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Assessment of Seepage and Discharge relation for Canal in Pakistan

(Case study Pehur Main Canal at Swabi)

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Abstract

Pakistan is an Agricultural Country and crops required water. The efficiency of the water Conveyance structure besides other parameters also depends on seepage losses. Due to its Importance, it is an important component in the design of natural channels. As Pakistan will face Water crises in near future, therefore there is need to conserve each and every drop of water. Due To its scarcity, water will become a very important commodity. A large number of analytical Equations are available in literature that needs to be assessed for a particular canal. In this Research Study seepage has been calculated for Pehur main canal located in Swabi District of Khyber Pakhtunkhwa using 1) Field measurements, and 2) Four equation from available Literature, 3) newly developed equation from the collected data. In this study for estimation of Seepage analysis, Discharge was measured in the field and the evaporation data was obtained From Tarbela gauging Station. Using field data including discharge and other canal parameters, Regression-based equation for seepage analysis is developed for this particular region. The Equation developed for the Estimation of seepage in this area is based on not only geometrical And flow parameters but also on the soil properties because it is necessary for accurate Estimation of water losses in the Conveyance network. This equation is based on the inflow-Outflow discharge method and boundary Materials, and is valid for earthen canals having the Same geomorphology. Results showed that the Equation developed in this research study Performed better than all other equation including Nazir Equation.

Key words: *water losses, inflow-outflow method, earthen channels, gauging station, multiple Regression, climate changes.*

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Introduction:

Water is the most valuable resource for entire bio life living on the planet earth. According to Statistics, approximately 2.05% of total water is frozen in glaciers, 0.68% as groundwater, and 0.011% as surface water in lakes and rivers (Pidwirny, 2006). This water is available for human Consumption, agricultural production, industrial use and sanitation. People living in the under Developed countries are suffering due to water crisis, which is becoming a key global issue (Starkey, 2012), Pakistan is no exception, where water is dwindling at an alarming rate. Recent Assessments suggest that per capita availability of water has declined by 5 times from 5,260 m3 In 1951 to 1,038 m^3 in 2010 (PWAPDA, 2012; ORSAM, 2013). If this trend continues, then by 2026, Water availability would further drop to about 800 m^3 per annum (GoP-PC, 2007), while it Will Further decrease to an extremely low level of 575 m3 in 2050 (ORSAM, 2013). At present, Pakistan Is classified as water stress country and by the year 2025, it will turn into a water scared Country. Therefore, the country will have to face a major challenge in water sector in the years to Come. The problem of water shortage will aggravate further if the available water resources were Not managed properly and used efficiently. The water security of the country is therefore a very Critical issue. No doubt Pakistan possesses one of the world's largest contiguous irrigation Systems; which is ranked 5th in the world and 3rd in Asia and is known as Indus Basin Irrigation

System (IBIS).

