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# GEOELECTRICAL AND GEOTECHNICAL EVALUATION OF SUBSOIL AT A PROPOSED ENGINEERING SITE, NE OF BAGHDAD CITY

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**ABSTRACT: -** Subsoil evaluation within a proposes site for civil engineering structure by using geoelectrical and geotechnical methods of investigation carry out. The study aims to provide information on the stratigraphy, thickness, nature, and competence of the subsoil. Eighteen (18) Vertical Electrical Sounding (VES) stations using Schlumberger configuration occupy and complement with geotechnical analysis of eighteen (18) soil samples collect at all the VES points at depth not exceeding 1m within the study area. The VES interpretations delineate four main geoelectric sequences which comprise of the top soil, mixture of clay and sand, gravely sand and sandy gravel. The top soils are generally thin (< 2 m) and majorly composes of clayey silt/ silty clay /sandy clay/ clayey sand/ fill materials. The layer resistivity ranges from 0.75-19.6 Ωm for topsoil, 1.71 - 6.7 Ωm for clay and sand mixture, 0.01 – 2.69 Ωm for saturated gravelly sand layer and 4.23- 4.61 Ωm for saturated sandy gravel layer. Low resistivity values at the study area are due to moisture and clay content within deposits at the study area. The geotechnical results show that the soil is relatively high clay content, intermediate to high moisture content and high plasticity. It concludes from the combined results above, that the topsoil is generally geotechnically less competence soil and may not serve as a good foundation material, therefore shallow foundation may not be feasible in studied area and, for engineering structure to be erected on such soil there is need for soil improvement or pilling to the sand layer.
**Keywords:** *Geoelectrical, resistivity, VES, Engineering structure, geotechnical survey.*

## 1- INTRODUCTION

In any engineering works such as buildings, dams and bridges, poor soil stability is one of the major factors that cause collapse, subsidence and havocs. On consideration of soil particles, certain clay soils for example, can expand greatly in volume if they are saturated with water during the raining season and also contract in volume when the water are lost especially in the dry season[(1)] . Thus, rise and fall in water content of the clay soils even when they are not under a long-term process of compression and stiffening are more susceptible to subsidence [(1),(2)]. However, citing any engineering works across such low bearing capacity material will result to foundation failure or differential settlement in the soils[(1)]. If a building is constructed at a site, without properly considering the underground strata or its load-bearing capacity, it may settle excessively or differentially, causing development of cracks in the building which may ultimately lead to its failure and collapse [(2); (3)]. However, since every engineering structure is seated on geological earth materials, it is imperative to conduct pre-construction investigation of the subsurface of the proposed site in order to ascertain the strength and the fitness of the host earth materials as well as the timed post-construction monitoring of such structure to ensure its integrity. In any engineering studies, large or small scale, it is desirable to investigate the detailed foundation conditions at the site. These studies are included determination of depth to the bedrock, the geotechnical integrity of the bedrock, the physical properties of foundation geomaterials and the groundwater condition of near-surface materials [(4), (5)]. Most civil and building engineers are preferred drilling of exploratory holes to obtain information about subsurface materials and to apply some geotechnical methods in order to assess the strength of materials for the support of infrastructures such as buildings and dams. Although, these techniques are good, they are expensive in terms of cost and might not give adequate information about the entire area and good depth of investigation may not be achieved. Therefore, it is imperative to complement these method with cost effective geophysical methods which are commonly applied in engineering site investigation [(6), (7)]. The geophysical methods are intended to supplement the direct methods, such as drilling not to substitute it. The number of borings required for adequate definition of subsurface conditions can be greatly reduced if the proper geophysical method is chosen. Also, the direct investigation is often limited by access, cost and ground damage consideration and, if the spacing between the boreholes is too large, anomalous ground conditions may be missed .In this case the geophysical methods enable such anomalous features to be mapped in detail at a relatively low cost [(8)] .The objective of this study is to integrate the geoelectrical method with those of laboratory geotechnical tests in order to determine the overburden thickness, delineate the subsurface layer and determine their geoelectric characteristics, determine the nature of the superficial deposits , investigate possible discontinuities and other exiting subsurface structures that may be inimical to the foundation of the any proposed engineering structure. It is also intended to evaluate the competency of the geologic materials underlying the study area to sustain the load of the proposed engineering structures.

