REGIONAL MODEL OF THE SOMES - SZAMOS AQUIFER (RO - HU)

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ABSTRACT: *The areal extent of the model was chosen to correspond to the physical limits of the aquifer. The separation line between Quaternary and Pliocene formations defines the vertical extent. For modelling, it was considered that the alluvial fan corresponds to the superposition of two aquifer units: the shallow aquifer (the Holocene aquifer) which is unconfined and the medium depth aquifer (the Pleistocene aquifer). The heterogeneity of the aquifer properties (hydraulic conductivities, storage parameters) and of the soil (directly connected with the natural recharge) was considered during the calibration phase. The calibration was performed using Groundwater Modeling System (EMS-i, 2002) both in steady state and in transient state, considering the zonation of the above mentioned characteristics. A transient simulation for the interval May 2002 - December 2002 represented the base for the model validation. After the model validation, several scenarii were considered for the future use of the aquifer. Among these scenarii, the most unlikely which was tested consists in doubling the present pumping rates for all production wells. According to the obtained results the aquifer seems not to be at risk from a quantitative point of view.*

Key words: conceptual model, heterogeneity, calibration, validation, predictions.

1. Introduction

In lowland permeable catchments, groundwater is commonly the main water resource, raising important issues of management and environmental protection. Especially lowland catchments are subject to a complex set of environmental pressures and associated management problems. This requires high quality experimental and measurement facilities, as well as the construction of numerical tools for integrated management of the groundwater resources.

The Project NATO SfP 973684 SQUASH was intended to improve the management of the Somes/Szamos aquifer in terms of groundwater quantity and quality.

2. Aquifer characterization

The lithology put into evidence that the layers developed from 30 m till a maximum depth of 130 m on the Romanian territory and 190 m on the western limit of the Hungarian territory represent the main aquifer due to their extent, hydrogeological parameters and abstracted discharges. To illustrate the aquifer development, in Figure 1 the main cross-section along the Somes-Szamos river is presented.

3. Developing the conceptual model

One of the most important steps in the mathematical modelling is the choice of the conceptual model of the aquifer. By keeping the essential features of the system, a reasonable compromise between the complexity of the aquifer and the available volume of reliable data concerning the structure and its hydrogeological parameters is proposed.

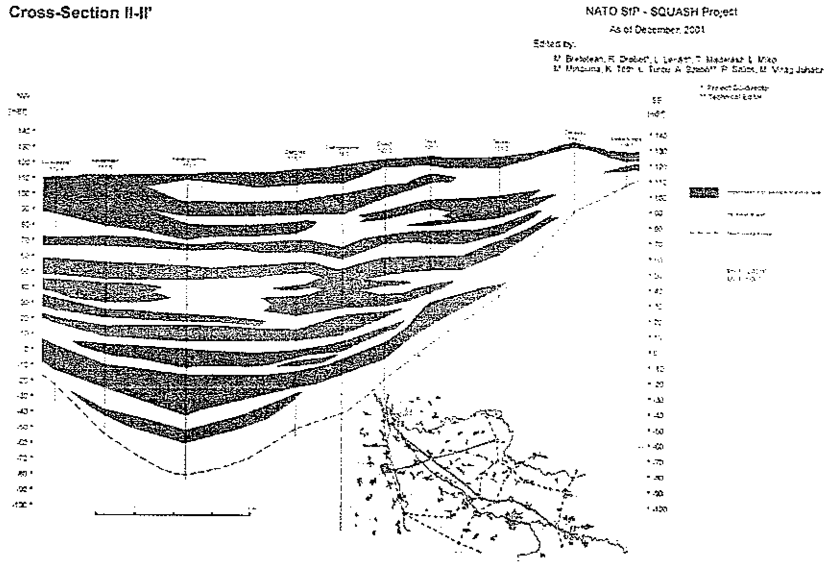


Fig. 1 Main cross-section along the Somes-Szamos river.

3.1. Vertical and areal extent

In the case of the Somes-Szamos aquifer the vertical extent of the model corresponds to the separation line between Quaternary and Pliocene formations. It can be considered that the alluvial fan corresponds to the superposition of two aquifer units:

- The shallow aquifer (the Holocene aquifer) is unconfined being formed by 2-3 layers hydraulically connected; it is located in the recent sediments of the meadows or in the lower terrace deposits.
- The medium depth aquifer (the Pleistocene aquifer), called subsequently for simplification the deep aquifer is confined and it represents the main aquifer for water supply in the region.

Belgian, Romanian and Hungarian teams agreed on a conceptual model consisting of two aquifers and an aquitard between them (Figure 2).

An existing map in Hungary, for measured values of the year 1990, put into evidence differences in water level between the lower Pleistocene and the upper Pleistocene groundwater levels (Figures 3 and 4).

