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A Model for Calculating the Rate of Seepage and Irrigation Channel Transition Efficiency

Kaveh Ostad-Ali-Askari[1*], Mohammad Shayannejad[2], Saeid Eslamian[2], Vijay P. Singh[3], Nicolas R. Dalezios[4], Morteza Soltani[5], Shahide Dehghan[6], Mohsen Ghane

[1]*Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran.*

[2]*Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran.*

[3]*Department of Biological and Agricultural Engineering & Zachry Department of Civil Engineering, Texas A and M University, 321 Scoates Hall, 2117 TAMU, College Station, Texas 77843-2117, U.S.A.*

[4]*Laboratory of Hydrology, Department of Civil Engineering, University of Thessaly, Volos, Greece & Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens, Athens, Greece.*

[5]*Department of Architectural Engineering, Shahinshahr Branch, Islamic Azad University, Shahinshahr, Iran.*

[6]*Department of Geography, Najafabad Branch, Islamic Azad University, Najafabad, Iran.*

[7]*Civil Engineering Department, South Tehran Branch, Islamic Azad University,Tehran,Iran.*

Corresponding Author:** ***Dr. Kaveh Ostad-Ali-Askari*, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran. Email: Koa.askari@khuisf.ac.ir*

Abstract: *Seepage problem and channel transition efficiency is one of the most important issues in managing and exploiting irrigation networks. Seepage rate should be minimized in the design and construction of irrigation channels. Anyway several methods have been represented to calculate seepage rate. Some methods that are numeral have their own complexity, and some methods are empirical. Due to the fact that the nature of the flow in the channels and the seepage of the walls are spatially varied flow, in this study, the governing dynamical equation is used and combined with the Chahar and Swamee equation. The final differential equation is solved by finite difference method (FDM), and the depth and flow rates of different cross sections of a channel are obtained. From the difference of flow rate in two cross sections, the seepage flow rate can be calculated. The information required for this method is the flow rate and flow depth at a downstream control channel, the hydraulic conductivity of the channel bed, the geometric characteristics of the channel, and the distance between the water table and the bottom of the channel. This model can be used for calculation of the transmission efficiency too.*

Keywords: *seepage, transition efficiency, the spatially varied flow*

1. INTRODUCTION

The problem of water loss from the channels is one of the most important issues to be considered in the design, management and exploitation of irrigation networks. This becomes especially important in drought conditions. Water losses from the channels involve seepage from their body and evaporation from the free surface of the water. As these losses increase, water transition efficiency decreases. In the earth channels, the majority of losses are due to penetration or seepage from the channel body. The losses due to evaporation are of particular importance in drought areas like the central plateau of Iran. Efforts have been made to calculate the seepage rate from the channels. Solutions for groundwater seepage problems have been developed since the pioneering work of Henry Darcy (1856). Subsequently, analytical solutions were presented by Harr (1962) and Polubarinova (1962). In general, the groundwater seepage problem can be solved by combining the Darcy law and the continuity equation. To obtain the equation some assumptions, such as Dupuit-Forchheimer assumptions, has been used. The resulting equation is a three-dimensional differential equation, and since the seepage is a three-dimensional phenomenon, the equation must be written and solved in three dimensions or at least in two dimensions. (In this section, the equation is known as the seepage equation). Generally, the methods for calculating seepage can be divided into two categories:

- Approximate and empirical methods: such as Muscat, Andronikov, Echevarria and Subramanian ways. In these methods, some information is required such as geometric characteristics of the channel, bedding features and groundwater depth. New empirical methods have been proposed by Chahar (2000) and Swami et al. (2001), they used this method to provide an optimal design of channels based on minimum seepage in 2002.
- Numerical methods: In these methods, the differential equation governing the seepage flow is solved numerically, which is referred to in several examples below:

Richardson (1911) introduced finite difference method, and Neumann and Witherspoon (1970) presented the finite element method (FEM) for solving the equation. Liggett (1977) presents the boundary element method (BEM). Boundary Element Method (BEM) is used to write equations for the location of discrete points on the free surface. Therefore, this method can determine the location of the water surface without solving the complete problem. Hartono (2002) used the numerical finite difference method (FDM) to solve the seepage equation for an irregular environment. In this method, the environment becomes an equivalent regular form.

