PhD thesis

ENVIRONMENTAL EFFECTS OF GROUNDWATER WITHDRAWAL IN SOUTH NYÍRSÉG

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Preliminaries, the aims of the dissertation

The study area (South Nyírség) is situated in the North-East part of the Great Hungarian Plain, in the vicinity of Debrecen city. Most of the area is built up by alluvial and fluvial deposits. The elevation of the study area ranges from 100 m up to 150 m. The uplifted center of the Nyírség hills to the North-East is the main groundwater recharge area. On the study area groundwater is used for drinking, industrial activities and in a small proportion for irrigation. During the peak output, in 1986, from four waterworks the total water use was estimated to be approximately 20 million m^3/year in Debrecen city. The groundwater withdrawal was concentrated on waterworks 2, close to which a pharmaceutical plant was constructed in 1952. During the operation of the factory dangerous products were disposed until 1970s. By this activity a serious contamination, which can be located only with difficulties at present, had been caused.

Three aquifers were identified in the Quarternary sediments based on the lithologic stratigraphic and hydraulic characteristics of the rock framework. The aquifers consist of unconsolidated sedimentary formations, predominantly sands, which are separated by clay and clayey sand aquitards.

The aquifers: 1.) Upper aquifer (unconfined)
2.) Middle Pleistocene aquifer (confined)
3.) Lower Pleistocene regional aquifer (confined)

The depth of the third aquifer, the focus of the groundwater withdrawal, is from 120 m up to 220 m. This study is based on last century research data.
The primary goal of the dissertation is to evaluate the relationships between the pumped lower Pleistocene aquifer and the natural environment, and how pumping influences the groundwater flow system.

Analytical methods

I searched the solution for the problem in a complex way by applying geological, hydrological, hydraulical, geostatistical, mathematical, geophysical and chemical methods.
The permeability distribution of the rock body was determined with software GSLIB (Deutsch és Journel 1992). The method provides the 3D presentation of the given attribute in a geo-cellular way by starting from a relation plane as a datum horizon (Geiger 2003). The hydraulic division of the rock body was made on the basis of water level data measured between April-May 2002 in the vicinity of waterworks 2 in wells filtered at different depths. The hydraulic

regime of the studied area was determined by constructing pressure-elevation profiles (Tóth 1979, Tóth and Almási 2001, Busa Fekete et al. 2004). The method displays the force potential in a very descriptive and graphic way.

The gravitational and magnetic anomaly maps were created by applying the Blakely-Simpson method (Blakely and Simpson 1986), which is well applicable in terms of map data systems for marking out the maximum points given by the construction of horizontal gradients.

The relation of the groundwater curve and precipitation data was investigated with cross-correlation analysis. Isohypses were made from the absolute values of water level by krieging.

The compaction observed on the study area was determined with the help of fuzzy arithmetics (Fang and Chen 1990, Bárdossy et al. 2000), based on fuzzy sets theory (Zadeh 1965).

The separation of groundwater flow systems was carried out on the basis of the concentration of univalent and bivalent main cations, chloride and total solved content (Varsányi 2001).

The seepage between aquifers was proved by ^{14}C (Marton 2000) and tritium concentrations, measured at the ATOMKI.

Calculations on the transportation of the contamination were made with software Processing Modflow (Chiang and Kinzelbach 2001), operating with the finite difference method.

New scientific results

1. *I have detected a North-South fault zone structure between waterworks 1 and 2, which divides vertically the lower Pleistocene aquifer.* Because of the vertical movement along the fault zone the West side of the Lower Pleistocene aquifer is situated upper with 30-40 meters than the East side. The fault can be traced down to the pre-Neogen basement. Above this fault zone the Tócó valley sets the boundary plane of two geographical regions: Nyírség and Hajdúság. This was proved by geophysical investigations. I have demonstrated with a 3D geostatistical model that the sandy layer above the aquifer is thicker in the centre part of the recharge area.

2. *Based on time series data, I have detected a 75-80 meter thick water body in which the hydraulic head changes uniformly with only a few centimeter difference within this interval.* This means that the clayey sediments between 16-20 meters have no hydraulic barrier role.

3. *I have demonstrated with the help of pressure-elevation profiles the different hydraulic conditions of pre Quarter sediments on the two sides of the Tócó valley.* I have observed that the West zone is overpressured already from a 500 m depth, contrary to the East side where overpressure appears below 2000 m only.

The Quarternary sediments have the same hydraulic condition, nevertheless, the pressure on both side of the Tócó valley is 1 MPa/km less than the hydrostatic pressure.

4. *I have found that there is a delayed relationship between water withdrawal from the Lower Pleistocene aquifer and the Upper Pleistocene unconfined groundwater level*. In case of waterworks 2 the delayed effect of exploitation on the unconfined water level is 3-5 years, depending on the distance of the monitoring well from waterworks 2. Concerning the other waterworks I haven't found any connection like this. I haven't found correlation between the sum of winter precipitation and the average unconfined water level data either. However, if the winter time increase of the unconfined water level data is compared to the sum winter precipitation a significant correlation can be found.

5. I have determined the value of landsubsidence due to groundwater exploitation with fuzzy arithmetics. *I have found that the landsubsidence in the centre of groundwater exploitation is between 0,27 and 1,08 m, but the most probable value is in the interval of 0,42 – 0,71 m*. I have assessed that there was enough time to the development of the calculated compaction. The use of fuzzy arithmetics is advantageous for landsubsidence, as it considers uncertainty very well.

6. I have investigated the origin of groundwater in the surroundings of waterworks by applying the hydrochemical data of the Groundwater Protection Project in 1999. *The identical origin of the groundwater of waterworks 1 and 2 is proved by Na and Ca+Mg ion concentrations. The Ca-MgHCO_3 type waters indicate that waters come from ground surface.* The higher Na and lower Ca+Mg ion concentration of waterworks 4 shows that the water have spent longer time underground, so ion exchange could be probable.

7. I have determined the horizontal and vertical extension of a complex contamination around waterworks 2. *According to my hydrodynamic model, the contamination has not filtrated horizontally farther than 250-300 m from its source, however, vertically it could reach at a 50-80 m depth due to the depression caused by water extraction.* Therefore the argillaceous sediments at the depth of 14-20 m have not been able to protect the deep aquifers from the contamination. My statement has also been confirmed by tritium isotope and hydrochemical analyses.

8. I have generalized the conclusions made during modeling, and investigated the role of lower boundary in the simulated groundwater flow. *I have also demonstrated that it is necessary to consider the hydraulic ability of base sediments when defining*

the lower boundary. This is particularly true in terms of an overexploited layer and places next to a compression zone boundary. I have observed that the conductivity of fault zones which cross the lower boundary have fundamentally modified the flow space. According to the model of groundwater flow, the study area lying West of the Tócó valley seems “to be propped up” from downward while the Eastern part seems “to be pulled”. This factor is very important in terms of waterbudget calculations and the maintenance of sustainable exploitation.