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Applied Mathematical Modelling 30 (2006) 352–366
APPLIED MATHEMATICAL MODELLING
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A finite volume simulation model for saturated–unsaturated flow and application to Gooburrum, Bundaberg, Queensland, Australia

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Received 1 January 2003; received in revised form 1 April 2005; accepted 25 May 2005
Available online 18 July 2005

Abstract

In this paper, a two-dimensional control volume finite-element computational model is developed for simulating saltwater intrusion in a heterogeneous coastal alluvial aquifer system at Gooburrum located near Bundaberg in Queensland, Australia. The model consists of a coupled system of two non-linear partial differential equations. The first equation describes the flow of a variable-density fluid, and the second equation describes the transport of dissolved salt via a form of the Fokker–Planck equation. The outcomes of the work demonstrate that transport simulation techniques provide excellent tools for hydraulic investigations even when complex transition zones are involved.

1. Introduction

Saltwater intrusion is an important environmental problem for coastal aquifers of Queensland, Australia. Coastal aquifer systems in Queensland supply up to 370 000 megalitres of groundwater

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0307-904X/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.apm.2005.05.007

per annum for irrigation, industrial and town water purposes. In this paper, a coastal alluvial aquifer system is studied as a test case. This particular aquifer system, which comprises the tertiary Elliott formation and Fairymead beds, has supplied water for irrigation during the past 40 years. A major problem that has arisen is that excessive demand for groundwater in these coastal areas has stretched the aquifers beyond their long-term yield and resulted in saltwater intrusion with a substantial loss of agricultural land [1]. Since the 1960s, 12 500 ha of land in Gooburrum alone have been lost to saltwater intrusion and the saltwater interface is estimated to be currently moving at around 100 m per annum in the highly permeable channels [2].

The dynamics of the circulation of saltwater in the region is still not well understood. Saturated–unsaturated, variable-density flow and transport modelling is a difficult problem, which is compounded by the fact that the regional aquifer in the Bundaberg area is unconfined, whereby the water surface fluctuates with time.

In this paper, a two-dimensional control volume finite-element model is developed to simulate saltwater intrusion in a vertical section of the heterogeneous aquifer system at Gooburrum. The research demonstrates that transport simulation techniques provide excellent tools for hydraulic investigation even when complex transition zones are involved. Furthermore, such tools have potential for assisting strategic decision making concerning water resource management.

2. Problem formulation

Groundwater level contours of the Bundaberg area indicate that the major flow direction of water in the upper aquifer is from the southwest to the northeast with the discharge mainly to the ocean [23]. Under such circumstances, preliminary assessments made from two-dimensional simulations can be reasonably informative. Here, a two-dimensional density-dependent, saturated and unsaturated flow and transport computational model is used to analyse the Bundaberg groundwater system. For this study, one vertical section is modelled (refer to section A–A′ in Fig. 1). The illustrated section A–A′ runs from the Pacific Ocean near Moore Park to a point about 14 km to the southwest of Moore Park. Note that the orientation of the vertical section

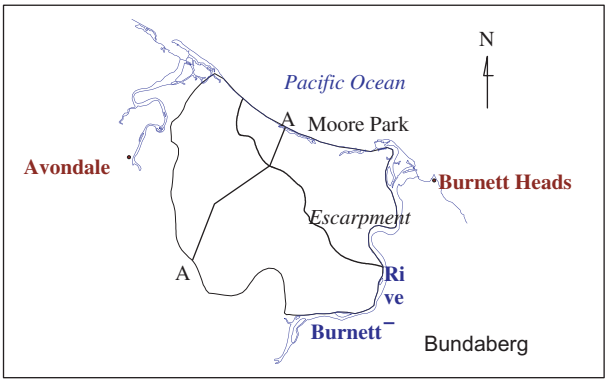

Fig. 1. Plan view of Gooburrum area.