In the same time, the field campaign organized in October 2001, showed also on the Romanian side differences of hydraulic head between the shallow and the deep aquifer in the range of 1 to 5 m (Figure 5), justifying thus the selected simplified model structure.

Maps of the thickness of the aquifer and confining layers are presented in Figures 6÷8.

The areal extent of the model was chosen to correspond to the physical limits of the aquifer. The only exception is the Western and the Southern limits in Hungary, where the Tisza and Kraszna rivers delineate the model.

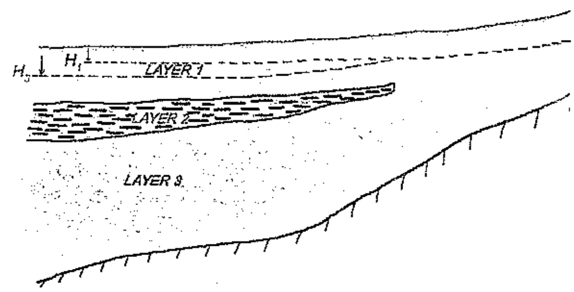


Fig. 2 Conceptual model of the Somes-Szamos aquifer.

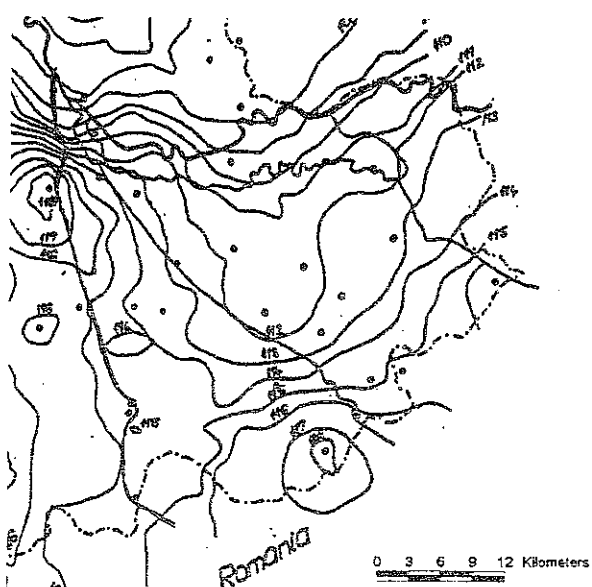


Fig. 3 Lower Pleistocene groundwater levels in Hungary - 1990.

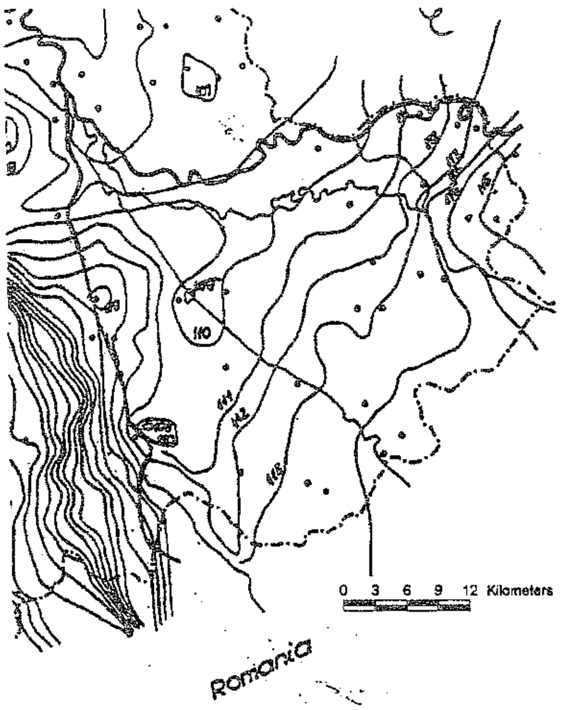


Fig. 4 Upper Pleistocene groundwater levels in Hungary - 1990.

The total surface of the aquifer in both countries is about 2.500 km^2.

3.2. Boundary conditions

Boundary conditions represent the connection of the aquifer with external systems and are very important to define a problem well posed, leading to a unique solution.

The following boundary conditions were used:

a) Specified heads (Dirichlet conditions) are prescribed at the Eastern limit to take into consideration the recharge produced by surface runoff at the contact between the hill slopes and the plain. The same boundary condition is used at the Northern limit along the Tisa/Tisza river for the first layer, at the Western limit along the Crasna/Kraszna river for the first top layer and at internal boundaries to model the connection between the first layer and the rivers Somes/Szamos and Tur/Túr.

b) Specified fluxes (Neumann conditions) are prescribed in the third layer corresponding to the recharge area at the SW boundary (Nyirseg highland area) to take into account the lateral recharge. In the North-East and South part of the model, no-flow boundary conditions were considered at the contacts with naturally low permeability geological environments. Finally, the production rates of the pumping wells represent another specified flux condition.

c) Semi-permeable boundary conditions (Cauchy or Fourier conditions) are prescribed at the Western limit to model the connection of the second and third layer with the Tisza river.

