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The Relation Between the Variation of Electrical Resistivity Values and Moisture of Soil at Baghdad University, Iraq

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Abstract

Six ERI profiles using Wenner Schlumberger array were carried out at Baghdad University (ALJadiriya campus) to investigate soil at two sites. The spacing between electrodes of four profiles surrounding the new building in the Campus at the first site is 1 m, and the profile length ranges from 50 to 90 m. In comparison, two across profiles in the garden to detect water seepage in the site. The inverted model of the studied profiles shows many high and low resistivity zone. The sedimentology and mineralogy of the soil samples analysis from a depth range of 15 to 100 cm from three pits confirm the high homogeneity of the soil in the studied site composed of (silt and clay). The low resistivity values coincided with the moisture and amount of vegetable and herbs growth. Therefore, the authors believe the main factor causing variation in the resistivity value in the study area is the moisture Factor.

Keywords: Electrical Resistivity Imaging; Seepage Investigation; Water content, University of Baghdad

العلاقة بين اختلاف قيم المقاومة الكهربائية والرطوبة في تربة جامعة بغداد, العراق

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الخلاصة:

نفذ (6) بروفايلات ERI (المقاومية الكهربائية التصويرية) باستخدام ترتيب Wenner Schlumberger في جامعة بغداد (حرم الجادرية) للتحري عن التربة في موقعين. التباعد بين الأقطاب الكهربائية هو 1 متر ، ويتراوح طول البروفايلات من 50 إلى 90 مترا. أربعة بورفايلات (مسارات) تحيط بالمبنى الجديد في الحرم الجامعي في الموقع الأول. في المقابل ، اثنين من االبروفايلات متقاطعة في الحديقة للكشف عن تسرب المياه في الموقع. يظهر النموذج المقلوب للبروفايلات المدروسة العديد من انطقة المقاومة العالية والمنخفضة. رسوبية ومعدنية لعينات التربة التي جمعت من نطاق عمق يتراوح بين 15 و 100 سم من ثلاث حفر. يظهر تأكيد التجانس العالي للتربة في الموقع المدروس المكون من (الطمي والطين). تتزامن قيم المقاومة المنخفضة مع

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الرطوبة الموجودة وكمية النباتات والأعشاب ، لذلك ، يعتقد الباحثون أن العامل الرئيسي الذي يسبب التباين في قيمة المقاومة في منطقة الدراسة هو عامل الرطوبة.

1. Introduction

Electrical resistivity surveying is usually used to investigate subsurface features. It has recently been utilised for environmental studies. It has already been used for various purposes, including groundwater investigation and agronomic practices management by focusing on the areas of extreme compaction, as well as assessing geological and hydrological characteristics [1]. ERI measures depend on the basic idea of the resistivity method, which is represented by passing an electric current through current electrodes and measuring the voltage on the potential electrodes. [2].

Electrical resistivity imaging is widespread and has been used as a before-excavation reconnaissance technique in numerous close-to-surface environmental and engineering studies over the last few decades [3].

Electrical resistivity has also been used to calculate the thickness of economic deposits of building materials like sand and gravel and to identify subsurface phenomena like gaping holes, valleys, and submerged canals. It is also widely used in environmental science and environmental protection [4].

The surveys can be conducted in one, two, or three dimensions at various scale resolutions ranging from very local to regional. The 2D resistivity surveys can map complicated geological formations that were previously impossible to map using traditional 1D resistivity survey results. [5].

Several additional studies have demonstrated a relationship between soil analysis and electrical resistivity imaging to generate continuous subsurface details and dig deeper into the subsurface by many meters. Numerous studies have been conducted on site layout approaches that produce optimal information utilising various ERI configurations and placed in various geological formations [6].

Electrical Resistivity Imaging was applied to establish an industrial site close to the Erbil-Kirkuk borderline to evaluate the lateral and vertical lithological variations of the karst and robust subsurface zones. The electrode spacing of 2 m was used in a Wenner array. Studied areas are separated into numerous blocks, and each block consists of many parallel profiles pointing in a certain direction [7].

The weak zones (fractures and cavities) within the subsurface gypsum layers and gypsiferous soils at the University of Al-Anbar in western Iraq were investigated. 2D electrical resistivity approaches were applied using dipole-dipole and pole-dipole arrays. The spacing was 2 m. The soil thickness in Al-Anbar was found to be ranged from 9.5 to 11.5 m [8].

The electrical resistivity imaging approaches were used at a test site in Venice to assess how well the building bases had been restored after being consolidated (Italy). The brick wall foundation's resistivity values are given the presence of void spaces and cracks. The wall's high resistivity (> 150 ohms.m) has been clarified. The wall's intermediate value resistivity volume (20–100 ohm.m) has been clarified by good sections of the wall foundation, and the wall's low-value resistivity volume (10 ohms.m) was discovered as a result of the total decay of the bricks and their complete replacement with totally degraded mud substance [9].

This study investigates topsoil heterogeneity in an engineering site constructed within the University of Baghdad, AL-Jadiriya- Baghdad- Iraq.

