Credibility Range of Dupuit-Forchheimer assumption in Steady Unconfined Flow to a Horizontal Drain

Mazda Kompani-Zare[1], Hongbin Zhan[2]
1- Desert Management Department, School of Agriculture, Shiraz University, Shiraz 71886, Iran.
2- Department of Geology and Geophysics, Texas A&M University, College Station, TX 77845-3115, USA

kompani@shirazu.ac.ir

Abstract

The credibility range of Dupuit-Forchheimer assumption in prediction of steady-state flow to an infinite horizontal drain in an unconfined aquifer is studied by utilizing analytical element method together with Genetic Algorithm. The functionality of the flow rate in respect to different hydraulic head of the constant-head boundary, drain radius, drain elevation, and distance to the constant-head boundary is also studied. It is found that Dupuit-Forchheimer assumption is credible in the distances more than 1.8 times of drain elevation from the drain where the distance between the drain and the costant head is about 10-12 times of drain elevation.

Keywords: Analytical element method; Water table; Horizontal drain; Dupuit-Forchheimer; Genetic Algorithm

1. INTRODUCTION

Determination of steady-state flow rates to horizontal drains is an important topic in dry-land ground water studies. In arid or semi-arid countries, horizontal drains are used for exploitation of ground water. In Iran these kinds of horizontal drains, which supply considerable proportion of the water demands, are named Qanats. The discharge rate to the drain approaches steady-state quite rapidly. By utilizing Dupuit-Forchheimer assumption it is possible to determine the steady-state flow rate to them analytically. But this assumption can not be always used. That is because of the considerable vertical flow component and variations in saturated aquifer thickness near the drain.

Numerical models are commonly used for simulation of flow into a horizontal drain (Chisyaki, 1984; Meiri, 1985; Anagnostou, 1995). Khan (1995) presented a formulation for steady state flow to a tile drain. He assumed that the water table did not intersect the drain. Sneyd and Hosking (1976) presented an approximation for flow to a radial constant-head drain. They assumed that the horizontal drain acted as a half fully penetrating well in a confined aquifer. In their solution, the flow above the drain elevation was not considered. Hazenberg and Panu (1991) presented a solution for non-axisymmetric flow in an infinitely deep aquifer with an infinitely long tile drain. Analytical solutions and approximations for steady-state flow into the tunnels have been presented by many investigators (Lie, 1998). In these studies they consider the water table surface as a constant-head recharging boundary. They also assumed constant saturated aquifer thickness. By utilizing Analytical Element Method (Luther and Haitjema ,1999, 2000), the vertical component of flow and variable saturated thickness are considered and flow to the drain can be predicted accurately. Analytical Element Method (AEM) is used by Luther and Haitjema (1999, 2000) for prediction of phreatic surface elevation near a partially penetrating well and is used by Kompani-Zare and Zhan (2006) for prediction of flow around a horizontal drain.

Dupuit (1863) and Forchheimer (1886) approximation was made originally for unconfined flow and consists of the assumption that the head is constant over the height of the aquifer. Many investigators used this approximation for determination of flow in unconfined flow condition (Strack, 1984). In this study, we want to find out how much error is introduced due to applying DF approximation in calculation of the discharge to the drain. And, in what distance from the drain the error due to this approximation is negligible.

To check the accuracy of flow rate calculated by using DF assumption, the flow rate to drain is calculated by AEM (Luther and Haitjema, 1999, 2000) and treated as the exact solution. By comparing the flow rates obtained by AEM and DF approximation, the error due to using DF assumption will be obtained.