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Electrical Resistivity Imaging (ERI) for Identifying Near-surface Bodies at Diyala University site, NE of Iraq

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Abstract

The current research demonstrates the ERI method's effectiveness as a supplementary engineering site investigation approach. Engineering site research is important to indicate the subsoil of proposed production sites. The benefit of the dipole-dipole array for ERI electrical resistivity imaging is that it provides informative records of subsurface geology and condition along with profiles. The dipole-dipole array was performed along with three parallel profiles at the Diyala University site to identify the buried facilities (pipes and cables) in the area. The buried electric cable embedded in a plastic tube was used for simulation to report and verify the field resistivity results. Interpretation of field facts confirmed that the used ERI method was robust in locating buried structures. The dipole-dipole array's strong horizontal sensitivity to subsurface resistivity releases made it possible to provide greater certainty of site characteristics concerning the buried systems. The results were consistent with the information on wells near the work site.

Keywords: Electrical Resistivity Imaging, Engineering Site Investigation, Near-surface structures, Diyala University site

المقاومة النوعية الكهربائية التصويرية للتحريات تحت السطحية لتحديد الاجسام القريبة من السطح في موقع جامعة ديالى، شمال شرق العراق

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الخلاصة

يوضح البحث الحالي فعالية طريقة ERI كنهج مكمل لتحريات الموقع الهندسية. يعد البحث الهندسي للموقع مهمًا للإشارة إلى التربة التحتية لمواقع البناء المقترحة. فائدة النشر بطريقة ثنائي القطب– ثنائي القطب للمقاومة النوعية الكهربائية التصويرية ERI بكونها تسجيلات مهمة للجيولوجيا تحت السطحية وظروفها على طول المسارات. في هذا البحث، تم استخدام النشر ثنائي القطب–ثنائي القطب على طول ثلاثة خطوط متوازية في موقع تطوير في جامعة ديالى، لتحديد المرافق المدفونة (الأنابيب والكيبلات) في المنطقة. تم استخدام االكيبل الكهربائي المدفون في أنبوب بلاستيكي للمحاكاة والاعلان عن نتائج المقاومة الكهربائية الميدانية والتحقق منها. المقاومة النوعية الكهربائية ثنائية الابعاد تعالج الاشكال المدفونة بشكل واضح، على الرغم من

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وجود بعض التعقيدات في المنطقة. أكد تفسير الحقائق الحقلية أن طريقة المقاومة النوعية الكهربائية ثنائية الابعاد كانت قوية في تحديد موقع التراكيب المدفونة وجعلت الحساسية الأفقية القوية لطريقة نشر ثنائي القطب– ثنائي القطب لإطلاقات المقاومة النوعية تحت السطحية بالإمكان توفير قدر أكبر من اليقين لخصائص المواقع فيما يتعلق بالأنظمة المدفونة. وكانت النتائج التي تم الحصول عليها مطابقة مع معلومات الابار القريبة من موقع العمل.

1. Introduction

The electrical resistivity method is one of the earliest geophysical survey techniques [1]. Electrical surveys can estimate the subsurface resistivity distribution by taking measurements on the ground surface. The real resistivity of the subsoil may be calculated using these data. Ground resistivity is affected by some geological factors, including mineral and fluid composition, porosity, and the degree of water saturation in the rock. Hydrogeological, mining and geotechnical studies have relied on electrical resistivity surveys for decades. It has lately been utilized in environmental surveys [2].

The earth's reaction to the flow of electrical current is the basis for geophysical resistivity methods. An electrical current is transmitted through the ground with these procedures, and the consequent potential difference between two potential electrodes is recorded, allowing us to measure the electrical impedance of the underlying material. The apparent resistivity is then determined by the observed impedance (potential-to-current ratio) and the electrode array design. The apparent resistivity data are displayed as 1D soundings, 1D profiles, or 2D cross-sections depending on the survey geometry to seek abnormal areas. Data are termed apparent resistivity because measured resistivity values areverages over the total current path length but are plotted at one depth point for each potential electrode pair [3].

Two-dimensional electrical technology is applied to reveal the water table and its impact on the area and study the fluctuation of the groundwater level. In addition, examine the buried facilities (buried pipes, cables, and other utility lines) at the study site.

