INTEGRATED HYDRO GEOLOGICAL - GEOPHYSICAL INVESTIGATIONS TO DETERMINE THE CHARACTERISTICS OF A SHALLOW AQUIFER IN TRANSYLVANIA DEPRESSION

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Introduction

The rapid growth of development needs (progressive urbanization, infrastructure) impose an increasing pressure on the water resources. In order to comply with the economic constrains (costs of water supply networks) and environmental issues, the use of water must follow the low impact development paradigm, and the water footprint must be as low as possible in order to create a sustainable economic and social environment. Safe and effective management of our natural resources is a major societal challenge (*Hubbard S. 2005*).Groundwater is one of the most used, accessible and in the same time vulnerable resource of our planet. A well - balanced exploitation of groundwater can create the premises for low impact, low energy consumption and good water management. This paper presents the results of an integrated hydro geological - geophysical study performed in order to design and develop a groundwater source for a temporal parking lot on the new Tg. Mures - Cluj Napoca highway, near Ludus Town. The research approach was conducted using traditional hydro geological analysis (field investigation and data processing and analysis) and also hydro - geophysical site investigation. This conjunction between different types of research approach decreased the level of uncertainty, and at the end provided a good and reliable water source.

Case study

The investigated area (Fig. 1) is located on the left bank of Mureș River, on the second terrace, in the south part of Ludus Town.

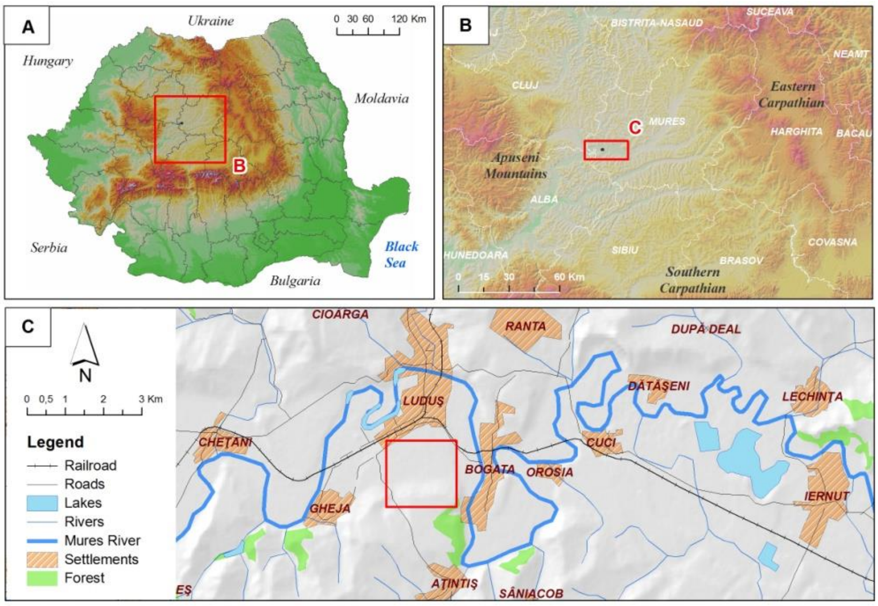

Fig. 1 Study area location (A- Location of the Transylvanian Depression; B - The study are within the Transylvanian Depression; C - The study area within the Mures river corridor)

The corridor of Mures River has a number of 8 terraces that can have a height difference of 130 -140 m from the river channel. According to the geological maps and other bibliographical information the lower terrace is Upper Pleistocene - Holocene formations and the upper terrace is Lower to Medium Pleistocene. The Pleistocene formations lay on a Miocene formation (Sarmatian). The Miocene is composed mainly from an alternation of clays and marls with a porous thin strata (sands, fine sand and silt). The lithological description from the geological map 1:200.000 of the second terrace (study area) shows a succession of permeable and impermeable strata, with a dominance in sand and gravel. This preliminary information was taken into account in the further investigations as a base line for the research and as premises for the shallow aquifer location.

Data and methods

The investigated area lacks in information regarding clear lithological and hydrogeological descriptions. Most of the water wells are residential traditional wells, with no borehole description and the closest wells (with lithological description) are located on the first terrace, near the Mures river bank. Taking into account the lack of information, a hydro geological and geophysical investigation campaign was performed in order to clearly delineate and characterize the shallow aquifer formation from the second terrace. Within the investigation area, a groundwater monitoring well belonging to the Romanian Water Administration was used to recreate the behavior of the groundwater level and response to precipitation. Data from January 2015 to July 2016 were analyzed in order to find the correlation between the water level and the quantity of precipitation.

