COMPLEX HYDROGEOLOGICAL STUDY OF THE ALLUVIAL TRANSBOUNDARY AQUIFER OF SOMES/SZAMOS (ROMANIA – HUNGARY)

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Abstract

Three research institutes from Belgium, Hungary and Romania and their end-users have been carried out a NATO Science for Peace Project (SfP 973684) for three years to investigate the transboundary alluvial aquifer of the Somes-Szamos River in an integrated manner. Due to the increasing amount of drinking water, one of the main objectives is to make possible a sustainable management of the regional groundwater resources on both sides of the Hungarian-Romanian border.

1 INTRODUCTION

Although many countries and hydrogeological experts had been aware of the importance and complexities of the management of transboundary aquifers since the early 1970s, very little was done to elevate the problem in international circles. In contrast transboundary rivers have received much greater attention leading to several treaties and conventions. Few treaties exist for aquifers. On the other hand, there is very little international experience in approaches or methodologies advocated for the shared management of transboundary groundwater resources. The significant differences between transboundary aquifers and rivers have not been pointed out in the existing treaties, resulting generally in a poor appreciation by decision makers of the value of the groundwater resources.

In 1999, the Department of Hydrogeology and Engineering Geology at the University of Miskolc on the Hungarian part and the Faculty of Hydraulic Techniques of the Technical University of Bucharest on the Romanian side were joined by the Hydrogeology Group of University of Liège to propose a transboundary investigation of the alluvial groundwater resource of the Szamos - Somes river for financial support by the SfP NATO Program. The effective start of the project in the scope of the NATO Science for Peace Program was on January 12, 2001 with the planned duration of 3 years. The main objective of the project is to provide the involved end-users with assistance and up-to-date information for an integrated, sustainable management of the transboundary aquifer. It was clear right from the beginning that the proposed goal is only achievable when the involved scientists could find a healthy and fruitful scientific and technical collaboration. The NATO Science for Peace Program has provided the participants with a perfect shelter to carry out this challenging topic. The program also stresses the importance of the participation of young scientists and students whose involvement in the project has been continuous during the three years.

Figure 1. Deliniation of the investigated area divided by the borderline between Hungary and Romania.

The Somes – Szamos groundwater resources are very important for a population of about 500000 inhabitants in Romania and Hungary. The possibility of joining the European Community is getting closer and closer for Hungary as well as Romania, so that the European Water Framework Directives should be applied in the two countries in the near future. Concerning these important aspects too, the main activities of the three-year-long research project can be grouped into the following tasks: collecting all existing data, building and development of a common database, new measurement campaigns, regional groundwater flow modeling, pilot studies of groundwater quality at local scale.

2 COLLECTING ALL EXISTING DATA, DEVELOPMENT OF A COMMON DATA-BASE

Reliability and validity of groundwater analysis strongly depend on the availability of large volumes of reliable data. Many factors may affect the behavior and the potential development of transboundary aquifers. Putting all data into a coherent and logical structure supported by a computing environmental helps to ensure validity and availability and provides a powerful tool for hydrogeological studies. A hydrogeological Geographic Information System (GIS) database that offers facilities for groundwater vulnerability analysis and detailed hydrogeological modeling has been designed and created by the Belgian team (Gogu et al. 2001). A "loose coupling" tool was also created between the spatial database scheme and the groundwater numerical model interface of GMS (Groundwater Modeling System). Following time and spatial queries, the hydrogeological data stored in the database can easily be used in different groundwater numerical models.

Based on the elaborated database structure, a common database has been created by the participants for the project purposes. The end-users of the project from Hungary and Romania made great efforts in order to collect all available information and data concerning the aquifer geology and geometry, the boundary conditions, the hydrodynamic properties, the hydrogeological parameters, the hydraulic heads as a function of time in the whole basin and the so-called stress factors (pumping rates, rainfall, recharge, infiltration, irrigation, natural discharge zones etc.). Data about solute transport hydrodispersive parameters, concentration levels for the main pollutants, and the diffuse and point contamination sources were also obtained and measured. Then, the collected data were fed into the common database.

