Detection of seepage water around Embankment dam at Farooj using of 2-D Electrical Resistivity Tomography (ERT)

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ABSTRACT

Due to the undeniable fact of decline in groundwater resources and the requirement to manage surface and subsurface groundwater, it is necessary to construct a variety of dams and embankment dams. One of the most important issues regarding to dams specially embankment dams is the Seepage. Therefore, the investigation and monitoring system are crucial in order to detect possible threats on the dam. Geophysical methods are non-destructive exploration techniques to investigate underground situation. The aim of this study is exploiting of electrical resistivity tomography (ERT) to figure out probable seepages around an Embankment dam at Farooj. This geophysical method can be successfully used to delineate and map these seepage pathways within the subsurface of the earth dam. Analyzing and interpretation of the data and final tomograms, it is recognizable that there are anomalous low resistivity zones within the bedrock with resistivity variation from 10 to 160 Ωma which are interpreted as zones of weakness representing preferential flow pathways for water from the impounding reservoir. Five profiles (180, 140, 275,230 and 135 m) designed and surveyed by Wenner-Schelumberger configuration array in the study area. Maximum depth of investigation is about 40 m.

Keywords: Electrical Resistivity Tomography (ERT); Seepage; Embankment Dam

INTRODUCTION

Water resources management is one of the most important developmental goals in countries which are located in dry and semi-dry regions of the world. Due to the seasonality of the rainfall and the lack of proper spatial distribution, storing and managing of surface waters by building of embankment dams is a critical issue in Iran. Since seepage is one of the most inevitable phenomenon of these structures, the issue of seepage control has always been a concern of engineers. Seepage. Anomalous seepage may occur sometimes by developing preferential flow paths in the dam body [1]. Thoughtless treatment of an abnormal seepage may result in piping in the dam that may eventually cause dam failure [2]. Therefore, seepage in an earth dam should be well controlled to maintain the dam's stability. Currently, the assessment of dam structures is based on geodetic and geotechnical monitoring instrumentation. However, the majority of these instruments do not provide repeatable and reliable information about the mechanisms occurring inside the body of dams that could compromise the integrity of the structure. There is a growing demand for the use of non-intrusive geophysical techniques to see into the dam and facilitate early detection or diagnosis of anomalous phenomena [3]. Geophysical methods can provide important information to define the safety level of dam infrastructure. In order to investigate the subsurface seepage conditions possible weak zones that could serve as seepage paths within the subsurface of the vicinity of the dam, a 2D electrical resistivity tomography study has been carried out within the two flanks and on the crest of dam.

GEOLOGY

The study area is located in the northeast of Iran, North Khorasan, and 19 km west of the Farooj City. The Dam location could be assigned by 58°09'34"E and 37°13'32"N coordinates (Fig. 1). From regional geological point of view, the study area is over old and new alluvium traces in the north of Kope Daq zone which is located at north of Binaloud- Aladagh Mountains. During the Quaternary period all types of alluvial, sedimentary, landslide and weathering debris in different forms are affected with slight slope by morpho-climate, morphogenesis and morpho-tectonic processes of the area. From topographical point of view, due to the orogenic phase function after the sedimentary conditions and coarse-grained sediments the conglomerates are sloping over neogeneous red formations.