The irrigation system, consists of 3 large dams/ reservoirs (Tarbela, Mangla and Chashma), 19 Barrages/ head works, 12 interlink canals, 2 major siphons, and 45 main canals about 64,489 oms Canals and distributaries carry water to 140,000 watercourses (Anonymous, 2010). Despite having This Well-established irrigation system huge amount of water is lost in conveyance system Creating Waterlogging and salinity problems. Out of 142 MAF of Annual River flows, about 92 MAF is diverted to the canal system, whereas about 31 MAF is lost in conveyance systems due To seepage (Anonymous, 2010).Seepage is the most dominant factor by which water is lost in the conveyance systems. The Accurate assessment of water losses from an irrigation conveyance system is vital for the proper Management of the system. Thus, quantitative information of seepage losses is indispensable. For Better operational planning and management of an irrigation system, an effective dependable Forecasting of the seepage is thus important. Seepage from canals, watercourses and small farm Channels is attributed to their earthen design, soil texture, silt deposition, groundwater table with Respect to water surface in the channels, depth of water in canal, and hydraulic conductivity of the Soil. Estimation of seepage losses is essential to make decisions while designing an irrigation Channel or allocating water supplies at the head of canal. Inflow-Outflow method has been used As bench mark method (Sarki et al., 2008). In this method actual discharges are measured between Two selected points on a channel. Seepage from canals occurs due to a combined effect of Gravitational force and water tension gradients (Hansen et al., 1980). According to Ali (2011) the Conveyance efficiency in irrigation projects is poor due to seepage, percolation, cracking and Damaging of the earth channel. Seepage losses in irrigation water conveyance system are very Significant, as it forms the major portion of the water loss in the irrigation system. The geometric Factors involved in the estimation of the seepage are the shape and dimensions of the irrigation Channel and the depth of the water table and the depth to an impervious layer etc. Sarki et al. (2008) Measured water losses in watercourse by ponding test method and inflow–outflow methods And found that losses were higher by 23% in ponded method. Bahramloo (2011) observed that the Water seepage losses in canal were between 5.41% and 22.4% per 1 km (1.12 to 2.95 m per day).Seepage rates are attainable either by direct measurement or indirectly by estimation. Various Methods are used to estimate the canal seepage rate such as empirical formulae, analytical or Analogue studies and the direct seepage measurement techniques, i.e. seepage meters, ponding Tests and inflow–outflow tests. These methods have their merits, demerits and limitations which Are well understood. Direct measurements are based on obtaining discharge measurements at Different Location along the earthen channel while in indirect methods, prediction can be made By empirical Formulas. Mowafy (2001) computed seepage losses by applying empirical formulas That were based on measured values of seepage obtained through different field methods. Seepage Is not only Wastage of water, but also may lead to other problems such as waterlogging and Salinization of Agricultural land by rising water table. Canal seepage varies with: the nature of the Canal lining; Hydraulic conductivity; the hydraulic gradient between the canal and the surrounding Land; Resistance layer at the canal perimeter; water depth; flow velocity; and sediment load. Seepage Rates are obtainable either by direct measurement or by estimation.Karad MM, Panke RA (2013) the studies on Estimation and measurement of seepage losses were Of much Interest to the irrigation scientist. The Research workers have done lot of work on the Seepage Aspect of the irrigation water Management. The attempt has been made to review the Research Work done in the past in respect Of evaluation and determination of seepage losses Through canals. Luthra (1980) found that the conveyance losses in the unlined canals varying between 25-60 Percent and the seepage losses in case of lined canal system were restricted depending on type of Material used for lining. Raju (1980) reported seepage loss from lower Bhavani distributor as 16 To 20 percent of the canal discharge. Bihari and Patel (1986) studied the conveyance losses in earthen channel and concluded that apart From steady state seepage, there could be a significant transit loss component that is not measured In steady state measurements. The Quantification Of seepage Rate in relation with its driving forces is necessary to estimate e.g. The effect of Different sizes in Terms of channel geometry on seepage. Keeping in view the above Facts, this Research has been conducted to estimate seepage losses using empirical equations and Compare With those measured through direct field method (i.e. Inflow-Out flow method). The objective of the present study is a continuation of seepage studies by reanalyzing extensive Field data measurements along earthen canal located in the Khyber Pakhtunkhwa area of Pakistan, For proposing simple practical equations of seepage estimation suitable for the existing condition And based on the inflow–outflow method.

Methods and Sites:

To quantify the seepage losses from earthen canals along Pakistan irrigation networks, one Conveyance canal was chosen in the north western region of Pakistan, as they proved to be Suffering from seepage problems in certain reaches. This canal regularly provide water for Irrigation and domestic use all the year. Figure 1 represents a schematic map showing the location Site for carrying out field measurements. Currently accepted methods of measuring seepage losses Are limited to inflow-outflow, ponding and seepage meter determinations. Each method has its Advantages and limitations. No single method is adaptable to all conditions of canal operations Encountered in the field. The ponding method may be the most accurate and dependable method, Especially suitable when the canal is small and not a conveyance, while the inflow-outflow method Of seepage measurement is quite accurate in long reaches and conveyance channels. However, as The selected earthen canal under investigation are conveyances, the inflow-outflow method is Chosen as the most suitable for the determination of seepage losses. For the present study, the field

Work was divided into two parts:

- Field measurements which include inflow-outflow rates, geometrical parameters of canal cross-sections and collection of soil samples.