3.3. Heterogeneity of the soil characteristics and recharge areas

The natural recharge of the aquifer is closely related to the soil characteristics. The main types of soils existing in the alluvial fan of Somes-Szamos river are presented in Paper 2

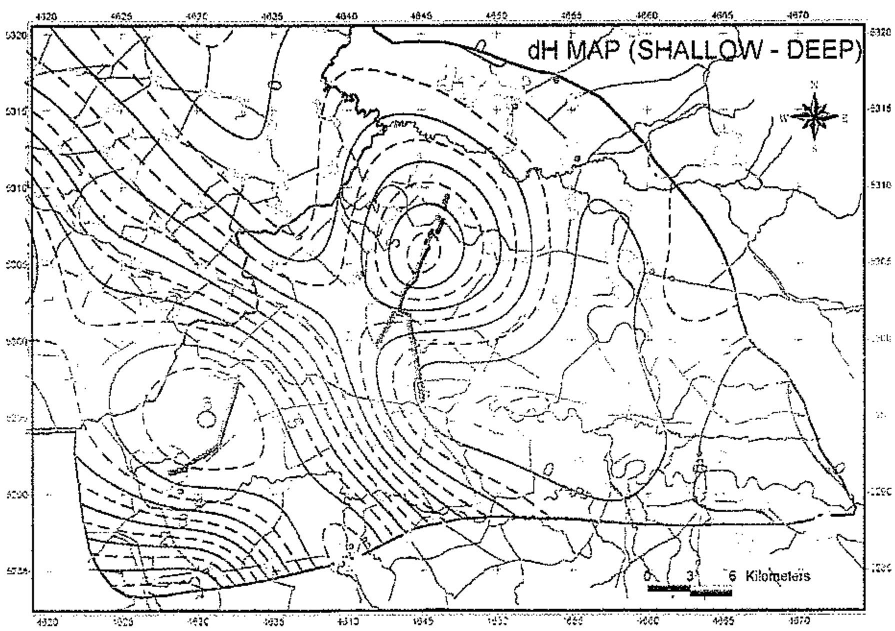


Fig. 5 Isolines of hydraulic head differences between the 'shallow' and the 'deep' aquifer.

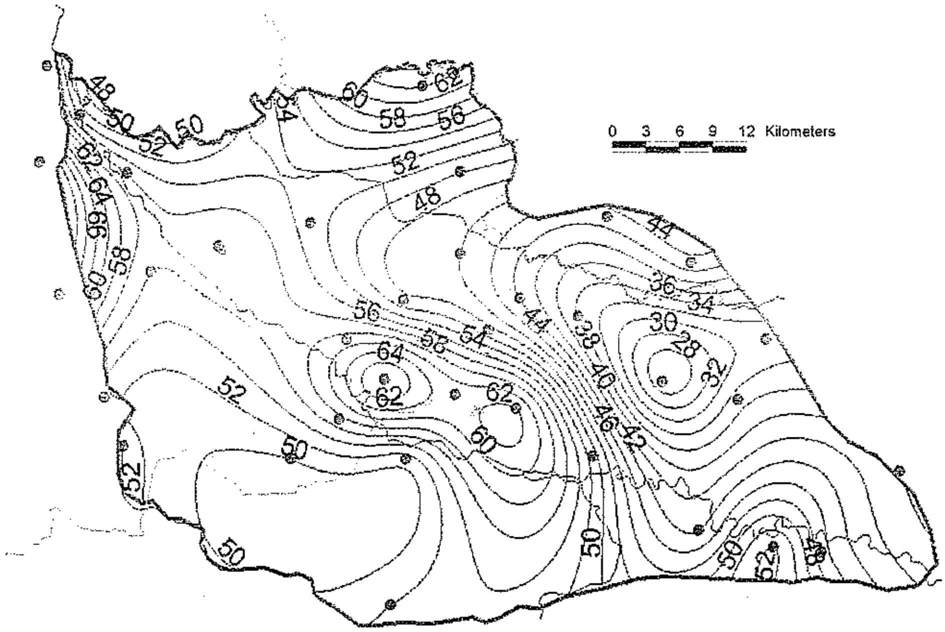


Fig. 6 Thickness of the model layers: the shallow aquifer.