In this research, a method for calculating seepage flow rate is presented based on the combination of the dynamical equation governing the spatially varied flow and the seepage equation of the Chahar and Swamee. Until now, the spatially varied flow equation has not been used to calculate the seepage flow rate from the channels, but to study the flow in perforated pipes (such as drainage pipes) it has been used by Kuchakzadeh et al. (2004).

2. METHODOLOGY

The equation governing the spatially varied flow can be deduced from the Saint-Venant equations, in the case of major water leakage (such as the seepage flow), which results in the following:

$$\frac{dy}{dx}=\frac{S_0-S_f+\dfrac{2Q.q}{g.A^2}}{1-Fr^2} \tag{1}$$

In this equation, A=the flow section, y= depth of flow in channel, S_0= bed slope of channel, S_f = friction slope, Fr = Froude number, Q= flow rate, q= the water flow rate per unit length of channel (seepage flow rate) and x indicates the direction of the flow.

The amount of seepage flow rate can be calculated from the following equation [11]:

$$q=K.F_s.y \tag{2}$$

In this equation, k=hydraulic conductivity of the porous medium and F_s = dimensionless seepage function.

Equations (1) and (2) can be used in any systems. Chahar and Swamee provided dimensionless seepage functions for different channels. As an example for rectangular channels, as follows:

$$F_s=\left(\left(\frac{2.5(b/y)^{0.84}+0.45}{(d/y-1)^{0.69}}\right)^{2.38}+((4\pi-\pi^2)^{0.77}+(b/y)^{0.77})^{3.094}\right)^{0.42} \tag{3}$$

In the above equation, b= bed width of the channel and d= depth of drainage layer

The following equation is obtained by combining equations (1), (2) and (3):

$$\frac{dy}{dx}-\frac{Q^2}{gA^3}\frac{dA}{dx}-\frac{2Q}{gA^2}K.F_s.y-S_0-S_f=0 \tag{4}$$

To obtain the equation (4), the Froude number in equation (1) is presented like: $Q^2/gA^3.dA/dy$ (g= Gravity acceleration). To calculate the friction slope, the Manning equation is used as fol

$$S_f=\left(\frac{n^2Q^2P^{4/3}}{A^{10/3}}\right) \tag{5}$$

In the above equation, n= Manning's Roughness Coefficient and the P= the wetted perimeter

The differential sentences of equation (4) are separated in terms of the finite difference method, and the other sentences are written as a mean of two consecutive points:

$$\frac{dy}{dx}=\frac{y_{i+1}-y_i}{\Delta x}\quad,\qquad \frac{dA}{dx}=\frac{A_{i+1}-A_i}{\Delta x}\tag{6}$$

The separated form of equation (4) is as follows:

$$y_i+\frac{\Delta x.Q_i.q_i}{gA_i^2}-\frac{Q_{i+1}^2.A_i}{2g.A_{i+1}^3}+\frac{Q_i^2.A_{i+1}}{2g.A_i^3}-\frac{Q_i^2}{2gA_i^2}-\Delta x.S_{f_i}/2-y_{i+1}+\frac{\Delta x.Q_{i+1}.q_{i+1}}{g.A_{i+1}^2}+\frac{Q_{i+1}^2}{2g.A_{i+1}^2}$$
$$-\Delta x.S_{f_{i+1}}/2+S_0.\Delta x=0\tag{7}$$

In the equation (7) y_i and Q_i are known (as a result the friction slope, the flow section and the seepage flow rate per unit length at the "I" point are known, since they all depend on the depth of the flow), y_{i+1} and Q_{i+1} are unknown. Therefore, another equation is needed. This equation is based on the conservation of mass law. The difference between the flow rates of two successive sections is equal to the seepage flow rate:

$$Q_{i+1}-Q_i=\frac{q_i+q_{i+1}}{2}\Delta x\tag{8}$$

By combining equations (7) and (8) a nonlinear equation can be obtained that can be solved by the Newton-Raphson iteration method. To do this, the depth and flow rate must be clear at a control section. Because the flow in the channels is sub-critical, this point of control should be at the downstream and the calculations should be started from the downstream. Finally, in each section, the depth and flow rates are calculated. Then, the amount of seepage flow rate can be calculated from equation (8). MATLAB software should be used for all calculations.