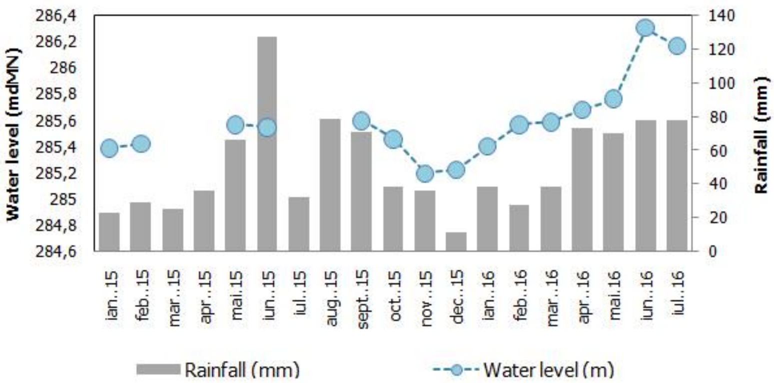

Fig. 2. Correlation between the groundwater level and the precipitation for the groundwater monitoring well

In Fig. 2 can be easily identified the rainfall dependent behavior of the water level. In that sense the premises of a shallow aquifer body with free surface was more clearly defined. The hypothesis of a free surface groundwater body existence in the second terrace had to be geometrically defined and also the piezometrical map needed an accurate interpretation. According to Constantinescu G. P., (1980) the works performed in 1960 in order to develop a water supply source for Ludus Town and the sugar factory, were a bad example of how an incomplete understanding of the hydrogeological characteristics influence the design and further the exploitation of the system. The principal objective of the water supply system was to extract around 6-20 l/s using a drain parallel to Mures River. During the exploitation phase no more than 4-5 l/s were obtain. However, important information were obtained from the background of this study: (1) the lithological description of the first terrace and (2) a piezometrical map of the south part of Ludus Town. This information along with direct measurements performed in the field (groundwater and topographical measurements for the domestic wells) were used to create a piezometrical map. One important information in hydrogeological field investigation for shallow aquifers is the presence of certain type of vegetation. The spontaneous vegetation (mainly tree formations) are an indication of the presence of a shallow groundwater table. Although the land use in the investigated area is mainly agricultural, islands of trees were identified in the field. The tree formation are represented by Alnus (Alder) and Salix (Willow), species known for their hydrophyte characteristics. The geometrical description (from the hydrogeological point of view) of the second terrace was performed using electric resistivity tomography. The measurements were made using 48 electrodes placed at a distance of 5m along a 235m profile. Data acquisition was made in the Schlumberger configuration with an IRIS Electric Pro equipment.

Results

One of the first outputs of the study was the piezometrical map (Fig 3). The map was constructed using the initial data (only the shape of the groundwater level isolines, the values were adjusted to 2016 values) from 1960 study (Constantinescu G. P., 1980), data from domestic wells and the monitoring well.

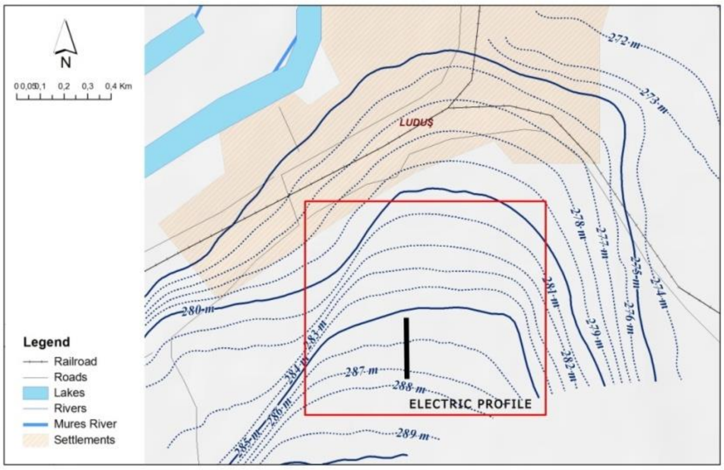

Fig. 3 - Piezometrical map of the study area (the black line represents the electric profile performed in the field)

The shape of the isolines (the piesometrical map) shows a clear groundwater flow direction that is from the upper region (South part - Bogata Hill) to the Mures River. The density (hydraulic gradient) of this isolines also have an importance regarding the hydraulic conductivity of the shallow aquifer formation.

