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RELATIONSHIP BETWEEN SEEPAGE AND DISCHARGE FOR KABUL RIVER IN DISTRICT NOWSHERA

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ABSTRACT

Seepage from rivers is one of the major problems involved in the water-logging of adjacent area to the river. However, the advantage of conserving water is indispensable as freshwater resources are declining. The Kabul River is one of the main rivers in Khyber Pakhtunkhwa, Pakistan. It transports poor quality water and discharges it in the Indus River at district Attock. Its long portion is passing through sandy clay soils. The quantity of discharge varies along its length at different sections. Eight years (2005-2012) monthly discharge data was used to calculate seepage losses. The seepage losses ($m^3s^{-1}km^{-1}$) along the length of river were calculated by using relationships presented by Nazir Ahmad, Molesworth and Yennidunia (Egyptian), and Pakistani Formula. An average value of these three equations was plotted against the discharge of Kabul River to develop Linear Logarithmic and power relationships. The seepage losses calculated using equation given by Nazir Ahmad were higher followed by Molesworth and Yennidunia (Egyptian), and Pakistani Formula.

Keywords: Discharge, river, seepage losses, water-logging.

INTRODUCTION

With the increasing demand of water supplies, the available freshwater is becoming significantly scarce and it will be harder to find new freshwater sources supplies in near future. The time is rapidly approaching when the only freshwater supplies available will be from unusable transpiration, evaporation, consumptive waste, inefficient storage and transportation practices. Seepage from the irrigation channels is a significant loss of freshwater which can be greatly reduced by following conservation practices.

The principal factors affecting seepage from an alluvial river/canal are attributed to nature of soil material, deposition of silt, groundwater table with respect to

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canal water surface, depth of water in canal, hydraulic conductivity of the soil, inflow of seepage water and chemistry of the soil and water. Although, in many parts of the world, seepage has posed a problem, admittedly of varying significance when these factors vary from place to place and population to population, relative land and water available resources (Bakry and Awad, 1997).

When the water table is very deep, the seepage loss from a canal in a homogeneous and isotropic porous medium can be expressed as (Swamee *et al.,* 2000):

$$q_s = kyF \quad ...(i)$$

Where:

q_s = seepage discharge per unit length of canal $m^2 .s^{-1}$
k = hydraulic conductivity of the porous medium $m .s^{-1}$
y = depth of water in the canal m
F = seepage function of channel geometry (dimensionless)

Ponding method is the most dependable and reliable method for measuring the quantity of water loss through seepage from the existing canals in a particular reach. It consists of construction of temporary water tight dyke of bulk head across the canal. The canal above the dyke is filled with water to a certain measured level. The level of water in the canal is recorded, after allowing the water to stand for some time. Any drop in the level is obviously due to seepage through the section of canal. Sufficient quantity of water is added the canal is to maintain its original level. This volume of water, which is measured accurately, is equal to total seepage loss during the particular time interval. The rate of seepage loss through the canal is equal to the volume of water divided by the time interval (Hameed, 2009). For the estimation of seepage, various methods are used from the proposed canals as well as its measurement in the existing ones (Netz, 1980). For proposed canals, seepage is usually estimated by empirical formulae or by graphical solution. The various important methods used for seepage from existing canals are usually evaluated by direct measurements such as inflow-outflow, ponding and seepage meter methods (Sarki *et al.,* 2008).

Mowafy (2001) applied different empirical formulae and analytical equations to evaluate seepage losses in the different sections of canal. Binnie and Partners (1980) published a report of the field study of seepage losses in the canal for the three stages and concluded that the maximum seepage losses occurred at a distance from 61 to 74 km. They found that the seepage losses in the first, second and third stages were: 1.9, 2.8 and 3.3 $m^3 s^{-1}$, respectively. Halim (1992) summarized different empirical seepage formulae and used them for evaluating the seepage losses in different Egyptian's canals.

