NEAR SURFACE INVESTIGATION OF MAPPED FRACTURE PATTERN AROUND UREJE DAM AXIS IN ADO-EKITI USING WENNER ELECTRODE CONFIGURATION

[1]Fawale, O., [2]Atoiki, V. O., and [3]Adeniyi, O.
[1, 2 & 3]Department of Science Technology, Federal Polytechnic, Ado-Ekiti, Ekiti State.
Corresponding Author: fawaleoluwakorede@yahoo.com

Abstract:
Reduction in water storage capacity of dams as a result of leakages has been observed to be a major occurrence in recent times. The situation has led to acute water shortage for irrigation farmers, highway construction workers and other nearby inhabitants making use of such dams. In view of this, a comprehensive electrical resistivity survey involving of conventional wenner electrode configuration was carried out around the Ureje dam axis in Ado-Ekiti with a view to investigate the fracture pattern and its orientation around the area. A total of five (5) resistivity profiles with 120m length each along the dam axis were completed. An electrode spacing of 5m was adopted for prospecting the faults and fracture pattern in the area. The area of study is located in the Southwestern region of Nigeria which form part of the Precambrian basement complex and lies within the geographical coordinates of 7°35.74′ to 7°36.26′ North and 5°12.45′ to 5°13.01′ East. The profiles along the dam bank showed low resistivity of three layers namely: wet sand (top soil), gravelly (mostly saturated) and basement (partially weathered). Areas away from the dam bank showed lateritic top soil, thin gravel layer and basement complex layer. The pseudosection map indicate the presence of a buried granitic intrusion with dyke-like characteristics across parts of the surveyed profiles while multiple vertical contacts and other associated fracture network appeared to be heterogeneously distributed.

Keywords: *Geoelectrical, Ureje, Wenner, Dam Axis, Ado-Ekiti*

How to Cite: Fawale, O; Atoiki, V. O; and Adeniyi, O (2025). Near Surface Investigation of Mapped Fracture Pattern around Ureje Dam Axis in Ado-Ekiti using Wenner Electrode Configuration. *RUGIPO Research and Technical Journal in Science and Agricultural Technology,* 4(1):1–10. https://elearning.rugipo.edu.ng/Rugipo_Tetfund_Journal_Research_Portal/.

INTRODUCTION

Dams are concrete or earth barriers built across a river for water reservoir and storage (Fatoba *et al.,* 2018). It is a vital tool in modern society which represents large economic values (Oladunjoye, 2010). Dams are also used to store water for industrial and domestic purposes such as domestic consumption, farming, hydroelectric power generation, construction, fishing, recreation and flood protection (Camarero and Moreira, 2017). Water storage in dams started early in history and are known as one of the oldest man-made constructions. The major categories of dams comprise embankment dams, gravity dams, buttress dams and arch dams, each differing in its design and structural function. Selection of an appropriate dam type primarily depends on multiple factors which includes the structural design, geological characteristics of the site, availability of construction materials, and the operational purpose of the dam (Ikard *et al.*, 2015; Akpokodje, 2001). However, it poses a high potential risk in the form of flooding if not properly maintained. The failure of a large dam with a large reservoir is dangerous and can also cause tremendous damage resulting in the loss of lives and property.

In view of this, adequate control measures are necessary to mitigate the risk, considering the resultant effect of dam overflow, an issue that has occurred in past years and remains a significant concern. Recently, the storage capacity of most dams has been depleted and the need to adequately identify the geological remote cause and secure other nearby inhabitants, farmers, and other construction workers around the area from experiencing such acute water shortage is imperative. Hence, a vision for independent geo-electrical studies around the area would be needed and important. In line with this goal, a geophysical study was conducted around the vicinity of the dam to evaluate the subsurface fracture system, the protective capacity of the aquifer, and the directional trends of these features. Conventional dam safety monitoring typically involves routine visual assessments and is complemented by basic instrumentation. However, such methods may fail to detect internal erosion until it has progressed significantly. Effective groundwater exploration in basement terrains necessitates a clear understanding of the aquifer's geo-hydrological properties in relation to its vulnerability to environmental factors (Abiola *et al.*, 2009). Studies have shown that approximately 15% of total precipitation contributes to groundwater recharge, though this proportion can range from 1% locally to 20% at the regional scale (Fatoba *et al.*, 2018). Plummer et al. (1999) also reported that groundwater accounts for around 0.61% of global water resources, a figure nearly 60 times higher than the total freshwater contained in surface sources such as rivers and lakes.