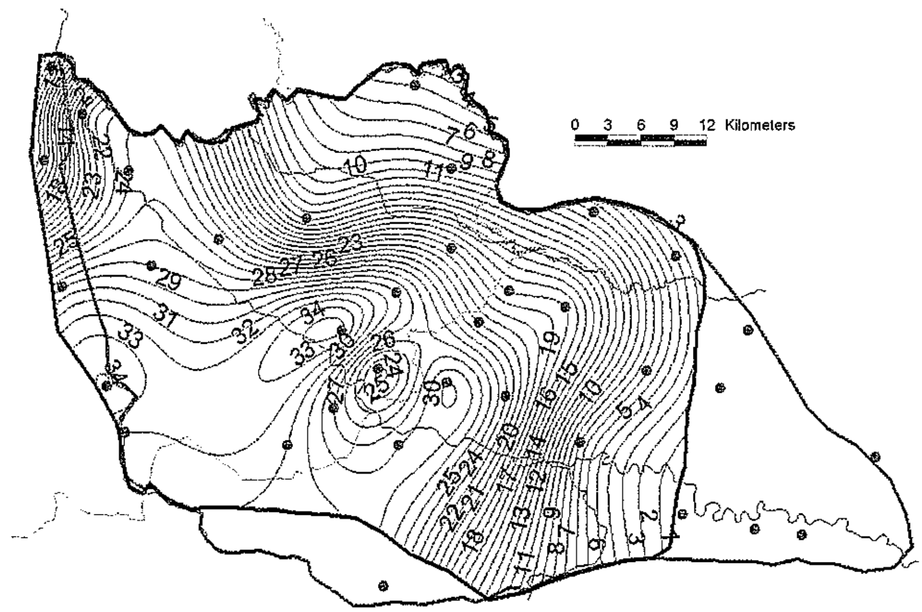


Fig. 7 Thickness of the model layers: the confining layer.

(General Characteristics of the Studied Area), Figure 3, while their main characteristics are listed in Table 1. An aggregation of soil types was necessary in order to reduce the number of recharge areas. A number of 5 zones were finally defined.

Soil characteristics for each recharge area were introduced in a conceptual model (Drobot et al., 1987; Drobot and Sirbu, 2003), which computes a water budget, based on a vertical discretization of the ground surface and unsaturated zone (Figure 9).

The mathematical model corresponding to the conceptual model presented here above examines the water content variations in each reservoir, by considering their interdependency. Input data consist in daily temperatures and precipitations. The computation consists in the evaluation of water content in the reservoirs at the end of each day, these values becoming initial values for the next day; the simulation continues until the end of the analysed period, which can be of dozens of years. The main advantage of this model is the

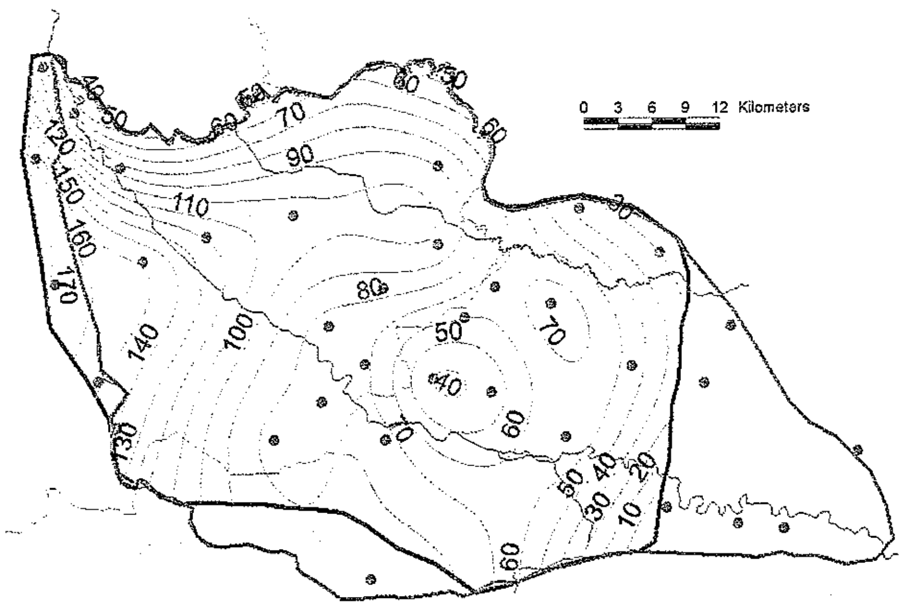


Fig. 8 Thickness of the model layers: the deep aquifer.

Table 1 *- Soil characteristics*

Type of soil	Soil depth (cm)	Total porosity (%)	Field capacity (%)	Wilting coeff. (%)	Hygroscopicity (%)
LUVIC ARGILLIC SOILS	140	45,33	23,1	10,8	7,2
CAMBISOLS	125	34,61	23,4	10,3	6,5
MOLLISOLS	137	47,00	20,9	8,3	5,4
UNDEVELOPED SOILS	150	49,50	25.4	8.3	5.5
HYDROMORPHIC SOILS (Humic Gley Soils and Gley Chernozems)	150		26.4	12.7	8.6
(Pseudogleys, Brown Forest Soils)	130		23.3	11.4	6.3

possibility of evaluating the history of the natural recharge.

