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Application of spectral analysis of daily water level and spring discharge hydrographs data for comparing physical characteristics of karstic aquifers

M. Rahnemaei[a], M. Zare[b,*], A.R. Nematollahi[c], H. Sedghi[d]

[a]*Irrigation Department, Shiraz Islamic Azad University, Shiraz, Iran*
[b]*Earth Sciences Department, Shiraz University, Shiraz 71454, Iran*
[c]*Statistics Department, Shiraz University, Shiraz, Iran*
[d]*Irrigation Department, Research and Science Campus of Islamic Azad University, Tehran, Iran*

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Abstract

Bivariate time series techniques (in spectral domain) of daily rainfall and water level of piezometers or discharge of springs in karstic aquifers are employed to evaluate the lag times (delay) of aquifers response to rainfall events. The evaluation results show that the physical characteristics of karstic aquifers can be compared with each other by using the outcomes of these analyses. With attention to dual porosity idea of karstic aquifers, two lag times (t_1, t_2) can be computed, which, are related to flow of water through larger fractures (conduit flow) and matrix of the rock (diffuse flow), respectively. Results obtained from these functions, correspond to the findings of physical characteristics, compiled from field investigations. Comparable to dual porosity idea in regard to recharge through the larger fractures (in the first step) and finer porosity of the rock (in the second step), the idea of 'Dual Recharge' in karstic aquifers is presented. Application of these techniques is verified using daily rainfall and water level of Qara, Sabzpooshan and Kaftarak piezometers and daily discharge of Qasreqhomsheh karst spring in Maharlu basin in Iran (52°20′–52°40′E and 29°20′–29°40′N) having different degree of karstification in their surroundings.

Keywords: Karst hydrology; Time series; Spectral analysis; Lag time; Karstification degree

1. Introduction

Due to heterogeneous structure of the karst systems and therefore, variable recharge regimes, karst system hydrogeological conditions are complex (Bonacci, 2001). Water infiltrates through the covered soils and/or through fractured and collapsed zones. Thereinafter, water reaches the saturation zone through the fracture networks and interconnected solution conduits. To characterize the flow regime, recharge and infiltration velocity through fractured hard rocks, we can use three types of conceptual models: the continûum, discrete, and dual porosity models. The continûum model assumes that the aquifer acts similar to porous media (alluvium), but in the discrete model

* Corresponding author.
E-mail address: zare@geology.susc.ac.ir (M. Zare).

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water flows more in fractures and separate conduits and, the dual porosity approach attempts to characterize groundwater flow in individual conduits or fractures as well as in the matrix portion of the aquifer. The question of which conceptual approach is most suitable for study of a given aquifer is somewhat a question of scale of the study and depends on availability of different factors such as hydraulic conductivity distribution, water table configuration, pumping test responses, variation in water chemistry, presence of karst features, variation in hydraulic head and borehole logging (ASTM, 1995).

Some references discuss the dual porosity model in the karst systems due to its advantages (ASTM, 1995; Ford and Williams, 1989; White, 1988). In this research, similarly, this idea is employed which, corresponds more to the statistical time series analysis results.

Originally, time series techniques were developed by researchers such as Jenkins and Watts (1968), Hannan (1970), Brillinger (1975), Box and Jenkins (1976), Wei (1990) and Brockwell and Davis (1996) and were used in hydrology by Thomann (1967), Quimpo (1968), Kareliotis and Chow (1970), Delleur (1971), Yevjevich (1972), Spolia and Chander (1973), Shashan et al. (1977), Ledolter (1978), Chow (1978), Lettenmaier (1980), Clark (1984) and Biddiscombe et al. (1985) and other specialists. Mangin (1981), Benavente et al. (1985), Obarti et al. (1988), Padilla and Pulido-Bosch (1995), Lee and Lee (2000) and Samani (2001) used these methods, specifically in karst and hard rock aquifer studies.

Mangin (1981) by the use of stochastic equations showed that a karst system can be viewed as a filter system and input signals such as rainfall can be compared with output ones such as water level and discharge changes.

Using time series analysis, Rahnemaei et al. (2004) showed that with the extent of karstification degree, variation of lag times (delay) become more complex with respect to data monitoring time intervals. It is shown that one should plan before hand an optimum

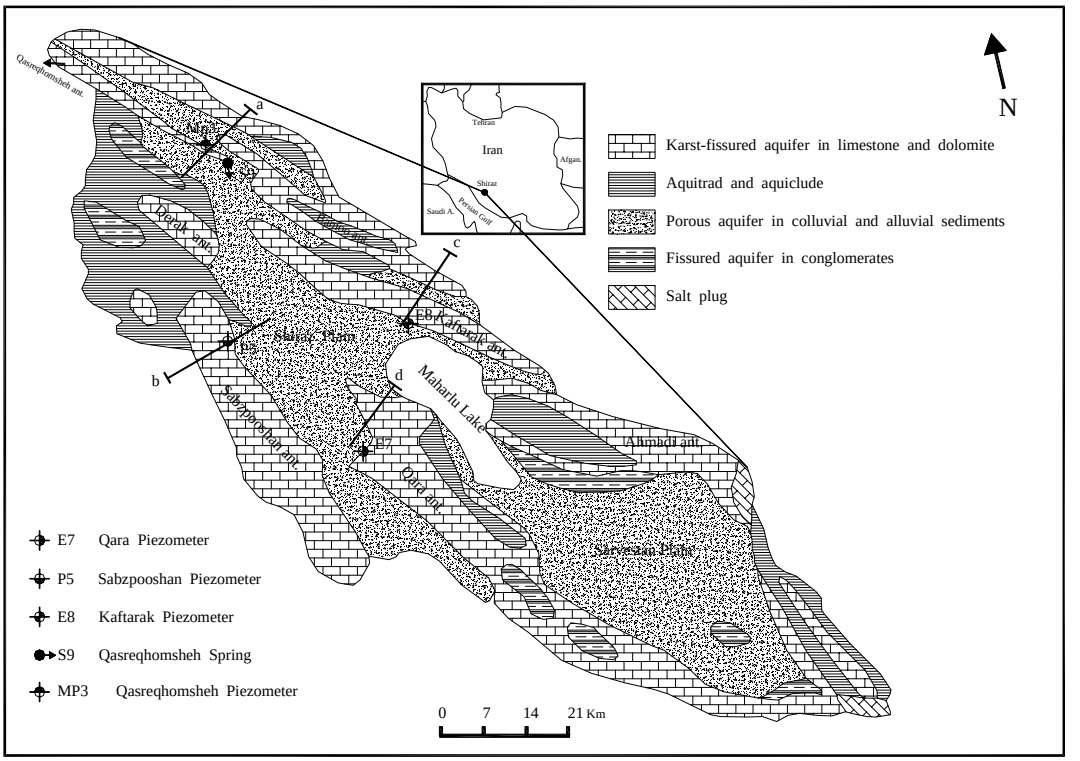

Fig. 1. Hydrogeological map of Maharlu basin in Fars Province, location of the studied piezometers and karst spring (TAMAB, 1995).