Several authors have adopted the 2D ERI technique for engineering site investigation to detect subsurface structures such as cavities and sinkholes [4], fractures [5], faults [6], buried utilities [7], walls [8], cracks [9] and tunnels [10].

This research aims to study the University of Diyala campus site and survey it electrically using a two-dimensional electrical resistivity imaging (ERI) method, as the site is intended to establish modern infrastructure. The site has not been previously studied. So ERI will be used to detect the subsurface buried utilities (such as pipes and cables) to avoid problems during future construction, as well as identify the groundwater level in the area that may affect the foundations of the infrastructure that will be constructed in the future.

2. Location and Topography of The Study Area

The study area is located in Diyala University in southwest Diyala Province, about 50 km to the northeast of Baghdad. The dimension of the site is 120*120 m with a total area of about 14400 m^2 with latitudes 33˚ 31' 42" N, 44˚ 49' 79" E, as shown in Figure 1. The surface of the study area is characterized by flatlands, which consist of modern alluvium deposits that contain layers of sand and clay. The climate situation is the most factor that influences the geological features and dominant in their forms.

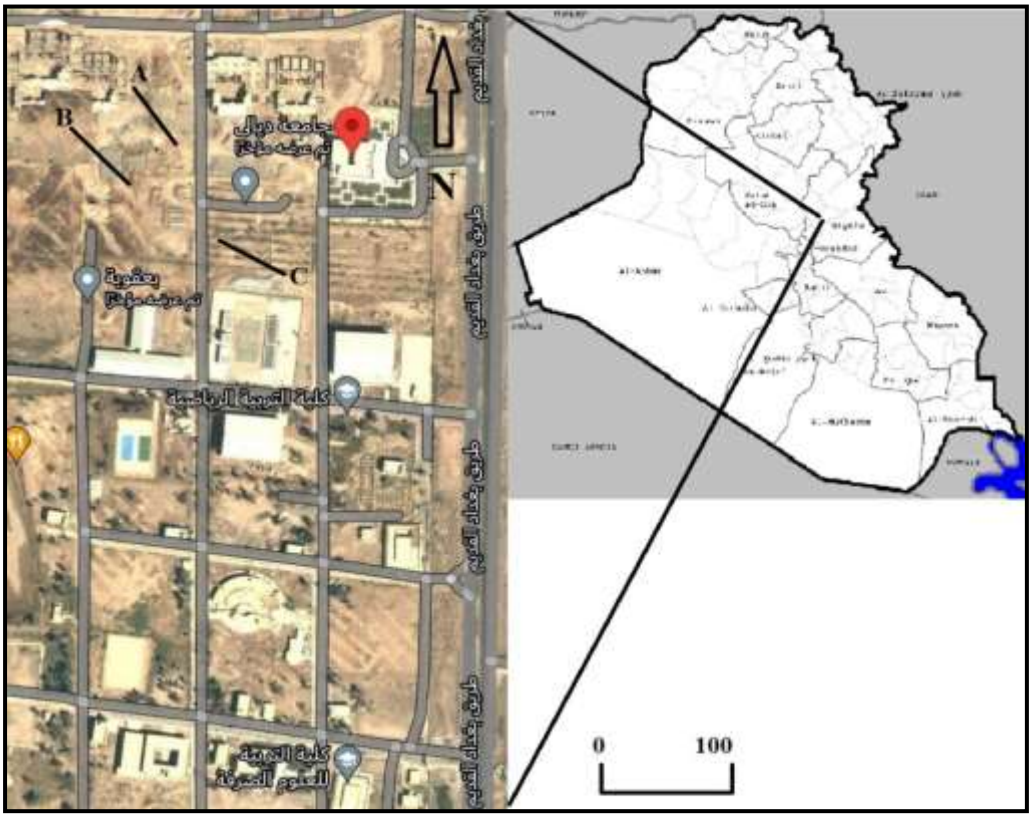


Figure 1: Satellite image showing the location of the study area

3. Lithological Setting of The Study Area

Geotechnical soil boring logs in the study area achieved by Al–Ebdaa Company (2015) were obtained using standard split spoon samplers used in the Standard Penetration Test (SPT) and Undisturbed Samples (US) (Shelby tubes).