2. Materials and Methods:

2.1 Location of the study area

Two studied areas located near Al-Khwarizmi Engineering College within the Campus of the University of Baghdad were studied. The first study area building is about 900 m, with latitude 33°16'15.66"N coordinates and longitude 44°22'26.42"E. The second study area is approximately 700 m2 and is represented as a garden, with latitude 33°16' 8.53" N and longitude 44°22' 23.09" E, Figure 1. The study area is situated within a flood plain with quaternary sediments. The sediment is made up of gravel, sand, and salt, mostly deltaic, lacustrine, and fluviatile sediments [10],[11].

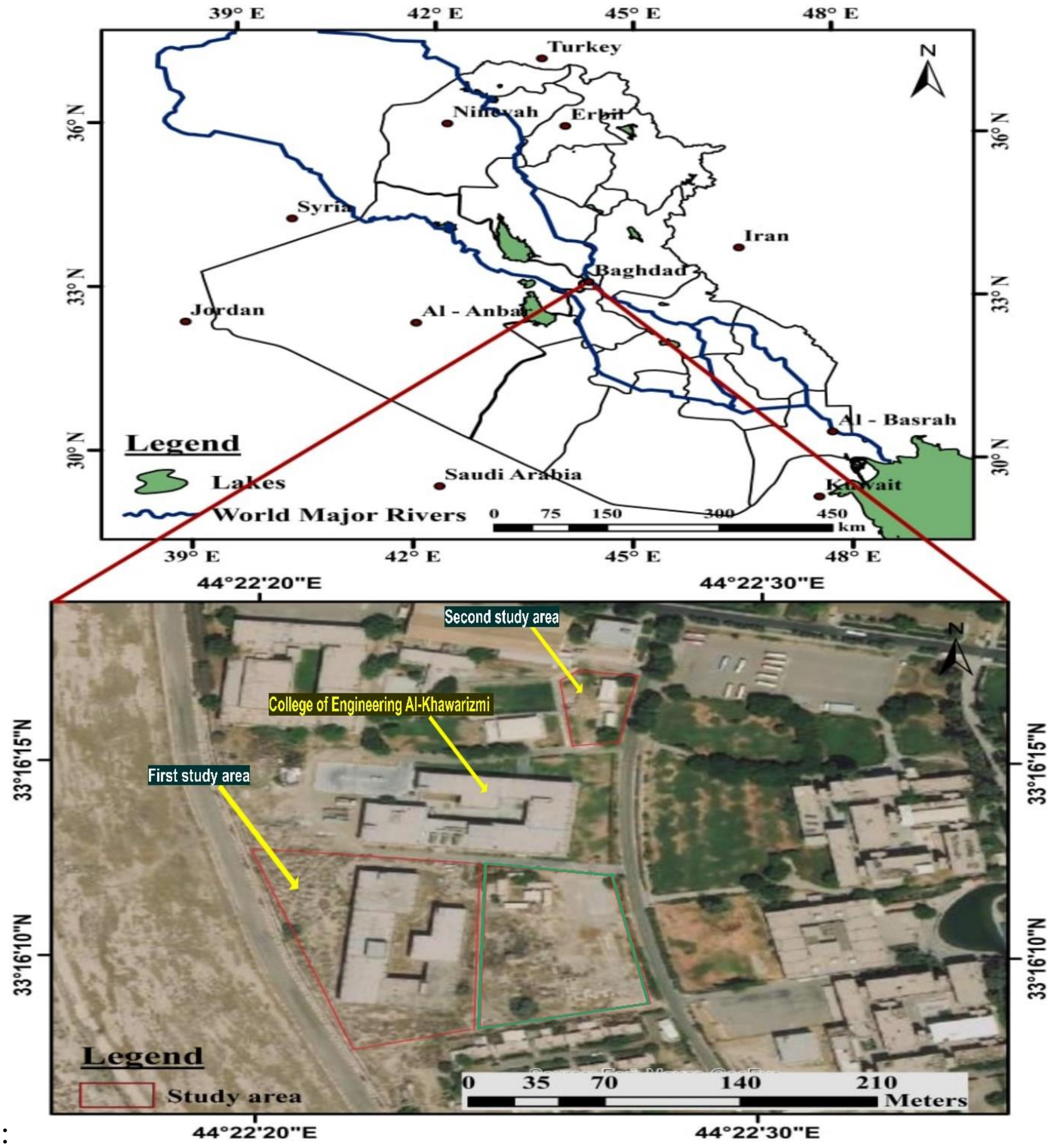

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Figure 1: The location map of the two study areas

3. Hydrogeology of the area:

The water level in the study area was measured in two walls consideration. Based on the coordinates in Table 1. The Engineering College's stadium was not far from Well -1. The distance between Well -1 and the Tigris River is approximately 450 meters at a ground elevation of 35 meters above sea level. The water table elevation is 28.8 m above sea level based on the water level measurement from the ground surface using sounder equipment, which was found to be 6.2 m. Figure 2, Well-2 is situated next to the Engineering College's Park and is 34 meters above sea level. About 680 meters separate Well-2 from the river. The water table is 28.4 m above sea level based on the water depth from the ground's surface, which is 5.6 m. The Tigris River's water level is 29 m above sea level, which implies that the river's water level determines the amount of water that flows into the study region.

