Pertanika J. Sci. & Technol. 1(1): 119-124 (1993)
ISSN: 0128-7680

Evaluation of Infiltration in Furrow Irrigation - Part 2 : Basic Infiltration Rate

T.S. Lee[1] and W.R. Walker[2]

[1]*Department of Field Engineering,*
Faculty of Engineering,
Universiti Pertanian Malaysia,
Serdang, 43400 UPM Selangor Selangor Darul Ehsan, Malaysia
[2]*Department of Irrigation Engineering,*
College of Engineering, Utah State University,
Logan, Utah, USA 84322

Received 24 June 1992

ABSTRAK

Komplikasi penentuan penyusupan didalam satu saluran furrow disebabkan ciri dinamik pengaliran air dan juga bentuk geometri saluran disamping faktur faktur lain. Penilaian penyusupan dalam sebuah furrow adalah penting demi untuk menilaikan penggunaan air dalam sistem sistem pengairan. Kegunaan persamaan Kostiakov dalam bentuk dipanjangkan dicadangkan untuk menentukan ciri ciri penyusupan dalam furrow. Akan tetapi, persamaan ini tertakluk kepada penilaian kadar penyusupan asas masa panjang, dimana ianya hanya ditentukan secara praktik melalui gerafhidro masuk keluar peristiwa pengairan yang susah dan memakan masa. Satu kaedah analisis yang berdasarkan teori gelombang kinematik dan data data aliran susupan dicadangkan untuk menilaikan kadar penyusupan asas yang penting untuk penentuan betul ciri ciri penyusupan aliran furrow.

ABSTRACT

Part 1 of this title was the simulation of the recession flow in a furrow. This part uses the recession simulation further to establish the basic infiltration rate in a furrow and, therefore, the infiltration characteristics in a furrow. Determining infiltration in a furrow is complicated by the dynamic flow nature of irrigation water, as well as the geometric shape of the channel, among other factors. The evaluation of this infiltration in furrows is important in order to evaluate the water use in such irrigation systems. The use of the Kostiakov equation in its extended form has been suggested for the determination of infiltration characteristics in a furrow. This equation, however, depends on the evaluation of the long-term basic infiltration rate, which can be determined practically by a long-term tedious inflow/outflow hydrograph of the irrigation event. An analytical method based on the kinematic wave theory and recession flow data is proposed here to evaluate the long-term basic infiltration rate pertinent to the correct evaluation of the infiltration flow characteristics in a furrow.

Keywords: Furrow, infiltration, recession flow

INTRODUCTION

The objective of this paper is to derive the analytical procedure to determine the basic infiltration rate in a furrow using field recession data.

The difficulty in associating a descriptive and simple relationship for soil water intake has been expressed and reiterated by many researchers. Many equations have been proposed, each taking into account the various conditions of the experiments. The difficulty in describing soil water intake is further compounded by the variable nature of the infiltration characteristics in both spatial and temporal dimensions.

Existing practical methods such as the single- and double-ring infiltrometers, blocked ponding for furrows, etc. have not only resulted in an unsatisfactory simulation of actual furrow infiltration but they are also time-consuming and costly. Most of the existing methods of evaluating infiltration consider stationary ponded water, whereas in furrow irrigation the infiltration characteristics are greatly influenced by the dynamic nature of flow, as well as the geometric shape of the furrow. With this consideration, Elliott and Walker (1982) investigated the extended form of the Kostiakov equation and suggested that the value of f_o, the long-term basic infiltration rate, can be determined independently of the time-dependent terms. The method is known as the inflow/outflow method. Another method involves utilizing data from blocked furrow tests. However, this method gives results whose magnitudes fluctuate too much. The other method of estimating f_o is based on referring to published values for the type of soil under consideration. The equation is the best solution for evaluating infiltration characteristics of the soil in furrows. In order to detrmine the soil constants of the equation, Christiansen *et al.* (1966) assumed a volume balance technique, which incorporates shape factors for the surface and subsurface flow profiles. Ley (1978) used an optimal search technique to determine the value of f_o in which advance rate and infiltrated volume were matched.

Now, the best method (Walker and Skogerboe 1987) is to use the extended Kostiakov equation and the two-point advance method coupled with a volume balance analysis. With this approach the advance flow trajectory was predicted through the use of the kinematic wave theory approach (Lee 1982). However, further use of this method can enable the exploitation of the recession flow data to be used to investigate the long-term basic infiltration rate as follows. This term is pertinent to the evaluation of the soil constants of the equation.