The physically based parameters of the model are obtained from the pedological information presented in Table 1. The remaining parameters are fitted so that the average values of the surface runoff, evapo-transpiration and aquifer recharge computed by the model are in good agreement with the hydrological balance of the corresponding area, respectively the water balance for the entire catchment. Because the examined area is very flat, the average value for the surface runoff is usually less than 5% of the multi-annual precipitation for the examined period. The real evapo-transpiration is in the range of 70 - 80 %, the natural recharge representing usually 10 - 20 % from the same value.

Some exception can still occur: for example, in the region of Ecsedi swamps the evapo-transpiration is equal to the potential evapo-transpiration and the natural percolation was considered as equal to zero; the water excess in this case is provided by the groundwater discharge.

The zonation of the recharge areas is presented in Figure 10.

3.4. Heterogeneity of the aquifer properties

Prior to the field campaigns, an inventory of all existing hydrogeological parameters was undertaken. As a result, a preliminary zonation of the hydraulic conductivities and specific storage coefficients for both aquifers was determined. In principle, in the Eastern part of the aquifer, characterized by coarse sediments, the hydraulic *snow reservoir* - it collects snow (solid precipitation)

surface reservoir - it models the interception and surface retention

sub-surface reservoir - it models the water content in the root zone

intermediate reservoir - it models the behaviour of the vadose zone

deep reservoir - it represents the aquifer

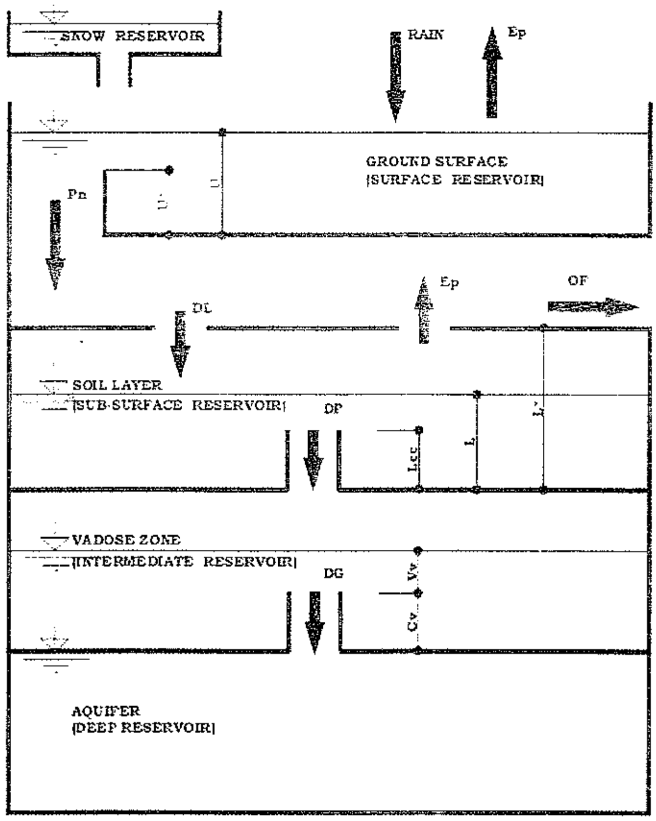


***Fig. 9** Conceptual model for evaluating natural recharge.*

conductivity is larger than in the Western part where finer sediments are dominant.

New pumping tests were undertaken in selected locations during the field campaigns. They confirmed the heterogeneity of the aquifer properties. Still, the parameters obtained during the pumping tests have a local character and do not measure areal properties as necessary in the regional model. In the same time, the duration of the pumping tests is limited to a few days maximum and the capacity of the aquifer to transfer water fluxes is not fully mobilised. As a consequence, the hydrogeological parameters for different zones have to be identified during the calibration phase. No matter which procedure is used (automatic calibration or trial-and-error method), the objective is to obtain a configuration of hydrogeological parameters that leads to the best agreement between the computed and the measured value of the piezometric heads.