In engineering geophysics, the electrical resistivity method has proven valuable for mapping bedrock structures, evaluating the uniformity of subsurface conditions and identifying potential sinkholes or faults. It is also applied in groundwater studies to assess salinity and determine the depth to the water table (Dahlin *et al.*, 1994; Hago, 2000). This is because the method has been historically utilised to distinguish different geological layers exhibiting different conductivity properties. The approach adopted in this study aims to identify and unravel the fractures and faults which characterise the subsurface structures beneath the dam axis while adopting electrical resistivity techniques with unusual electrical resistivity responses.

MATERIALS AND METHOD

Location and Geology of the Study Area

The Ureje Dam axis, situated approximately 1.0 km east of Ado-Ekiti along the Afe Babalola University–Federal Polytechnic road, lies within the geographic coordinates of latitudes 5°17′N to 5°25′N and longitudes 7°58′E to 7°67′E (Figure 1). The area forms part of the Precambrian crystalline basement complex of southwestern Nigeria, with the local geology characterised mainly by granite-gneiss and migmatite formations (Abiola *et al.*, 2009; Obasi *et al.*, 2012; Fawale and Ojo, 2017). The primary rock formations identified in the area include the undifferentiated migmatite–gneiss–quartzite complex, charnockite, older granites, and relatively younger, unmetamorphosed dolerite dykes (Rahman, 1989). These lithologies typically exhibit low porosity and minimal permeability. In basement complex regions, the most productive groundwater zones are usually associated with thick weathered layers overlying fractured bedrock (Oyedele and Olayinka, 2012). Such water-bearing zones are commonly marked by distinctly low resistivity values (Olorunfemi and Fasuyi, 2012).

Climate and topography

The study area lies within the tropical rainforest zone and experiences a typical bimodal climate comprising distinct wet and dry seasons. It is characterised by consistently high annual temperatures and significant rainfall occurring mainly between April and October. The dry season, spanning from November to March, is marked by minimal precipitation. The region receives an average annual rainfall of approximately 1300 mm, with around 100 rainy days recorded each year. Annual temperatures in the area range from 18°C to 34°C. The landscape is gently undulating, with elevations varying between 350 and 370 meters above sea level. The soil profile comprises gravel, lateritic deposits, alluvial soils, clay, sandy clay, and topsoil. The lowland areas feature minor outcrops, while isolated inselbergs are present toward the outskirts of the region (Olanipekun *et al.*, 2020)

Drainage and vegetation

The region is drained by several streams and rivulets, including Ireje, Elemi, Omisanjana, and Awedele, all of which ultimately discharge into the Ose and Owena Rivers before flowing into the Atlantic Ocean (Rahman, 1989). The area falls within the equatorial climatic zone and features typical rainforest vegetation, characterized by a multi-layered canopy structure with dominant tree species such as mahogany, iroko and obeche.