The study area is composed mainly of a clayey soil layer, with the description mentioned below:

1) 0.0m-15.0m: The light change to dark brown clayey soil with a high content of gypsum and soluble salts in some locations at the top layer. According to the Unified Soil Classification System (USCS), the soil can be classified generally as low plasticity clay (CL).

2) 15.0m-40.0m: The dark gray sandy soil. According to USCS, the soil can be classified generally as poorly graded sand (SP), silty sand (SM), and poorly graded sand-silty sand (PS-SM). According to the geotechnical soil borings drilled in the area by Al-Ebdaa Company ((2015, the surface soil consists of a light to dark brown low plasticity clay (CL) layer up to 13m Figure 2.

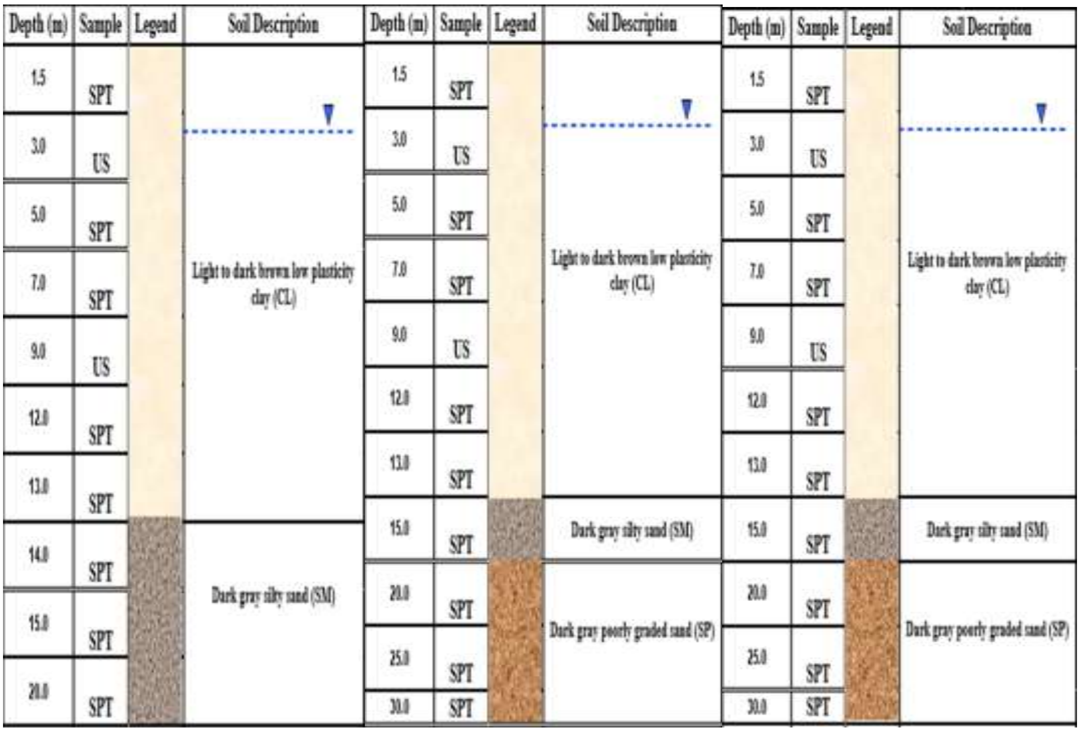


Figure 2: Geotechnical soil boring logs in the study area [11].

4. 2D Electrical Resistivity Imaging Technique

2D ERI technology uses more electrodes arranged along with the profile and connected to the electrical resistivity system via a multi-core cable [12]. The apparent resistivity of the bipolar array, adopted in the present study, was obtained using current (C1 and C2) and voltage (P1 and P2) electrodes. A dipole-dipole array was selected because it gives good signal strength and sensitivity to resolving horizontal and vertical resistivity changes [13], as shown in Figure 3. The values of electrical resistivity obtained are arranged in pseudo-sections of apparent resistivity, giving qualitative approximations of the electrical resistivity distribution. Therefore, inversion is required to obtain the field data's true 2D resistivity section.