- Laboratory tests to determine the physical properties of the collected soil samples.

Figure 1. Layout and cross sections of study area

Measurement of seepage losses by direct field method

The inflow-outflow method is considered one of the practical and reasonably accurate methods Under dynamic flow conditions suited to actual field conditions. In present study, this method was Used to measure seepage losses in an unlined canal and used as bench mark method due to its Performance over time and advantage of applying in flowing condition in the water channel. The Method involves measurement of discharge at two points. The initial point was considered as Inflow and the other point at a downstream side as outflow. The discharge at both points was Determined by using Velocity Area method. In this method Velocity at different sections was Determined by Current meter as shown in the Figure 2 below while area was calculated from the Cross section.

Figure 2. Current Meter Reading

Average velocity was estimated by averaging the velocities taken at each sub section of a section As shown in Figure 3. Velocities taken at extreme sub section using one point method while in Between using two point method.

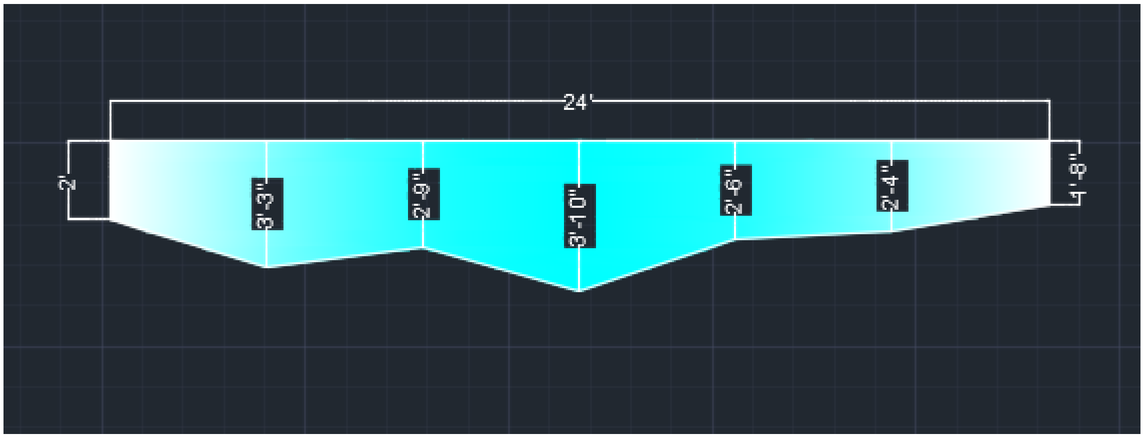

Figure 3. Cross sectional area of flow

Velocity area Method:

The velocity-area method is the most common method of estimating river flow. As the term Implies, the flow is the product of the average velocity in the cross-section and the cross-Sectional area of flow.

Q = A* V

Where,

Q : Discharge/Flow in canal

A : Cross sectional area of flow

V : Average Velocity

The seepage losses were determined using following equation:

S = Inflow - Outflow

Measurement of hydraulic parameters of selected Canal

Hydraulic parameters of selected canal was measured and are presented in Table 1. First the Average velocity was find out by taking the average of all the readings in one section, it consist of One point method and two point method, Two point method was used in the center of the canal While one point method was used in the extremes of the canal. Cross sectional area and wetted Perimeter were calculated from the sections drawn in AutoCAD. Hydraulic Radius was estimated By division of Area and perimeter, and the Flow/ Discharge was calculated by the product of the Area and average velocity. Soil constant was taken from the table after the soil was tested in the Laboratory.