## 2- LOCATION AND GEOLOGICAL SETTING OF THE STUDY AREA.

The study area is located at AL-Rashidiya area, 5 km north east of Baghdad city (Fig. 1). It lies between latitude (33° 33` 20"- 33° 33’ 30" N) and longitudes (44° 22` 31" - 44° 22` 42" E), Within Mesopotamian basin which is characterized by thick sediments cover. Most of these sediments are fluvial [(9)]. Two boreholes with 30m and 18m depth are drilled by NCCL 2000 (Fig.2) .According to these boreholes, the Soil section in the study area is composed of two layers. The first layer composed of mixture with various amount of clay and sand and silt, and its thickness ranges between (8.5m -15m). The second layer is composed of mixture of sand and gravel extending to the end of drilled boreholes. Gypsum content in the study area is low and range between 0.11-14% [(10)].

## 3- MATERIAL AND METHODS

An integrated geoelectrical and geotechnical survey was achieved by NCCL (2000) in order to investigate subsurface soil at a proposed site for construction of power plant, eastern Baghdad city. Geoelectrical survey involves application of Vertical Electrical Sounding (VES) using Schlumberger array for eighteen (18) stations distributed along six profiles across the study area (Fig3). Terrameter SAS 300 resistivity meter was used for geoelctrical survey. The maximum distance between current electrodes (AB) was 200 m. and the maximum distance between potential electrodes (MN) is10 m. The apparent resistivity values obtained from sounding survey were plotted against electrodes spacing (AB/2) on a bi-logarithmic graph paper to generate depth sounding curves. The field curves were preliminarily interpreted manually by using partial curve matching techniques ,using a 2-layer master curves and the corresponding auxiliary curves (Ebert method), to determine the thickness and resistivity of the layers. The models derived from manual interpretation were fed into computer for 1-D computer assisted interpretation involving ipi2win (2008) software to get a better fit in each case. The fit in all cases is within the error limit of 5.0%. The final interpreted results were used for the preparation of geoelectric sections and maps.

Geotechnical survey involves collection of undisturbed and disturbed soil samples from burrow pit at depth not exceeding one meter from different locations within the site as shown in Figure (3). The natural moisture content of the samples collected from the field was determined in the laboratory within a period of 24 hours after collection. This was followed by air drying of the samples before they were subjected to the following tests: natural moisture content, grain size analysis, Atterberg limits.

## 4- RESULTS AND DISCUSSION

### Geophysical Results

The results of the research were presented as field curves, geoelectric sections and maps. The summary of the VES interpretation results are shown in Table 1. The VES curves are composed of three layers curves (K, Q type), four layer curves (HK, KH, KQ, AK, QH type) and five layers curves (KHK and QHK type) where is the K type is the predominant. Figure (4) illustrate some types or resistivity curves and result of its interpretation at the study area.

### Geoelectric Sequence

The VES interpretation results were used to prepare 2-D geoelectric sections displayed in Figures (5) and (6). The geoelectric sections delineate maximum of four main geoelectric /geologic subsurface layers comprising the top soil, mixture of clay and sand layer, gravely sand and sandy gravel. The top soil varies in composition from clayey silt to silty clay , sandy clay and fill material in some places with resistivity values ranging from 0.75-19.6 Ωm and thickness varying from 1 -8.3 m. The resistivities of the mixture of clay and sand layer are generally within the range of 1.71 - 6.7 Ωm. The thickness values varying from 5.05 -32.4m. The saturated gravelly sand layer is resistivity values varying from 0.01 – 2.69 Ωm, while its thickness ranges from 5 -15.4m. This layer appear as a fourth layer along profile BB. The fourth layer consist to saturated sandy gravel layer , its resistivity ranges from 4.23- 4.61 Ωm. This layer appear as third layer along profile BB with thickness varying from 20.5 -34.4m. There are two types of lenses are appeared in some places at the study area, the first type is high resistivity values ranges from 5.7 -13 Ωm, and thickness ranges from 0.9-2.2m representing fill material or gravel lens. The second type of lens representing clay lens which is low resistivity values ranging from 0.75 – 2.46 Ωm, and thickness varying from 3.4 -7.26m.

### Isoresistivity and Isopach Maps of the Topsoil

Figures (7) and (8) show the iso-resistivity and isopach maps of the topsoil respectively. As revealed by the isoresistivity map, the resistivity values of this layer are low indicating clayey silt or silty clay soil with gradual increasing in resistivity value toward the eastern and western parts of the study area due to increasing of sand content or presence of fill materials in soil. The Isopach map of the topsoil shows that the top soils are generally thin with the highest thickness up to 2.9 m in the middle and eastern parts of the area. The predominant thickness of the topsoil is generally < 2 m.