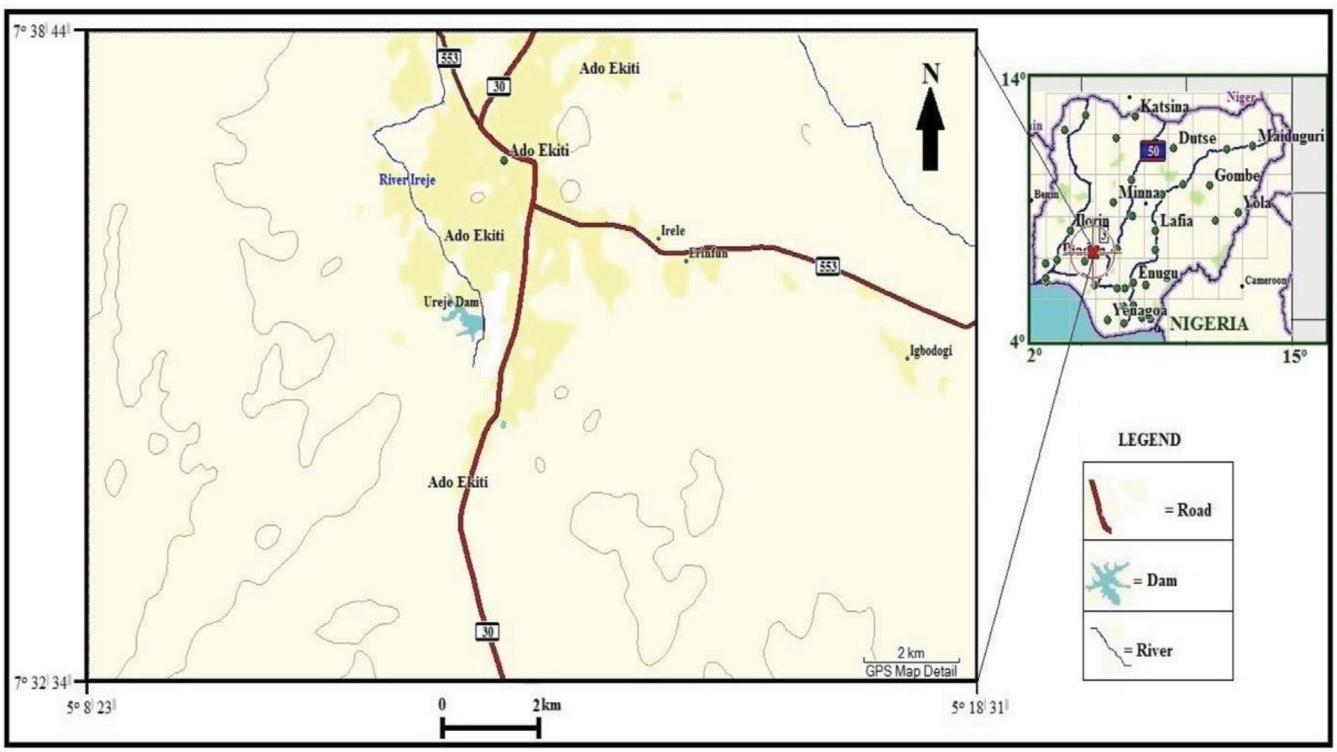

Figure 1: Geological location map of the Study area. (After Fatoba *et al*., 2020).

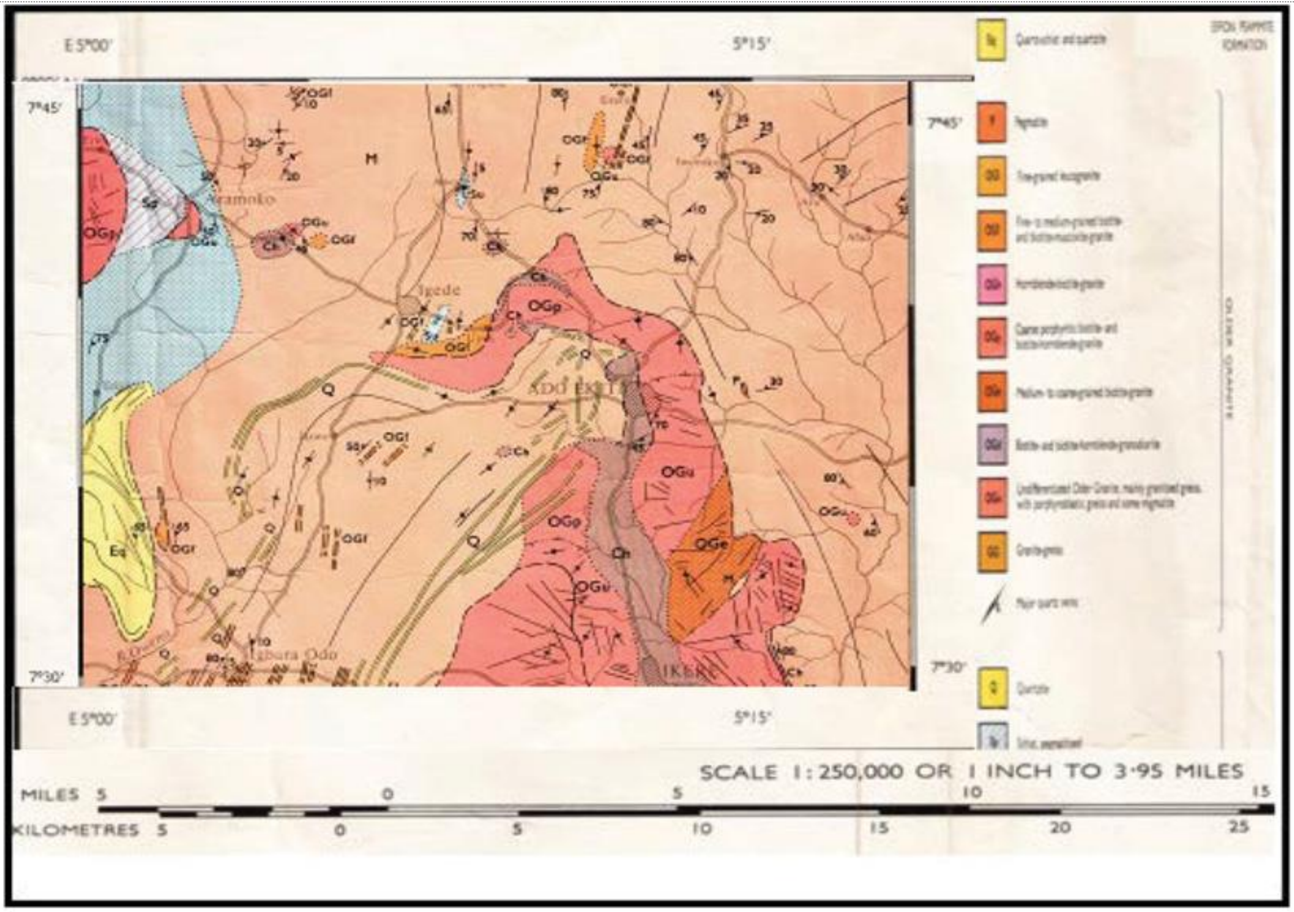

Figure 1: Geological map of Ado-Ekiti Township (After Ajibade and Umeji, 1989).

