Parameter estimation for part of the transboundary Upper Jurassic - Lower Cretaceous BG-RO aquifer

P. N. GERGINOV & T. V. OREHOVA

Department Hydrogeology, Geological Institute – Bulgarian Academy of Sciences, 24, Acad. G.Bonchev str., Sofia 1117, Bulgaria

orehova@geology.bas.bg

Abstract The Upper Jurassic - Lower Cretaceous aquifer is the most productive in Bulgaria. It has national importance as a huge groundwater reservoir and is a transboundary aquifer shared between Bulgaria and Romania. Modelling is a powerful method for the purposes of groundwater management. Part of this aquifer was modelled. Due to large modelled area, available data on transmissivity values are insufficient for the simulation. Parameter estimation clarifies the transmissivities in the region, where practically there are no filtration tests. The geometry of the transmissivity zones had been marked by combination of pilot points and area approach. Thus the information from investigations was filled with the modelling results.

Key words Upper Jurassic-Lower Cretaceous aquifer; transboundary aquifer; groundwater modelling; PEST; water management

INTRODUCTION

The Upper Jurassic - Lower Cretaceous aquifer is the most productive in Bulgaria. It is situated in north-east part of the country and covers about 20000 km^2. The calcareous formations (J_3-K_1v limestone and dolomite) are up to 1000 m thick and are fissured and locally highly karstified (Antonov & Danchev, 1980). It has national importance as a huge groundwater reservoir and is a transboundary aquifer shared between Bulgaria and Romania. In spite of detailed studies made in the region, an actualisation of the information is necessary, including regional analyses concerning its groundwater resources and balance elements.

The groundwater flow is directed mainly to east and north. The aquifer is used for water supply of towns and villages in the region, partly for industrial purposes. The groundwater depth varies largely from 10 to 217 m (General Master Plans, 2000).

The basic aims of the study are collecting of data, regional characterization and detailed concept of the aquifer, and testing of the methodological approaches for similar estimates. Parameter estimation is an essential stage of the modelling study. Part of the aquifer is considered, as a base for the further studies.

AREA AND BOUNDARIES

The present study was conducted for a part of the Upper Jurassic - Lower Cretaceous aquifer with area of 4000 km^2 (Fig. 1) – fissured and karstified aquifer, which is strongly heterogeneous.

The north-western boundary of the area coincides with a groundwater divide, which separates the groundwater flow between the Black Sea and the Danube river basins (General Master Plans, 2000). The southern boundary is assigned lithologically – it is related to the replacement of limestone with low permeable terrigenous formations. The north-eastern boundary follows a flow line, and is considered as no-flow boundary. Both NW and NE boundaries are marked with several local piezo-maximums, which denote areas with relatively low transmissivity and/or high recharge values.

Fig. 1 Map of Bulgaria with the study area.

The eastern boundary of the studied region coincides with the Venelin-Aksakovska dislocation, where sinking of the layers occurs, which is step-wise and associated with a system of faults.

The advantage of using part of the aquifer are as follows: (i) the areas, with substantial interaction of the studied aquifer with overlaying aquifers (K_1h-b-apt aquifer, Sarmatian N_1s and others) are avoided; (ii) the areas with thermal waters are avoided; (iii) the developed methodical approach is based on a local area.

METHODS

The methods include analysis of the available geological, tectonic and hydrogeological information. For the modelling purposes a database was created.

Modelling is a powerful method for the purposes of groundwater management. Hydrogeological models are widely used for simulation of regional groundwater flow in porous media. Lately they are used for typical karst aquifers as well (Angelini & Dragoni, 1997; Larocque *et al.*, 1999).

In general, modelling of heterogeneous media such as karst aquifers presents a real problem. Recent studies show the ability of equivalent porous media models to simulate regional groundwater flow in moderately and highly karstified aquifers (Larocque *et al.*, 1999, Scanlon *et al.*, 2003).

One of basic obstacles during modelling is that the aquifer contains regions both with very low and very high transmissivity values. This circumstance requires good knowledge of other factors besides hydrogeological ones. Such are tectonic and lithological features, which are inseparable part of each hydrogeological system.

