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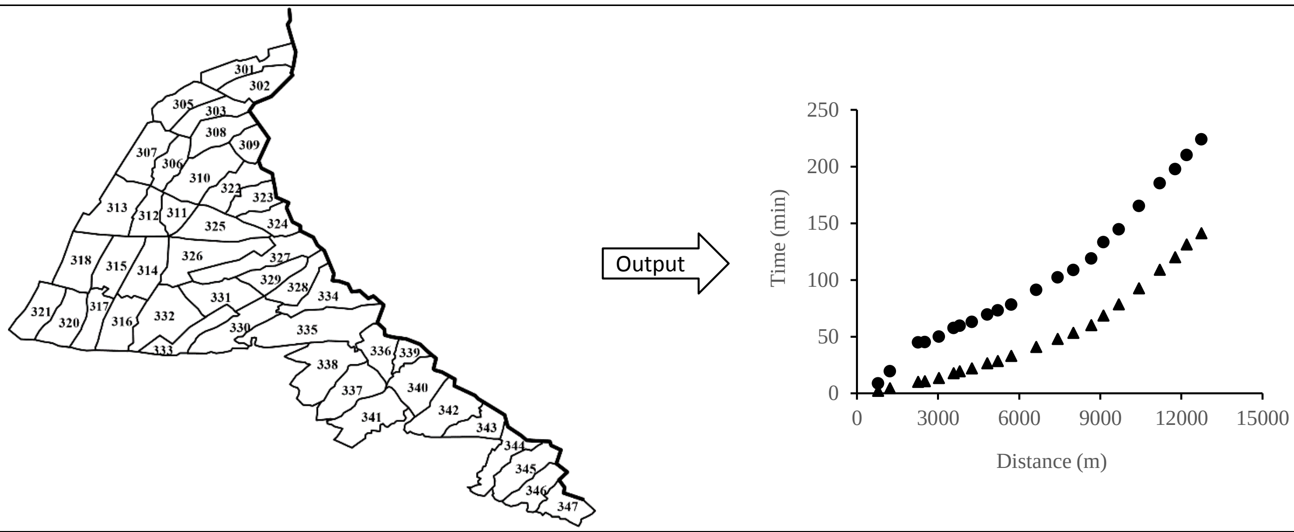
Investigation of analytical formulas for the travel and response time of irrigation canals (Case study: Bilevar irrigation network)

Mohammad Saeid Bahrami, Mohammad Mehdi Heidari*, Arash Ahmadi

Department of Water Engineering, Faculty of Agricultural Science and Engineering, Razi University, Kermanshah, Iran.

GRAPHICAL ABSTRACT



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ABSTRACT

The improper operation performance of many irrigation channel is nearly a result of the lack in understanding transient flow phenomena due to the implementation of water delivery in the irrigation canal. Travel and response time are the most important characteristics of unsteady flow in open canal affecting the operation performance. Solving the Saint Venant equation and using hydrodynamic models is usual method to assess the response and travel time, but limited access and the complexity of the application of those caused to introduce simple methods for calculating them. Two analytical methods introduce to determine the travel and response time. The diffusion wave approximation and gravity wave can be used for the travel time and the diffusion wave and Ankum's formula are used for the response time. In this study, the travel and response time has calculated using HEC-RAS and compared in approximate methods. The results show that the gravity wave is used to determine the travel time for short canal and the diffusion wave method is suitable for long canal reaches. In BLMC channel, the average response time error to distance of 3000 meters for Ankum's formula is 5.1 percent, and the error of diffusion wave model is 5.5 percent from 3000 meters to the end of the canal. In this study, the effect of variation in input discharge on travel and response time are investigated. It has effect on travel and response less than 3 % and 5 %, respectively.

1. Introduction

The not-so-good performance of irrigation networks and its effect on decreasing the productivity of agricultural water emphasizes the need to review and reform the traditional design and operation methods of irrigation networks. One of the factors that can have a great impact on the performance of irrigation systems is the creation of unsteady flow due to the implementation of water delivery and distribution programs in the network and the performance of operation activities in response to water demand changes. Travel and response time are the most important characteristics of unsteady flow that affect the network's performance and operation. Travel and response time can be a few hours in short channels or a few days in longe channels. The definition of travel time, is the time that the effect of discharge change's reaches the downstream station and response time, is the time needed to transfer the flow from one steady state to a new steady state. From a practical standpoint, the time needed for 90 and 5 percent of the discharge changes to reach the desired location are the response and travel time respectively (Schuuramans. 1990). The travel and response time can be calculated by Saint-Venant equations using hydrodynamic