Canal Reach	Area	Wetted Perimeter	Hydraulic Radius (R=A/P)	Avg Flow Velocity	Flow/Discharge	Soil Constant
M	m^2	m	M	m/sec	m^3/sec	C
0+000	10.32	22.78	0.45	0.17	1.79	0.0015
0+140	5.57	19.19	0.29	0.32	1.78	0.0015
0+310	4.63	17.23	0.27	0.38	1.76	0.0015
0+490	5.61	18.09	0.31	0.30	1.73	0.0015
0+650	5.44	18.47	0.29	0.31	1.70	0.0015
0+740	5.40	20.36	0.26	0.31	1.70	0.0015
0+860	5.80	18.15	0.32	0.29	1.70	0.0015
0+970	6.06	15.89	0.38	0.28	1.69	0.0015
1+045	5.33	18.11	0.29	0.32	1.68	0.0015
1+175	6.99	18.82	0.37	0.24	1.67	0.0015
1+245	5.95	17.90	0.33	0.28	1.67	0.0015
1+385	5.57	18.37	0.30	0.29	1.66	0.0015

1+520	5.90	17.82	0.33	0.28	1.65	0.0015
1+670	4.55	15.79	0.29	0.36	1.63	0.0015
1+835	5.71	17.95	0.31	0.28	1.61	0.0015
2+015	5.44	17.78	0.30	0.29	1.58	0.0015
2+180	4.29	15.62	0.27	0.36	1.56	0.0015
2+345	4.56	15.47	0.29	0.34	1.54	0.0015

Table 1. Hydraulic parameters of selected Canal.

Empirical Formulae used for seepage losses estimation:

Four empirical equations were used in this stud, which are discussed as following;

i) Moles worth and Yennidunia (Egypt)

$$S = C * L * P * R^{0.5}$$

Where,

S : Conveyance losses for a given canal length in m^3/sec

L : Length of the canal in km,

P : Wetted perimeter in m,

R : Hydraulic radius in m, and

C : Constant depends on soil types, for clay equal 0.0015 and for Sand equal 0.003.

ii) Mowafy (2001)

Mowafy also developed another equation and analyzed seepage losses from unlined canal in the Northern Indus Basin in Pakistan. In this equation, relationship between seepage losses per canal Mile and channel discharge is given as follows:

$S=0.04Q^{0.68}$

Where,

S : Seepage loss in cusec per channel mile

Q : Channel discharge in cusec

iii) Nazir Ahmad Formula

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:

$S= (0.04*Q^{0.68}/56.81)$

Where,

S : Seepage losses in m^3/s/km length of canal.

Q : Channel Discharge in m^3/s

iv) Pakistani Formula

S = 5.Q^0.0652.P.L/10^6

Where,

S : Seepage losses;

Q : Discharge **(**ft^3/sec**)**

P : Wetted perimeter in feet and

L : Length of channel in feet.

Results of Data Analysis:

Owing to the main objective of the present study, the experimental and field measurements along The reach of the selected canal was carried out and the variables covering in the measurement data, Flow parameters, and seepage values, were also calculated. Results of soil analysis showed that The Boundary materials for both bed and banks of the selected reach was sandy to sandy clay soil. The graph shows that Nazir Ahmad equation has a good value of R^2 i.e. (0.51) which is greater Than that of remaining three empirical equations (Moles worth & Yunnidunia, Mowafy and Pakistani Equation). The developed equation shows (R^2= 0.99) which is even greater than Nazir Ahmad Equation. The statistical performance of this equation is quite reliable and results shows That it is linearly fit with the model values as shown from the table 2. The below equation is Developed from the graph which is having good value of R-square and very less value of Root Mean square error (RMSE).
S = 0.0004Q + 0.0003

Method	**Equation**	**R-Square**	**RMSE**
New Developed	y = 0.0004x + 0.0003	0.9999	0.000241
Moles worth and Yennidunia	y = -0.0006x + 0.003	0.0069	0.003663
Mowafy	y = 0.0047x + 0.0111	0.3183	0.014265
Nazir Ahmad	y = -0.0886x + 0.1647	0.5182	0.028151
Pakistani	y = -8E-05x + 0.0005	0.004	0.039546