Materials

Field measurements were conducted using the low-frequency PELI 1300 portable resistivity meter. Additional equipment included a signal booster, four metallic electrodes, current and potential electrode cables, hammers, measuring tapes, data sheets, and communication devices such as walkie-talkies and mobile phones to coordinate long-profile setups.

Method

In this investigation, five (5) geophysical profile lines were established along the dam axis, each extending 120 meters, using the Wenner electrode configuration. Data collection was executed in two phases. The initial phase involved a geological reconnaissance survey of the study area, during which preliminary field assessments were conducted at the research site. The purpose of this investigation was to evaluate the geological structures and the flow characteristics of the aquifer system (Oladunjoye, 2010). Three (3) of the survey profiles were positioned along the dam bank, while the remaining two (2) were established along the stream bank. Apparent resistivity (ℓ_a) values were plotted against electrode spacing along each profile line to visualize the lateral and vertical distribution of subsurface resistivity, thereby providing insights into the lithological configuration of the study area. Measurements were conducted using varying electrode spacings to probe different subsurface depths (Fawale *et al.*, 2011). As electrode spacing increases, the injected current penetrates deeper into the ground, allowing for the acquisition of apparent resistivity values corresponding to increasing depths (Osemeikhian and Asokhia, 1994; Chambers *et al.*, 2006). To ensure a detailed understanding of the subsurface formations, electrode spacings were systematically varied from 5 m to 30 m at uniform intervals of 5 m. Accordingly, the survey was executed with electrode spacings of 5, 10, 15, 20, 25, and 30 meters across all five (5) profile lines.

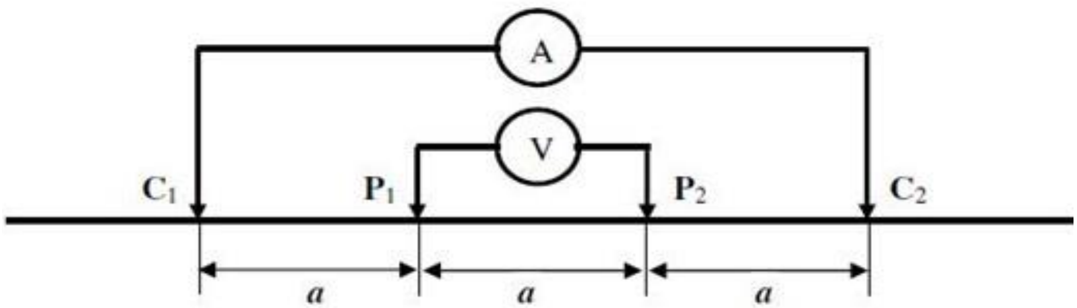

Figure 3.0: Wenner Electrode Configuration array arrangement.

The geometric factor, G for the above configuration arrangement can be obtained as

$$G = \frac{2\pi}{\left\{\frac{1}{a}-\frac{1}{2a}-\frac{1}{2a}+\frac{1}{a}\right\}}$$
$$= 2\pi a$$

The resistivity, ρ value for the Wenner electrode array

$$\rho = R \times G = \frac{\Delta V}{I} \times G$$
$$\rho = \frac{\Delta V}{I} \times 2\pi a$$

Where : ρ = Resistivity on Wenner configuration.
ΔV = Potential Voltage (Volt).
I = Electric Current (Ampere).

RESULT AND DISCUSSIONS

A Pseudosection data plotting which is an imaging or mapping of the underlying structure was performed to obtain the apparent resistivity distribution, variation and the subsurface geological picture of the area of study.

The profile 1 shows resistivity variation which ranges from 64 to 910 Ωm (Fig 4.0). This location or profile is approximately 20 m from the flank of the dam. The 2-D resistivity structure developed, gives shallow and low resistivity distribution at the top soil less than 100 Ωm between 35.0 − 114.5 m away from the starting point. The depth of this low resistivity is about 2.0 m, after which the resistivity increases to about 500 Ωm with a depth of about 3.0 m beneath the Earth's Crust. A Dyke was observed in this profile from a depth of about 10.0 m along 27.5 − 77.5 m with resistivity ranges between 1515 − 12735 Ωm.