*Corresponding author Email: mm.heidari@razi.ac.ir

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models. But, limited access, complexity of application and the requirement of high expertise in the application of those models requires the innovation of simpler methods. Burt and Plusquellec (1990) considered the response time is a function of a volume of the dynamic storage and input discharge changes. Schuuramans (1990) used canal routing and diffusion approximation to present analytical equations for calculating the response time for canal reaches. Ankum (1995) considered the response time for canal reaches is a function of the input discharge, volume of the dynamic storage and travel time, and presented an analytical equation for calculating the response time. Schuuramans et al. (1995) linearized the Saint-Venant equations around initial condition and presented to derive an approximation model for a canal with backwater effects. Their model is able to route sudden changes of the input discharge, and the response time can be calculated accordingly. Strelkoff et al. (1998) investigated the effect of the initial depth and the boundary conditions due to some hydraulic structures at the end of the reach on the unsteady flow characteristics. They indicated that the effect of the type of the downstream structure on the unsteady flow hydraulic is more than the initial upstream depth, also in the condition where there is a weir at the end of the reach, the travel and response time are less, relative to the condition where there is a gate. Kouchakzadeh and Montazer (2005) proposed a correction factor for the Ankum's equation using the sobek hydrodynamic model. Munier et al. (2008) used the frequency response of a channel and proposed LBLR (linear backwater lag and route) model for simulating the unsteady flow. This model can evaluate the effect of the backwater due to the downstream structure. Munier et al. (2010) presented an explicit equation for calculating the response time using the LBLR model and linearizing the rating carve equation of the structure downstream of the canal. It should be noted that their equation only applies to one reach of an irrigation network. Belaud et al. (2013) calculated the discharge change downstream of a reach and response time based on first-order routing model and considering the effect of the backwater curve. Heidari and Kouchakzadeh (2016) linearized saint venant equations and developed semi-analytical solutions for unsteady flow in irrigation channel based on Laplace transform. Some tests of unsteady flow were simulated and verified the equations. The results showed that the error of model increases with decreasing froud number and increasing the rate of sudden changes of discharge. Fang et al (2018) solved unsteady flow equation according to the method of characteristics and a model was developed to simulate the flow in the channel of the Yintang irrigation district. Liao et al. (2019) introduced a delay time method with combining the theory of constant gradient flow with volume compensation. The delay time can prepare references for the determination of delay time in feed forward control. Kumar (2020) combined the manning's equation with parameters of kinematic wave and proposed an equation for travel time in canals. The result showed the deep rectangular cross-sectional channel has the highest travel time. The operation discharge and the input discharge changes of a canal are effective factors on the travel and response time, which are investigated in this research. Ankum's method is used in backwater conditions in canals, but its accuracy has not been investigated yet. Diffusion approximation method has been presented for one reach and in the condition without backwater. In this research the accuracy of these methods for calculating the response time is investigated and the diffusion approximation method is corrected for backwater conditions.

2. Materials and methods

2.1. Travel time and response time in irrigation network

The equations governing unsteady flow include continuity and the momentum equation which are known as the de saint venant equations. Assuming no lateral outflow, saint venant equations can be written as (Cunge et al. 1980):

$$\frac{\partial y}{\partial t}+\frac{1}{T}\frac{\partial Q}{\partial x}=0 \tag{1}$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}(VQ)+gA\frac{\partial y}{\partial x}=-gAS_f \tag{2}$$

where, t is time, x is location, g is acceleration of gravity, Q is discharge, A is cross-flow, y is water level relative to the base level, T is top width, V is velocity and S_f is energy slope.

The de saint venant equations have not analytical solutions that it should be solved using numerical methods, and the time required for the system to achieved 5 % and 90 % of the discharge variation at the downstream end of the canal considered as travel and response time. A lot of hydrodynamic models are presented to simulate unsteady flow that one of them is HEC-RAS model. HEC-RAS was developed by U.S. army engineer hydrologic engineering center to simulate river systems, dams and flow profile calculations in steady and unsteady state (Brunner. 2008). Saint-Venant equations have no analytical solution. Therefore, various approximate solutions are considered for Saint-Venant equations, based on which the travel and response time can be estimated. The acceleration terms in the momentum equation can be neglected as they are small compared with the channel bed slope in most approximate solutions (Henderson. 1966). Some approximate methods for simulating unsteady flow include: storage routing, muskingum method, kinematic wave routing, and diffusion approximation. In recent years, the diffusion wave approximation has been widely used to simulate the flow, the diffusion wave equation has obtained according to Eq. 3 (Cunge et al. 1980):

$$\frac{\partial Q}{\partial t}+C_D\frac{\partial Q}{\partial x}=D\frac{\partial^2 Q}{\partial x^2} \tag{3}$$

where, C_D is diffusion wave celerity and D is the diffusion coefficient that are non-linear functions of flow depth and discharge. Discharge changes in irrigation canals are small percentage of the initial discharge, so it can be assumed C_D and D coefficients as constant and solved the diffusion wave equation analytically, according to Eq. 4 (Carslaw and Jaeger. 1959):

$$Q(x,t)=Q_1+\frac{\Delta Q}{2}\left\{\mathrm{erfc}\left[\frac{x-C_Dt}{\sqrt{4Dt}}\right]+\exp\left[\frac{C_Dx}{D}\right]\mathrm{erfc}\left[\frac{x+C_Dt}{\sqrt{4Dt}}\right]\right\} \tag{4}$$

where, Q_1 is initial discharge, ΔQ is the variation in discharge, Q (x, t) is discharge hydrograph, x is distance from upstream end, t is time and erfc is complementary gaussian error function that is defined as (Winitzki. 2003):

$$\begin{aligned}&\mathrm{erfc}(x)=1-\sqrt{1-e^{-x^2\left(\frac{4/\pi+0.14x^2}{1+0.14x^2}\right)}} && x\ge 0\\ &\mathrm{erfc}(x)=1+\sqrt{1-e^{-x^2\left(\frac{4/\pi+0.14x^2}{1+0.14x^2}\right)}} && x<0\end{aligned} \tag{5}$$