ESTMIATION OF SEEPAGE LOSSES BY EMPIRICAL EQUATIONS

A number of empirical formulae are used to estimate seepage losses. Some of them are reproduced below:

Formula by Nazir Ahmad

Ahmad (2007) developed an empirical formula to calculate seepage losses in a canal for a given section. Seepage is function of discharge in a given length of canal and is reproduced below:

$$S = \frac{0.04 * Q^{0.68}}{56.81} \qquad ..01$$

Where:
S = Seepage losses in $m^3s^{-1}km^{-1}$ length of canal.
Q = Channel Discharge in $m^3.s^{-1}$

Formula by Molesworth and Yennidunia (Egypt)

Molesworth and Yennidunia used an equation quoted by Magdy (2001). In this equation, seepage is function of canal length, wetted perimeter, its hydraulic radius and a soil factor that varies with soil type. Seepage is calculated as:

$$S = C * L * P * R^{0.5} \qquad ..02$$

Where:

S = the conveyance losses for a given canal length m^3s^{-1}
L = the canal length in km
P = the wetted perimeter in m
R = the hydraulic radius in m
C =the factor depends on soil types, for clay 0.0015 and for sand 0.003.

Pakistani Formula

This formula has been quoted by Kavita and Khasiya (2014). Seepage losses are related to the discharge of a channel, length of channel and wetted perimeter of channel section. The formula is reproduced as:

$$S = \frac{0.142 * Q^{0.0652} * P * L}{10^6} \qquad ..03$$

Where:

S = Seepage losses in m^3s^{-1}
Q = Discharge in m^3s^{-1}
P = Wetted perimeter of wetted section in m
L = Length of channel in m.

Mortiz Formula USSR

Magdy (2001) quoted a formula known as Mortiz (USSR). Seepage losses are function of discharge of channel, its mean velocity and a constant. The value of this constant depends on soil type. The formula is reproduced below:

$$S = 0.0035 * C * \left(\frac{Q}{V}\right)^{0.5} \qquad ..04$$

Where:
S = Seepage losses in $m^3 .s^{-1} .km^{-1}$length of canal
Q = discharge $m^3 .s^{-1}$
V = Mean velocity m $.s^{-1}$
C = Constant value depending on soil type 0.34 for clay and 2.2 for sand soil.

Indian Formula

Kavita and Khasiya (2014) used a formula which was derived using the data taken on Indian channels. The seepage rate is related to water depth, area of wetted perimeter and a soil factor. The formula is reproduced as:

$$S = C * a * d \qquad ...05$$

where:
S = Seepage losses in m^3s^{-1}
d = Depth in m
a = Area of wetted perimeter in million m^2
C = Factor depends on soil types, (1.1-----1.8)

Davis and Wilson formula

A formula, to estimate seepage losses in lined and unlined canals, has been suggested by Davis and Wilson which has been quoted by Binnie and Partners (1980). Seepage losses are function of length, wetted perimeter, depth of water in canal, and velocity of flow. A constant depending on type of lining was introduced by them. The formula is given below:

$$S = 0.45 * C * \frac{P * L}{4 * 10^6 + 3650 * \sqrt{V}} * d\frac{1}{3} \; ...06$$

Where:
S = Seepage losses in $m^3m^{-1}day^{-1}$
L = Length of canal in m
P = Wetted perimeter in m
d = Water depth of canal in m

V = velocity of flow in m .s^{-1}

C = Constant value which depends on type of lining and varies between 1 and 10

METHODOLOGY

Study was conducted on the River Kabul, one of main rivers of Afghanistan and tributaries of Indus River. This river rises in the Sanglakh Range in Afghanistan. It is separated from the watershed of the Helmand by the Unai Pass. It flows for about 700 km and joins Indus River near Attock.The discharge data was obtained when river was flowing through its Pakistan section.