### Geotechnical Results

Table 2 shows the summary of the geotechnical results. The percentage passing 0.075mm ranges from 87 – 98%. These ranges of values indicate high quantity of clay in the topsoil [11]. The natural moisture content of tested soil samples ranges from 11 - 24% with an average 21%. This shows that the natural moisture content of the soil in the area is relatively medium to high at its natural state. Moisture variation is generally determined by intensity of rain, depth of collection of sample, soil texture, and nature of plasticity, low permeability and high ability to retain water [12]. Plasticity chart shown in figure (9) indicate that the soil at the study area is intermediate (CI) to high plasticity soil. The liquid limit (L.L), the plastic limit (P.L) and the plasticity index (P.I) of the soils ranges from 33 – 55%, 16 – 26% and 15 -33% respectively. The recommended value by the Federal Ministry of Works and Housing [13] for liquid limit, plastic limit and plasticity index are 50%, 30% and 20% respectively. In the study area, it is shown that the maximum value of the liquid limit is56% greater than 50%. . The liquid limit value greater than 50% is interpreted as poor foundation materials but if less than 50%, it gives clay type called kaolinitic in nature which is not a big threat to foundation [14] ,[15] .The plastic limit and plasticity index values for most samples are greater than 30% and 20% respectively except in some places at the study area thus, the tested soil samples are of high consistency limits indicating high percentage of clay content in the soil hence, it shows a poor engineering property since the higher consistency limits soil, the less the competency as a foundation material [11], [15] **.** From the aforementioned geophysical and geotechnical results, shallow foundation may not be feasible in this area because of the presence of clay material that are very close to the surface. Therefore, for engineering structure to be erected on such soil there is need for soil improvement or pilling to the competence layer.

## 5- CONCLUSION

The integrated geoelectrical and geotechnical investigations carried out at proposed site for construction of power plant is revealed the presence of four main geoelectric sequences within the study area which comprises of the top soil, mixture of clay and sand , gravely sand and sandy gravel. The top soils are generally thin (< 2 m) and majorly composed of clayey silt/ silty clay /sandy clay/ clayey sand/ fill materials. The geotechnical results show that, the soils are generally of relatively medium to high natural moisture content. It is relatively high clay content and high consistency limits. The layer (topsoil) constitutes the layers within which normal civil engineering foundation is founded. All the determined geotechnical parameters of the subsoil are greater than the specification recommended for foundation material. It isconcluded from the combined results above, that the topsoil Formation is generally geotechnically less competence soil and may not serve as good foundation material.

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Table (1): Summary of the VES Interpretation Results

| VES no. | *P1* Ωm | $P_2$ Ωm | *P3* Ω*m* | *P4* Ωm | *P5* Ωm | $h_1$ m. | $h_2$ m. | $h_3$ m. | $h_4$ m. | Curve type |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *2.44* | *1.68* | *2.91* | *1.74* | - | 1 | 7.26 | 15.4 | - | HK |
| 2 | *19.6* | *2.68* | *1.02* | *4.5* | | 1 | 6 | 6 | - | QH |
| 3 | *8.56* | *0.75* | *3.93* | *1.86* | - | 1 | 0.6 | 15.5 | - | HK |
| 4 | *0.75* | *2.25* | *4.35* | *0.7* | - | 1 | 14.9 | 20.9 | - | AK |
| 5 | *1.31* | *1.7* | *4.61* | *1.56* | - | 2.6 | 7.7 | 23.6 | - | AK |
| 6 | *5.7* | *3.26* | *4.23* | *0.72* | - | 1.18 | 13.2 | 34.4 | - | HK |
| 7 | *1.15* | *2.52* | *1.03* | *4.49* | - | 1 | 7.25 | 15.4 | - | KH |
| 8 | *1.54* | *9.59* | *3.1* | *1.46* | - | 1 | 1.05 | 31.8 | - | KQ |
| 9 | *9.5* | *13* | *4* | *2.6* | - | 2 | 2.2 | 24 | - | KQ |
| 10 | *2.69* | *4.66* | *1.53* | - | - | 8.3 | 15.4 | - | - | K |
| 11 | *14.4* | *3.7* | *2.19* | *6.76* | *1. 25* | 1 | 6.5 | 8.5 | 22.7 | QHK |
| 12 | *7.85* | *4.77* | *1.63* | - | - | 4.3 | 31.3 | - | - | Q |
| 13 | *0.9* | *5.7* | *0.8* | *6.7* | *0.01* | 1 | 0.9 | 3.11 | 19.5 | KHK |
| 14 | *1.29* | *3.38* | *1.68* | - | - | 1 | 21.5 | - | - | K |
| 15 | *2.96* | *4.85* | *2.69* | - | - | 2.96 | 7.4 | - | - | K |
| 16 | *1.06* | *6.23* | *1.33* | *3.36* | *1.03* | 1.38 | 1.95 | 4.9 | 33.2 | KHK |
| 17 | *0.86* | *2.46* | *4.38* | *0.96* | - | 1 | 7.26 | 15.4 | - | AK |
| 18 | *1.07* | *4.23* | *1.39* | - | - | 1 | 32.4 | - | - | K |