The wave celerity and diffusion coefficient can be calculated from Eqs. 6 and 7 (Chanson. 2004):

$$C_D=\frac{5}{3}\frac{Q_1}{A_1}\left(1-\frac{4}{5}\frac{A_1}{P_1T_1}\sqrt{1+Z^2}\right) \tag{6}$$

$$D=\frac{Q_1}{2T_1S_0} \tag{7}$$

where, S_0 is slope of the bed canal, Z is the side slope of the canal, P is wetted perimeter, A is flow area, T is top width and subscript 1 refer to the initial steady state. Schuuramans (1990) to calculate C_D and D in steady flow has proposed Eqs. 8 and 9, respectively:

$$C_D=V_{re}(1+K) \tag{8}$$

$$D=\frac{Q_{re}}{2T_{re}S_{f(re)}}\left[1-\left(KF_{re}\right)^2\right] \tag{9}$$

$$K=\frac{2}{3}\frac{\ln(R_2/R_1)}{\ln(A_2/A_1)} \tag{10}$$

where, F_r is froude number, R is hydraulic radius, subscript 2 refer to the final steady state and re represents reference values. Reference values are considered as the amounts in which 90 percent variation occur, for example Reference value for discharge and velocity are equal to:

$$V_{re}=V_1+0.9(V_2-V_1) \tag{11}$$

$$Q_{re}=Q_1+0.9(Q_2-Q_1) \tag{12}$$

C_D and D coefficients that provided by the researchers has been offered in uniform flow but, regulatory structures and offtakes in irrigation networks cause to gradually-varied flow, so the hydraulic parameters and coefficients of diffusion wave are vary in different locations. In order to calculate the C_D and D coefficients in gradually-varied flow, it should calculated the place average of diffusion wave parameters for initial and final steady state conditions from the beginning to the end of the reach of canal and then averaging the resulting two values. Obviously, under these conditions, the accuracy of calculation is decreases than uniform flow. Diffusion wave celerity and diffusion coefficient in non-uniform flow is calculated from the canal beginning to the desired point by Eqs. 13 and 14:

$$\bar{D}_n = \left(0.5\sum_{i=1}^{i=n} X_i\left(\bar{D}_1+\bar{D}_2\right)_i\right) / \sum_{i=1}^{i=n} X_i \qquad (13)$$

$$\bar{C}_{Dn} = \left(0.5\sum_{i=1}^{i=n} X_i\left(\bar{C}_{D1}+\bar{C}_{D2}\right)_i\right) / \sum_{i=1}^{i=n} X_i \qquad (14)$$

where, $\bar{C}_{Dn}$ and , $\bar{D}_n$ are wave celerity and diffusion coefficient in non-uniform flow from the canal beginning to reach n-th, , $\bar{D}_1$ and $\bar{D}_2$ are place average of diffusion coefficient for the initial and final steady state flow, $\bar{C}_{D1}$ and $\bar{C}_{D2}$ are place average of wave celerity for the initial and final steady state flow and X_i is the length of reach i-th. By dimensionless analytical solution of the diffusion wave, Eq. 15 is provided to calculate travel time:

$$T_t = \frac{\tau_t \bar{D}_n}{\bar{C}_{Dn}^2} \qquad (15)$$

where, τ_t is dimensionless time coordinates that is defined as (Vatankhah and Kouchakzadeh. 2007):

$$\tau_t = \frac{4.828\chi^{1.55}}{1+7.757\chi^{0.5}+36.22\chi^{-0.455}} \quad 0.05 \le \chi \le 4 \qquad (16)$$

$$\tau_t = \frac{1.5\chi^{2.404}}{1+10.33\chi^{0.5}+2.25\chi^{1.349}} \quad 4 \le \chi \le 100 \qquad (17)$$

where, χ is dimensionless distance coordinates and defined as:

$$\chi = \frac{\bar{C}_{Dn}x}{\bar{D}_n} \qquad (18)$$

Schuuramans (1990) using the diffusion wave has provided Eq. 19 to calculate the response time:

$$T_{res} = \frac{\tau_r \bar{D}_n}{\bar{C}_{Dn}^2} \qquad (19)$$

where, T_{res} is response time, τ_r is dimensionless time coordinates, which is calculated using the table provided by Schuuramans. Also by dimensionless analytical solution of the diffusion wave, Eqs. 20 and 21 are provided (Vatankhah and Kouchakzadeh. 2007):

$$\tau_r = \frac{3.182\chi^{1.772}}{1+1.205\chi-0.854\chi^{0.0349}} \quad 0.05 \le \chi \le 4 \qquad (20)$$

$$\tau_r = -0.7+2.286\chi^{0.5}+0.904\chi^{1.014} \quad 4 \le \chi \le 100 \qquad (21)$$

