the measuring of the flow velocity at two points in the channel.

$$\text{Seepage loss} = (Q_1 - Q_2) \quad (5)$$

Where, conveyance loss in (ft^3/s)

Q1 =Discharge at the upstream of the channel (inflow) (ft^3/s)
Q2 =Discharge at the downstream (outlets discharge – outflow) (ft^3/s)

3.1 Inflow-outflow Method

When using inflow outflow technique, the measurements of the water flow are conceded out at one time so that the evaporation losses in the open channels are neglected (Sunjoto, 2010). The quantity of evaporation from open surface of the water is very minor, so neglected these loss and the losses occurring in the canal segment are all neglected from the seepage (Akkuzu, 2012). In generally the evaporation losses in the irrigation systems in not taken into consideration (Saeed and Khan, 2014). To determine the conveyance water losses (transmission losses) by inflow outflow technique using the following equation (Abid, 1995):

$$Q_{tl} = Q_{loss} = Q_{in} - Q_{out} + Q_{int} - Q_{div} \quad (6)$$

Where,

$Q_{loss} = Q_{tl}$: Transmission losses or conveyance losses (ft^3/s),
Q_{in}: Inflow to the reach (ft^3/s),
Q_{out}: Outflow from the reach (ft^3/s),
Q_{int}: Intervening inflow (ft^3/s), and
Q_{div}: Total of diversions from the reach (ft^3/s).

3.2 Ponding Method

Seepage losses is measured in this technique by reserved the water in the canal to the working depth almost and then measure the decrease in the surface of water with the time, and then the losses are calculated by dividing the low volume of the water to the time. This technique is considered more accurate as compare to other techniques, but it is conducted with the obstruction of operational process of the canal about two weeks (Gupta, 2016).

3.3 Calculation of Conveyance Losses

The loss of water from the canal due to seepage and evaporation is a substantial part of the usable water. By the passage of time the water reaches to the field, more than half of that water supplied at the head of the canal is lost in seepage and evaporation, but here in case of open channel we ignore the evaporation loss. Thus, the canal conveyance losses of the canal were calculated by,

$$\text{Conveyance loss} = (Q1 - Q2)/Q1*100 \quad (7)$$

Where,

Q1 =Discharge at the upstream of the channel (inflow) (ft^3/s)
Q2 =Discharge at the downstream (outlets discharge – outflow) (ft^3/s)

3.3.1 Evaluating Conveyance Efficiency

Water is transported through the canal network, watercourses and channels frim the sources such as reservoirs, rivers and the dams to the field for the crop use. Conveyance efficiency is used to evaluate the efficiency of the system conveying water. Water conveyance efficiency were calculated by,

$$\text{Conveyance efficiency} = (Q_1/Q_2)*100 \quad (8)$$

Where,

Q1 =Discharge at the upstream of the channel (inflow) (ft^3/s)
Q2 =Discharge at the downstream (outlets discharge – outflow) (ft^3/s)

3.4 Hydraulic Factors on Conveyance Efficiency

Many hydraulic parameters which are correlated with the conveyance efficiency of the channel. However, it is very problematic to examine their effects considering them instantaneously. So, this study used the transmission features to see the hydraulic factors on these channels. In using the manning's formula to analyse the effects of the hydraulic parameters on conveyance efficiency; the actual value of manning's roughness coefficient, wetted perimeter and bed slope were compared with the designed values.

$$Q = 1/n* AR^{2/3} S^{1/2} \quad (9)$$

$$n= (R^{2/3}AS^{1/2})/Q \quad (10)$$

Where,

Q = discharge of the channel (m^3/s)
R = (A/p) = Hydraulic radius (m)
A = Wetted cross-sectional area (m^2)
s = bed slope
n = Manning's roughness coefficient

3.5 Statistical Analysis

Data collected on all parameters were analysed statistically using R-language of version 3.6.0 (Core Team, 2013).

4. RESULTS

The data collected and consequent caused includes the results obtained by conducting the described research work, keeping in view the main objective of the research. The section deals with the results and discussions obtained, from the analysis of the different data collected, for the three selected distributaries. The particular study area methodology is deliberated previously, where different techniques for the measurement of the water losses have also been discussed. Inflow-outflow method has been selected due to its inclusive range. Polynomial regression for the prediction and analysis were performed.