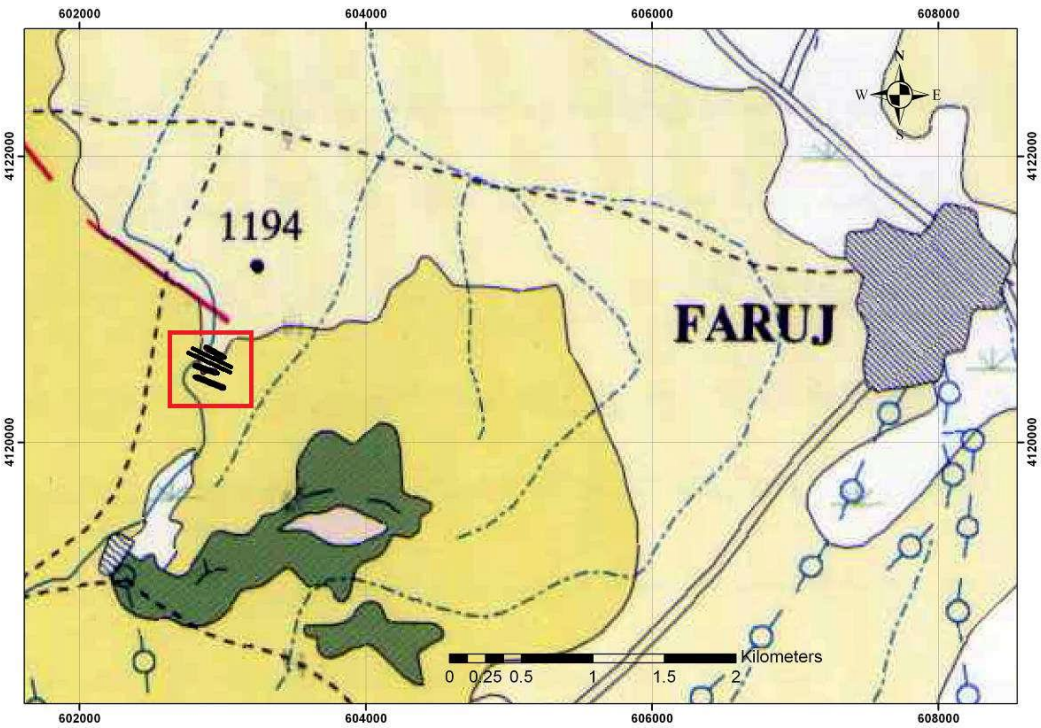

Figure 1. Geology map of the project area. Project Location is shown by red rectangle

2-D ELECTRICAL RESISTIVITY TOMOGRAPHY (ERT)

The electrical resistivity tomography (ERT) is one of the most widely used geophysical methods in geological, hydrogeological, and geo-environmental investigations [4, 5]. The intrinsic electrical resistance of materials and the resistance contrasts between them is basically what the geophysical resistivity methods rely on. The resistivity of earth materials is determined by injecting electrical current into the ground and measuring the resulting potential difference. Resistivity profiles have been successfully used to detect seepage paths in dams [5]. Dahlin and Johansson [6], Johansson and Dahlin, [7], had earlier applied this method to study the embankment of dams. The objective was to detect the potential seepage paths and assess conditions of the foundation at the dam with Electrical Resistivity Tomography (ERT) method. The study involved a preliminary survey, followed by electrical resistivity measurements and interpretation of measured data by using computer software in the laboratory.

DATA ACQUISITION, PROCESSING, AND INVERSION

Resistivity determinations are usually made by injecting a specified amount of electric current into the ground through a pair of current electrodes and then, with the aid of a pair of potential electrodes, measure the potential difference between any two points at the surface caused by the flow of the electric current in the subsurface. From the measured current and the voltage values, the ensuing resistivity is determined. The electrical resistivity of the soil depends on saturation, porosity, permeability, ionic content of the pore fluids and clay content. The ABEM Lund Imaging system comprising of Terrameter SAS 1000 supplemented with an automated multi-electrode system was used in collecting the 2D electrical resistivity data. The lengths of profiles range from 140 to 275 m with a unit electrode spacing of 5 m.