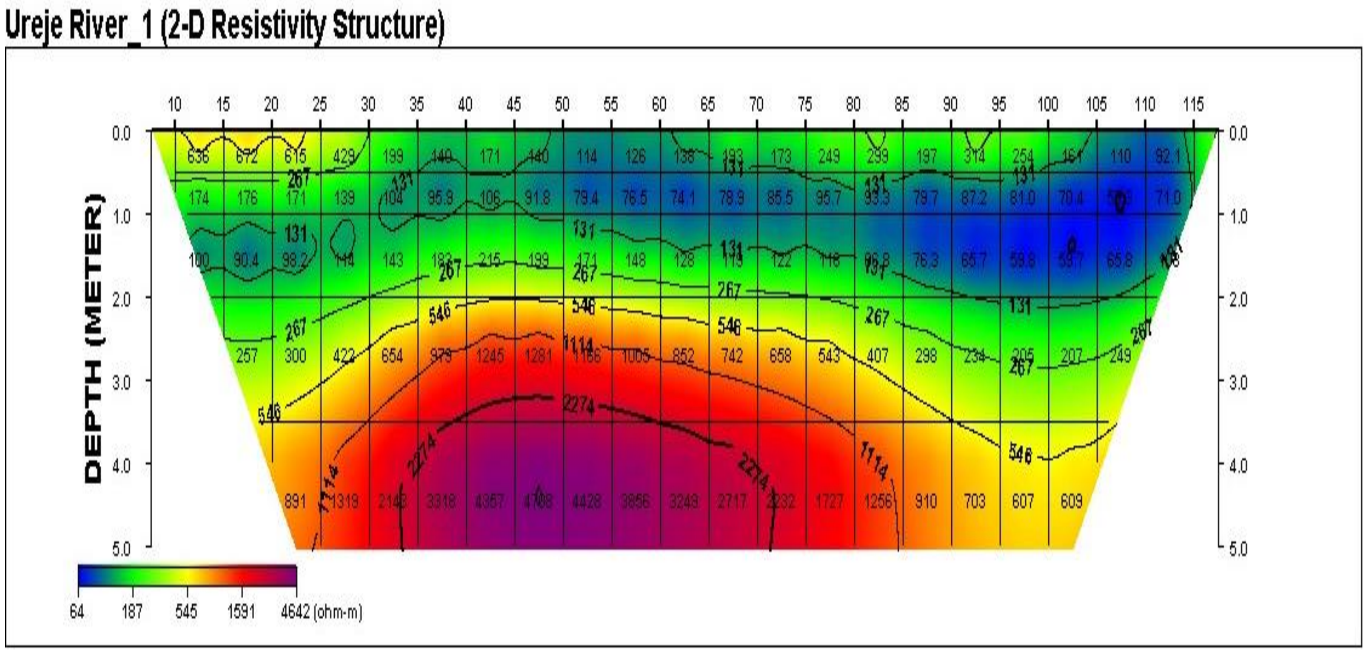

Figure 4.0: Pseudosection along Traverse A – A[1] for Profile 1.

The 2-D resistivity map of profile 1 is similar to profile 2 (Fig. 5.0), with the little difference in the relative distance from the dam flank. This profile is about 50 m away from the dam. The dyke observed in profile 1 is now manifested in profile 2 with a high resistivity value. Therefore, we can account for the relatively low resistivity of the dyke found in profile 1 to the saturation of water received by this profile. The shallow low-resistivity zone observed in this profile exhibits a reduced lateral extent. It extends only between 54.5 and 62.0 meters laterally, with an approximate depth of 4 meters. A comparable low-resistivity zone appears toward the profile's edge, suggesting soil saturation in that section. The lithology arrangement in this profile is quite different from that of profiles 1 and 2. The 2-D resistivity structure indicates a distribution of low resistivity values concentrated in the topsoil, suggesting higher moisture content or conductive materials near the surface. The resistivity structure of this profile is relatively uniform except at the point above 2.5 m where there is high resistivity of about 1200 Ωm which depicts the presence of basement at this point. Though this basement shows low resistivity as it moves down at this point, this indicates that either this basement is fractured or weathered. The top-soil low resistivity slightly steep down its depth and its about 9 m at the point 50 − 57.1 m from the starting point. The resistivity distribution is high at the edges but relatively low in the middle of the profile. This insinuates the presence of a fracture.