The gravity wave can be used approximately to determine the travel time due to unsteady flow in irrigation canals. In The gravity wave assume the channel is frictionless and the slope of the channel is zero. Travel time based on gravity wave is calculated from Eq. 22:

$$T_{t(n)} = \sum_{i=1}^{i=n} \frac{X_i}{\left(V_1+\sqrt{gD_{h1}}\right)_i} \qquad (22)$$

where, $T_{t(n)}$ is the travel time of reach n-th, D_{h1} is hydraulic depth of initial steady state and g is the gravity acceleration. It should be noted that depth and velocity are calculated using the manning equation in uniform flow and in gradually-varied flow the average depth and velocity are calculated for each reach by using backwater profile. Ankum (1995) has considered the response time as a function of discharge variation in reach, $\Delta Q_{in(i)}$, volume variation of water between the initial and the final steady state in reach, $\Delta V_{dyn(i)}$, and travel time and leads to the following expression of the response time:

$$T_{res} = 2\sum_{i=1}^{i=n} \frac{\Delta V_{dyn(i)}}{\Delta Q_{in(i)}} - \sum_{i=1}^{i=n} T_{t(i)} \qquad (23)$$

It should be noted the gravity wave approximation is used to calculate travel time in Ankum's equation.

2.2. Introduce Bilevar irrigation network

Bilevar irrigation network is located in the northern part of kermanshah province in iran. The irrigated command area of this modern irrigation system which is fed from Gavshan reservoir is about 7638 hectares. The system consists of two irrigation districts including BRMC (Bilevar right main canal) and BLMC (Bilevar left main canal). In the present study left main canal (BLMC) was selected. The canal is 12734 meters long and fed about 3250 hectors of the agricultural land using sprinkler system. There are 22 ''in-line'' cross-regulators (duckbill weirs) and 27 offtake structures along canal, 23 offtakes are connected to a pond and necessary pressure for sprinkler irrigation is provided by a pump, others are baffle sluice module (Neyrpic orifice module) and the required pressure for sprinkler irrigation is supplied by gravity due to the difference level of water in canal and farms. Fig. 1 shows the BLMC canal and farms of Bilevar irrigation network. It should be noted the system includes B3 and B4 irrigation districts, B4 has a centered pumping station in 8666 meters distance from the beginning of the canal that is completely automated. According to data of delivery schedule in previous, the maximum and minimum operation discharge of BLMC is 1.18 and 2.11 m^3/s, respectively.

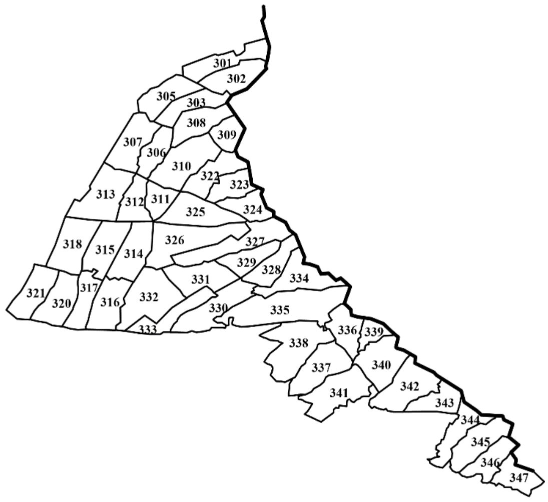


Fig. 1. The BLMC canal and farms of Bilevar irrigation network.

3. Results and discussion

The parameters required for evaluating developed equations for travel and response time were determined using the unsteady flow simulation results of HEC-RAS model. Due to the diverse cropping pattern on district of B4 in each irrigation period, the discharge had changed up to 20 % in some cases. Therefore, unsteady flow had simulated due to changes of 5 to 20 % of discharge in unit of B4 by hydrodynamic model for maximum and minimum operation discharge. To simulate the unsteady flow by Hec-Ras, space and time step need to be entered. In this research, the value of these are 10 m and 1 min, respectively.

3.1. Travel time and response time in Bilevar irrigation network

Unsteady flow along Bilevar channel was simulated due to change of 20 percent of discharge in unit of B4 in maximum operation condition by using HEC-RAS model, and travel and response time had calculated for different sites and shown in Fig. 2.

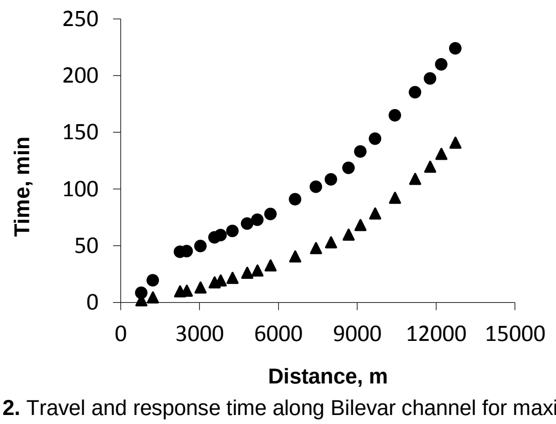
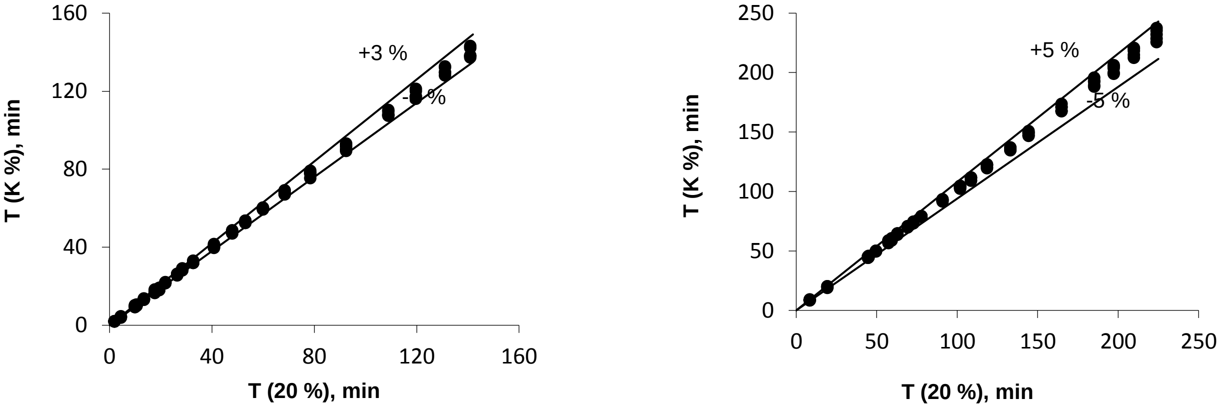