Table (2): Summary of the Geotechnical Results

| Sample No. | Gravel% | Sand% | Silt% | Clay% | M.C% | L.L% | P.L% | P.I% |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 7 | 51 | 42 | 24 | 55 | 33 | 22 |
| 2 | 0 | 7 | 38 | 55 | 11 | 52 | 31 | 21 |
| 3 | 0 | 2 | 53 | 45 | 11 | 53 | 31 | 22 |
| 4 | 0 | 9 | 38 | 53 | - | 55 | 31 | 24 |
| 5 | 0 | 8 | 49 | 43 | 23 | 53 | 31 | 22 |
| 6 | 0 | 3 | 56 | 41 | 18 | 56 | 32 | 24 |
| 7 | 0 | 2 | 50 | 48 | 22 | 52 | 31 | 21 |
| 8 | 0 | 4 | 48 | 48 | 23 | 55 | 32 | 23 |
| 9 | 0 | 4 | 55 | 41 | 18 | 51 | 30 | 21 |
| 10 | 0 | 5 | 48 | 47 | - | 52 | 30 | 22 |
| 11 | 7 | 18 | 53 | 22 | - | 15 | 7 | 8 |
| 12 | 4 | 16 | 45 | 35 | - | 15 | 7 | 8 |
| 13 | 0 | 5 | 50 | 45 | 20 | 54 | 34 | 20 |
| 14 | 0 | 7 | 55 | 48 | 18 | 33 | 16 | 17 |
| 15 | 0 | 18 | 60 | 22 | - | 56 | 31 | 25 |
| 16 | 0 | 5 | 63 | 22 | 22 | 50 | 30 | 20 |
| 17 | 0 | 2 | 63 | 35 | 22 | 39 | 20 | 19 |
| 18 | 0 | 5 | 51 | 44 | 19 | 39 | 19 | 20 |


study area

Figure (1) Location map of the study area.