A view of the Kabul River (courtsy Google)

Data on monthly discharges of Kabul River were obtained from the Hydrology Section of Irrigation Department, Peshawar for eight years (2005-2012). This data was compiled, analyzed, and the seepage was estimated using three different approches by Ahmad (2007), Molesworth and Yennidunia and Pakistani Formula given in literature. The average values of discharge data was used to develop linear, logarithmic, and power relationships. These three equations were developed as a function of discharge and discussed in results section.

$$S = f\ (Q)$$

Where:
S = Seepage in $m^3sec^{-1}km^{-1}$ of river length
Q = Discharge in m^3sec^{-1}

RESULTS AND DISCUSSION

Seepage is defined as the process of movement of water from the bed and sides of the channel into the soil. It has main role to play in the total water available in a system. Its measurement or estimation is essential to evaluate the total quantum of water in a conveyance system that is to be used by agriculture, industry, and domestic purposes. Several empirical formulae have been developed and are reported in the literature. We applied three equations and estimated the seepage losses and the results are illustrated in Figure 1. The data in figure reveal that method proposed by Ahmad (2007) estimated seepage losses by about two times higher as compared to Molesworth and Yennidunia and Pakistani formulae.

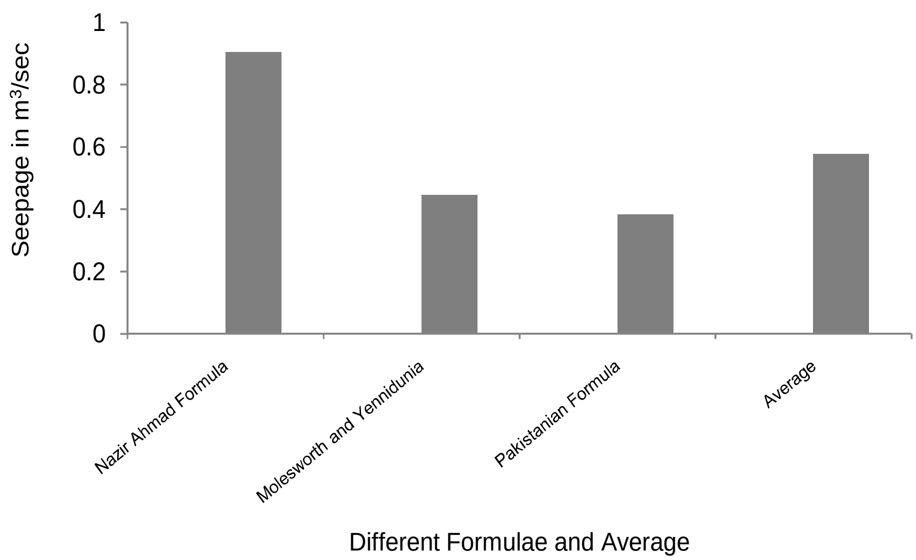

Figure 1. Seepage losses estimated using different formulae

The average value of seepage calculation were plotted against discharge. Linear, logarithmic, and power solutions were applied to develop equations. The data on average discharges were used to develop simple practical equations for seepage estimation suitable for the existing conditions of Kabul using three empirical equations used in this study. Three equations (linear, logarithmic and power) were developed based on monthly average discharge using eight years historical data, and each equation could be safely used according to the availability of river discharge in m^3s^{-1}.

Linear solution

The linear relationship between seepage and discharge is shown in Figure 2. There is strong positive correlation between seepage and average discharge. The coefficient of correlation R^2 value for linear equation is 0.99 which confirms this. These results suggest that the seepage losses increase with increasing discharge along the length of river.