Fig. 2. Travel and response time along Bilevar channel for maximum discharge operation.

Travel and response time for unit of B4 are 60 and 119.5 minutes, respectively, and 141 and 228 minutes respectively for the last intake.

Unsteady flow along Bilevar channel was simulated due to changes of ±5, ±10, ±15 ± and ±20 percent of discharge in unit of B4 and travel and response time had calculated. Fig. 3 shows the travel or response time due to changes of 20 percent of discharge, T (20 %), against to the travel or response time due to different discharges changes, T (K %). The effect of variation in input discharge on travel and response time is less than 3 % and 5 %, respectively. One of the effective factors on response time is ratio volume of the dynamic storage to input discharge changes ($\Delta V_{dyn}/\Delta Q_{in}$) (Ankum. 1995). By increasing variation in input discharge, the storage wedge variation will increases as same percentage and thus change the flow does not have much impact on response time. Unsteady flow maybe occurs in maximum or minimum operation discharge. The velocity and depth of flow change in the operation discharge, so, initial discharge effect on travel and response time. Fig. 4 shows the travel and response time in the minimum discharge operation, T_{Qmin}, against to the travel and response time in the maximum discharge operation, T_{Qmax}, along Bilevar channel.



(a) (b)

Fig. 3. Effect of variation in input discharge on (a) Travel time and (b) Response time along Bilevar channel for maximum discharge operation.

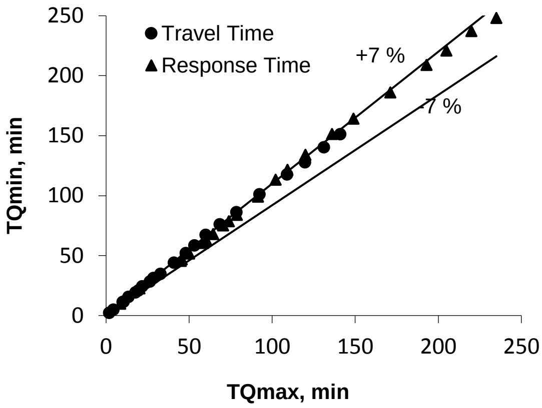
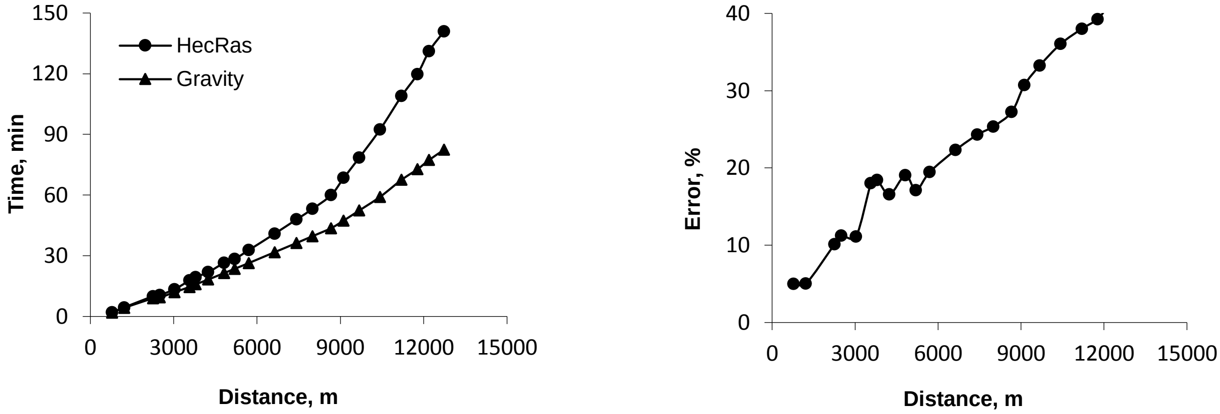


Fig. 4. Travel and response time in the minimum against to the maximum discharge operation.

There is a direct relationship between the wave celerity and discharge, in other words, canal discharge reduction caused decrease wave celerity and increase travel and response time. So the travel and response time in the minimum discharge operation are higher than maximum operation. The most difference of travel and response time for minimum and maximum discharge operation along Bilevar channel is 10 and 20 minutes respectively.