The data collected in the common database were used first to create some basic maps (Madarasz 1999) using the GIS ArcView software in order to be able to choose some basic assumptions about the groundwater flow model. These steps were necessary to build up the final conceptual model before the modeling phase. As part of this work, one important question was to determine the number of layers in the model. For example, the different piezometric maps have been produced. Separated piezometric maps for the deep and the shallow parts of the aquifer have been drawn based on the groundwater levels measured during the two field campaigns of October 2001 and April 2002 (Dassargues et al. 2001). It has been observed that the differences in the hydraulic heads between the shallow and deep aquifers were generally 1-2 meters, which clearly indicated the hydraulic difference between the two units. On the basis of this information we were allowed to distinguish two aquifers separated by a confining layer in the regional flow model. Of course, the position of the confining layer had to be determined based on the geological cross-sections provided by the geologists. The three layers of the groundwater flow model can be considered as hydrogeological units although the geology is much more complex as it can be seen on the longest cross-section shown in Figure 2. Due to the simplification, only one hydraulic unit exists in the eastern part of the basin: the unconfined aquifer. On Figure 3, a map is shown with the location of the exploitation wells (nearly 300) in the region.

On the basis of analysis of the available data, new field campaigns of measurements have been carried out focusing on the following aspects: hydraulic head levels, pumping tests for hydrodynamic parameters, groundwater quality campaign, tracer tests for the local assessment of transport parameters and isotope measurements for dating groundwater.

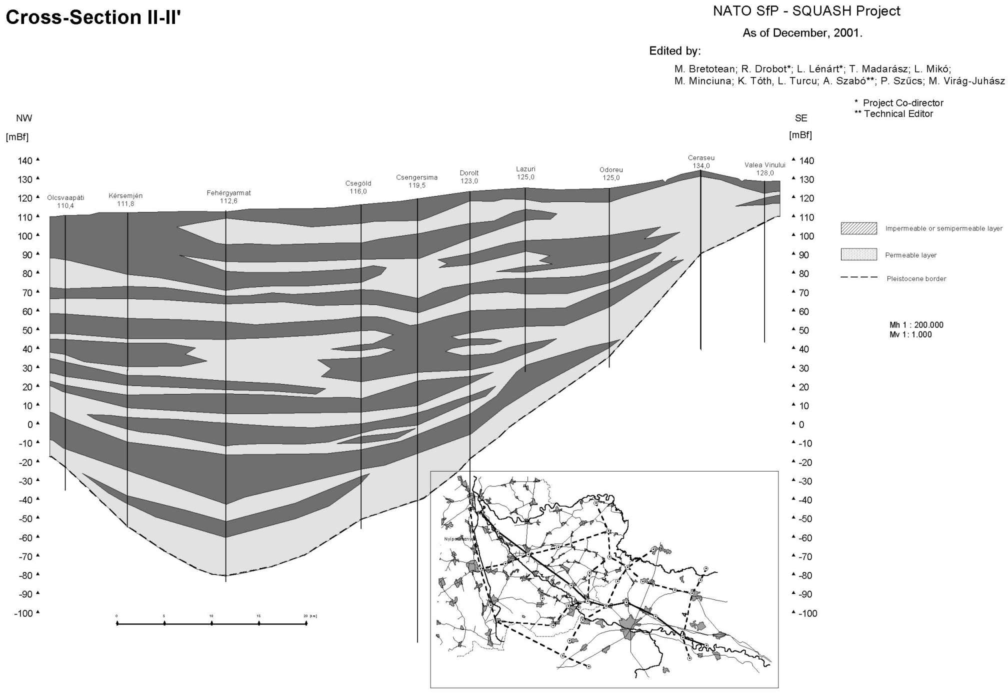

Figure 2. The longest geological cross-section (NW-SE) in the central part of the investigated transboundary aquifer.