Table 1: Measured level of water in the channel and the discharge for the three reaches in Faisalabad irrigation zone

Reach No.	Channel name	Reach length (m)	Water level in channel(m)	Average wetted perimeter (m)	Discharge of inflow (m^3/s)	Discharge of outflow (m^3/s)	Discharge of outlets (m^3/s)
1	Lagar Disty	7012.2	1.93	4.38	1.11	0.85	0.25
2	Nasrana Disty	5048.8	1.88	3.77	1.27	0.98	0.28
3	Sehtiwala Minor	6060.98	1.62	2.49	0.44	0.17	0.26

4.1 Water Loss Rate in the Channels

The loss rate was determined through the inflow outflow method for every selected channel by dividing each channel in three sections, head (inflow), middle (outlets discharge) and the tail (outflow). Inflow outflow and outlets discharge was computed at each point in the channel is given in table 4.1. The difference discharges is taken as the loss. Two tests were performed in each distributary for water loss estimation.

Table 2: Results of the Inflow-outflow test-1 for the Lagar Disty, Nasrana Disty and Sehtiwala Minor

Reach	Inflow (m^3/s)	Outflow (m^3/s)	Outlet's discharge (m^3/s)	Water loss (m^3/s)	Wetted surface (10^6m^2)	Seepage rate (m^3/s /10^6m^2)	Water loss (%)
Lagar Disty	1.11	0.85	0.25	0.0119	0.0308	0.386	1.19
Nasrana Disty	1.27	0.98	0.28	0.0092	0.0190	0.486	0.92
Sehtiwala Minor	0.44	0.17	0.26	0.0093	0.619	0.619	0.93

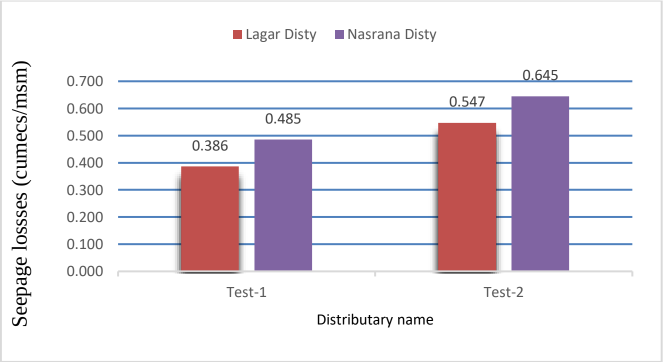

Figure 2: Seepage losses in lined section by inflow outflow test in selected distributaries

Table 3: Reduction in conveyance losses by lining of selected water channels

Water channel name	Flow rate	Average seepage losses in channel before lining	Average seepage losses in channel after lining	Reduction in seepage losses	Average water saving
	(m^3/s)	($m^3/s/10^6/m^2$)	($m^3/s/10^6/m^2$)	($m^3/s/10^6/m^2$)	(%)
Lagar Disty	1.11	2.238	0.386	1.853	82.8
Nasrana Disty	0.89	1.805	0.486	1.319	73.1
Sehtiwala Minor	0.44	3.008	0.618	2.395	79.5

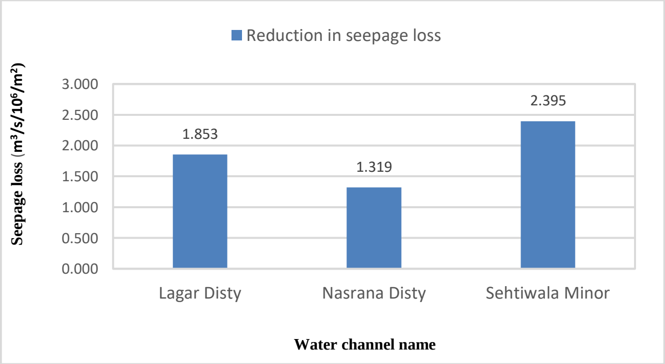

Figure 3: Graphically representation of reduction in seepage losses by lining of selected channels

4.2 Comparison of Water Loss in Pre and Post Lining of the Selected Cchannels

Comparing the rate of the seepage loss between the canal for lined and unlined. The water losses for channels unlined started just immediately the water was being discharged into the channel. The conveyance efficiency in the lined channel is more than that of unlined channel because the seepage losses will be more in unlined channel than that of lined channel which as shown in the figure 4 (Soomro et al., 2018).