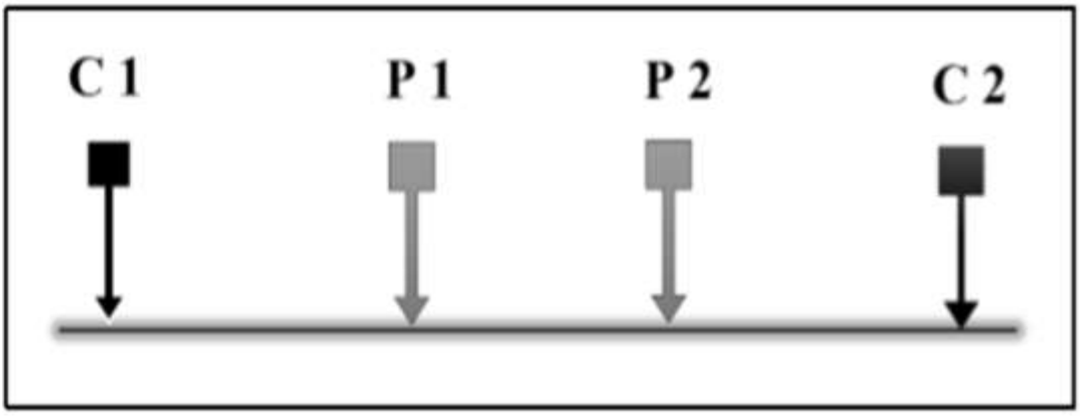


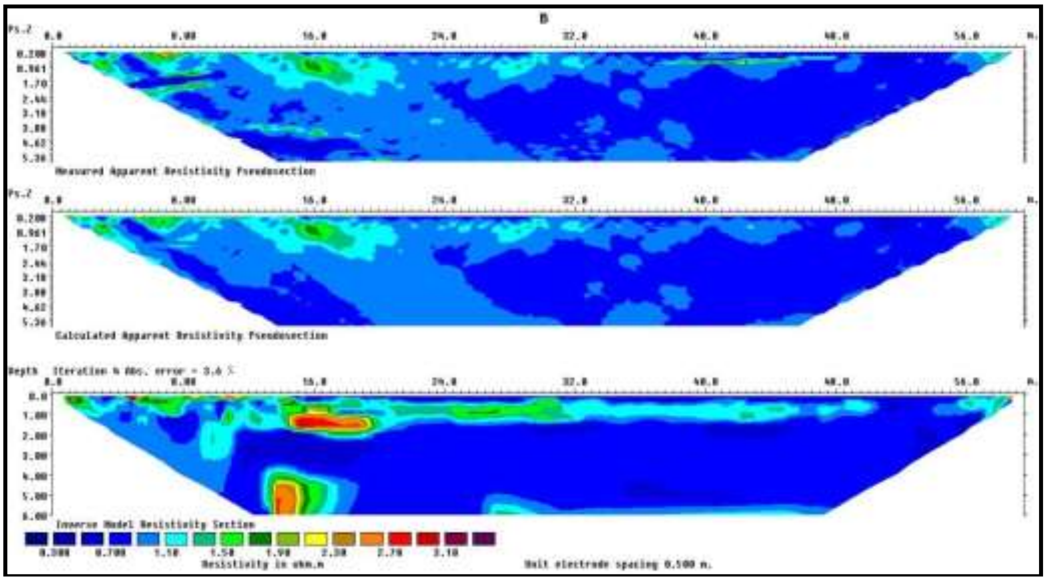
Figure 3: A sketch diagram shows the traditional array [14].

5. Field Work

The 2D ERI survey was performed using a dipole-dipole array on three parallel profiles, 3 meters apart, located at the Diyala University campus. According to the drilling of geotechnical soils in the site achieved by Al-Ebdaa (2015), the topsoil consists of a layer of light to dark brown clay with low plasticity (CL) up to 13 m Figure 2. The study area has recently undergone a massive drive to build new educational facilities. Existence of subterranean infrastructure in the area, including pipelines, electricity cables, and construction materials. An investigation of the geotechnical site is essential for exploring the underground condition and location of buried structures for a future engineering project.