Table 2. Results of Different equations

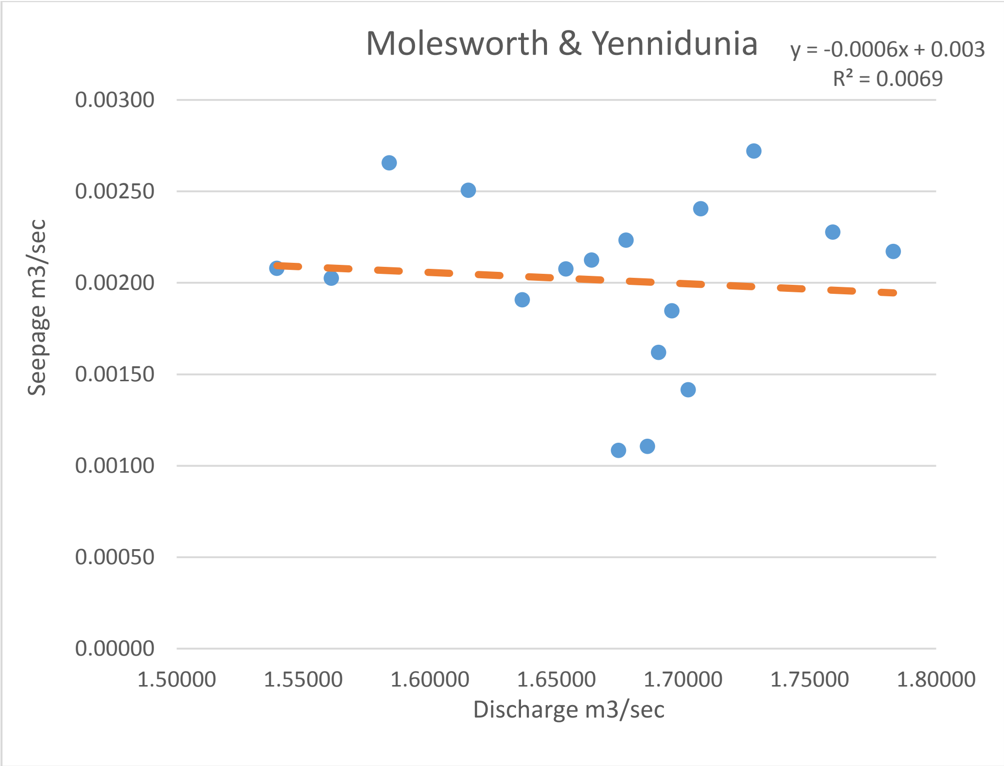

Figure 4. Moles worth & Yennidunia Equation

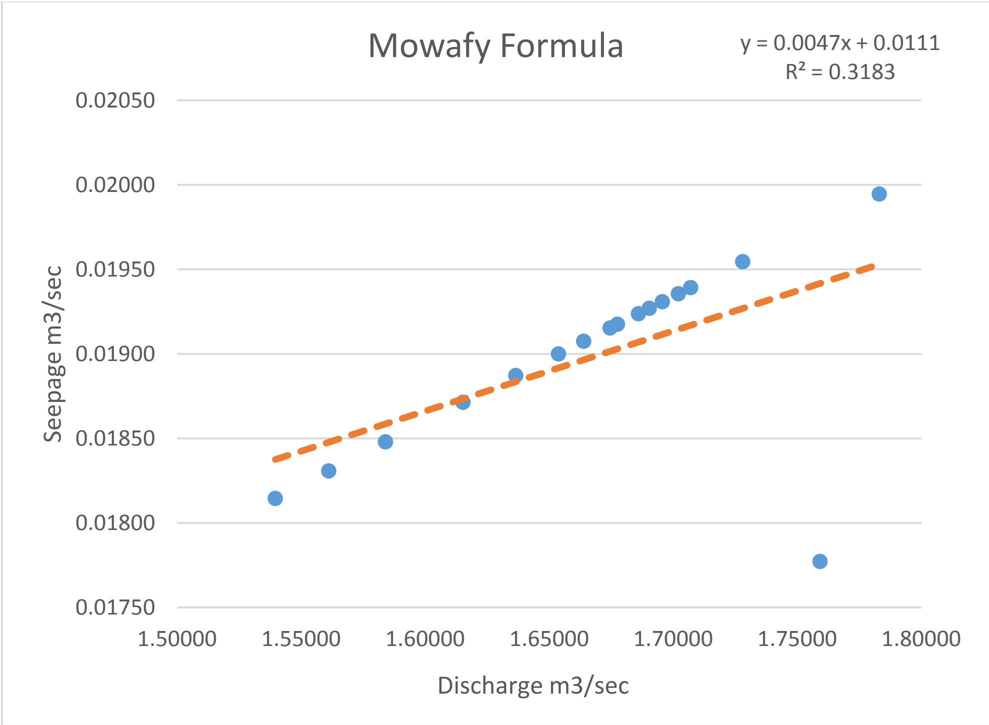

Figure 5. Mowafy Equation

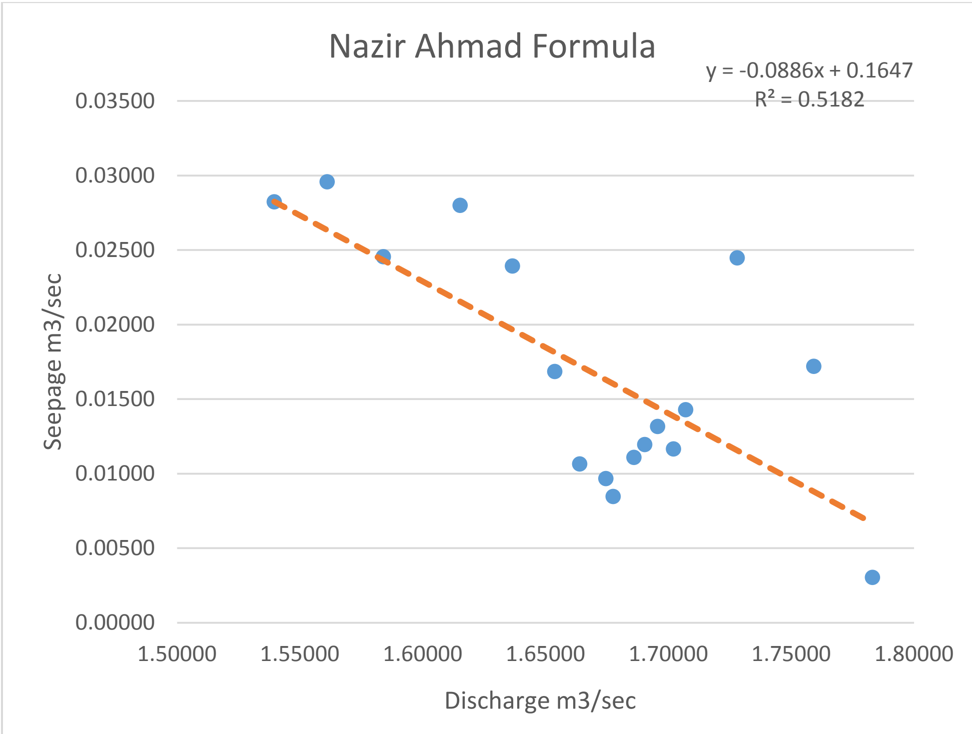

Figure 6. Nazir Ahmad Equation

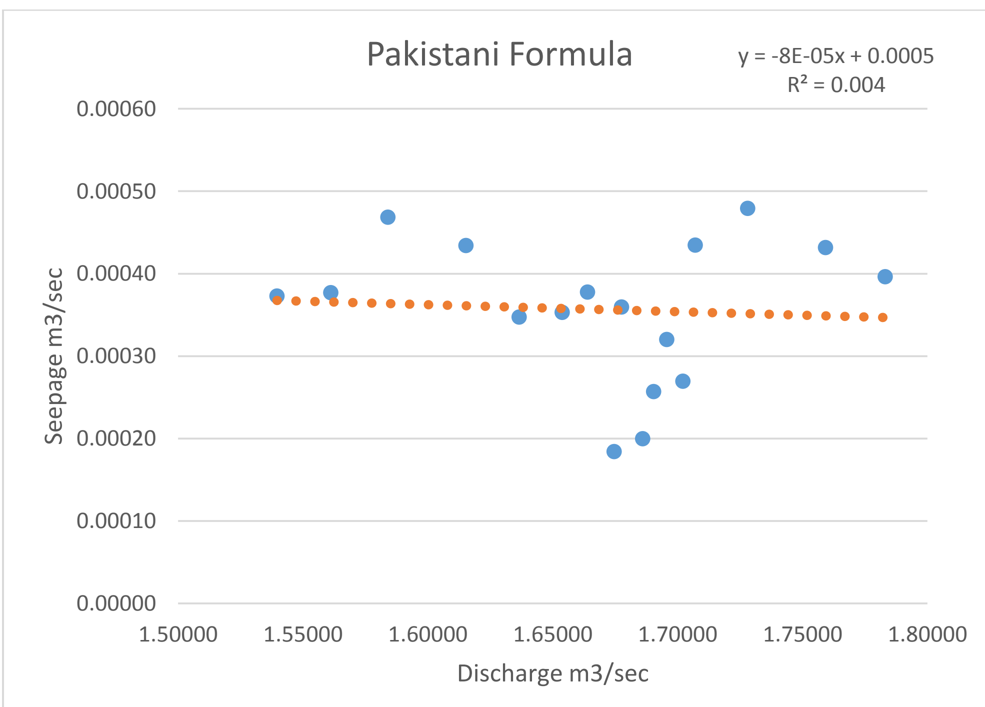

Figure 7. Pakistani Formula