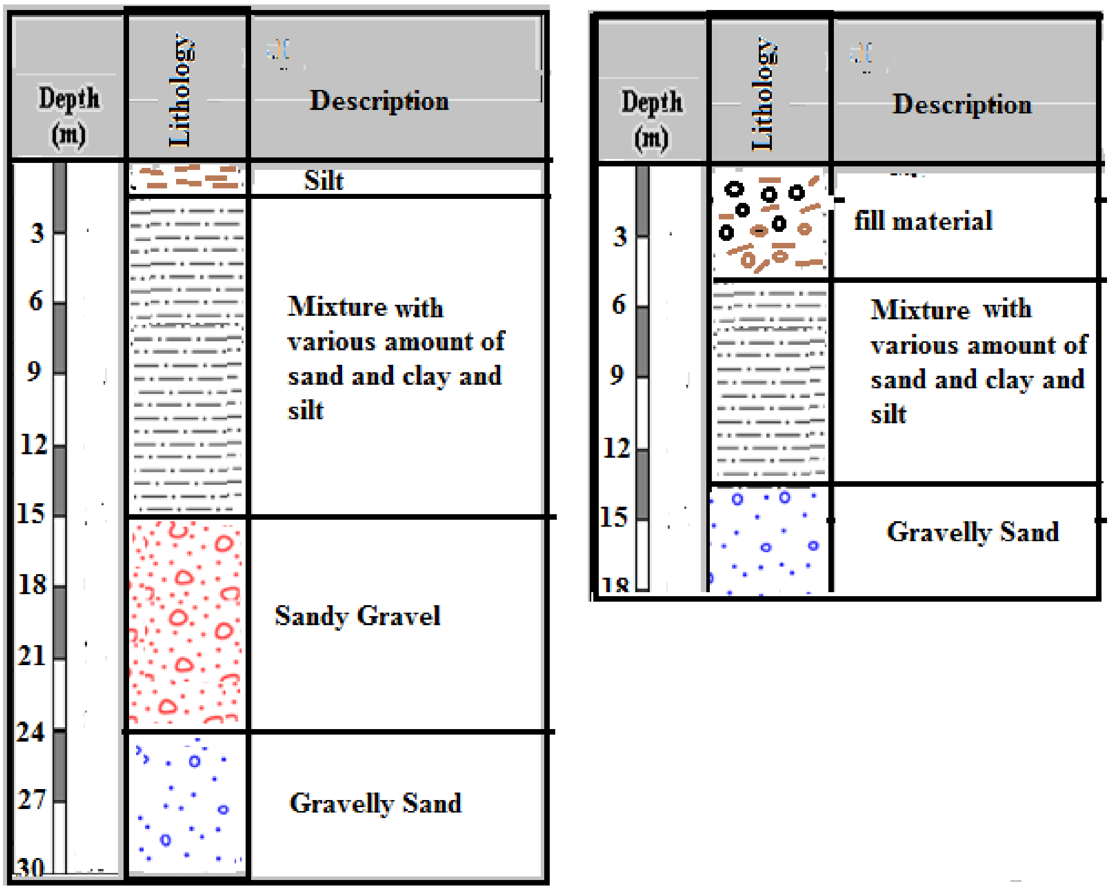



Figure (2) Soil section in B.H.1, B.H.2 in the study site after NCCL2000 (modified)

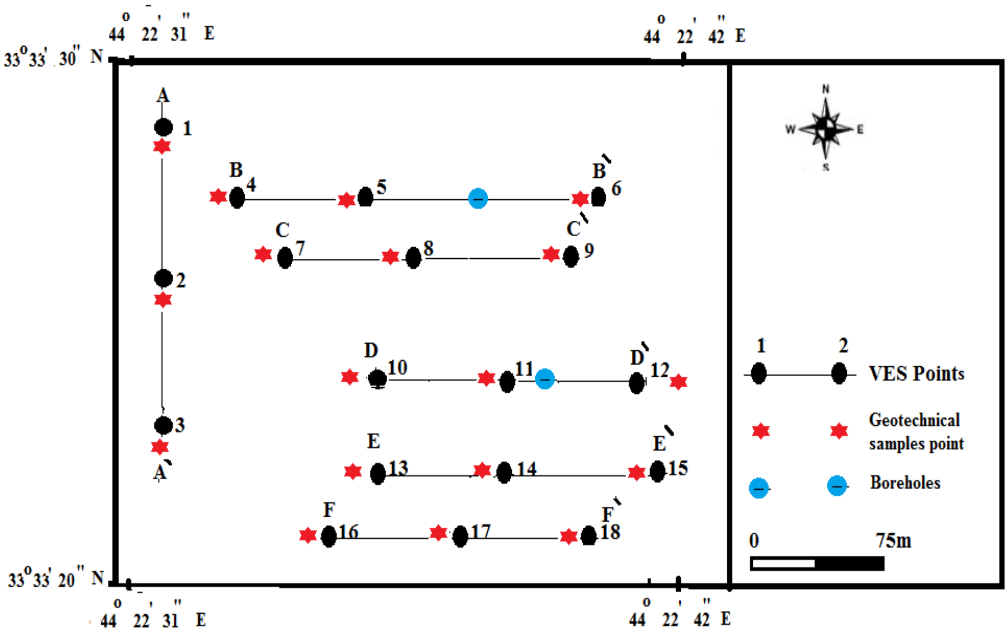



Figure (3) Data Acquisition Map of the Study Area Showing the Vertical Electrical Sounding Stations and the Geotechnical Sampling Points