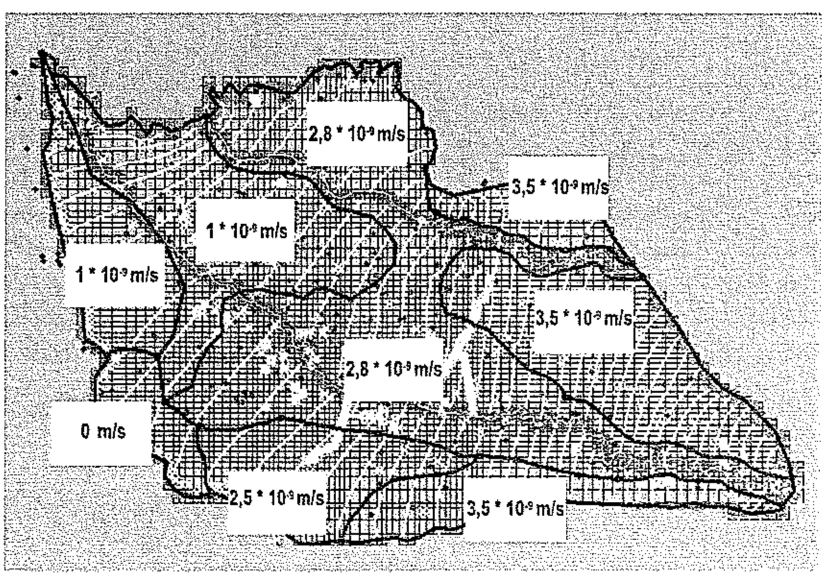


***Fig. 10** Zonation of the recharge areas.*

4. Calibration and validation of the model

The calibration was performed using Groundwater Modeling System (EMS-i, 2002) both in steady state and in transient state. The steady state calibration was based on piezometric levels measured during the field campaign of October 2001. Considering the pluviometric regime, 2001 was a medium year; in the same time, in October the groundwater levels are low, corresponding to a dry period.

The spatial distribution of differences between measured piezometric heads and the computed values after calibration is presented in Figure 11. The obtained errors: 1,63 m for RMSE (Root Mean Square Error), respectively 1,16 m for MAE (Mean Absolute Error) were considered acceptable taking into account the total change of about 40 m of the hydraulic heads in the modeled area.

The hydraulic conductivities zonation after steady state calibration is presented in Figure 12.

The transient state simulation for the calibration of the specific yield, respectively of the specific storage coefficients was undertaken for the interval January 2001 - April 2002. The hydraulic conductivities obtained at the end of the steady state calibration were kept unchanged during the transient calibration. The history of groundwater levels, pumping rates, recharge values and time dependent boundary conditions for stress periods of one month were used as additional data. The hydraulic heads at the beginning of January 2001 were obtained by steady state simulation using data characterizing the year 2000. By a trial - and - error procedure, the storage coefficients were successively adjusted until an acceptable RMSE value was obtained for the time dependent water levels in the observation wells.

The storage parameters derived at the end of the transient calibration are presented in the Figure 13.

After the calibration, a transient simulation for the interval May 2002 - December 2002 represented the base for the model validation.

5. Model predictions

After the model validation, several scenarii were considered for the future use of the aquifer. Among these scenarii, the most unlikely which was tested consists in doubling the present pumping rates for all production wells. A steady state simulation showed that the drawdowns resulted in the 1st layer are less than 0,5 m, while in the 3rd layer representing the main aquifer for water supply the maximum drawdowns are 1,5 m (Figure 14).

In the 3rd layer the drawdowns reach the inpervious limit of the model, but on the other hand do not interfere with the recharge limits.