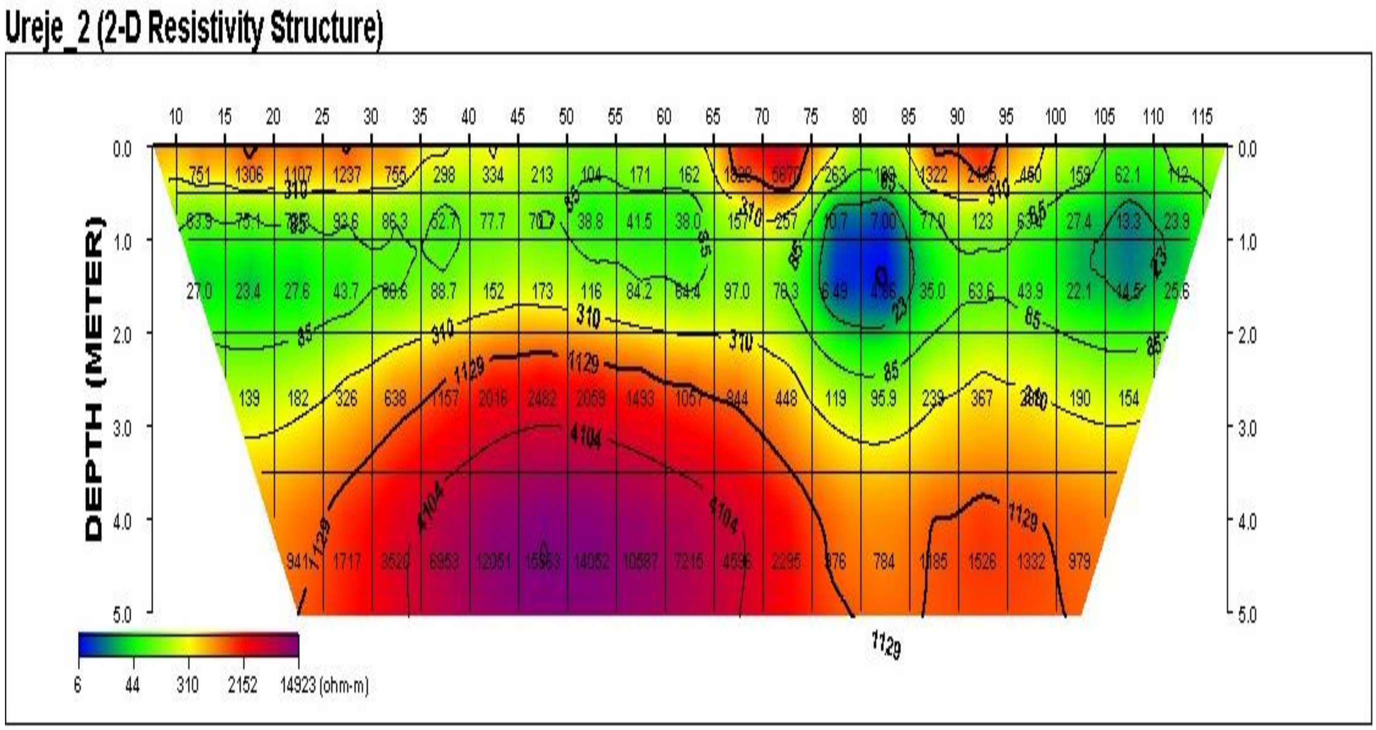

Figure 5.0: Pseudosection along Traverse B – B[1] for Profile 2.