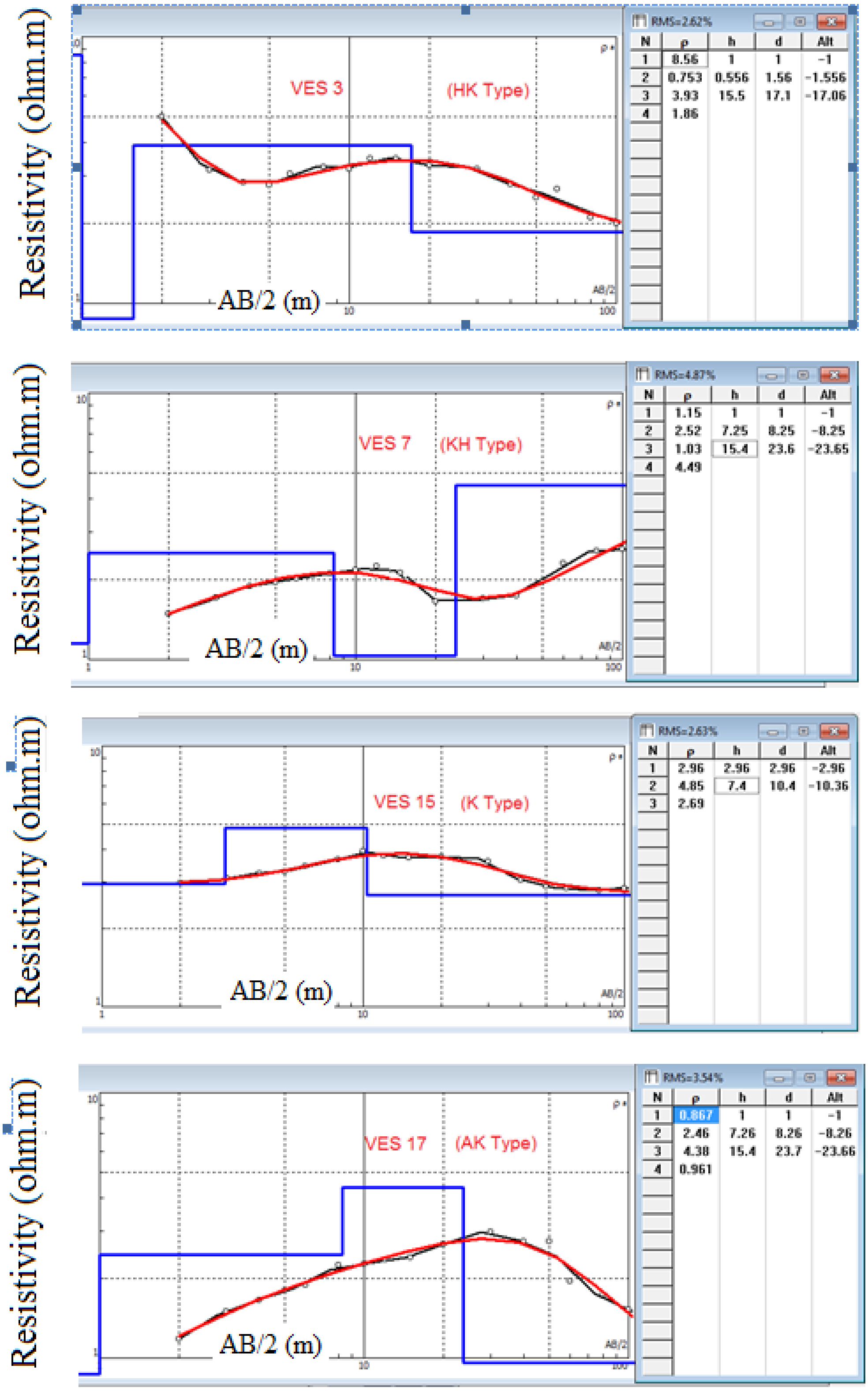



Figure (4) Typical VES Curves obtained in the study area.