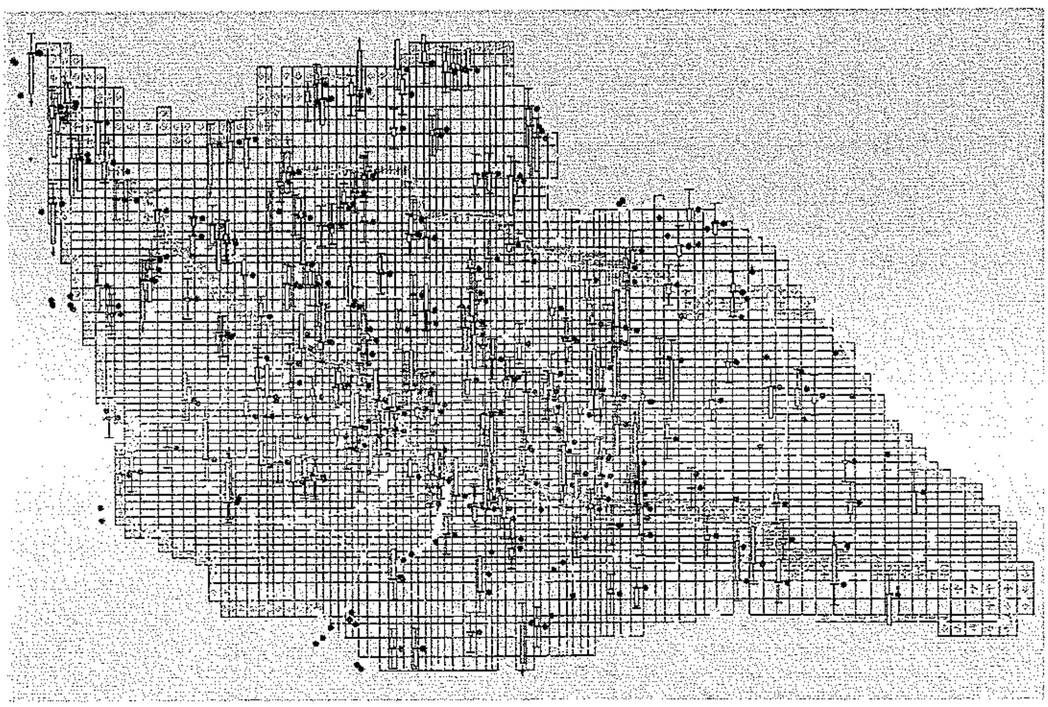


Fig. 11 Differences between measured and computed heads after calibration

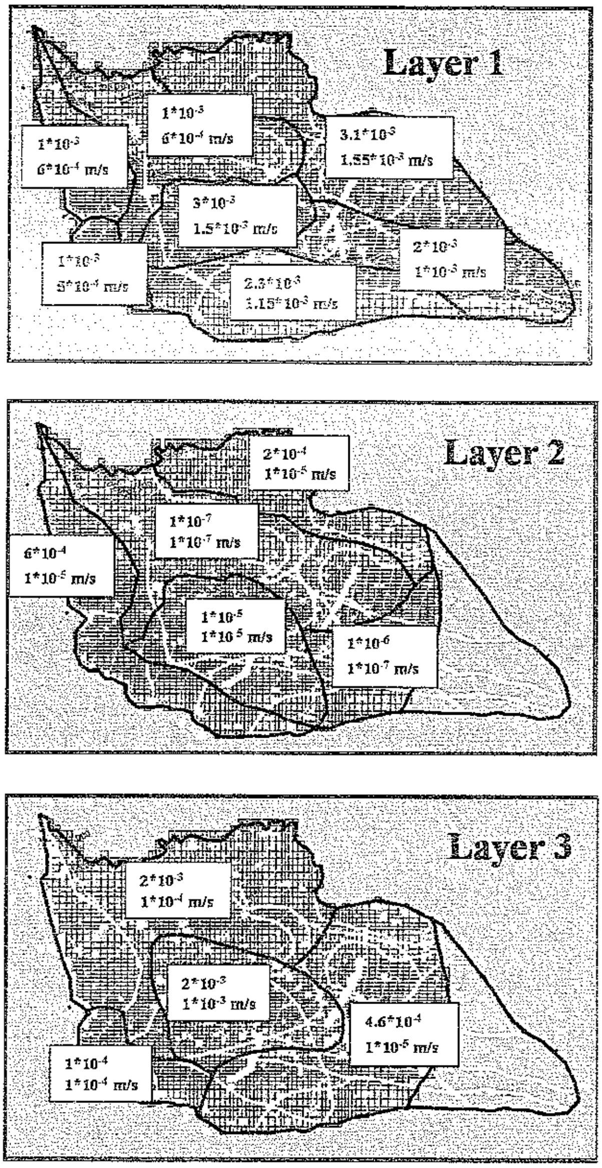


Fig. 12 Zonation of the hydraulic conductivity after steady state calibration.