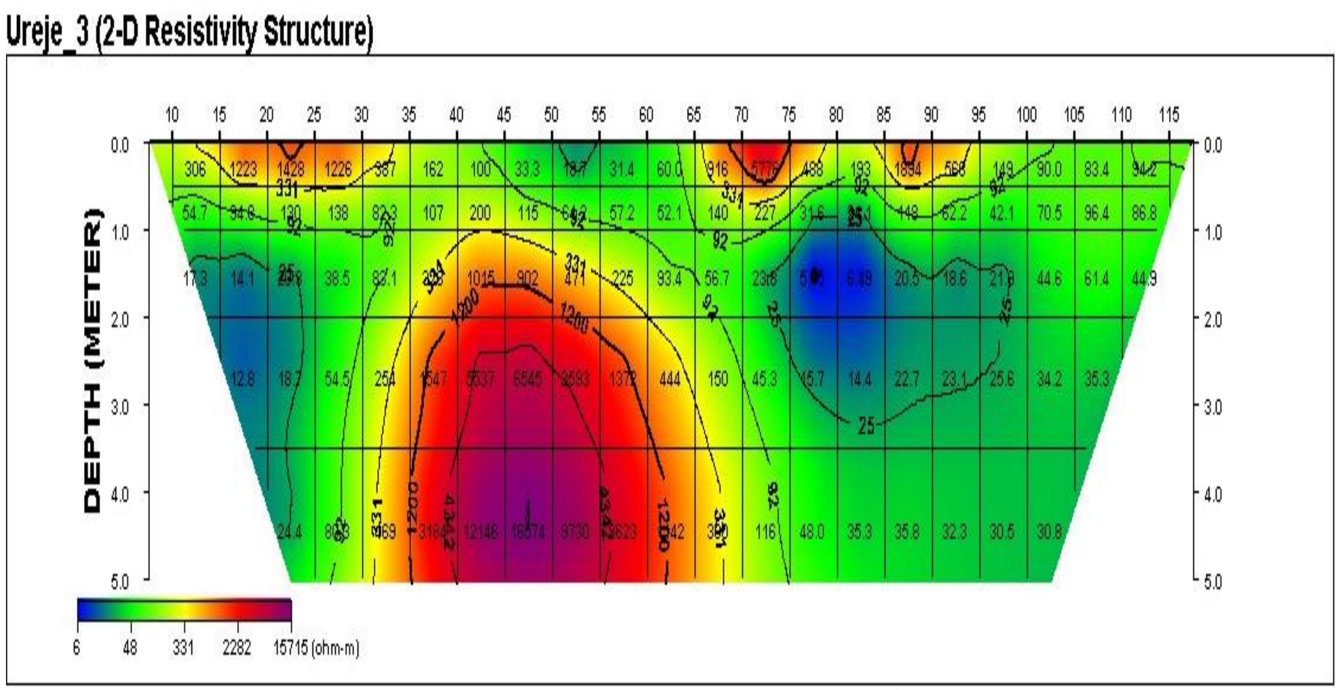

Figure 6.0: Pseudosection along Traverse C – C[1] for Profile 3.

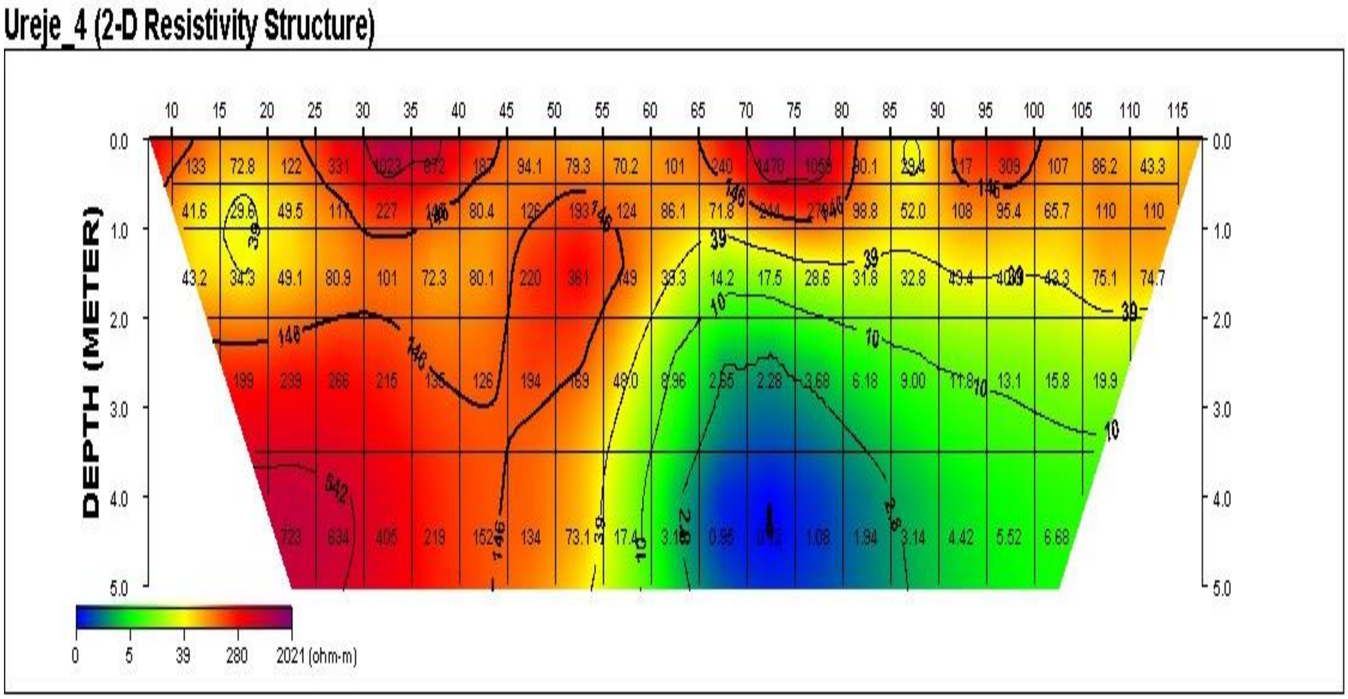

Figure 7.0: Pseudosection along Traverse D – D^1 for Profile 4.