Table 1: coordinates for both well-1 and well-2

Wells	Latitudes	Longetudes	Water Level (A.S.l) m
Well-1	33°16'23.15"N	44°22'21.20"E	35
Well-2	33°16'18.87"N	44°22'30.56"E	34

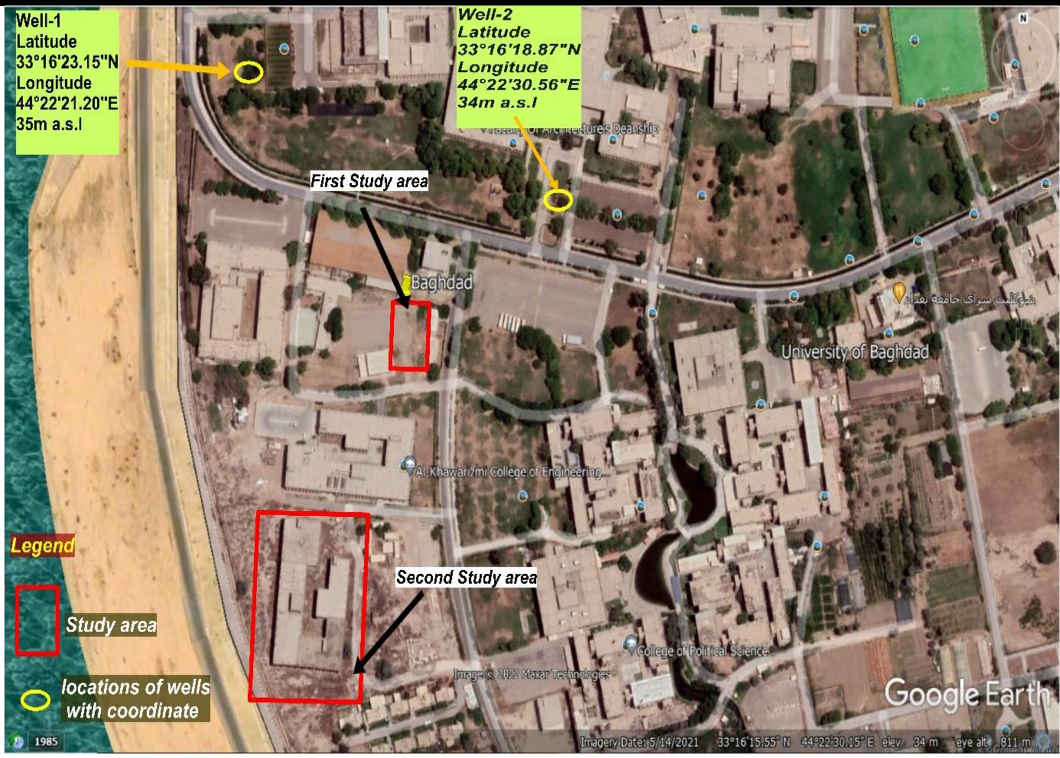
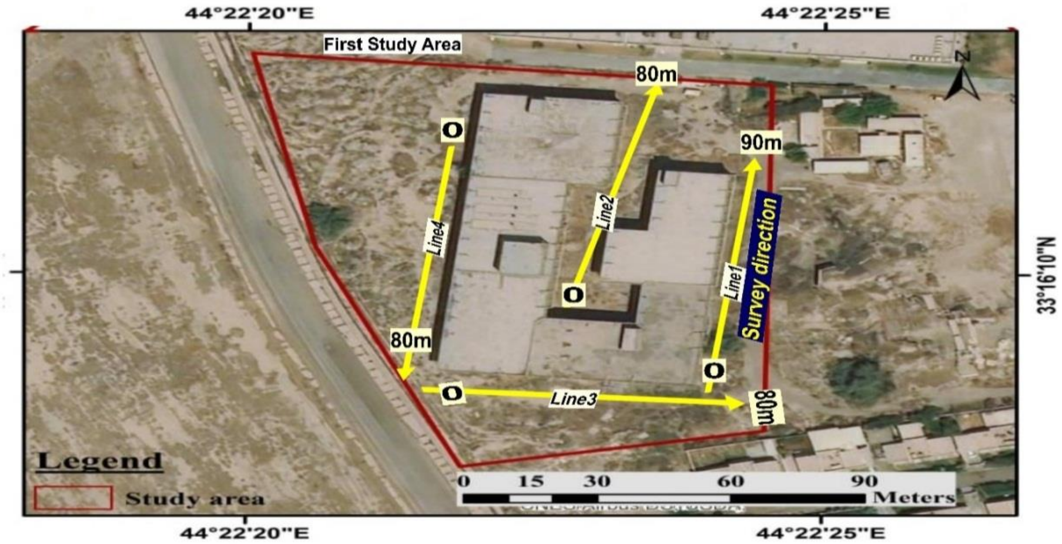


Figure 2: Location well-1 and well-2 by Google Earth, with coordinates close to the study area by an aerial satellite image of Baghdad University.