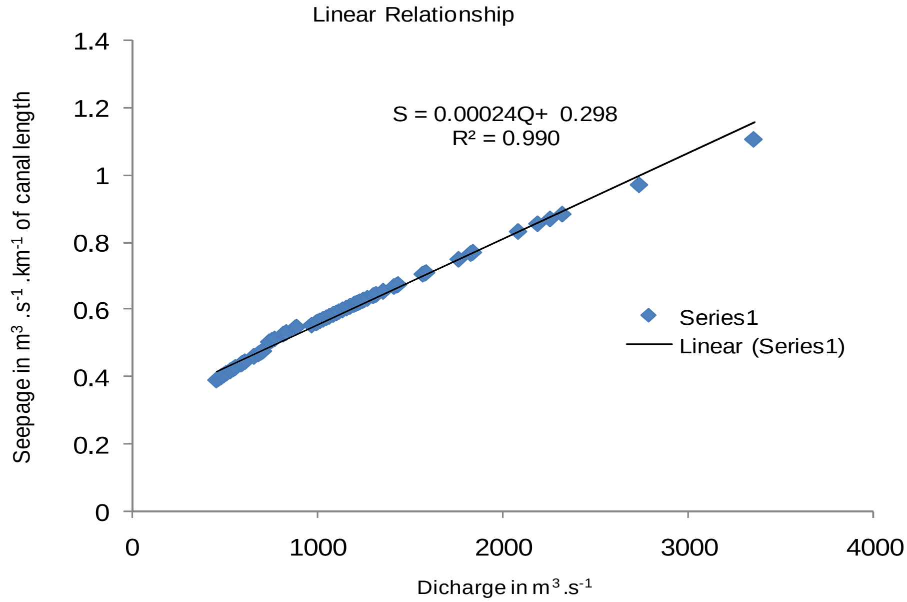

Figure 2. Relationship between seepage and discharge using linear solution.

Equation 7 below has been developed using linear solution to estimate seepage rate in m^3s^{-1} when discharge is in m^3s^{-1}:

$$S = 0.00024 * Q + 0.298 \qquad \ldots 07$$

Where:

S = Seepage in $m^3s^{-1}km^{-1}$ of river length
Q = Discharge in m^3s^{-1}

Logarithmic solution

The logarithmic relationship between seepage and discharge is shown in Figure 3. Figure shows a positive correlation within a certain range of discharges with R^2 value of 0.955 for logarithmic solution. These results suggest that the seepage losses increase with increasing discharge up to certain limit but then it becomes unreliable to estimate seepage losses that proposes a caution to use equation developed using logarithmic solution, particularly, for discharges less than 550 $m^3s^{-1}$and greater than 2250m^3s^{-1}.

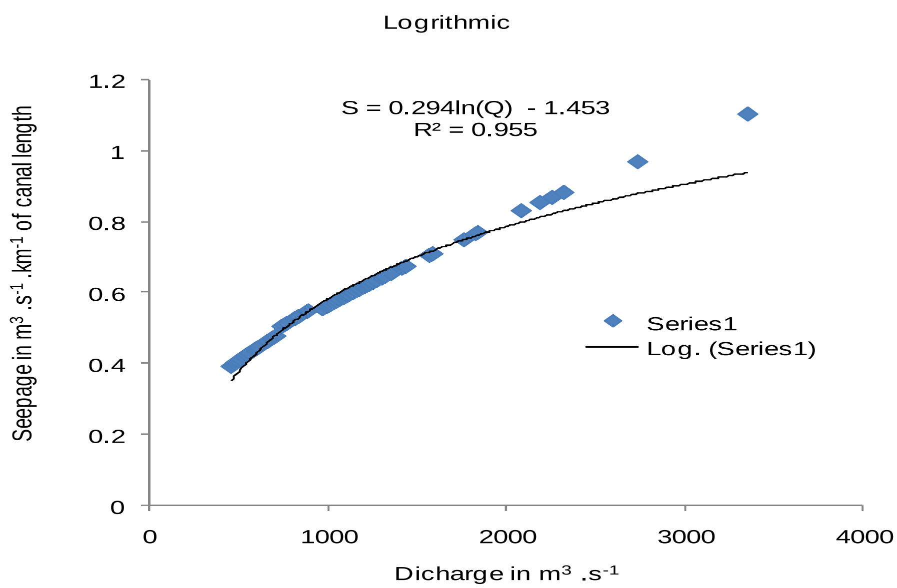

Figure 3. Relationship between seepage and discharge using logarithmic solution.

Equation developed using logarithmic solution to estimate seepage rate in m^3s^{-1} and discharge in m^3s^{-1} is given as:

$$S = 0.294 * ln(Q) - 1.453 \qquad ...08$$

Where:

S = Seepage in $m^3s^{-1}km^{-1}$ of river length
Q = Discharge in m^3s^{-1}

Power solution

The power relationship between seepage and discharge is depicted in Figure 4. Figure shows a positive correlation between seepage and average discharge. The coefficient of correlation R^2 value for power equation is 0.995 which reveals that seepage rate is function of discharge rate. These results suggest that the seepage losses increase with increasing discharge along the length of river.