Two-dimensional electrical resistivity imaging profiles were centered over an existing buried concrete cast to verify the suitability of the dipole-dipole group to identify the buried shallow structures. For each profile [15], one hundred twenty electrodes were connected with a minimum electrode spacing of 0.5 m to the ABEM SAS 4000 resistivity system to collect the apparent resistivity data. RES2DINV uses the finite difference method based on regular least-squares optimization procedures [16]. To produce a true 2D model of subsurface resistivity distribution from apparent resistivity data. The software repeatedly determines the resistivity of the model blocks that will closely produce the measured apparent resistivity data. The dipole-dipole method was chosen because it is more suitable in areas with acute resistivity limits [17].

The resistivity survey was carried out along three parallel lines (A, B, and C), shown in Figure 4. These lines are surrounded by the University of Diyala infrastructure, and are situated inside a flat expanse of topsoil. The coordinates of the center point of the array line (A) (N 33 41 1.8") (E 44 36 6.4"), coordinates of the center point of the array line (B) (N 33° 41 2") (E 44° 36 6.5") and coordinates of the center point of the array line (C) (N 33° 41 2.2") (E 44° 36 6.6"). Most of the areas of the inverse model had low resistivity ranging from (0.7-1.5 ohm.m) and this is because the survey area has muddy layers saturated with groundwater.