4. Fieldwork:

4.1 Data acquisition and processing:

The fieldwork was carried out in March 2022. Data was collected over four lines for the first area using a 2D electrical resistivity imaging approach, as shown in Figure 3. The electrode spacing was 1 m, with Line-1 = 90 m, Line-2 = 50 m, Line 3 = 80 m, Line 4 = 80 m, The length of Lines 5 and 6 in second region of 60 and 50 meters, respectively. For field data measurements, a Wenner-Schlumberger configuration array was used. Data collection was done using a Syscal Pro Switch 120 electrode computer-controlled device. The theoretical measuring errors were excluded. The measurement sequence is designed to make n range from 1a to 6a. To minimise noise level and subsequently minimise field measurement error, all metal electrodes were calibrated and meticulously handled to reduce the contact resistance between them and the ground surface to less than 1 kilo ohm.



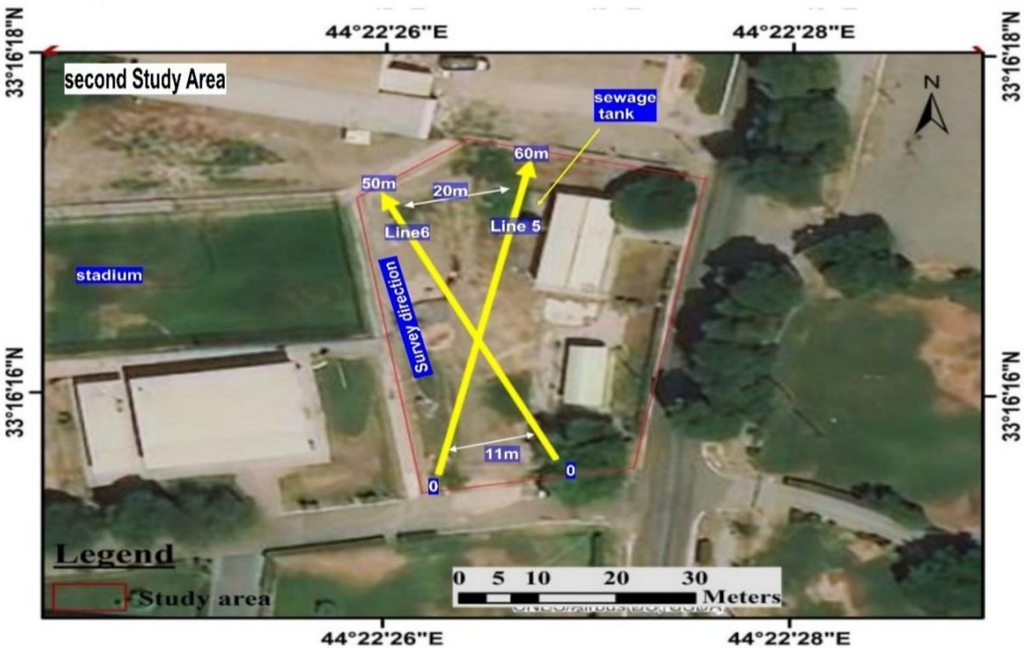


Figure 3 : Location and direction of the first and second study areas.

The second fieldwork includes soil samples collected from two electrode locations—electrode number 34 (with high resistivity) and electrode number 55 (low resistivity) at various depths (15-100 cm) at line 5. The analysis of soil samples aimed to understand the nature of resistivity values vary with soil heterogeneity, The soil samples' PH and TDS were measured, and a chemical analysis was performed per Folk's recommended protocol [12].

The 2D resistivity measurements were processed and interpreted using the RES2DINVx64 program, version 4.8.12. [13].

5. Results and discussion:

5.1 Laboratory analysis

The laboratory analysis of the selected samples, as shown in Table 2, revealed a resistivity contrast between areas with high and low resistivity for the same line and the effect of moisture. The low resistivity values of line-5 are interpreted as water seepage because line-5 (Electrode 55) locate 2.5m away from the source sewage tank. The high resistivity values in line-3 are related to compaction soil and Dehydration [14].

Table 2: states the results of soil sample TDS and PH Laboratory tests.

Sample Number	Line No	Electrodes No	Depth (cm)	Resistivity	PH.	TDS (ppm)	Electro-Conductivity EC (μs/cm)
A	3	52	15	High (410)	7.4	195	334
B	3	52	50	High	7.6	110	176
C	3	52	100	High	7.5	108	216
D	5	34	15	High	7.7	145	270
E	5	34	100	High	7.2	130	224
F	5	55	50	Low (15)	7.2	128	239
G	5	55	100	Low	7.1	178	300

The high resistivity values between 0-15 cm are related to high compaction and gravel.

5.2- 2D inversion and modelling

The 2D inverse results of the Wenner-Schlumberger configurations were shown using Robust Inversion Model Constraints for two lines considered (profiles). The inverse model represents the true image used during interpretation. The electro-conductivity in the study area was discovered to be directly related to the TDS value.

5.2.1 Line-1

The interpretation of line 1 shows many electrical zones. With a length of 90 m and a maximum depth of investigation in the model section of 19 m, the 2D inversion resistivity pseudo section of line-1 trends from N to S (Figure 4). After seven iterations, the resistivity values (in ohm.m.) shows a root means square (RMS) is 1.78%. The geometric features and location of the buried objectives were evident in this section. To resolve horizontal and vertical variations in resistivity while detecting or discovering the subsurface. The low resistivity extent to depth reaches about 2 meters from the first electrode to the 32nd electrode. Most bodies with the highest resistivity are located within the unsaturated zone to a depth of approximately 6 m. The upper layer has a resistivity range of approximately 20–170 ohm.m.