3.2. Analytical formulae for the travel and response time of irrigation canals

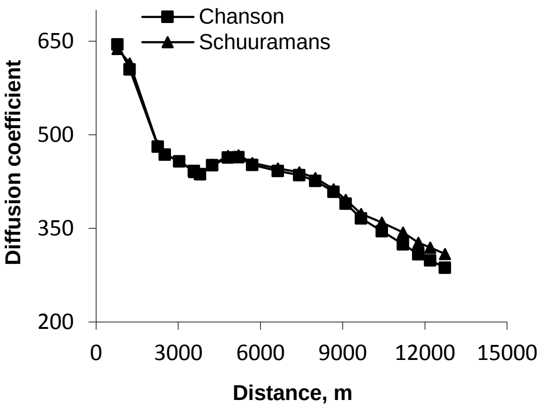
Gravity and diffusion wave can be used approximately to determine the travel time in irrigation canals. In gravity wave method the average velocity and hydraulic depth for any reach is determined according to backwater profile, and travel time is calculated according to Eq. 14. Fig. 5 shows the travel time based on gravity wave and its error for maximum discharge operation along Bilevar channel. The error of gravity wave for calculating travel time is low at the beginning channel and it will be increased by increasing the distance. The maximum error of gravity wave for travel time at the beginning channel up to 3000 meters is approximately 11.2 percent. In this method assume the channel is frictionless and wave celerity is calculated higher than the actual amount, so gravity wave method estimates the travel time less than the actual time. In diffusion wave method, wave celerity and diffusion coefficient calculated for each reach using the scheme of Chanson (2004) and Schuuramans (1990) and then the average of the coefficients determined by using Eqs. 13 and 14.



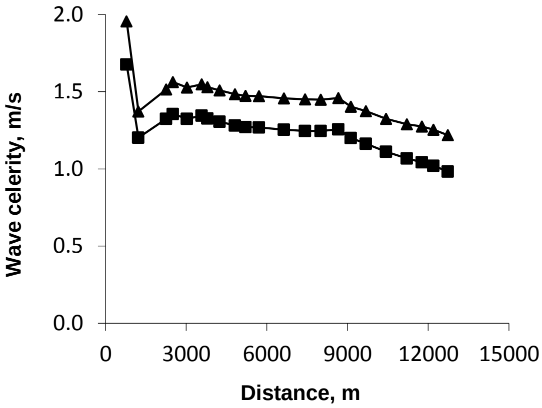
(a) (b)

Fig. 5. (a) Travel time based on gravity wave and (b) The percentage error of gravity wave for maximum discharge operation.

In Fig. 6, the average of wave celerity and diffusion coefficient for maximum discharge operation is shown along Bilevar channel. Discharge and velocity of water in downstream parts of the network is less than upstream parts, so by increasing the distance, the wave celerity and diffusion coefficient decreases from the beginning of channel. Chanson and Schuuramans schemes are almost calculate the same amount for diffusion coefficient, but the wave celerity in Schuuramans method is more than Chanson scheme. Travel time can be calculated by estimating the wave celerity and diffusion coefficient using Eq. 16. Fig. 7 shows the travel time and the error value based on diffusion wave method for maximum discharge operation. Considering that the travel time is the time at which the variation of discharge is observed at the downstream end of the reach, so if wave celerity and diffusion coefficient is calculated based on the initial conditions, Eq. 16 has better accuracy.



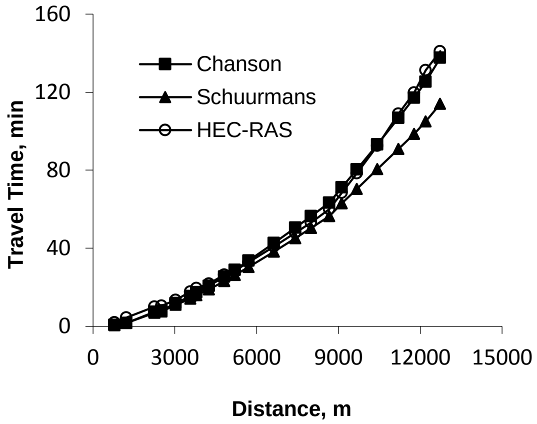
(a)



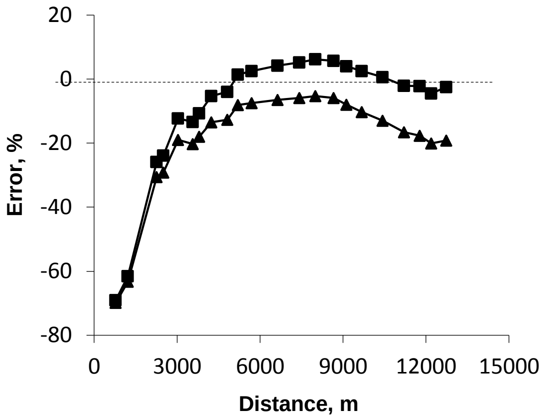
(b)

Fig. 6. (a) Average of diffusion coefficient and (b) Wave celerity for maximum discharge operation along Bilevar channel.

Chanson scheme calculate the D and C_D coefficients based on the initial conditions, so it has better accuracy in the calculation of travel time compared to Schuuramans scheme. Error of calculating travel time by using the diffusion wave method is more at the beginning of the canal and decreases with increasing distance. The maximum percentage error of calculating travel time on the basis of Chanson scheme from 3000 meters to the end of the canal is 8.9 percent.