Data obtained in the geoelectrical investigation were processed using the **RES2INV** software obtaining a good match of the measured profile with the one generated by direct modeling. By knowing the value of the aquifers formation water resistivity (R_w), 7 Ωm, measured on water samples collected from near wells(300m uphill of the site) the resistivity of the water-filled formation (R_0) could be estimated using Archie's law: $F = a * P^{-m}$ (1), $R_0 = F * R_w$ (2) For determining the formation resistivity factor (F) there were considered 4 sets of Archie parameters (a-tortuosity factor, m-cementation exponent) most used in the literature and three porosity (P) values: 30%, 35%, 40%, typical for unconsolidated well sorted cohesionless soils. The use of chemical fertilizers on the studied site can led (by infiltration) to an increase in underground water mineralization, resulting in a decrease in electric resistivity. Thus, this factor was taken into consideration by using three possible values for the formation water resistivity: 7 Ωm, 6 Ωm and 5 Ωm.

Lithological type	Empirical model	a	m	0.4	0.35	0.3
				Formation factor		
Unconsolidated sand	*Winsauer, 1952*	0.62	2.15	4.45	5.92	8.25
Shaly sands	*Carothers, 1968*	1.65	1.33	5.58	6.67	8.18
Medium sands	*Carothers, 1968*)	1.45	1.54	5.95	7.30	9.26
Sands	*Timur,1972*	1.13	1.73	5.51	6.95	9.07

Table - 1Different coefficients and exponents used to calculate the formation factor (F)

The obtained values were statistically processed, the most probable value for the water-filled (aquifer) formation resistivity being 41 Ωm. Based on the previous parametric study we can conclude that the aquifer has the highest probability of being represented on the electric resistivity section close to the value of 41 Ωm, between 6m and 11m (delimited by the white dashed lines). The higher resistivity values, located on the section on top of the aquifer, are associated with the unsaturated zone, and the lower resistivity values are associated to clays that form the base of the aquifer.

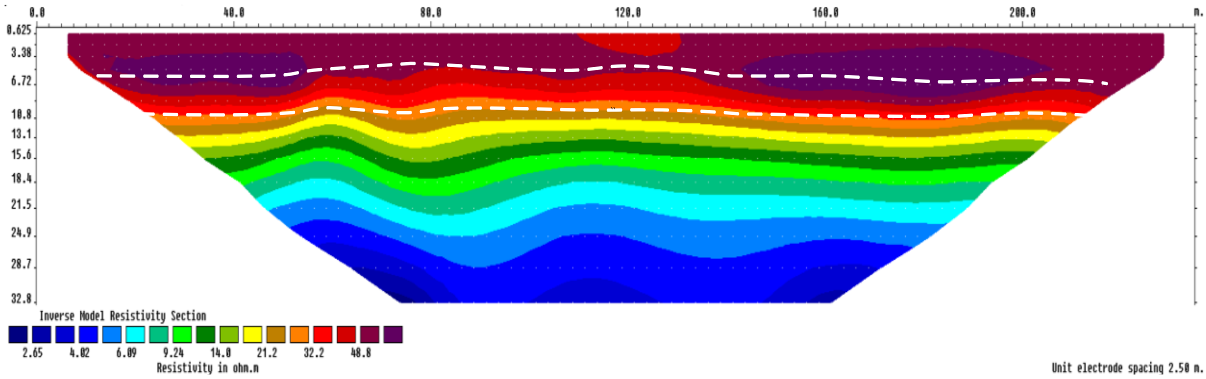

Fig. 4 –Resistivity section

The investigations performed for the study area created the necessary data to proper design a water supply well. The well was drilled up to 11 m and the shallow aquifer was found between 6 to 8 m, depths that corresponded with the geophysical investigation. Also the groundwater table had a hydraulic head difference from the piezometrical map of only 30 cm. Hydraulic tests were performed in the water well (efficiency and performance) and the optimal flow rate was calculated (2.1 m^3/hour at a drawdown in level of 80 cm),the hydraulic conductivity being 48 m/day (specific for sand and gravel formations).

Conclusions

This study points out the importance of an integrated approach for different engineering investigations. The hydrogeological investigations allowed to identify and characterize a potential free surface shallow aquifer, and the geophysical investigations determined the in-situ potential geometry of the formation.

Bibliography

Hubbard S, Rubin Y (2005) - Introduction to Hydrogeophysics, Hydrogeophysics, Published by Springer, ISBN-10 1-4020-3101-7

Constantinescu G. P., (1980), Captările de ape subterane din România, Editura Tehnică, Bucureşti;