At present stage of the study, the simulation is applied to describe basic tendencies of the groundwater flow. As a result, overall concepts for the aquifer behavior and distribution of the heads are obtained.

GROUNDWATER MODELLING

Hydrodynamic conditions of the groundwater system and head distribution as a result of natural recharge and discharge and pumping wells are simulated by MODFLOW (as a module of GMS 4.0). The solution is based of the finite difference method, with taking into account initial and boundary conditions.

Defining of transmissivity of the aquifer is important stage for constructing a groundwater model. Due to large modelled area, available data on transmissivity values are insufficient for the simulation. Here Inverse Modelling approach had been used (module PEST from GMS 4.0). It gives possibility to define transmissivity values in the area, based on measured groundwater heads.

It is known that distribution of heads is governed by both transmissivity of the medium and recharge to the aquifer. For the purposes of the simulation, the recharge has been considered as known. The main recharge areas are related to outcrops of the carbonate formation. For this reason, two values have been used for the recharge intensity, the higher referred to outcrops, and the lower – to the rest area.

The internal boundary conditions are Devnenski and Zlatinski springs and pumping wells within the area.

During the simulations, the next assumptions were made:

- Vertically the model is one layered in steady state conditions.
- It is necessary parameter estimation by inverse modelling to be used for clarification of different transmissivity zones.
- The simulation is based on measured groundwater levels for the period 1978-1985.
- The precipitation is the only source of feeding of groundwater, as the recharge has the highest values in the outcrop areas – 0.000674 m day^{-1} *vs* 0.0000986 m day^{-1} in the rest of the model.

Input data

The realization of the model was made by construction of grid with 10500 cells. The size of the cells was refined closely to the extraction wells.

On the three of the boundaries we entered no flow boundary conditions with Q = 0, except the eastern one, which is drain.

There are 18 extraction wells in the model with total flow rate 78063 m^3 day^{-1}.

Another conditions within the area are Devnenski and Zlatinski springs, with discharge values 320000 and 34560 m^3 day^{-1}.

Simulation

There were several stages in groundwater modelling – building of conceptual model, construction of a model, parameter estimation run and forward model run.

The geometry of the transmissivity zones had been marked by combination of pilot points and area approach. Pilot points are such points in which we search the values of hydraulic conductivity. They gave us the spreading tendencies in the area. Afterwards the zones with the final geometry were delineated by area approach, according which the measured water levels correspond again to the model solution by entering hydraulic conductivities in areas.

The transmissivity values for delineated zones obtained from PEST simulations are presented in Fig. 2.