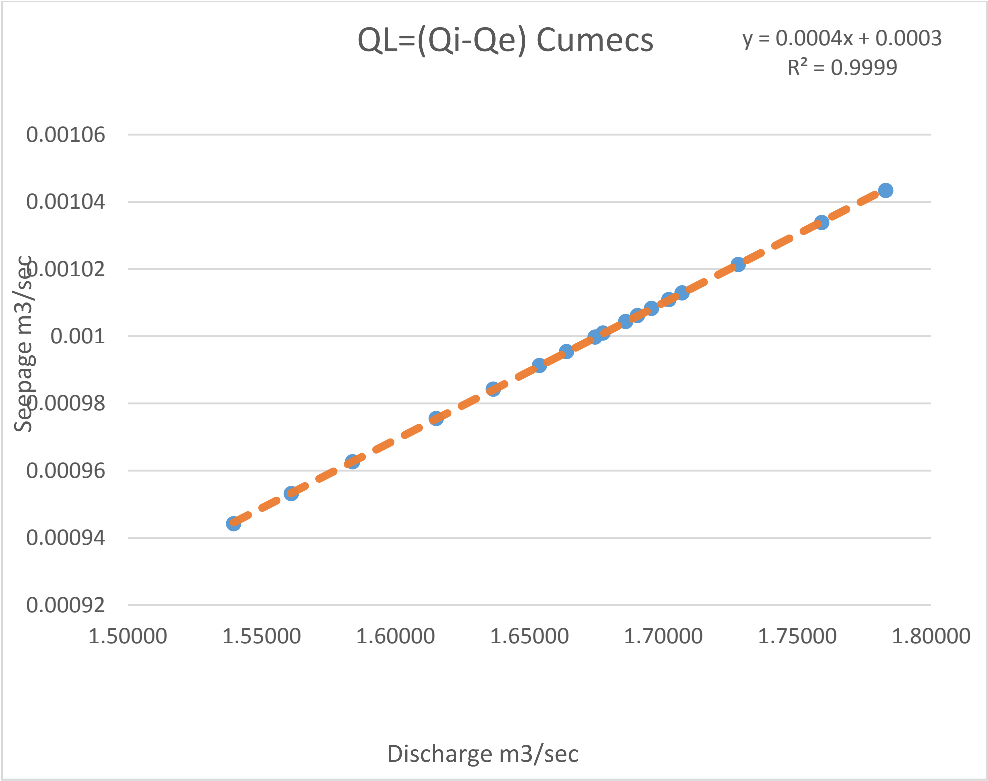

Figure 7. Developed equation Graph

Conclusion:

The Pakistan formula does not consider any other hydraulic or soil parameters except discharge For seepage computations. It appears that only discharge is not enough to estimate seepage losses. Hence, this equation cannot be used for seepage losses estimation for clay loam soil. The results Of this study may be supposed to be referred by the scientist decision makers for further research. We recommend using this newly developed equation for computing Seepage losses in all canals Of Pakistan which are similar (same Geomorphology) to Pehur Main Canal.

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