Zone (A), based on laboratory analysis, composed of silt and clay with little sand, has resistivity values ranging from 333 to 416 ohms. m. to depth reach about 11 m. This zone extends within the saturated and unsaturated zones and represents high heterogeneity compared with other zones. The inverted model shows high resistivity values from north to south of the line at a depth of 2m related to unsaturated zones. The lower resistivity values are related to the unsaturated range.

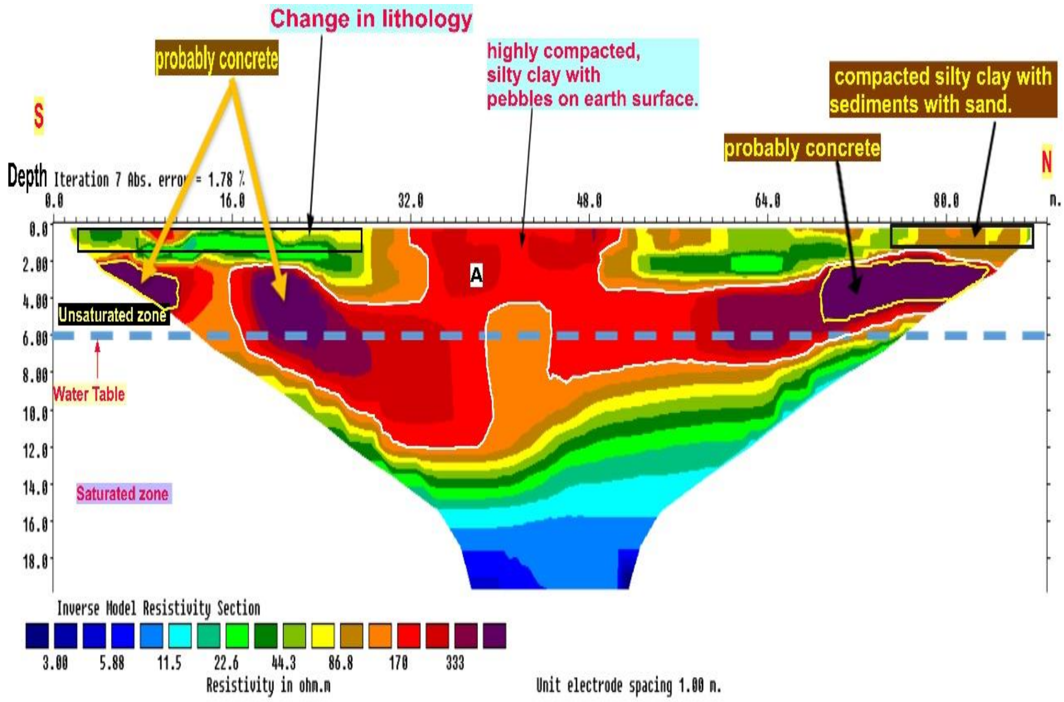


Figure 4: The inverted section for line -1, showing resistivity variation and water table

5.2.2 Line-2

Inverse model interpretation for Line-2: it is semi-parallel to Line-1 but different in direction (Figure 5) and displays a section of resistivity ranging from 3 to 416 ohm.m. After seven iterations, the RMS is 2.5%. The length of line 2 is about 80m and the maximum depth of 17m. Zone (A) reflects the highest heterogeneity from the first electrode to the 71 electrodes, with a resistivity range of 333–416 ohm.m. The thickness extends from the surface to different depths. A semi-circular body at a depth of 6 meters extends to a depth of approximately 10 m. That affected the layer between the electrodes 32 and 45, with the highest electrical resistivity of 416 ohms. m. The body is parallel to the same body in the middle or center array for line 3 with the same depth. The author believed it might be contacted between them. There are also several anomalies, particularly at the edges of bodies extended in a lateral direction. The significant anomaly below the water table interpreted may be highly compact soil or concrete mass.