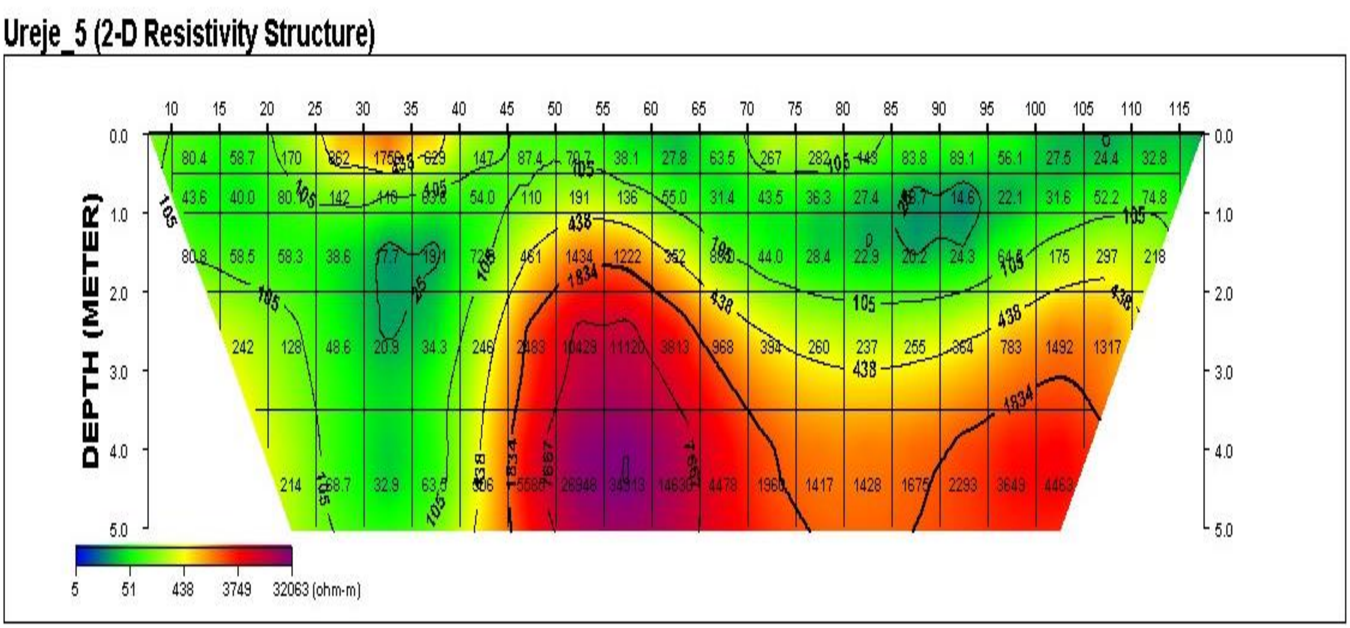

Figure 8.0: Pseudosection along Traverse E – E^1 for Profile 5.s

The 2-D resistivity structure in profile 3 shows high resistivity at the top-soil, which ranges from 234 – 1800 Ωm with a depth of about 5.0 m. But the internal Crust has a relatively low resistivity structure across the profile. But at point 27.5 – 45.0 m from the starting point, there is a spot with a very low resistivity value of about 18.2 Ωm, which depicts the presence of an aquifer at this point. The 2 D − resistivity structure of profile 4 shows the presence of many vertical contacts with their fractures. There is a relatively high resistivity value from the starting point to about 20 m along the profile. Low resistivity was found after this zone which is due marshy structure of the area, which subtends to about 42.5 m. The relatively high resistivity continues to about 75 m away from the starting point. There is a vertical contact after this point, which shows very high resistivity of about 798 Ωm.

CONCLUSION

In this study, high resistivity areas and low resistivity areas were identified along the Ureje dam axis. The high resistivity areas may indicate gravel, sand, and rock fragments lying on top of elevated solid rock. The low resistivity areas may indicate areas where the host rock has been lowered by faulting and/or fracture which contains water, making the area less resistive to electrical current. In this way, the water content from the dam is lost through the small opening of the fracture in the subsurface. The pseudo-sections map obtained for profile $A-A^1$ and $B-B^1$ look similar. This is because they share the same weak zones and fractures, likewise their depth to basement is relatively equal and this shows that they both exhibited similar lithological arrangement. The fracture pattern of the study area is unevenly distributed. The weathered basement found in $C-C^1$ discontinues in $D-D^1$ despite they are in the same flank but continues at $E-E^1$. This is because the $D-D^1$ (Profile 2) is characterized by outcrops. It can be concluded that shallow geophysical prospecting involving multiple scales techniques could be adopted as tool for identifying and precisely locating weak zones and faults in areas with relatively young deposits at the surface. Also the depth to the basement in the study area is shallow. Conclusively, the reduction in the water level experienced at the Ureje dam in recent time can be traced to the fracture observed around the flank of the dam which are observed to be consistent towards the bank.

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