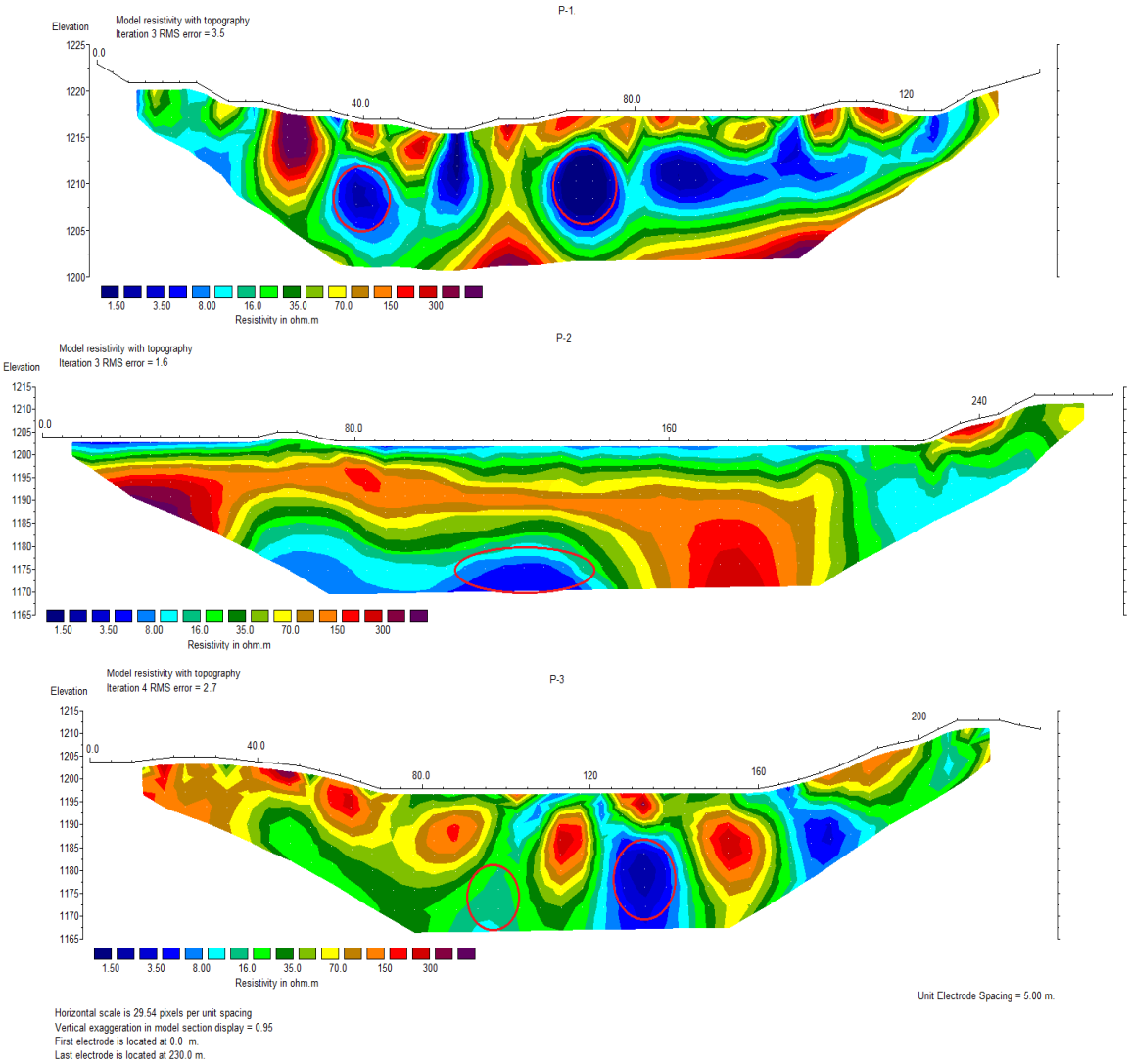

Figure 2. Resistivity sections of P-1 to P-3 profiles which the locations is shown in figure 2. Anomalies in each section has shown by red circles with values less than 1.5 ohm.m. It is clear that at least two seepage ways is identifiable in these sections in the depth of 5 to 7 meters under the Dam.

The raw data obtained for this work, comprising of measured apparent resistivity, were processed using the appropriate computer program. The 2D model used by the program divides the subsurface into a number of rectangular blocks. The program then determines the resistivity of the rectangular blocks that produces an apparent resistivity pseudo section which agrees with the actual measurement. ERT is a typical example of ill-posed problem. Regularization is the most common way to solve this kind of problems. The inversion routine is based on the smoothness-constrained least squares method and can be used for many electrode configurations, including those used in this study. Optimization method tries to reduce the difference between the calculated and measured apparent resistivity values by adjusting the resistivity of the model blocks subject to the used smoothness constraints.

RESULTS AND INTERPRETATION

Subsurface geophysical investigations and surface geological mapping around Farooj Dam revealed some interesting geological features and structures that represents zones of weakness and structural anomalies that may allow excessive water loss from the dam. Some of the structures/features revealed by the 2D resistivity models were characterized by anomalous low resistivity within the high resistivity competent host rock. Erosional channels delineated in the dam reservoir area represented Figure. 2. 2D electrical resistivity model beneath profile 1 showing the dam's reservoir floor. The red circles show water-saturated weathered rock. 2D electrical resistivity model beneath profile 2 showing a low resistivity area in the dam reservoir floor similar to the structure mapped on the surface (P-1). At least two cavities were delineated in the downstream section of the dam. Overall the study confirms the appropriateness of electrical resistivity survey for investigating dam and similar engineering infrastructures. The methods and

procedure used for the study can be applied to any dam and other similar engineering infrastructures to assess their safety status and proffer remedial action where necessary, in order to prevent sudden collapse of the infrastructure.

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