(a)



(b)

Fig. 7. (a) Travel time based on diffusion wave and (b) Percentage error of diffusion wave for maximum discharge operation along Bilevar channel.

Diffusion wave method has high error to determine the travel time at the beginning of the irrigation network due to the more local and convective acceleration terms and gravity waves can be used. So, for more accurate predictions of the travel time for longer canal reaches it is recommended to use the diffusion approximation. Fig. 8 shows the travel time based on approximate methods, T_{ta}, against the hydrodynamic model, T_{tm}, for maximum discharge operation in BLMC channel.

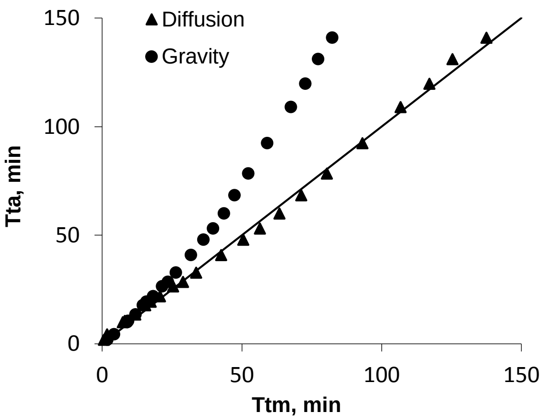


Fig. 8. Travel time based on approximate methods against hydrodynamic model for maximum discharge operation in BLMC channel.

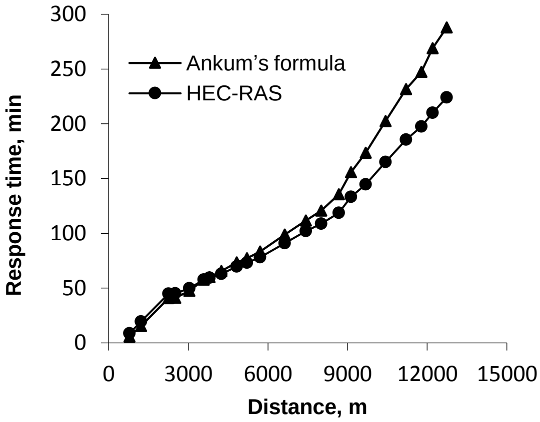


Fig. 9. Response time for maximum discharge operation along Bilevar channel based on Ankum's formula.

The response time of an open canal system after a change in flow rate can be calculated by using Ankum's formula and the diffusion wave method approximately. The response time for different stations are shows in Fig. 9 using Ankum's formula according to Eq. 23 for maximum discharge operation along Bilevar channel. The response time after changes of ±10, ±15 ± and ±20 percent of discharge in unit of B4 in flow rate based on Ankum's formula, $Tr_{(an)}$, and hydrodynamic model, $Tr_{(m)}$, for maximum discharge operation in BLMC channel calculated and shown in Fig. 10. The maximum error of Ankum's method in response time calculation of Bilevar irrigation network is 30 percent.

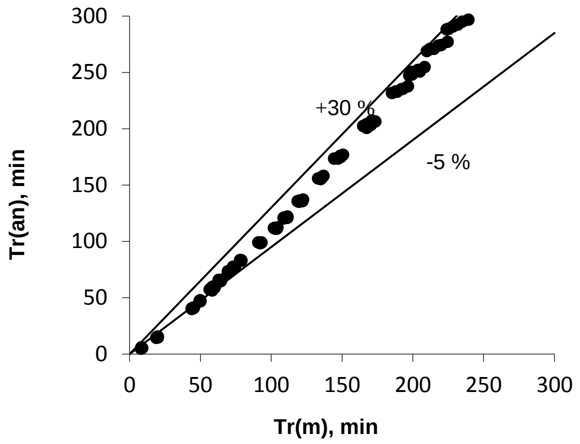
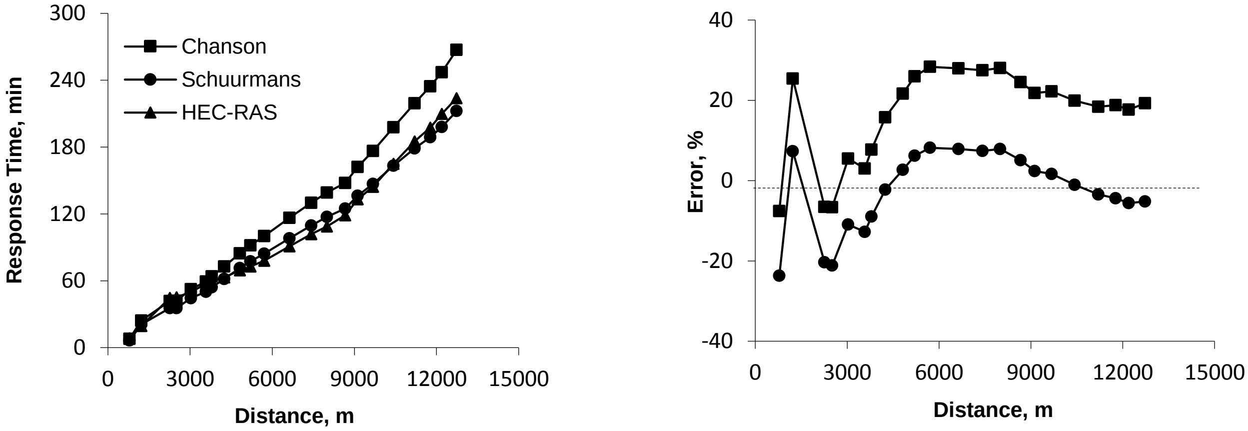


Fig. 10. Response time based on Ankum's formula against hydrodynamic model for maximum discharge operation along Bilevar channel.