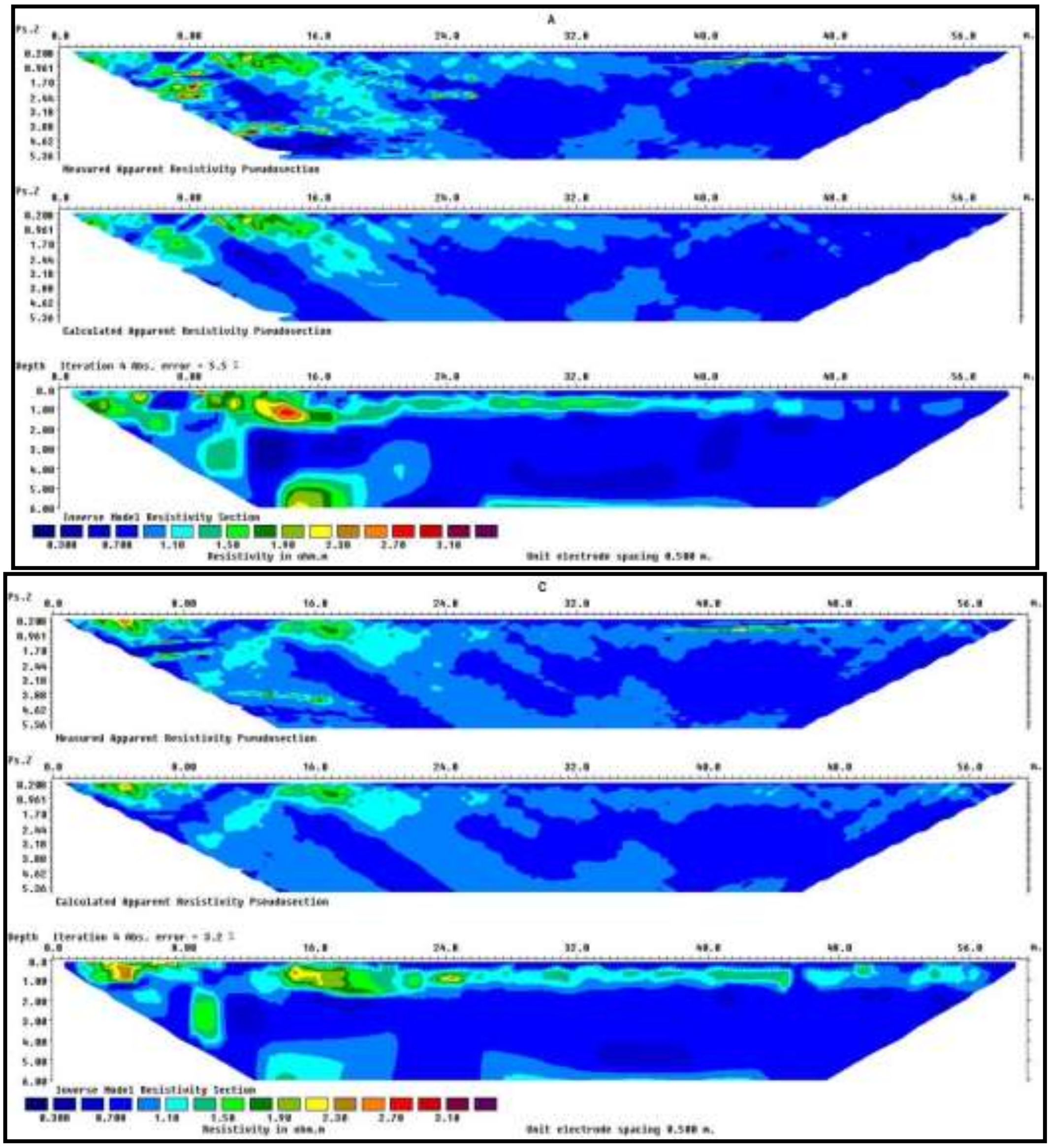


Figure 4: The measured and calculated pseudo section with the resistivity model of the survey points (A, B and C).

6. Results and Discussion

The dipole-dipole array was chosen because it is more suitable in areas with acute resistivity limits and for detecting horizontal and vertical variation in the subsurface area [18]. The measured field data quality is very good, with a very low RMS error of about (3.2%-5.5%), which is an acceptable result for the interpretation showing the distribution of subsurface resistivity, as shown in Figure 5.

Generally, the distribution of subsurface soil resistivity in the inversion models of the study site Figure 5 shows a wide low resistivity along the profile line for an array. The low resistivity in the inverse model is due to the presence of clays with low resistivity and high conductivity, as shown in the stratigraphic section in Figure 2.

From this survey and along Line A, the inverse model will generally have a lower resistivity of 0.3 to 1.3 ohm.m Figure 5a, and the lower resistivity is due to the clay layers being of lower resistivity. As for the area between the electrode (22 to 30) has a high resistivity ranging from 1.5 to 3.10 ohm. m, which appears after excavation where a buried concrete casting with electric cables in the study area was detected at a depth of approximately 75 cm, as shown in Figure 6. The area between the electrodes (27- 40) has a high resistivity ranging between (1.5 – 2.30) ohm.m at a depth of 6 meters, which is the remains of rubble, the foundations of old buildings.

The layer of the surveyed profile B is characterized by its low resistivity with a thickness of about 5 m. This layer represents the clayey Figure 5b. The area between poles 27-39 at a depth of 75 cm and between poles 22-32 at a depth of 6 m has a high resistivity ranging between 2 - 3.5 ohm.m. These areas represent the remains of the rubble of old buildings.

Generally, the distribution of subsurface soil resistivity in the inversion models of the study site of survey line C Figure 5c shows a broad low in soil resistivity at different depths along the profile line for the array dipole-dipole.

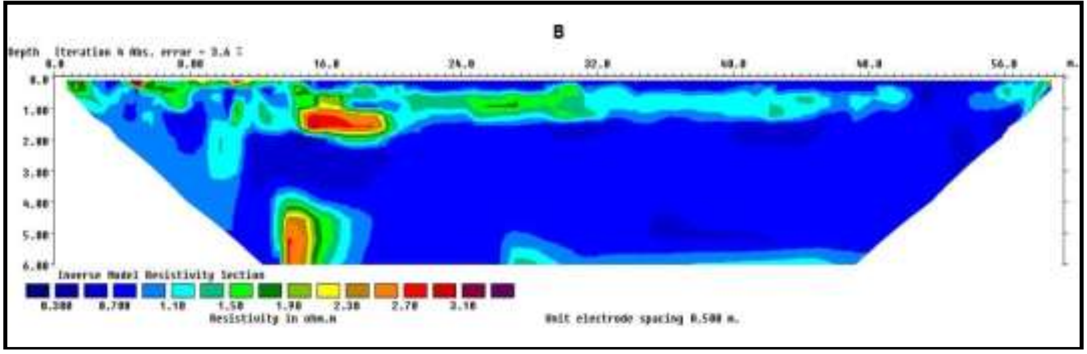


Figure 5a: The inverted resistivity sections for lines A.

