22nd Salt Water Intrusion Meeting

SWIM 2012

Armação dos Búzios·RJ
JUNE, 17·22

Proceedings

MODELLING AND GROUNDWATER MANAGEMENT OF A KARSTIC COASTAL AQUIFER: THE CASE OF SALENTO (APULIA, ITALY)

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Keywords: *Seawater intrusion, groundwater modelling, groundwater management, coastal karstic aquifer*

1. INTRODUCTION

The coastal karst aquifers are known to be highly vulnerable to anthropogenic and natural changes, and in particular to the overexploitation of groundwater resources. The high degree of vulnerability is due to their intrinsic characteristics, anthropogenic pollution, and the effects seawater intrusion. The progressive population concentration in coastal areas and the increasing discharge overlapped to peculiarities of karstic coastal aquifers constitute a huge worldwide problem, particularly relevant for coastal aquifers of the Mediterranean basin. In Italy, Apulia, with its coastline extending over 800 km, is the region with the largest coastal karst aquifers. The predominant karstic Apulian features make the region extremely poor of surface water resources and rich of high quality groundwater resources. These resources still allow the social and economic development of population, improving agricultural and tourist opportunities. The continuous increasing well discharge causes or contributes to the groundwater quality degradation, often making the groundwater unusable for irrigation and drinking (Polemio et al. 2009). The strategic importance of groundwater resources and its wise management for Apulian population is due to these risks (Cotecchia and Polemio 1998, Margiotta and Negri 2005). The aim of this study is to define the efficacy of existing management tools and to develop predictive scenarios to identify the best way to reconcile irrigation and drinking water demands with enduring availability of high quality groundwater. The Salento (Salentine Peninsula), was selected being the Apulian aquifer portion exposed to the highest risk of quality degradation due to seawater intrusion.

2. STUDY AREA

Apulia can be described distinguishing four main hydrogeological structures (HSs), Tavoliere, of clastic nature (Quaternary), and Gargano, Murgia, and Salento, constituted by limestone and dolostone, which constitute a typical karstic environment (Fig. 1). Focusing on the contiguous Murgia and Salento HSs, from a geological point of view, they consist of almost similar Mesozoic carbonate rocks but show different hydrogeological characteristics. In particular, the Quaternary tectonic differential movement between the two hydrogeological structure put the Salento in condition to drain a large amount of Murgia groundwater (Cotecchia 1979). The Salento feed coming from Murgia is discharged through some Ionian and Adriatic coastal springs located in the northern Salento. The selected study area was the southern Salento, where the aquifer recharge is only due to the direct rainfall infiltration. The landform is at horst and graben, where the *graben consists of Plio-Pleistocene deposits, which are interposed between tabular reliefs of Mesozoic limestone. The main aquifer, called "deep aquifer", is constituted by Mesozoic limestone. The piezometric slope is generally in the range 0.1 to 2,5‰; the maximum piezometric head is less than 4 m asl. Groundwater flow is widespread confined far from the coast, not only where the aquifer top is below the sea level, as observed in the eastern portion of study area (Cotecchia et al., 2002). Where limestone does not outcrop, calcarenite, sands and conglomerates can constitute a shallow aquifer. In the study area can be distinguished more shallow aquifers, each one able to exchange water with the deep aquifer, mainly feeding this one (Calò et al. 1992).*

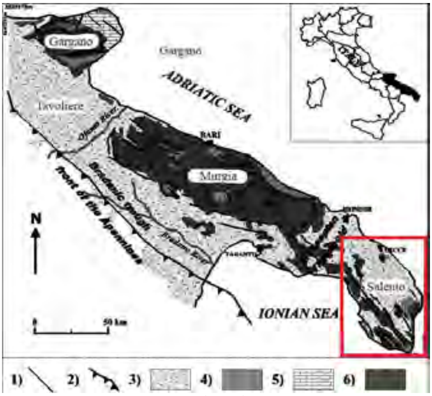

Fig.1 Geological scheme (modified after Beneduce et al. 2004). 1 Fault, 2 front of the Apennines, 3 recent clastic cover (Pliocene–Pleistocene), 4 bioclastic carbonate rocks (Paleogene) and calcarenites (Miocene), 5 carbonate platform rocks (Upper Jurassic-Cretaceous), 6 chert-carbonate rocks (Upper Jurassic- Cretaceous). Red Line – study area

3. ESTIMATION OF RECHARGE RATE

The natural recharge is a critical input for planning sustainable use of groundwater resources, therefore was defined the hydrogeological balance of the study area. The DEM was discretized using 25-meter resolution ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data. The DEM altitude ranges from 0 to 214 m asl (35 m asl as average). Rainfall and temperature monthly data of 13 gauges were considered from 1925 to 1975; the period was selected to avoid the trend effect of climate change, particularly relevant in the area from the eighties, as highlighted by Polemio and Casarano (2008). The mean annual rainfall ranges from 544 mm to 946 mm (727 mm as mean gauge value). The mean annual temperature ranges from 15.5 to 17.5 C° (mean equal to 16.6 C°). Using a multiple linear regression function of the altitude and the distance from the Adriatic coast, the rainfall and temperature was determined in each cell, operating in a GIS environment. The monthly real evapotranspiration was determined using the traditional and affordable Turc method, using the modified temperature approach (Polemio et al. 2000). At the end, the mean annual net rainfall was calculated in each cell: it ranges from 68 to 343 mm, 173 mm an average. The recharge or infiltration was calculated using an infiltration coefficient (IC) (defined as infiltration/net rainfall ratio) for each hydrogeological complex, assuming values equal to 1 inside endorheic areas (Fig. 2). The mean annual recharge was equal to 150 mm.