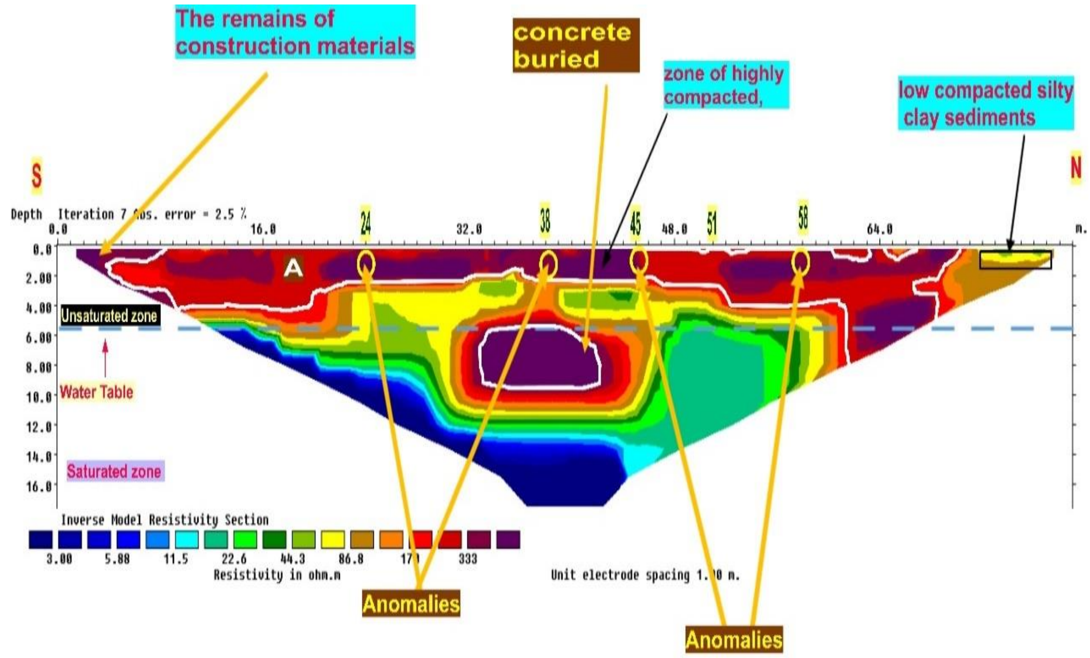


Figure 5: The inverted section for line -2, showing resistivity variation and water table

5.2.3 Line -3

The line3 inverted model has a length of 80m and a maximum depth investigation of 17m (Figure 6). The line3 showed in the W-E direction after seven iterations. Zone A reflects the highest resistivity with a range of 333-416 ohm.m. The soil samples collected from electrode 52 were composed of silt and clay with a small amount of sand at a depth of 1 m. Zone A extend from electrode 35 to electrode 64 with a thickness of about 4m within the unsaturated zone. The circular or semi-circular body shape below the water table may be a concrete mass. The anomalies appeared in this line beneath electrodes 20, 26, and 32, but also 38 and 45, which represent the edges of the body buried and electrode 52.

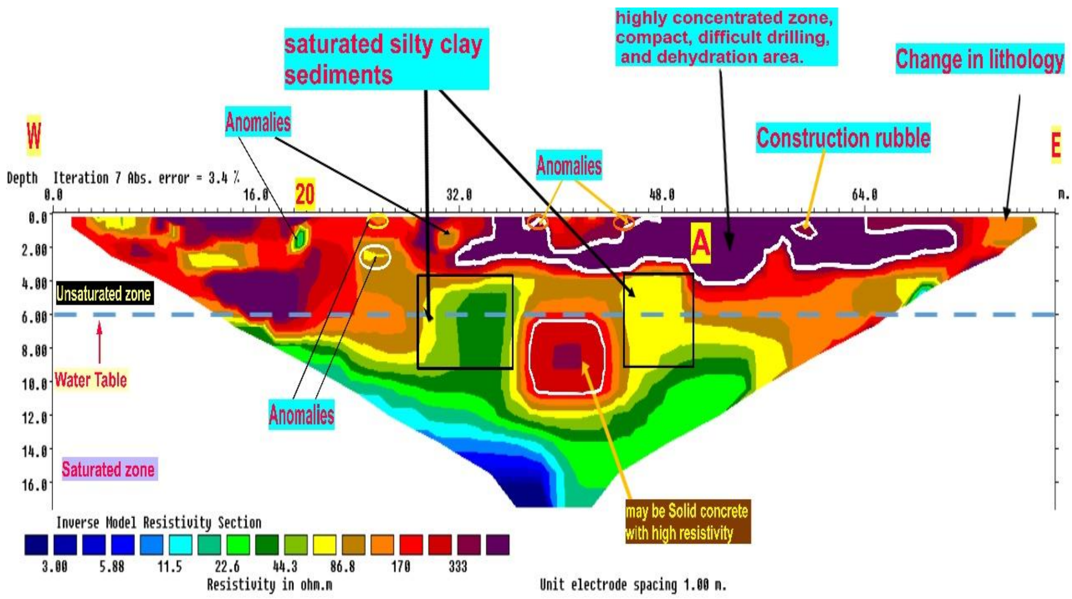


Figure 6: The inverted section for line -3, showing resistivity variation and water table

5.2.4 Line 4

The length of profile line-4 was 80m (Figure 7). After seven iterations or repetitions, the resistivity values vary from 3 to 416 ohm.m with an RMS of 2.4%, corresponding to the Wenner–Schlumberger array. The resistivity is higher than 333 ohms.m. It runs parallel to line -1, South-North, but in the opposite direction, it is North-South. There is less heterogeneity compared with other sections. The high-resistivity zones are most likely to take the shape of horizontal or lateral extensions. The low resistivity with a range of 3-50 ohm.m. The variance in resistivity can be due to the different materials taking shape within different sediments.