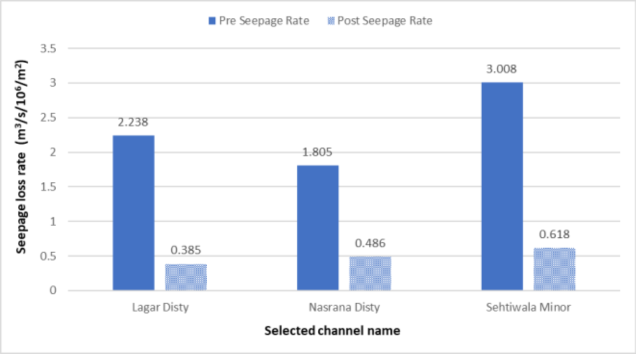

Figure 4: Comparison of seepage losses between pre and post lining of the channel

4.3 Assessment and Analysis of Hydraulic Parameters of the Selected Distributaries

Analysing the hydraulic parameters of the selected distributaries, and further analysis of the data showed that trends in canal seepage rate existed for flow velocity, and the three water channels. Geometry properties of these channels include wetted perimeter, flow area, and hydraulic radius. The data showed that as canal inflow rate decrease the seepage increased. For the wetted perimeter, flow area, and hydraulic radius data, the seepage increased as these values decreased. In order to develop predictive equations, the characteristics of the cross-section were related to the percent loss.

4.3.1 Correlation between seepage loss and flow velocity

Analysing the data for seepage rate versus flow velocity exhibited an exponential trend as shown in figure 5. This relationship exhibited a coefficient of determination (r^2) of 0.78 and is displayed in figure 4.5 as well as in Eq. (11).

$$S = 0.6545e^{-0.6235V} \tag{11}$$

Were S = percent seepage loss (%) and
V = flow velocity (m/sec)

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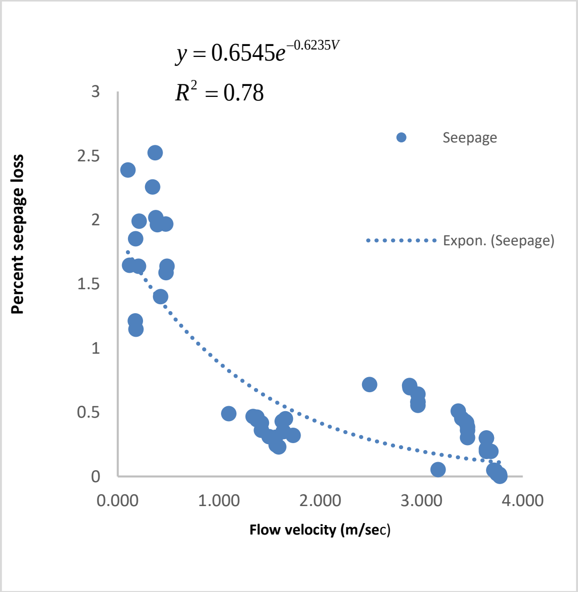

Figure 5. Relationship between flow velocity and percent seepage loss

4.3.2 Correlation between seepage loss and canal geometry (wetted perimeter)

In addition to analysing the inflow rate versus seepage loss, geometric properties of the inflow canal were plotted against the seepage rate. The data for seepage rate versus upstream wetted perimeter exhibited an exponential trend figure 6. The exponential relationship developed exhibited a coefficient of determination (r^2) of 0.80 and is displayed in figure 4.6 as well as in Eq. (12).

$$S = -0.327e^{0.017P} \quad (12)$$

Were S = percent seepage loss (%) and P = wetted perimeter (m)

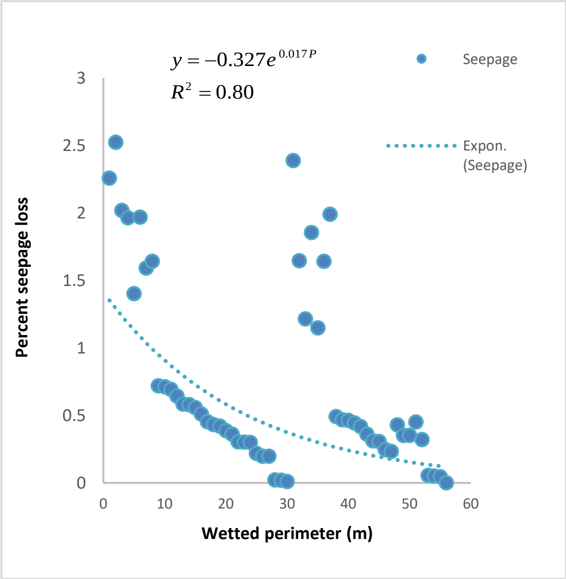

Figure 6: Relationship between seepage loss and wetted perimeter

4.3.3 Correlation between seepage loss and flow area

The data for seepage rate versus flow area also exhibited an exponential trend as shown in figure 7. The exponential relationship developed exhibited a coefficient of determination (r^2) of 0.78 and is displayed in figure 47 as well as Eq. (13).

$$S = -0.802e^{0.156A} \quad (13)$$

Were S = percent seepage loss (%) and A = flow area (m^2)

