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On the use of neural networks to evaluate groundwater levels in fractured media

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Abstract

This paper evaluates the feasibility of using artificial neural network (ANN) methodology for estimating the groundwater level in some piezometers implanted in unconfined chalky aquifer of Northern France. These aquifers are the most susceptible to depletion and contamination, with the recharge rate and dominant processes determining their level of vulnerability. Groundwater level simulation in a chalky media is regarded as a difficult subject in hydrogeology due to the complexity of the physical processes involved, the variability of piezometry in space and time and the aquifer response in fissured and matrix blocks. In the present project, after a detailed geologic and hydrogeologic study of the sector, we simulated the groundwater level by Neural Network. The first objective was to determine the most influential parameters which impact groundwater level in fissured chalky media. The second objective was to investigate the effect of temporal and spatial information by considering current and past data sets along with the use of a variety of piezometer readings. The third objective was to simulate the groundwater level in a selected piezometer. The reasonably good ANN-based simulations revealed the merit of using ANNs and specifically Multi Layer Perceptron (MLP) models. The proposed ANN methodology using minimal lag and number of hidden nodes, along with the optimal number of spatial and temporal variables consistently produced the best performing network-based simulation models.

Keywords: ANN; Chalk; Groundwater; Fractured media; Backpropagation algorithm

1. Introduction

The chalky aquifer represents the most significant groundwater reservoir of northern France because of the large expansion of Cretaceous outcrops and their hydraulic characteristics. The chalk becomes aquifer only when the cracks developed in the chalk provide significant water flow paths especially where fissures are developed. A number of mathematical models describing groundwater levels in fractured porous media have been developed over the past three decades (Delattre, 1969, Vandycke et al., 1991,

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Bracq and Delay, 1997). The distinction between these models arises from differences in the conceptual model upon which they are based and the methods used to solve the governing equations. The calibration of these models are difficult because the numbers of parameters to estimate specially in the chalky media. 'Black box' models like Artificial Neural Networks (ANN) can resolve these problems. In this paper a detailed formulation of the ANN methodology to simulate groundwater level in unconfined aquifer is presented.

There have been a number of reported studies that have used ANN to solve problems in hydrology because of their ability to model both linear and non-linear systems. For example, Coulibaly et al. (2000) applied an ANN to forecast reservoir inflow and river flow prediction. The ANN methodology has been applied also to forecast rainfall (Luck Kin et al., 2001). Parkin et al. (2001) used ANNs, coupled with a 3-D numerical model, to model river-aquifer interactions. In the geotechnical domain, Kurup and Dudani (2002) used ANN to profile the stress history of clays from piezocone penetration tests. In chalky media, we mention for example, forecasting of turbid floods in a karstic media (Beaudeau et al., 2001) and determination of aquifer outflow influential parameters, simulation and forecasting of aquifer outflow in a fissured chalky media (Lallahem and Mania, 2002, 2003a,b).

The objective of this paper is to identify the temporal data necessary to calculate groundwater level in one piezometer. For that we tried to find an adequate relationship between all model input parameters that have major influence on groundwater level. The first step of this work is to improve the model design, by studying the effect of a nearby piezometer that is situated at the same geological and hydrogeological compartment and has the same order of distance between the piezometer and its outlet.

The second step is to model the system by changing the value of lag time (k). We stopped this iteration procedure once we have achieved a reasonably good superposition of validation and training graphic plots and an optimal RMSE value.

The third step is to test the increase of output nodes on the convergence of the model and on level piezometry simulation.

2. Material

2.1. Case study: fissured chalky media in northern France

The area chosen for this study is located in the North Paris Basin (northern France) (Fig. 1). The Paris Basin is under an oceanic climate where temperature is about 10 °C in average. The average annual rainfall is between 700 and 1000 mm. The evapotranspiration is about 500–600 mm y^{-1}. The annual effective rainfall over a period of 30 years shows that the amount of water available for surface runoff and groundwater recharge is estimated at about 300 mm. The annual surface runoff is low since it represents between 5 and 10% of the effective rainfall. The basement is comprised of the chalky grounds of Senonian and Turonian stages (Fig. 2). In the studied sector, the Senonian formations set includes, at the base, a clayey formation called Gault. It is surmounted by a Cenomanian marly-carbonated set. The Turonian

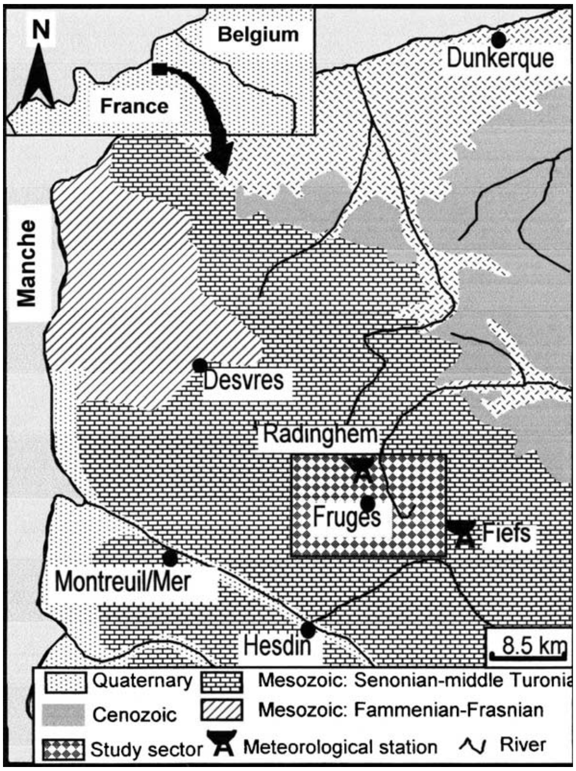

Fig. 1. Geologic map and localisation of the study zone.