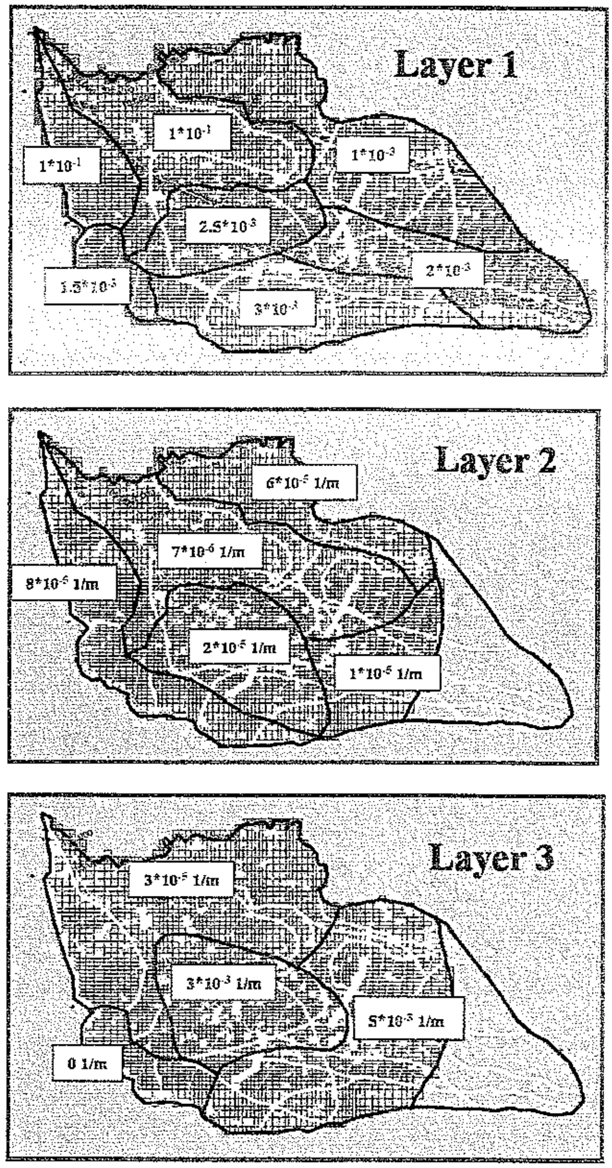


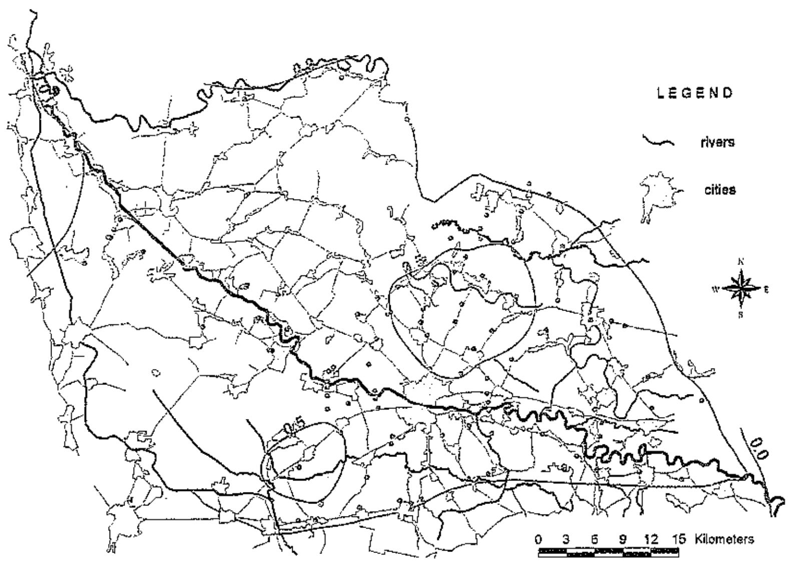
Fig. 13 Zonation of the specific yield (layer 1) and specific storage (layers 2 and 3) after transient calibration.

Thus, the results provided by the model can be considered as correct; still, possible changes in the water fluxes have to be examined. As previously mentioned the tested increase of the pumping rates is not likely in the foreseen future. According to these results the aquifer seems not to be at risk from quantitative point of view.

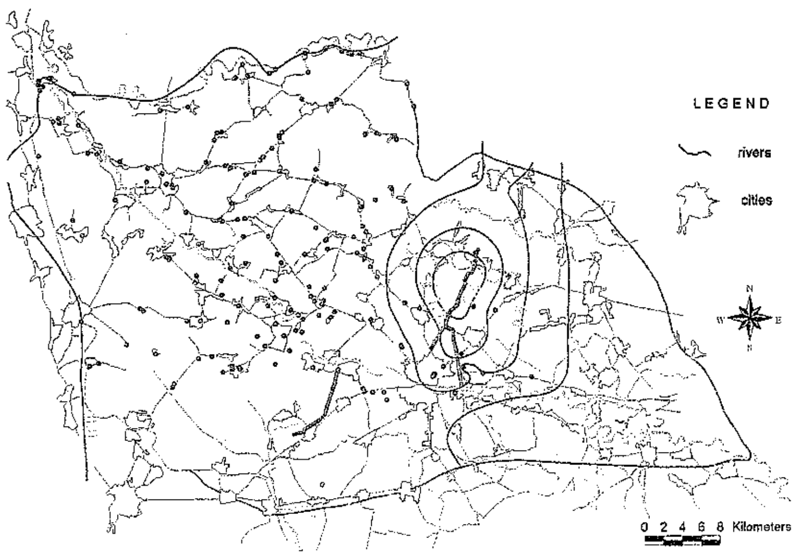
6. Final remarks

The research Project NATO SfP 973684 SQUASH gathered together the expertise of 3 teams from Belgium, Hungary and Romania, which worked together for more than 3 years. The regional model of the Somes-Szamos alluvial fan is one of the most important outputs of this project. A huge volume of data (more than 250.000 registrations) obtained from old archives and 4 field campaigns represented the informational base for the mathematical modelling.

Due to the complex structure of the aquifer, a simplified conceptual model was defined. Despite the fact that this model was calibrated and validated some uncertainties persist. In fact, any model is an instrument of knowledge and interpretation of the reality; by solving some problems, it raises other problems and questions about the real structure and behaviour of the modelled system. Among the problems that have to be solved in the future one can mention: the sedimentology of the Somes-Szamos alluvial fan and the corresponding hydrogeologic conceptual model, the role of the Ecsedi swamps in the aquifer budget, the utility of increasing the heterogeneity degree, the necessity



a)



b)

Fig. 14 *Drawdowns due to doubling present pumping rates*
a) *shallow aquifer;* ***b)*** *deep aquifer.*

of discarding the water levels measured by the wells penetrating layers that are not isolated etc. Still, these reserves do not put into question the quality of the present model and the obtained results. They suggest only possible developments both from theoretical and practical points of view.

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