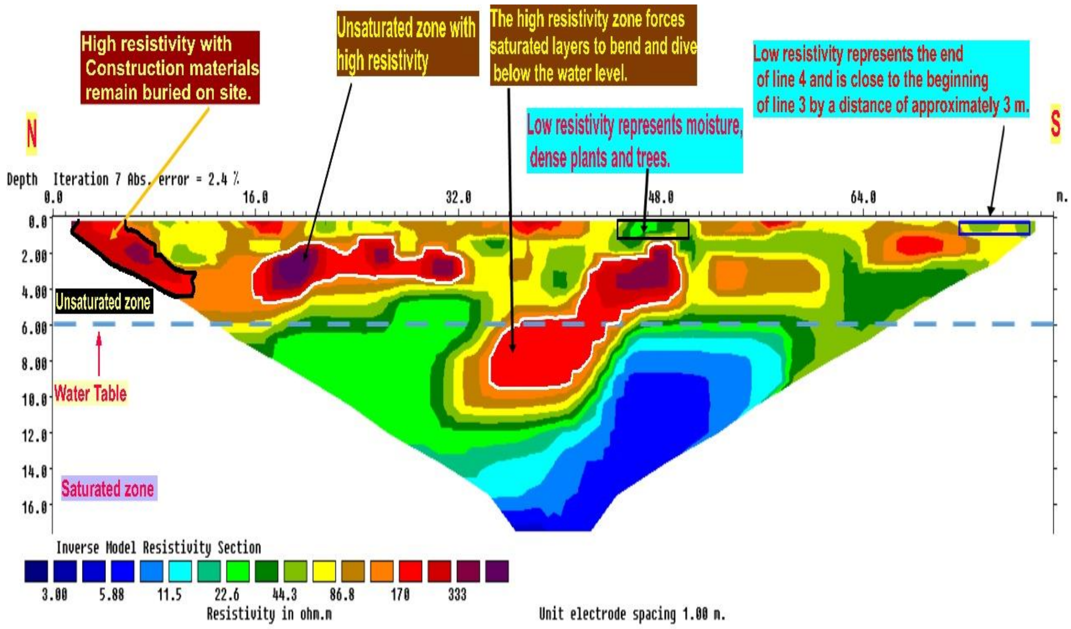


Figure 7: The inverted section for line -4, showing resistivity variation and water table

5.2.5 Line -5

The inverted model based on line 5 explained the laboratories results with a length of about 60m from SW to NE (Figure 8). After seven iterations to become RMS is 2.6% (12 m, maximum depth), the strong imbalance or difference in resistivity values (3 to more than 333 ohm.m) due to heterogeneity revealed in topsoil elements or components. The low resistivity values range from 3 to 11 ohm.m due to seepage water content with the increase in the clay and silt percent and the decrease in the sand percent of collected samples. Several factors influence the resistivity values that cause them to be high or low and thus the occurrence of heterogeneity. The change in nature or forms of sediment is also heterogeneous. These factors include water content (moisture), Dehydration, compaction, and granular size. Wet soil shows very clearly from electrode no.1 to electrode no.22, representing the intersection with electrode 19 in line 6.

Zone A denotes an interbed in this area (depth that extends from the surface to approximately 4 m) with line-6. The high resistivity of more than 333 ohms. m within the unsaturated zone and represents an expansion from electrode 22 to electrode 41

The seepage from a sewage tank located at a distance of 2.50m from electrode 55 in line 5 leads to reduced resistivity values and may affect the foundation of the building.

Figure 8: The inverted model of line -5. (A) Placement of sewage tank adjacent to the pit. (B) The depth of the pit; is 100cm.

5.2.6 Line -6

The inverted model of line 6 has a length of 50m and direction SE to NW (Figure 9). After seven iterations, the RMS of 1.63% and a maximum depth of about 11m show the range of resistivity values from 4 to around 333 ohms.m. The concrete was discovered in excavation samples on the work site from electrodes 1 to 5, starting from 20 cm from the top surface. The area between electrodes 7 and 18 represents clay and some sand, a water-saturated area. High levels of moisture characterise the areas. Water samples were transferred to the laboratory to identify TDS and measure conductivity, which showed or revealed that TDS was 118 ppm and conductivity was 236 µS/cm.

Zone A represents the shared area or interbedded area between lines 5 and 6 which is highly compacted and extends from electrode 23 to electrode 42. The depth of up to 2 m within the unsaturated zone represents an evident near-surface inhomogeneity because of Dehydration and compaction. Based on laboratory analysis, silt and clay were spread more than sand.