4. GROUNDWATER MODELING

The numerical modelling was based on a "partially-physical partially conceptual" approach, with the simplifying hypothesis of an equivalent porous media. Several authors consider these choices the most flexible to model water flow and transport at the regional scale in karstic areas (Andresonn and Woesser 1992, Dufrense and Drake 1999, Scanlon et al. 2003), especially for predictive management objectives (Schwarz and Smith 1988). The numerical code used was SEAWAT (Langevin et al. 2003) that combines the three dimensional groundwater flow model MODFLOW (McDonald & Harbaught 1988) with the solute transport code MT3DMS (Zheng and Wang 1998). For the spatial discretization, considering the Peclet number, the study area was divided into 280-meter squared cells. 12 layers and 97,2008 cells were used to pursue an accurate hydrogeological discretization. The model surface morphology was defined using DEM data. The geometrical 3d features and hydrogeological parameters for each hydrogeological complex were defined using published (maps from ISPRA, the national institution for the environmental protection and research, and PTA, the Apulian regional water protection plan) data and unpublished, from CNR IRPI geodatabases and surveys. Inactive or no flow cells defined the internal boundary conditions, along the remaining portion of the aquifer, and the marine areas; CHB (constant head boundary-Dirichlet condition) cells were used to shape the coastline, where the constant sea salt concentration was assigned.

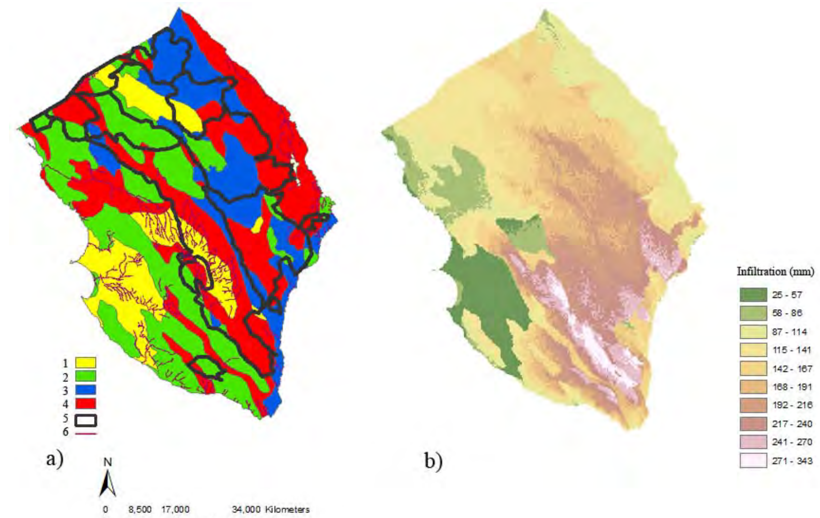

Fig.2 a) Hydrogeological complexes and endorheic areas. 1) Pleistocene sands and conglomerates (IC 0.35; Kx $5*10^{-6}$; Ky $5*10^{-6}$; Kz $1.9*10^{-8}$); 2- Upper Cretaceous limestone (IC 0.9; Kx $9*10^{-4}$; Ky $9*10^{-4}$; Kz $2.58*10^{-2}$); 3- Andrano Calcarenite and Pietra Leccese (IC 0.7; Kx $1.4*10^{-5}$; Ky $1.4*10^{-5}$; Kz 10^{-6}); 4- Leuca and Gravina Calcarenites (IC 0.6; Kx $1.9*10^{-5}$; Ky $1.9*10^{-5}$; Kz $5*10^{-6}$); 5- Endorheic areas (C.I. 1); 6- drainage network; b) Mean annual recharge or infiltration map.

The steady-state model calibration slightly modified the hydraulic conductivity, which was formerly defined on the basis of pumping tests and literature data. Groundwater head observations of 18 wells were compared to the simulated groundwater heads (Fig. 3). These piezometric data were acquired during the thirties, when the discharge was so low that quite natural flow conditions can be hypothesized (Polemio et al. 2011).

5. CONCLUSION

Preliminary results of steady flow and of spatial variability of groundwater salinity are now available. These results are the basis for next phases of a Ph.D. activity. The next phase will be the validation of the model using additional well-head data and sensitivity of analysis before define some simulating scenarios. This model improving will be the basis to simulate the space and time evolution of the seawater intrusion phenomenon and to define tools for sustainable management of groundwater resource.

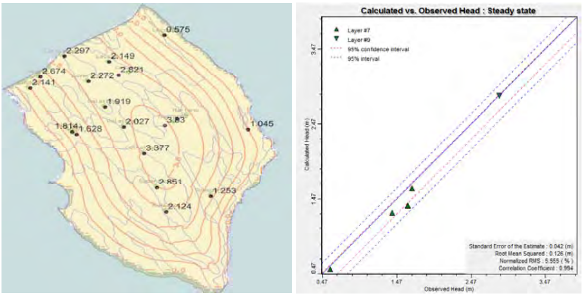

Fig.3 Comparison between head observation (point) and calculated (line).

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