8.2 RESISTIVITY IMAGING OF AQUIFER STRUCTURE WITH 2D/3D INVERSION OF DIRECT CURRENT RESISTIVITY AND AUDIO-MAGNETOTELLURIC DATA

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ABSTRACT

In this study, direct current resistivity (DCR) and audio-magnetotellurics (AMT) methods were applied to identify aquifer structures and/or fracture zones in limestone units that are likely to supply wells located near the study area and actively covering the water demand. DCR studies were performed along 5 lines and AMT measurements were taken in 13 stations. The orientations of the DCR lines were selected considering the determination of the aquifer recharge direction. DCR measurements were collected using a pol-dipole electrode array (left and right-sided) for better lateral separation. A total of 4650 apparent resistivity data were measured on 5 lines. The measurement time of AMT data collected as a time series at each station varies between approximately 2-5 hours. Station intervals are approximately 100 metres to cover the entire study area. Both the 2D and the 3D inversion were carried out separately for the data collected using the two methods. The resistivity distribution of a total area of 30 hectares (500 m x 600 m) was revealed. In 2D inversion, the RMS values of DCR models and AMT models were below 3% and 5%, respectively. In the 3D inversion, the RMS values are 3.2% and 9.7%, respectively. All the models obtained were interpreted separately and together and aquifer structures and fracture zones were identified on the subsurface resistivity models. Interpreted geophysical models, geologic, hydrogeologic and drilling information were evaluated and interactions of these structures and zones with the existing water well were revealed.

KEY WORDS: Direct current resistiviy, audio-magnetotellurics, resistivity, inversion, aquifer

INTRODUCTION

By using geophysical methods, the structure of the earth's interior can be revealed with data measured on the ground. Each geophysical method sensitive to one physical parameters. Hydrogeophysics one main branch of applied geophyscial studies. The geophyscial methods are used to investigate groundwater.

In hydrogeophysical studies, mainly "Direct Current Resistivity (DCR)" method is used to investigate aquifer structures (Binley and Kemna, 2005; Rubin and Hubbard 2006; Candansayar 2008; Gündoğdu and Candansayar 2018; Demirci et al. 2017, 2020). Additionally, the deep structure of the aquifer or geothermal areas are successfully revealed by the Audio Magnetotelluric (AMT) method (Giroux et al. 1997; Falgas et al. 2011; Erdoğan and Candansayar, 2018; Gomo, 2023).

In this study, it was investigated whether the activities of a limestone quarry located within the borders of Ankara province would affect the well that provides water to the nearby settlement. For this purpose, the aquifer feeding the water well and/or limestone fracture zones were imaged by using 2D/3D DCR and AMT data inversion. Thus, the interaction of the water well and the limestone quarry was revealed.

METHOD and APPLICATION

In the study, the structure of the aquifer from the surface to a depth of 150 meters was investigated using the DCR method, and the structure up to 500 meters was investigated using the Audio-Magnetotelluric (AMT) method.

Direct current resistivity (DCR) method is one of the oldest geophysical methods that examine geological units depending on the resistivity parameter. Today, DCR data are collected by sounding-profile measurement technique along a line using multi-channel/electrode measurement systems and these data are evaluated with 2D or 3D inversion algorithms. In this study, DCR data were collected with the sounding-profile measurement technique on five separate lines using AGI SuperSting R8/IP brand multi-electrode and multi-channel measurement system. A pole-dipole electrode array was used to achieve high lateral resolution (Candansayar 2008). The number of electrodes used varies depending on the condition of the lines in the field (ranging from 34 to 112). A total of 4650 apparent resistivity data were obtained from measurement (potential differences) on five lines and subsurface resistivity models were obtained by performing 2D inversion of each line separately. Additionally, 3D inversion was performed using three lines that were almost parallel to each other out of these five lines.

Magnetotelluric (MT) is a geophysical method that determines the subsurface resistivity structure using naturally occurring electric and magnetic field variations. In the AMT method used in this study, the internal field created by atmospheric events containing frequencies greater than 1 Hz is used as a source. In the method, two components of the electric field (Ex and Ey) and three components of the magnetic field (Hx, Hy, and Hz) are measured as a function of time using pots and coils, respectively. The first measured E and H fields are transferred to frequency domain by using FFT and impedance and tipper tensors are estimated in frequency domain from the electric and magnetic field components.

MT data is generally measured along a line and the measured data is interpreted using 2D inversion algorithms. In this study, we measured AMT data on 13 stations (Fig. 1). The measurement time of AMT data collected as a time series at each station varies between approximately 2-5 hours. Before performing the 2D inversion of the MT data, the ground-electric direction, which is assumed to be constant, was determined by phase tensor (Caldwell et al., 2004) analyses. After decomposition analysis, impedance tensor is rotated by using estimated rotation angle and TE and TM mode impedances are selected after hthe rotation. We interpreted TE and TM mode data byu using 2D inversion algortihm (Candansayar, 2008; Candansayar and Demirci, 2012).