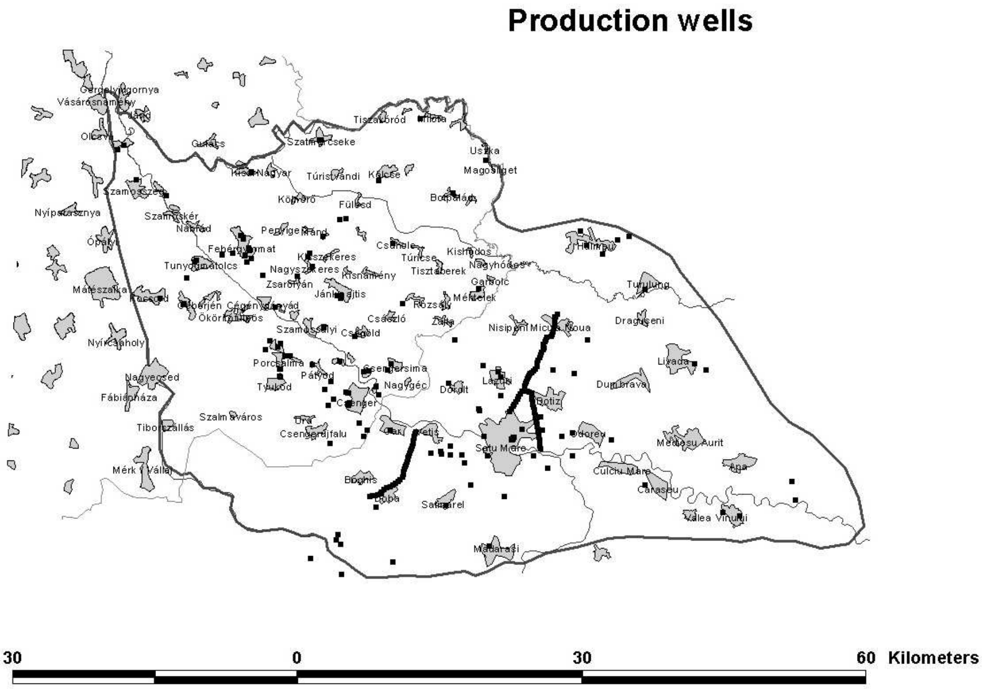

Figure 3. Location of the pumping wells in the investigated area.

3 REGIONAL AND LOCAL SCALE GROUNDWATER MODELING, SUSTAINABLE MANAGEMENT

A common regional groundwater flow model has been built as a very effective tool for a possible joint management of groundwater resources. Based on the obtained information gained during the different ArcView projects, the regional flow model has been created with GMS 3.1 program package (Environmental Modeling Research Laboratory 2000). We followed the conceptual model approach in order to have the flexibility for further changes. The conceptual model was build up in the Map module of the GMS package. The MODFLOW package was applied to simulate the regional flow (Anderson and Woessner 1992). In the Map module, 6 different coverage types including all the necessary information were created to build up the model. After creating the different coverage layers in the Map module, a grid system was created. The base cell size was 1000 meter. The maximum cell size was 2000 meter. Of course, grid refinement was also made in the neighborhood of the productions wells. Finally, we obtained a refined grid system with 18309 cells. To define the cell geometry, a scatter point file with borehole layer information was imported in the 2D Scatter Point module. This file was used to make the interpolation for MODFLOW layers. In the 3D Grid module, we applied the "Check Simulation" option to correct possible layer errors. As we had all necessary information in the coverage folders, we were able to run the MODFLOW package for different simulations (Anderson and Wang 1982).

In the "Sources and Sinks" coverage, the Arcview shape files were imported to get the border of the region, the river system and the common Gauss-Kruger coordinate system. The boundary conditions were also assigned here. At the Northern boundary, along the Tisza/Tisa river, specified head conditions were chosen for the three model layers. This was justified because the earlier investigations showed no difference in water levels between the shallow and deep aquifer along the Tisza/Tisa river. This is a very significant river, which probably regulates the groundwater water flow from or into the aquifer on the North side of the model. At the Western border, the specified head conditions were applied along the Kraszna/Crasna river for the first top layer. For the third layer, a Neuman specified flux condition was introduced because it is known that from the Nyirseg highland there is a groundwater flow in the deep aquifer from South-West to North-East. A rough estimation of an inflow about 0.2 m^3/s along the border is given by local hydrogeologists. To simulate this phenomenon, several sinks were introduced in the cells along the border. In the North-East and South part of the model, no-flow boundary conditions were chosen representing contacts with naturally low permeability geological environments. In the Eastern part, at the foothills, prescribed head condition was given to simulate the input from run-off on the hill slopes. The "river package" was applied for the Szamos/Somes and Tur rivers with a bottom river conductance of 0.00005 m/s. There are four river water level measurement locations for the Szamos/Somes and the same for the Tur river. The measured values were used for prescribing river water levels to the model. The average water depth in the river is 1.5 m for the Szamos/Somes, and 1 meter for the Tur. The values of three river water level measurement locations were used to provide the specified heads along the Tisza/Tisa and Kraszna/Crasna rivers. The production wells were also included here in this coverage. They were imported using a "well data file".