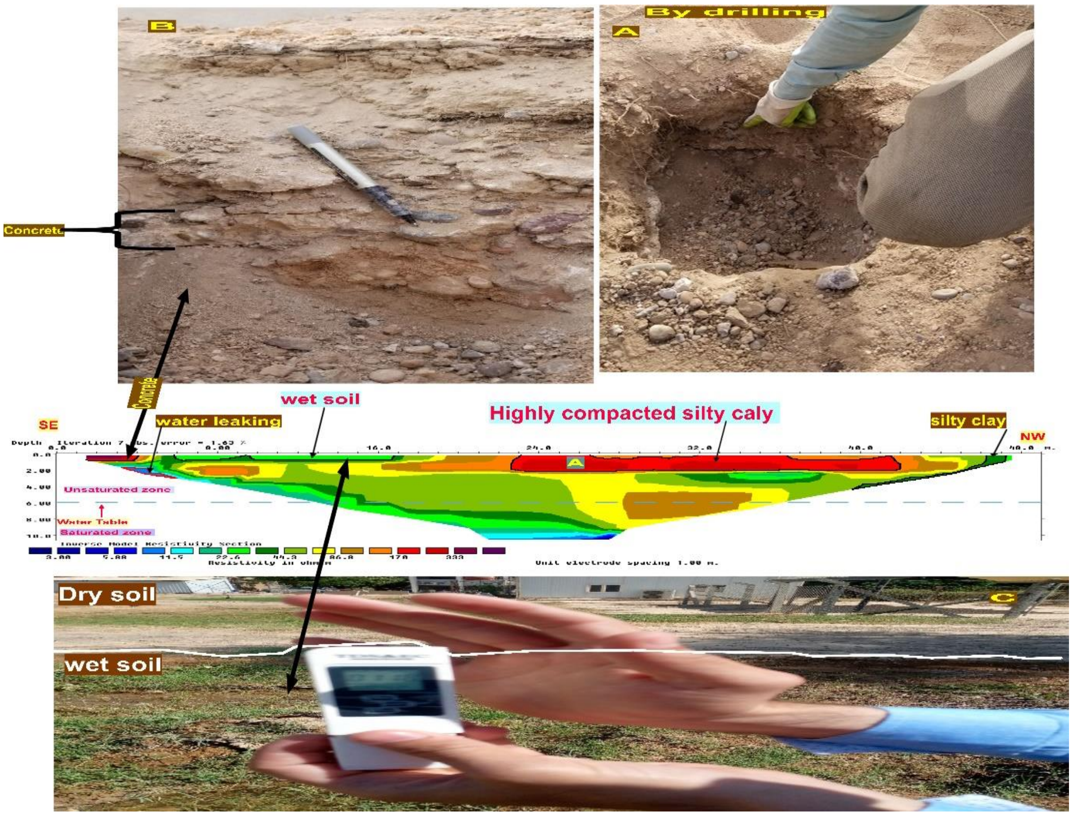


Figure 9: The inverted model of line -6. (A) concrete parts. (B) shows the thickness of concrete. (C) line 6 from the 8th electrode representing wet soil to the 19th electrode representing dry soil.

6. Types of heterogeneity in the topsoil

A- Compaction

The effect of compaction on agricultural soils is indeed not uniform and irreversible. Soil structure changes locally (or spatially) and temporally during compaction by equipment or other things, as several generative processes occur. Soil compaction is among the most important environmental issues produced by conventional farming. The effect of soil compaction is very high in our field, and it was very clear that lines 1, 3, 4, 5, and 6 worked on the height of resistivity readings, so soil compaction is one of the factors of heterogeneity.

B- size granular

The grains' diameter, form, and size significantly influence the value of electric resistivity, resulting in an insulation system and a substantial rise in the values of electric resistivity as smooth soil samples[15].

1. Gravel represents a coarse grain with sizes ranging from 2.0 to 150 mm.
2. Sand represents a softer granule with a size range of 0.06 to 2.0 mm.
3. Silt is a soft granule with dimensions ranging from 0.002-0.06 mm.
4. Discovered very soft granules as small as 0.002 mm.

The Laboratory analysis of the two study areas consists mostly of silt and clay, with 90% and not more than 11% sand.

C-Moisture content for soil

The amount of moisture retained by the soil influences the values of electrical quality resistivity, in which the electrical quality resistivity differs between unsaturated and saturated soils, including soft gravel and silt. Then, in general, the resistivity values in unsaturated soils are more significant than those in water-saturated soils[16]. Laboratory analyses In March 2022 were made to determine the association between resistivity and moisture in the specimen within the study site, representing line 5 in wet garden soil (low resistivity) and line 3 in dry soil (high resistivity). The core samples collected through drilling show Re-saturated with distilled, de-ionised water to wetness levels between the limits of shrinking and liquid to create images of the effect of soil moisture using the resistivity-moisture relationship. As a result, a general increase in moisture content was observed near electrode 55 (line 5), which was associated with a source from a sewage tank. The wettest zones represent moisture with the most effective trend. However, when compared to samples collected from line 3 from electrode 52, So, even though moisture is not the only factor affecting electrical resistivity values, other factors include Dehydration, grain size, TDS, and conductivity but the main factors effects resistivity reading in our study area.

D-PH and TDS

The PH and TDS values were used to evaluate the "potential of hydrogen" (or "power of hydrogen"), which is a chemical scale for determining the acidity or alkalinity of aqueous solutions [17]. The fertile land and the Tigris River nearby serve as a salt filter. The PH and TDS values were not high.

E-Mineral content

The mineral composition of many samples was studied and found to be nearly equivalent to all samples taken near high or low resistivity values position. The soil sediments are composed chiefly of Clay and Silt (more than 90%) and sand, less than 10%. Therefore, the authors believed it does not affect the resistivity value.

7. Conclusions:

A 2D electrical survey (Wenner- Schlumberger array) carried out at two sites on the Baghdad University campus led to many conclusions: many high and low resistivity values were detected in a cross-soil section along measured profiles. The study of sediment type indicates that the soil is composed mainly of clay and salt. The homogenous soil type found in all positions had low or high resistivity values, indicating that the resistivity values do not reflect the sedimentary type. The TDS and PH values of the soil also do not affect the resistivity values directly. Therefore, the authors believed that mentioned parameters have a low effect on the resistivity variations. The field observation, such as the presence of a sewage tank near profile-5, water pipes, and growing vegetable positions found to be related to the low resistivity values, so it is possible to consider the water content is the main factor affecting the variation in resistivity values in the study area.

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