3. Conclusion

At the downstream of a wide 2 km long channel, with a width of 20m and a slope of 0.0005 and a Manning's Roughness Coefficient of 0/025, a bore is installed and it shows the flow rate 20 cubic meters per second. At this section of control, the flow depth is 1.73m.

The hydraulic conductivity of the channel bed is 3.14m / day and the static surface is located at high depths ($d\rightarrow$ infinite).

By solving equations (7) and (8), the depth and flow rate are calculated and the results are presented in Fig. 1. According to this figure, it can be said that the flow rate variations are linear and its amount at the upstream end of the channel is 22.01 cubic meters per second. Therefore, the amount of seepage within 2 kilometers is 2.01 cubic meters per second. Thus the transmission efficiency is 91%. The depth of flow has increased from the upstream to downstream in spite of seepage, because according to equation (1), if we neglect bed slope of channel and the friction slope and given that the Froude number is less than one, the right side of the equation will be positive, and the left side ($\frac{dy}{dx}$) should be positive too. So the flow depth increases in flow direction.

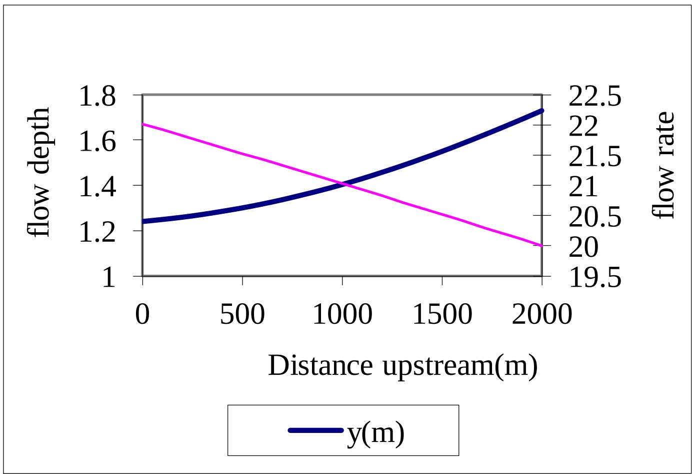

Figure1. *Changes in depth and flow rate in an earth channel*

REFERENCES

[1] Ostad-Ali-Askari, K., Shayannejad, M. 2015, Study of sensitivity of Autumnal wheat to under irrigation in Shahrekord, Shahrekord City, Iran. International Journal of Agriculture and Crop Sciences, 8 (4), 602-605.

[2] Shayannejad, M., Akbari, N., Ostad-Ali-Askari, K. 2015, Study of modifications of the river physical specifications on muskingum coefficients, through employment of genetic algorithm. International Journal of Development Research, 5(3), 3782-3785.

[3] Ostad-Ali-Askari, K., Shayannejad, M. 2015, The Reviews of Einstein's Equation of Logarithmic Distribution Platform and the Process of Changes in the Speed Range of the Karkheh River, Khuzestan province, Iran. International Journal of Development Research, 5(3), 3786-3790.

[4] Ostad-Ali-Askari, K., Shayannejad, M., Ghorbanizadee-Kharazi, H. 2015, Assessment of artificial neural network performance and exponential regression in prediction of effective rainfall, International Journal of Development Research, 5(3), 3791-3794.

[5] Shayannejad, M. Akbari, N. and Ostad-Ali-Askari, K. 2015, Determination of the nonlinear Muskingum model coefficients using genetic algorithm and numerical solution of the continuity. Int. J. of Science: Basic and Applied Research, 21(1), 1-14.

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