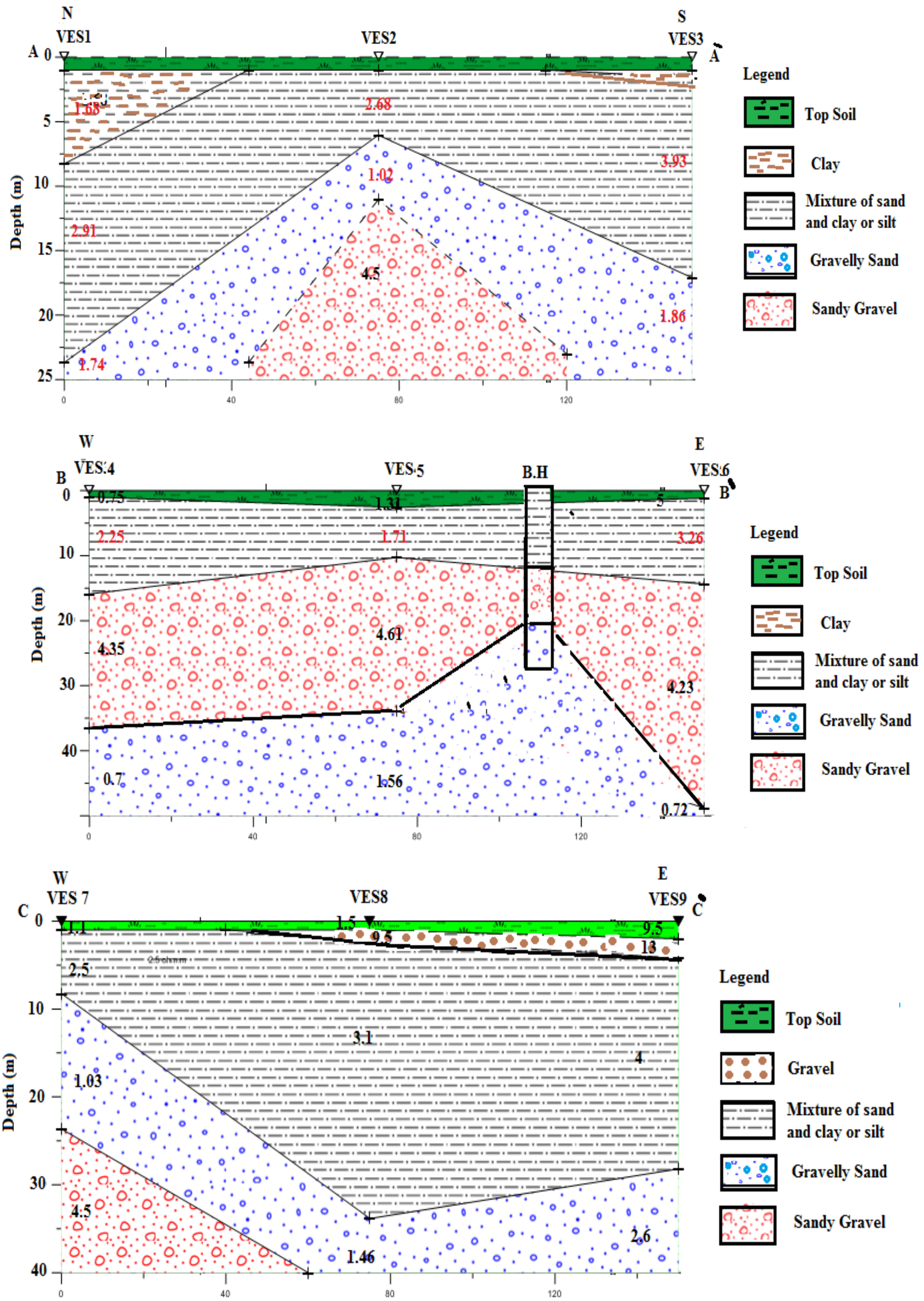



Figure (5) Geoelectrical cross section along profiles AA', BB', and CC'