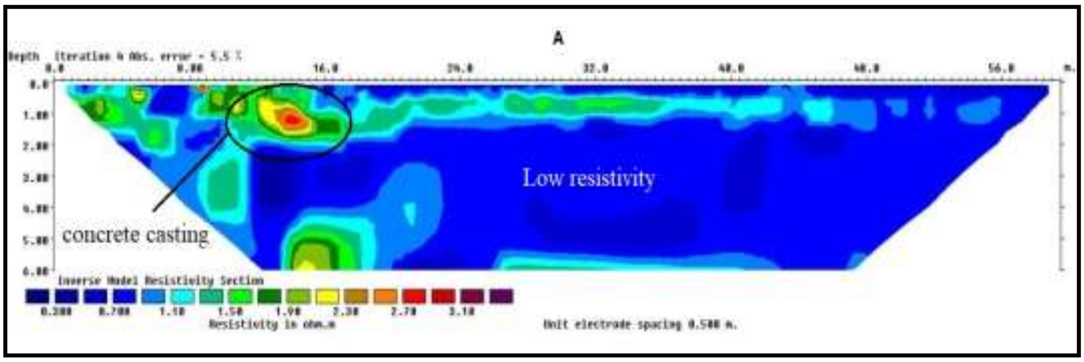


Figure 5b: The inverted resistivity sections for lines B.

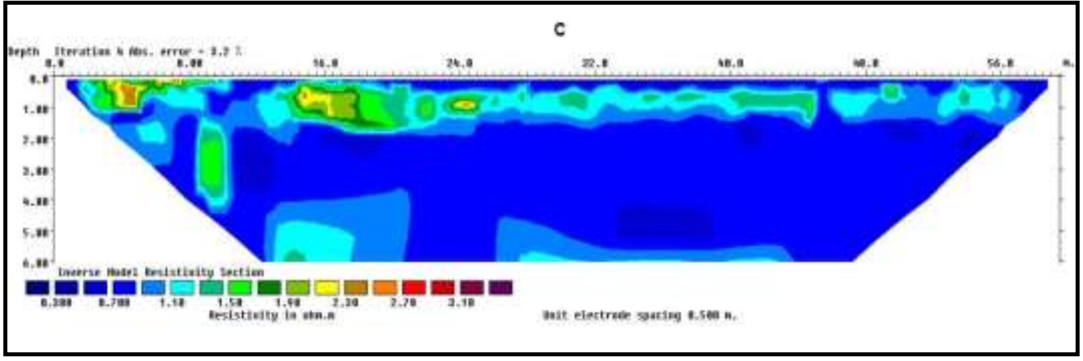


Figure 5c: The inverted resistivity sections for lines C.

The quantitative interpretation of the inverse model shows that there is a vertical gradient in the underground resistivity and that the surface resistivity increases with increasing depth due to the increase of sandy layers that help to increase the electrical resistance, and these layers appear after the depth of 7 m.

Figure 6: The buried concrete casting within the study site.

6. Conclusions

The 2D ERI survey was performed using a dipole array along three parallel lines to reveal the shallow bodies buried at the University of Diyala site northeast of Baghdad. Interpretation of field and inverted data indicates that the 2D ERI technique effectively resolved the buried body. In 2D ERI sections, the geometry and placement of the buried tube were fairly mirrored. The findings demonstrated that the dipole array was more sensitive than the Wenner and Schlumberger setup to changes in horizontal and lateral resistivity in the ground caused by the presence of the buried body. Note that dipole-dipole is more used for deep penetration. Electrical resistivity is a good method for continuous measurements on various scales. Besides, two-dimensional electrical resistivity imaging is an effective method for soil characterization in contrast to regular digging, which disturbs the soil. The dipole-dipole method was chosen because it is more suitable in areas with acute resistivity limits and for detecting horizontal and vertical variation in the subsurface area.

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