Fully Coupled Simulation for Surface Water Flow and Solute Transport in Basin Fertigation

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Abstract: Full implicit solutions are constructed for all terms of the Saint–Venant equations and advection–dispersion equation. Thereafter, a global coefficient matrix for forming algebraic equations is established to realize the simultaneous solution of both surface water flow and solute transport equations and a full-coupled model between the surface water flow and solute transport is constructed for basin fertigation. This model completely eliminates splitting errors, which exist in common solutions for both of the aforementioned equations. Moreover, the proposed model can take any time steps and is no longer constrained by stability conditions, such as the CFL (Courant, Friedrichs and Lewy) number and Peclet number. These advantages of the full-coupled model obviously improve the computational efficiency and accuracy, and its applicability in practical simulations. Three basin fertigation experiments are conducted to validate the performance of the proposed full-coupled model. The results show that the developed model achieves good fit between the simulated and observed results, and presents more efficiency than the existing model. **DOI: 10.1061/(ASCE)IR.1943-4774.0001103.** *© 2016 American Society of Civil Engineers.*

Author keywords: Basin fertigation; Full coupled; Simultaneous solution; Surface water flow; Solute transport.

Introduction

Fertigation is an interesting alternative fertilization approach in basin irrigation (Playán and Faci 1997). In basin fertigation, the fertilizer is dissolved prior to application and yields a more effective usage of fertilizer and higher reduction of labor, energy, and soil compaction than conventional fertilization (Abbasi et al. 2003; Perea et al. 2010). In analyzing fertilizer performance, field experiments and numerical models are commonly used. Numerical models present advantages such as low cost, low power, and relatively complete performance values over field experiments. Moreover, numerical models have become an indispensable tool in the optimization and management of basin fertigation in recent years.

In the existing numerical models of basin fertigation, pure advection models were first constructed to simulate the surface fertigation process. Thereafter, optimum fertilizer application practices were identified (Playán and Faci 1997; Ebrahimian et al. 2014). Only the advection term is introduced because advection is dominant in basin fertigation. The essential reason is that advection and dispersion terms are hyperbolic and parabolic types in partial differential equation theory, respectively (LeVeque 2002). Different types result in numerical solution problems. Specifically, the hyperbolic term is commonly solved by using both explicit time and upwind space schemes, whereas the parabolic term is suitably solved by using both implicit time and central-difference schemes (Morton and Mayers 2005). As such, the operator-splitting method is introduced to first solve the advection term. Thereafter, the dispersion term is solved by using the advection results (García-Navarro et al. 2000; Zerihun et al. 2005; Zhang et al. 2012). The numerical solutions based on the operator-splitting method have been widely used to simulate the solute transport in basin fertigation (Murillo et al. 2005). In these solutions, the advection terms of both surface water flow and solute transport are usually coupled to decrease numerical errors (Begnudelli and Sanders 2006; Burguete et al. 2009).

The existing numerical models of basin fertigation exhibit some disadvantages. First, the Saint–Venant equations are commonly solved by using the explicit time scheme except for bed friction, which is solved solely by the operator-splitting method to improve stability. The explicit time scheme results in small time steps, and the operator-splitting method induces additional and unnecessary errors (splitting errors) (Liang and Marche 2009). Furthermore, low efficiency and accuracy are exhibited, and the applicability of numerical models decreases in practical simulations. Second, the commonly used operator-splitting method to solve the solute transport equation also induces small time steps because of the explicit scheme of the advection term (Morton and Mayers 2005). Moreover, additional splitting errors emerge in solute transport as well. In general, these defects decrease the efficiency, accuracy, and applicability of numerical models in simulating basin fertigation.

In this work, a full implicit time solutions for all terms of the Saint–Venant equations and advection–dispersion equation was developed, which is an improvement of the model by Zhang et al. (2012). Thereafter, the global coefficient matrix of forming

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Note. This manuscript was submitted on May 19, 2015; approved on June 10, 2016; published online on July 20, 2016. Discussion period open until December 20, 2016; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Irrigation and Drainage Engineering***, © ASCE, ISSN 0733-9437.