MATHEMATICAL DEVELOPMENT

Since the analytical solution of the recession flow in Part 1 of this paper is based on a value of constant basic infiltration rate $f_{o,}$ it offers an approximation method to determine the optimal value of this parameter. Equations 21 and 25 in Part 1 were derived to determined the recession times and the inlet flow depths during recession flow respectively (see *Fig.*

2 in Part 1). These equations are repeated here respectively in Equations 1 and 2 for convenience.

$$t_o^* = \frac{h_o^{*\sigma_2 - \gamma_2}}{\gamma_1(\sigma_2 - \gamma_2)} \tag{1}$$

and

$$h_o^* = \left\{ \frac{\gamma_1(m + 1 - \gamma_2)}{m + 1} X^* \right\}^{\frac{1}{m+1-\gamma_2}} \tag{2}$$

The characteristic recession time T' was defined as equal to R_o/f_o and the characteristic recession's "advance" was defined as

$$X' = \frac{Q\,0.06\,T'}{A\left(\frac{R_o}{y_o}\right)} \tag{3}$$

where Q is in litres per second, T' in minutes and X' in metres.

Since $t_r^* = t_r/T'$ and $x^* = x/X'$ where t_r and x are the time and location of the trailing end of recession respectively, T' and X' can be solved for with these four equations. Thus solving for a given field recorded (x, t_r) coordinate, we have

$$\frac{t_r}{T'} = \frac{1}{\gamma_1(\sigma_2 - \gamma_2)} \left\{ \frac{\gamma_1(m + 1 - \gamma_2)\sigma_1 y_o^{\sigma_2} R_o X}{(m + 1)Q0.06T' y_o} \right\}^{\frac{\sigma_2 - \gamma_2}{m+1-\gamma_2}} \tag{4}$$

Rearranging and with further simplification,

$$\frac{t_r}{T'} = \frac{1}{\gamma_1(\sigma_2 - \gamma_2} \left\{ \frac{\gamma_1(m + 1 - \gamma_2)\sigma_1 y_o^{\sigma_2 - 1} R_o X}{(m + 1)Q\,0.06} \right\}^{\frac{\sigma_2 - \gamma_2}{m+1-\gamma_2}} \left\{ \frac{1}{T'} \right\}^{\frac{\sigma_2 - \gamma_2}{m+1-\gamma_2}} \tag{5}$$

$$T' = \left\{ \frac{1}{t_r \gamma(\sigma_2 - \gamma_2)} \right\}^{\frac{1}{\frac{\sigma_2 - \gamma_2}{m+1-\gamma_2} - 1}} \left\{ \frac{\gamma \, 1(m+1-\gamma_2)\sigma_1 y_o^{\sigma_2 - 1}}{m + 1Q0.06} X \right\}^{\frac{\sigma_2 - \gamma_2}{m+1-\gamma_2} \frac{1}{\frac{\sigma_2 - \gamma_2}{m+1-\gamma_2} - 1}} \qquad (6)$$

From field data (t_r, x) and using equations for T', its value can be evaluated and subsequently with $T'=R_o/f_o$, we can solve for f_o. An average f_o can be derived from a few sets of field data points.

RESULTS AND CONCLUSIONS

From the actual field data (Elliott 1980) two sets of irrigation data are presented as shown in *Fig. 1 and 2* (Printz farm, Colorado) to illustrate the recession predicted f_o value compared with the measured f_o value. It is to be noted that the values of the soil infiltration parameters k and a are different for both cases of the recession predicted f_o and the measured f_o. This is due to the fact that these values are calculated from the two point advance volume balance approach (see part 1) once the field advance data and the values of f_o are obtained. As can be seen from the prediction of the advance (the advance simulation is shown here in passing, to illustrate the results of its simulation, on which its derivation principles are used for this recession simulation) and recession trajectories, the simulation is more exact when we use the f_o values calculated by the analytical method.

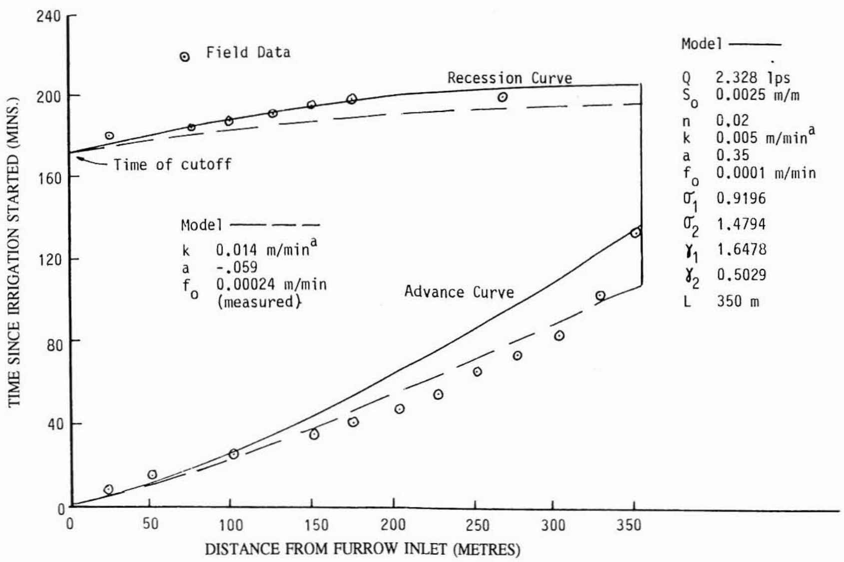

Fig. 1. Predicted and observed furrow recession and advance using an approximated f_o for irrigation event P 8-2-1, Colorado. [Field data source: Elliott 1980]