The error of Ankum's method will be increased by increasing the distance from the beginning of the canal and make the response time greater than hydrodynamic model. In Ankum's method, the response time is dependent on travel time. Travel time in this method is calculated based on gravity wave that it is less than hydrodynamic model due to ignoring the friction, so the Ankum's method estimates the response time more than the actual time. The response time can be calculated using Eq. 20 by calculating the wave velocity and diffusion coefficient of Chanson and Schuuramans methods. Fig. 11 shows the response time and the error value based on diffusion wave method for maximum discharge operation. The average error of diffusion wave method base on Chanson and Schuurmans in response time calculation of Bilevar irrigation network is 18.2 % and 7.1 %, respectively. As the response time is the time period that 90 percent of unsteady flow changes reach to the considered place, so Eq. 20 will be more accurate if the wave celerity and diffusion coefficient is calculated based on 90 % variation of discharge, accordingly the Schuuramans method is more appropriate than Chanson scheme. Diffusion wave method is less accurate at the beginning of the irrigation network due to the large local and convective acceleration terms and it is better to use Ankum's method.



(a) (b)

Fig. 11. (a) Response time based on diffusion wave and (b) Percentage error of diffusion wave for maximum discharge operation along Bilevar channel.

Fig. 12 shows response time based on Ankum's and diffusion wave method against hydrodynamic model in maximum operation condition. From the beginning to the distance of 3000 m of Bilevar channel, the average error of Ankum's and diffusion wave method in calculating the response time are 5.1 and 16.3 respectively, and from the distance of 3000 meters to end of the channel, the average error of these mentioned methods are 18.5 % of 5.5 %. Thus, Ankum's method is appropriate from the beginning of the canal to the distance of 3000 meters and diffusion wave method is appropriate from the distance of 3000 meters to the end of the channel.

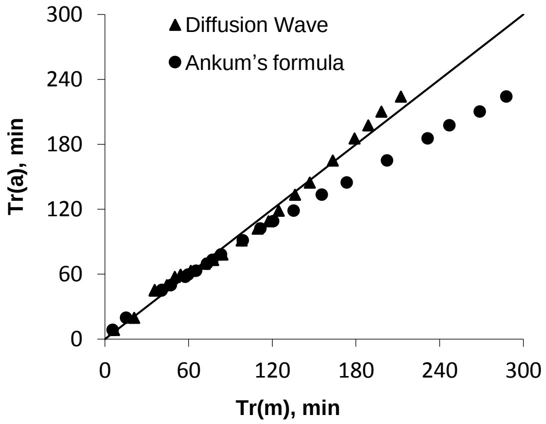


Fig. 12. Response time based on the diffusion wave and Ankum's formula against hydrodynamic model.

4. Conclusions

In this study, travel and response time in the minimum and maximum discharge operation was calculated for Bilevar irrigation network using HEC-RAS model. The travel time for maximum and minimum discharge operation is respectively, 141 and 151 minutes at the end of the network, and response time is respectively, 228 and 248 minute. Wave celerity is directly related to the canal discharge; therefore, in minimum discharge operation, the wave celerity is less and travel and response time are more than the maximum discharge operation. Variation in input discharge is one of the effective factors on unsteady flow characteristics. Unsteady flow was simulated for ±5, ±10, ±15 ± and ±20 percent of discharge in unit of B4 and the travel and response time was calculated. Results showed that variation in input discharge has effect on travel and response time less than 3 % and 5 %, respectively. The gravity and diffusion wave can be used approximately to determine travel time in irrigation channel. The gravity wave method assume the channel is frictionless, therefore estimated the travel time less than the real time. Energy loss at the end of the network is more than the beginning of the canal. So, the gravitational wave method for calculating the travel time at the end of the network more error than the diffusion wave. The maximum error of gravity wave for calculating travel time at the beginning channel up to 3000 meters is 11 % and it will be increased by increasing the distance. The wave celerity and diffusion coefficient are calculated for Bilevar irrigation network, and travel time estimated by diffusion wave approximation. The error of the diffusion wave method for calculating travel time is more at the beginning of canal and decreases with increasing the distance. The maximum Error of calculating travel time base on diffusion wave method and Chanson scheme from 3000 meters to the end of Bilevar canal is 8.9 percent. Response time can be calculated by Ankum's and diffusion wave methods. The error of Ankum's method will increase by increasing the distance from the beginning of channel and estimates response times greater than the hydrodynamic model. In Ankum's method, the response time is depend on travel time, and it is calculated based on gravity wave that is less than the hydrodynamic model, so the Ankum's method calculates the response time more than real time. The error of Ankum's method at the beginning of channel is low, so this method is appropriate for short channel reaches, and the error of diffusion wave method from the distance of 3000 meters to end of Bilevar channel is low, thus diffusion wave approximation is appropriate for long canal reaches.

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