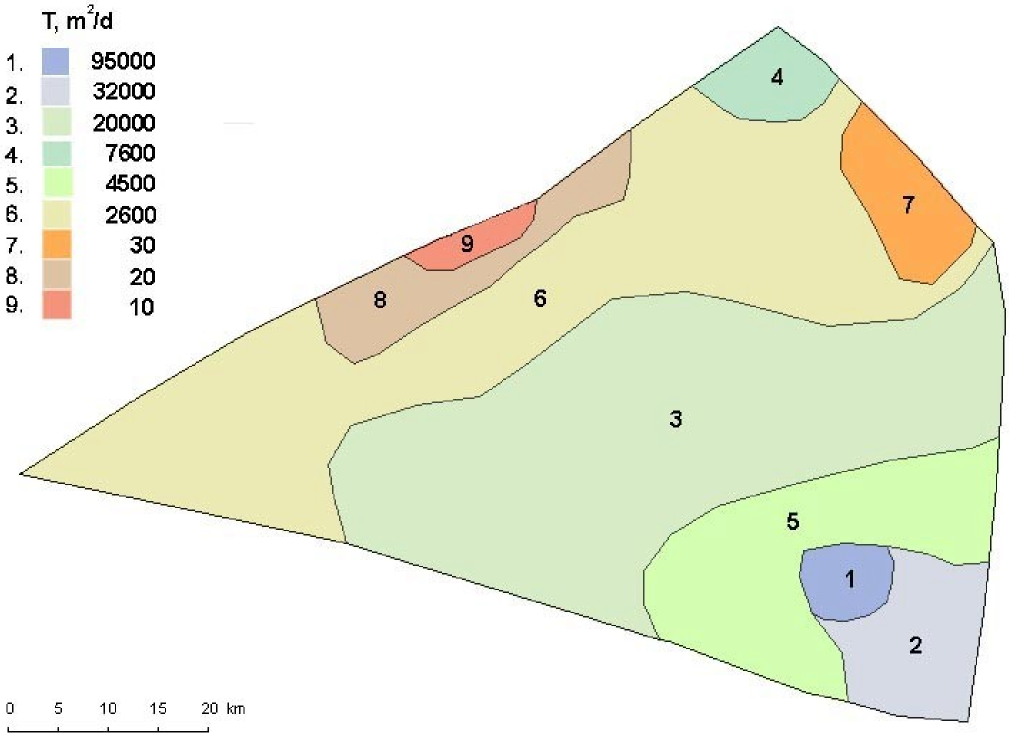

Fig. 2 Distribution of transmissivity in the modelled area.

For the calibration the most appropriate were the results from the measured groundwater levels for the period 1978 – 1985 (Fig. 3).

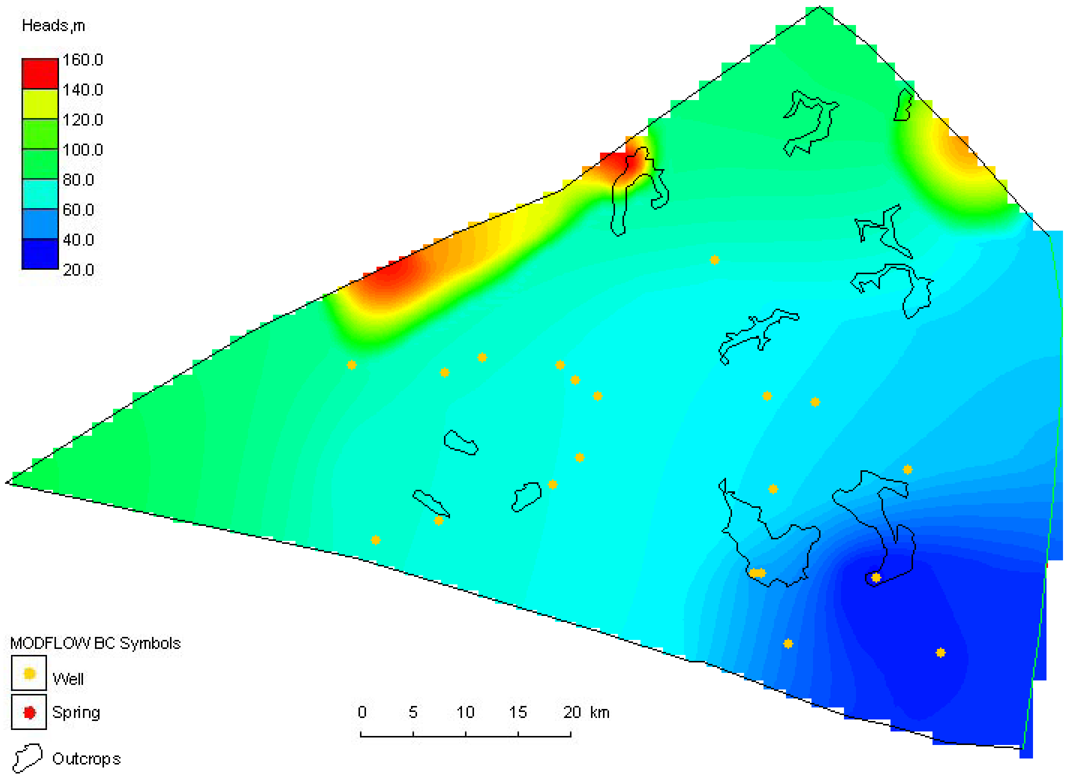

Fig. 3 Modelling solution for groundwater heads for the period 1978 - 1985.

Calibration points are available in the whole area and gave us a good image of water heads distribution. The calibration curve represents the correspondence between real water levels and modelling solution (Fig. 4).