Based on the annual and monthly average meteorological data (precipitation, temperature and evapotranspiration) and the information about agricultural irrigation, different zones were delineated in the region in the "Recharge" coverage (Caravia et al. 1997). Generally speaking, from West to East, the observed recharge values are increasing. The "Layer 1, Layer 2 and Layer 3" coverage folders contain the model parameters, which were adapted during the calibration process. The spatial distribution of both the horizontal and vertical hydraulic conductivity values were adjusted in order to reach an acceptable calibration of the calculated piezometric heads to measured ones. The delineation of different zones was based on the information obtained from the geologists. The "Observed heads" coverage contained the necessary data for the calibration process. Both a trial-and-error and an automated parameter estimation processes (Szucs and Ritter 2002, Szucs 1998) were applied for different sets of observed hydraulic heads during the calibration. Figure 4 and 5 are showing the calibrated flow model in the shallow and deep aquifers for the Somes/Szamos basin. After calibration, several scenarios with variable water production rates, recharge and surface water level values have been simulated. Fortunately, it appears that the water budget of the transboundary aquifer seems to be well balanced, and a sustainable water management can hopefully be maintained in the future in the region. With the recharge rates of nowadays, doubled groundwater production in the basin would not cause harmful consequences. Of course, besides providing the adequate amount of groundwater, the water quality aspects should also be in the focus of the investigations (Juhasz 2002). To cover the quality aspects, local scale transport modeling was required. To build a reliable transport model, some additional accurate information about the hydrodispersive properties is required from the different hydraulic units of the investigated aquifer.

Figure 4. The regional groundwater flow model of the shallow Somes/Szamos alluvial transboundary aquifer.

Locally, some groundwater quality problems were observed in the basin. For example, it is very important to delineate rigorously protection zones around groundwater pumping wells according to the local environmental laws and regulations (Derouane & Dassargues, 1998). Based on available geological data and results from performed tracer tests at each local site, some local groundwater transport models are being developed now. Detailed multi-tracer test investigations are being carried out under the professional guidance of the Belgian team. For each site, the boundary conditions of the transport model will be deduced from the regional groundwater flow model results (Mateescu et al 1995). In some cases, different scenarios for optimization of the needed remediation schema (Filep et al. 2002) for particular contaminated zones (Szabo et al. 2000) will be simulated (Wiedemeier et al. 1999). These results will possibly be used for the rehabilitation program of some parts of the former Ecsedi swamp. Originally, the Ecsedi swamp was the largest wetland area (more than 400 km^2) in Hungary This nature conservation program could provide natural circumstances and habitat for a special water ecosystem. The obtained results will be also helpful for the effective protection against the harmful consequences of inland water on both sides of the border.

Figure 5. The regional groundwater flow model of the deep Somes/Szamos alluvial transboundary aquifer.

4 SUMMARY

The sustainable management of water resources requires a multidisciplinary approach (Lenart and Papai 2000). But level of difficulties considerably increases in the case of the international river basins and aquifers. Good and reliable information is crucial to facilitate cooperation among aquifer stakeholders. All stakeholders should have easy access to good, reliable data on abstractions, water quality and aquifer water levels.

The Szamos/Somes alluvial groundwater resources are very important for a population of about 500000 inhabitants in Hungary and in Romania. The increasing amount of drinkable water demand and different human activities require a sustainable management of the natural groundwater resources. A three-year-long NATO Science for Peace Project (SfP 973684 – 'SQUASH project') has been carried out to investigate the Szamos/Somes transboundary aquifer. The main objectives that the project is reaching, are the following:

- to make possible a sustainable management of the regional groundwater resources;
- to develop scientific and technical collaboration of all concerned partners;
- to set in the common basis for long term future monitoring in the border region;
- to measure and analyze the impact of human activities on groundwater quality.

On the basis of the obtained results, the international project is developing guidelines to provide both water supply companies and regulatory authorities the means to manage the groundwater quantity and quality simultaneously. It was of course the occasion to exchange the data between Hungary and Romania to develop a common database, which can be maintained and expanded by the scientists of both sides and end-users in the future. This project also provides the end-users (national authorities, local waterworks and municipalities, and environmental agencies) with useful information to supply adequate quantity and high quality of water for the citizens in this region. Some beneficial nature conservation aspects of the proposed project could also be highlighted. The completed program can serve as a very good example to strengthen the official Hungarian and Romanian relations and political collaborations connected to surface water and groundwater management. The partnership in sustainable water management is seen to be an important outcome of the completed project.

The Groundwater Modeling System (GMS) is a powerful pre-processor and post-processor that can be used effectively for various groundwater numerical modeling operations. For the chosen GMS version (GMS 3.1), the hydrogeological attribute data can be directly introduced or they can be imported from a specific format file. The need for importing data in GMS exists in the three steps of groundwater flow modeling: conceptual model design, model construction, and calibration. The hydrogeological GIS database elaborated by the Hydrogeology Group of the University of Liege offers good capabilities for hydrogeological modeling as well as other hydrogeological studies. Data verification and validation, automatic data treatment, the global view of the hydrogeological data and maps of the aquifer parameters can easily be generated.

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