Aquifer Analyze using Cellular Automata Algorithm

M.H Afshar[1], M. Khadem[2]

1- Associate professor, School of Civil Engineering, Iran University of Science and Technology, P.O. 16765-163, Narmak, Tehran, Iran, Tel: 0098-21-77240097, Fax: 0098-21-77240398
2- Ms Student, School of Civil Engineering, Iran University of Science and Technology, P.O. 16765-163, Narmak, Tehran, Iran, Tel: 0098-9111530281, Fax: 0098-21-77240398

Corresponding Author's E-mail: majed_khadem@civileng.iust.ac.ir

Abstract

The present paper describes the implementation of a two-dimensional (2D) Cellular Automata (CA) for solving groundwater problems. The basic elements of CA algorithm such as updating rule, definition of cells and its neighbors are first explained. The updating rule is obtained by discretization of the groundwater governing equation and each node generated by domain discretization is used as a CA cell. The method is tested against a hypothetical aquifer problem indicating excellent performance in comparison to the existing Finite Difference Method (FDM). In addition, one of the most significant advantages of the employed CA algorithm over the conventional FDM is that it can produce the same results with lower computational costs especially in large scale problems. The results show the proposed method can be used as an efficient and powerful approach for simulating complicated groundwater problems with arbitrary boundary conditions.

Keywords: automata, Finite difference method, Confined aquifer, piezometric head

1. INTRODUCTION

One of the major water management fields of researches and studies nowadays is groundwater management, since it is vital and dwindling source of water throughout the world that needs urgent attention. Dealing with these types of problems is usually involved with simulating or analyzing the aquifer that is obtaining the response of the system due to some hydrological parameter variation.

A conventional method of achieving the mentioned aim is to use numerical methods such as finite difference method (FDM) and finite element method (FEM). These methods usually lead to solution of a system of equations for the aquifer, which is costly from the computational point of view, especially in large-scale problems. Researches conducted in this field belong mostly to more than past two decades. Upadhyaya and Chauhan[1] simulated a semi-infinite aquifer by solving the Boussinesq equation using the conventional FDM. They also analyzed a sloping aquifer receiving constant recharge using FEM [2]. Nguyen and Raudkivi[3] approached an analytical solution for various sorts of aquifers using Laplace transform. As said, all these methods are time consuming and to some extent outdated.

Although CA was born many years ago [4], it is a newly introduced to water resource problems that is capable of solving complicated optimization and simulation problems by simple commands and definitions. In this paper, a standard 2D CA is described and employed to analyze a confined, 2D and heterogeneous aquifer, showing great capability of handling different types of groundwater problems with lower computational cost.

2. CELLULAR AUTOMATA ALGORITHM

As said, the concept of CA was first introduced von Neumann [4] and then Ulam [5]. Recently, this algorithm has been applied to various engineering problems such as biology [6], physics [7], image processing [8] etc. In fact, "A cellular automata is a decentralized computing model that provides a good platform for performing complex computation with the help of only local information" says Afshar and Shahidi [9]. In order to figure out how CA handles problems, some important definitions should be explained first.