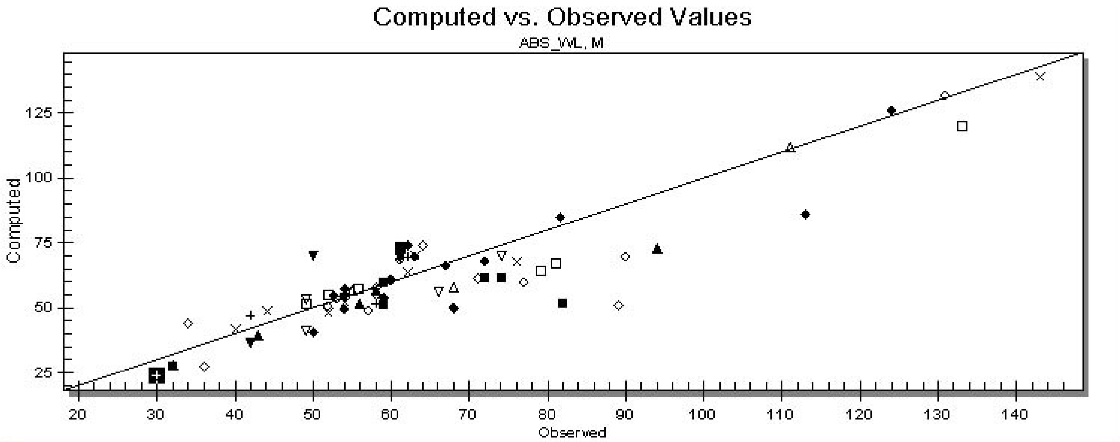

Fig. 4 Calibration curve.

According to its structure, the aquifer presents a multi-layer aquifer system. At this stage of the study one-layer aquifer was considered. This approach was necessary to simplify the model, however it is reasonable due to hydrodynamic unity of the aquifer.

Romanian hydrogeologists point out on the strong vertical anisotropy of this aquifer (Zamfirescu *et al.*, 2005). More rigorous approach, based on multi-layer system, should account for this fact.

The aquifer is defined as strongly heterogeneous. The values of transmissivity assessed from pumping tests can differ highly at short distances.

CONCLUSION

Simulation with PEST module delineates zones with different transmissivity. Real observations of groundwater levels for the period 1978-1985 had been used.

Finally the model area has 9 transmissivity zones within. The range of values is from 10 to 96000 m^2 day^{-1}. The highest are in the area with the most intensive draining of the aquifer – Devnenski springs. The lowest values are situated around northwest boundary, close to an existing groundwater divide.

According to the previous investigations in Romania, the highest values for the transmissivities in the aquifer in Romania corresponds to the highest levels in Bulgaria.

Parameter estimation clarifies the transmissivities in the region, where practically there are no filtration tests. Thus the information from investigations was filled with the modelling results. Good combination between modelling and research activities can result in better knowledge of natural groundwater conditions.

REFERENCES

Antonov, H., & Danchev, D. (1980) *Groundwater in the Republic Bulgaria*. Sofia, "Technika", 360 p. (in Bulgarian).

Angelini P., & Dragoni, W. (1997) The problem of modeling limestone springs: the case of Bagnara (North Apennines, Italy*),* 612 – 618. *Groundwater* **35**(4).

General Master Plans for utilization of the water resources in Bulgaria. Project supported from Bulgarian Ministry of Environment and Water (2000) Hydrogeological background and assessment of groundwater resources. http://www.bluelink.net/water/ (In Bulgarian) Cited 15 June 2007.

Larocque, M., Banton, O., Ackerer, P. & Razack, M. (1999) Determining karst transmissivities with inverse modeling and an equivalent porous media, 897-903. *Ground water* **37**(6).

Scanlon, B.R., Mace, R.E., Barrett, M.E. & Smith, B. (2003) Can we simulate regional groundwater flow in a karst system using equivalent porous media models? Case study, Barton Springs Edwards aquifer, USA, 137–158. *Journal of Hydrology* **276**.

Zamfirescu, F., Danchiv, A., Popa, I., Popa, R. & Rudolph-Lund, K. (2005) The karstic aquifer system of Southern Dobrogea (Romania). In: *Water Resources and Environmental Problems in Karst - Cvijić 2005*: Proc. of the Int. Conf. (ed. by Z. Stevanović, P. Milanović). Belgrade, 239 – 248.