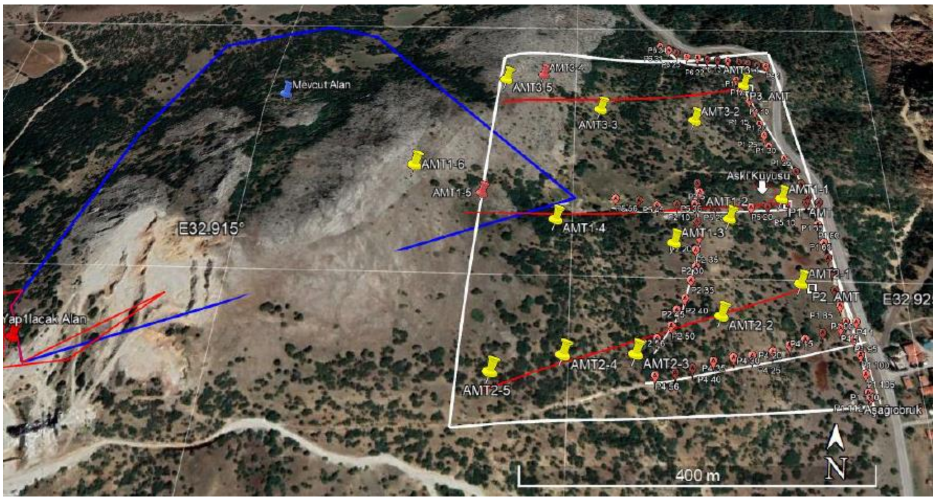

Figure1 Blue polygon: current boundaries of the limestone quarry, white polygon: geophysical study area boundaries, yellow symbols: AMT stations, white lines within the study area: DCR lines, the white down arrow: current water well. The settlement can be seen in the east of the study area.

RESULTS and CONCLUSION

The resistivity distribution of a total area of 30 hectares (500 m x 600 m) was revealed. In 2D inversion, the RMS values of DCR models and AMT models were below 3% and 5%, respectively. In the 3D inversion, the RMS values are 3.2% and 9.7%, respectively.

While interpreting the models, they were divided into three resistivity zones (A: $\rho < 40$, B: $40 < \rho < 100$, C: $\rho > 100$) using the geological map and stratigraphy of the region and the water drilling log. While zone A shows talus and weathered metamorphics, zone B is associated with Central Anatolian Volcanics and zone C is associated with Karakaya Complex. All obtained models were interpreted separately and together. Three DCR and AMT lines are parallel to each other in direction (P4-AMT2, P5-AMT1 and P6-AMT3). Here, two parallel lines (P4-AMT2, P5-AMT1) are presented and the mentioned zones are shown on the models (Figure 2). In both interpreted models, conductive zones on the surface correspond to talus and weathered rocks. If we compare the drilling log and the resistivity models (from DCR and AMT), groundwater is around the border of zone C and zone B just above it. It is seen that the deep part of the Karakaya volcanics retains water because it is not weathered, and its aquifer feature is the clastic units within the Karakaya volcanics and the Central Anatolian Volcanics.

The slope of the limestone blocks in the Karakaya Complex, which is exposed on the surface in the study area, is seen to be towards the west from the AMT models. Therefore, there is no fault zone towards the aquifer in the east. Considering all the results, it has been demonstrated by geophysical models that the existing water well will not be affected.

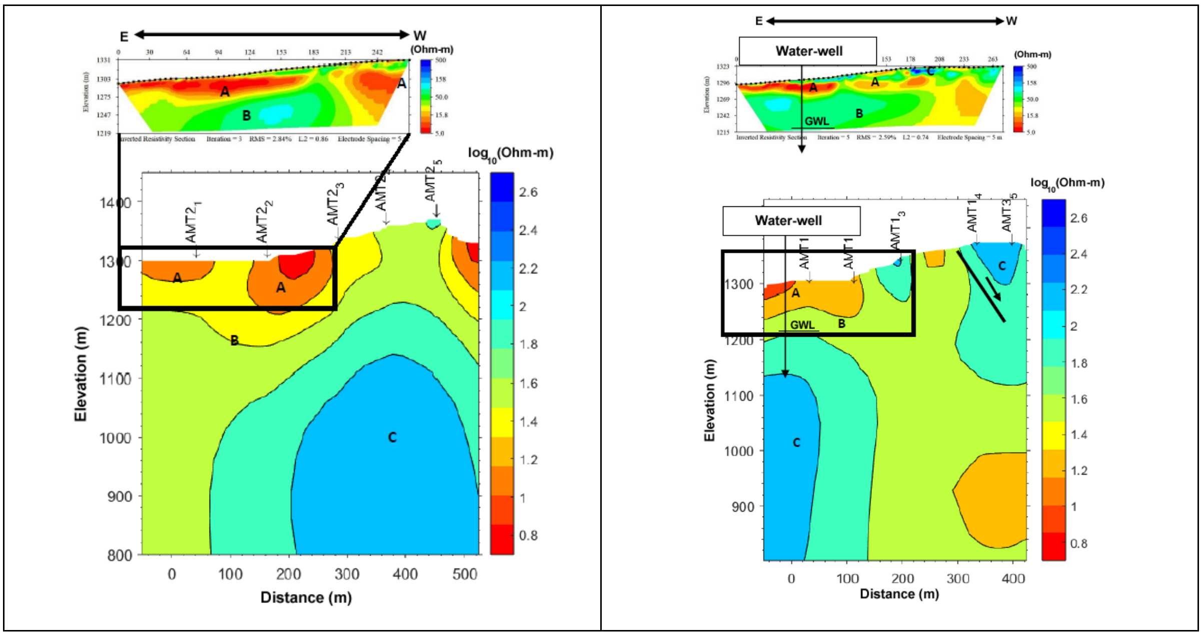

Figure2 Interpretation of P4-AMT2 and P5-AMT1 profiles.

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