However, for discharges greater than 3250 m^3s^{-1} the equation might under estimate the seepage losses, hence caution is required to estimate seepage for higher discharges.

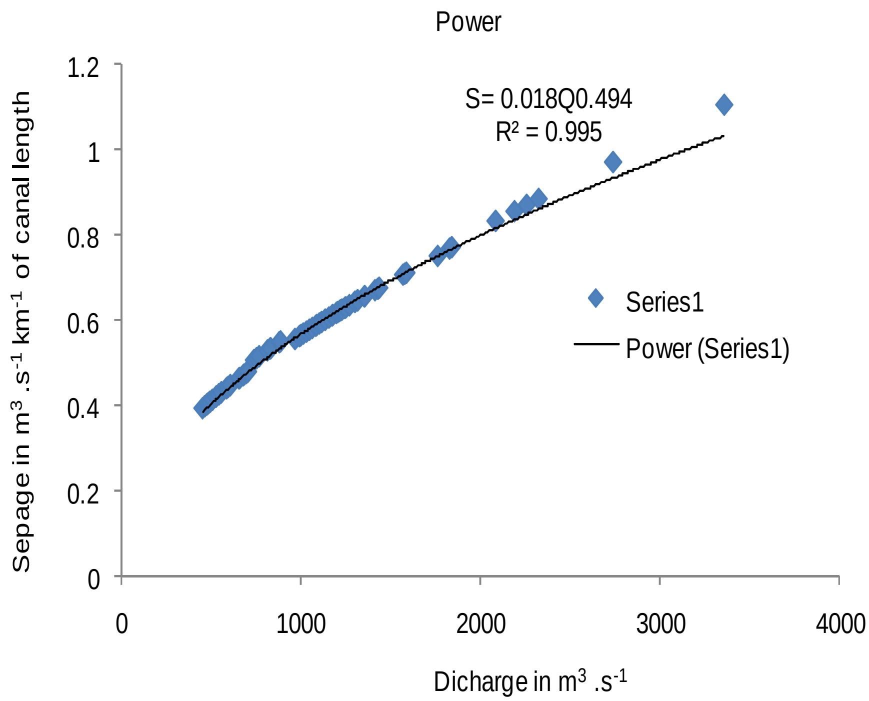

Figure 4. Relationship between seepage and discharge using power solution.

The equation given below had been developed that can be used to estimate seepage rate in m^3s^{-1}per kilometer length of river and discharge rate in $m^3.s^{-1}$.

$$S = 0.018 * Q^{0.494} \quad ...09$$

Where:

S = Seepage in $m^3s^{-1}km^{-1}$ of river length
Q = Discharge in m^3s^{-1}

CONCLUSION

Study was conducted on the River Kabul which is one of the main tributaries of Indus River. Kabul River is unlined and irregular shaped so analytical equations are sometimes difficult to use and may not provide estimates of seepage losses. Three empirical equation were used to estimate the seepage and then linear, logarithmic and power solutions were applied to develop regression equations for

Kabul River. The linear and power equations showed a highly positive correlation between seepage and discharge with coefficient of correlation R^2 value equal to 0.99 and 0.995, respectively. The linear equation could be used to determine seepage losses for higher values of discharge. Though, the coefficient of correlation R^2 value is maximum for power equation; however, it may not be suitable to estimate seepage losses for too high i.e. over 3250 m^3s^{-1} discharges. Almost similar trends could be seen for logarithmic equation where R^2 was 0.995. However, for logarithmic equation and power equations, some values of discharge i.e. greater than 3250 $m^3.s^{-1}$ and lower than 550 $m^3.s^{-1}$ could be unreliable to estimate seepage losses.

The main factor which largely influences the seepage losses is the soil factor that has not been considered here. But, the developed equations are based only on discharge which is a limiting factor for areas having different soil properties than those used in this study. The equations may be calibrated to use in the areas having different soil properties.

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