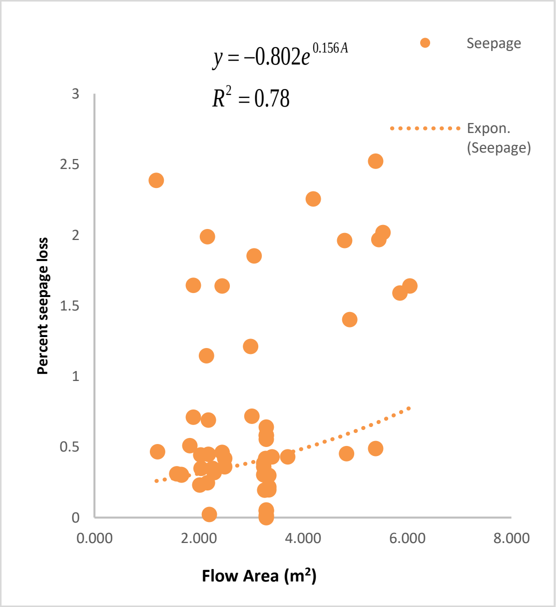

Figure 7: Relationship between seepage loss and flow area

4.3.4 Correlation between seepage loss and hydraulic radius

The data for seepage rate versus hydraulic radius also exhibited an exponential trend figure 8. The exponential relationship developed exhibited a coefficient of determination (r^2) of 0.82 and is displayed in figure 4.8 as well as Eq. (14).

$$S = -0.7324e^{0.1790H} \quad (14)$$

Were S = percent seepage loss (%) and H = hydraulic radius (m)

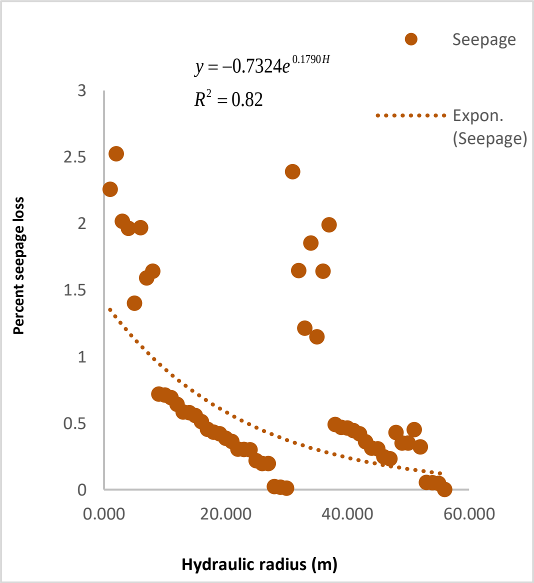

Figure 8: Relationship between seepage loss and hydraulic radius

Overall, the four developed equations display similar exponential trends. The variation in the collected data is minimal and four equations are significant as the coefficient of determination (r^2) is not <0.76 for any of the developed equations. These equations present the opportunity to predict canal seepage losses based on the four easily measured parameters inflow rate, wetted perimeter, flow area, and top width.

5. DISCUSSIONS

This study was undertaken to assess the impacts of hydraulic parameters of the channel on the water conveyance losses. The experimental site was selected in Rechna Doab. The site is located in the command area of Chenab and Ravi rivers. The research was conducted in the area of Faisalabad irrigation zone. The purpose of this study was to assess the impacts of these parameters and to investigate the seepage loss from the channel and compare the seepage losses of the pre and post lining of the

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channel. The Inflow-outflow method was used for the measuring of inflow and outflow, and outlets discharge of the channel. The discharge of inflow and outflow was measured by using the current meter. At different points in the channel, the value of width and depth were measured and then using different formulas of the hydraulic parameters such as cross-sectional area, wetted perimeter, hydraulic radius, bed slope, flow velocit**y,** etc and obtain their values. Maps of the experimental sites were obtained from the Punjab irrigation department, Lahore. The data regarding water channel design data, existing data and proposed data, the total length of lining, the natural surface level of the channels, full supply level of the channels and the measured value of seepage losses of the channel before lining. Integrated agriculture is the largest water consuming sector in the world. Increasing demands and competition for water with other sectors make it vulnerable to save the water. The overall objective of this research is to assess the impacts of hydraulic parameters of water channels in Faisalabad irrigation zone. The hydraulic parameters data results obtained for channel seepage are reasonable. From the collected data four predictive equations for canal seepage were developed in the present study.

$$S = 0.6545e^{-0.6235V} \quad (1)$$

$$S = -0.327e^{0.017P} \quad (2)$$

$$S = -0.802e^{0.156A} \quad (3)$$

$$S = -0.7324e^{0.1790H} \quad (4)$$

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