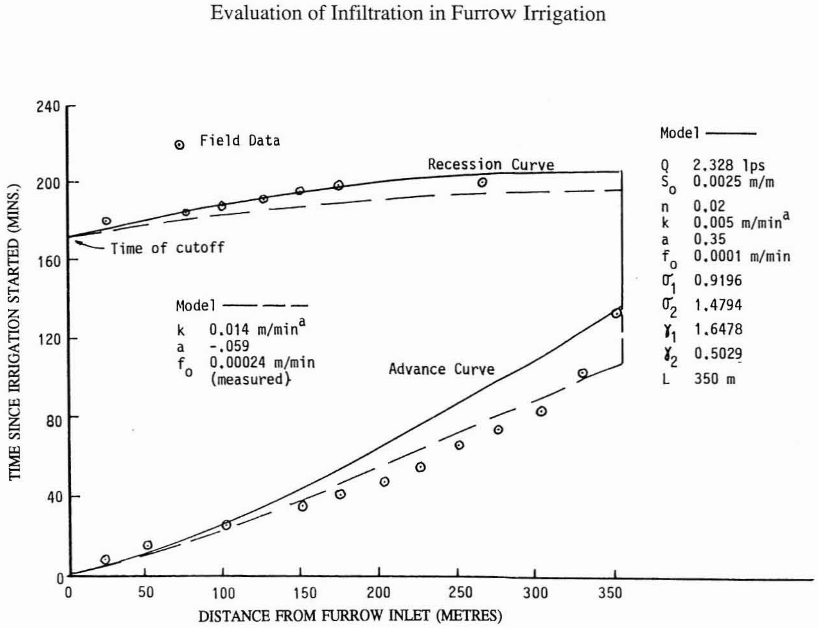

Fig. 2. Predicted and observed furrow advance and recession using an approximated f_o for irrigation event P 3-2-5, Colorado. [Field data source: Elliott 1980]

The recession time and distance data in a furrow irrigation event can be used to evaluate the basic infiltration rate. Hence, the evaluation of the soil infiltration parameters can be done without having to tediously measure the inflow-outflow hydrographs during irrigation. With the evaluation of the basic infiltration rate, the two point advance and volume approach for the furrow can be used to determine its infiltration parameters.

REFERENCES

CHRISTIANSEN, J.E., A.A. BISHOP, E.W. KIEFER JR. and Y.S. FOK. 1966. Evaluation of intake rate constants as related to advance of water in surface irrigation. *Trans. Amer. Soc. Civil Engin.* **9(5)**: 671-674.

ELLIOTT, R.L. 1980. *Compilation of Furrow Irrigation Field Evaluation Data.* Fort Collins, Colorado: Colorado State University.

ELLIOTT, R.L. and W.R.WALKER 1982. Field evaluation of furrow infiltration and advance functions. *Trans. Amer. Soc. Agric. Engin. Paper* No. 80-2075.

LEE T.S. 1982. Kinematic-wave simulation of furrow advance and recession. Master of Science in Engineering Thesis, Utah State University, Logan, Utah.

LEY T.W. 1978. Sensitivity of furrow irrigation performance to field and operation variables. Master of Science Thesis, Colorado State University, Fort Collins, Colorado.

WALKER, W.R. and G.V. SKOGERBOE. 1987. *Surface Irrigation : Theory and Practice.* New Jersey: Prentice Hall.

APPENDIX - LIST OF SYMBOLS

f_o	-	basic infiltration or intake rate
A	-	cross-sectional area of flow
Q	-	discharge
WP	-	wetted perimeter of flow
B	-	surface width of flow
y	-	depth of flow
t	-	advance time
σ_1, σ_2	-	parameters from $A = \sigma_1 y^{\sigma_2}$
Γ_1, Γ_2	-	parameters from $WP = \Gamma_1 y^{\Gamma 2}$
x	-	distance of flow
t_r	-	recession time
α, m	-	constants of stage discharge relationship
S_o	-	slope of furrow
n	-	Mannings number
a,k	-	soil infiltration parameters
L	-	length of furrow
R_o	-	hydraulic radius or depth
j	-	number count of characteristics
c	-	subscript of parameters at nodes
s	-	subscript at shock wave advance
h_o	-	inlet flow depth at recession
T'	-	characteristic time
X'	-	characteristic distance
A'	-	characteristic area of flow
A^*	-	dimensionless area of flow
Q'	-	characteristic discharge
Q^*	-	dimensionless discharge
WP'	-	characteristic wetted perimeter
WP^*	-	dimensionless wetted perimeter
T'	-	characteristic time
t^*	-	dimensionless time
X'	-	characteristic distance
X^*	-	dimensionless distance of flow