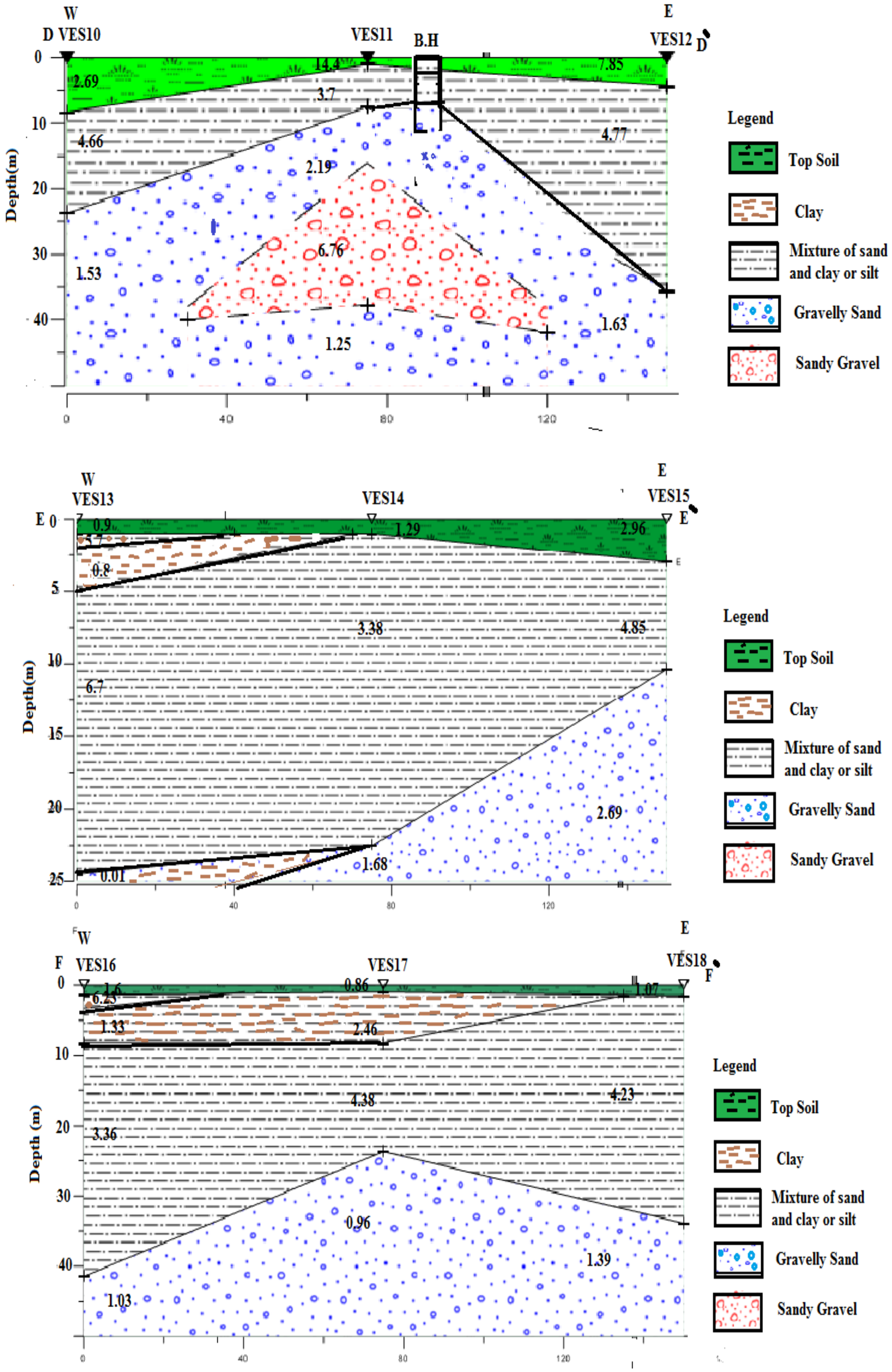



Figure (6) Geoelectrical cross section along profiles DD’, EE’, and FF’

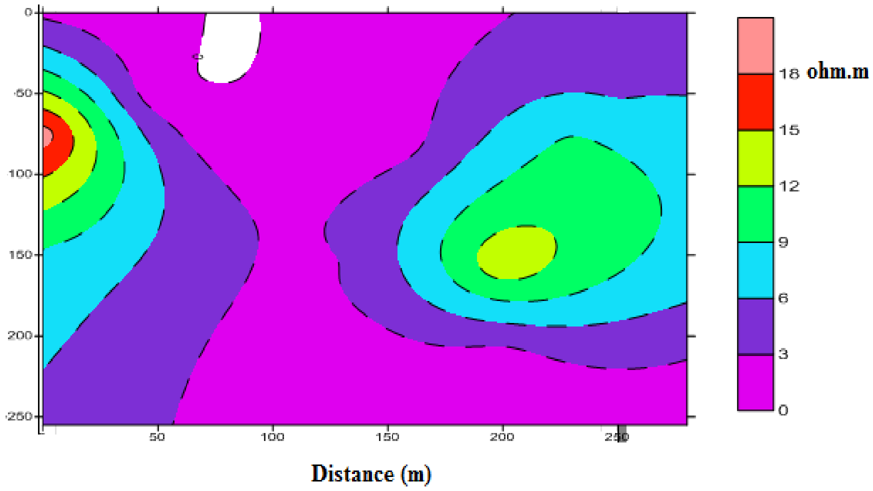



Figure (7) Isoresistivity Map of the Topsoil

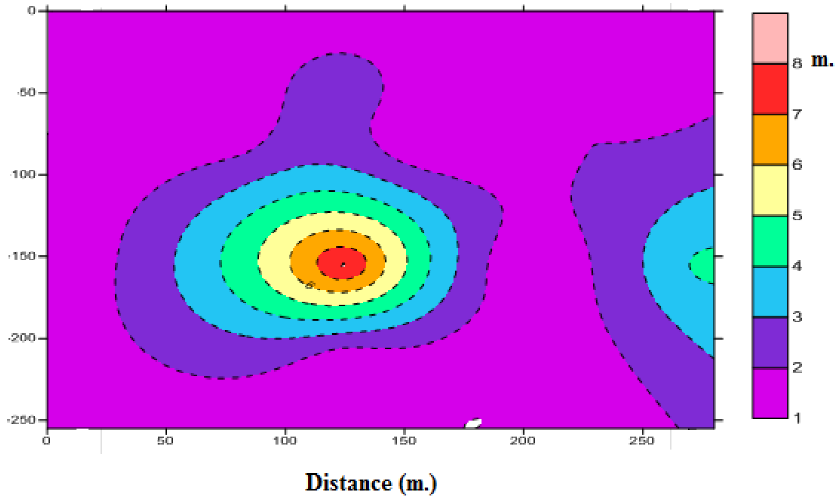
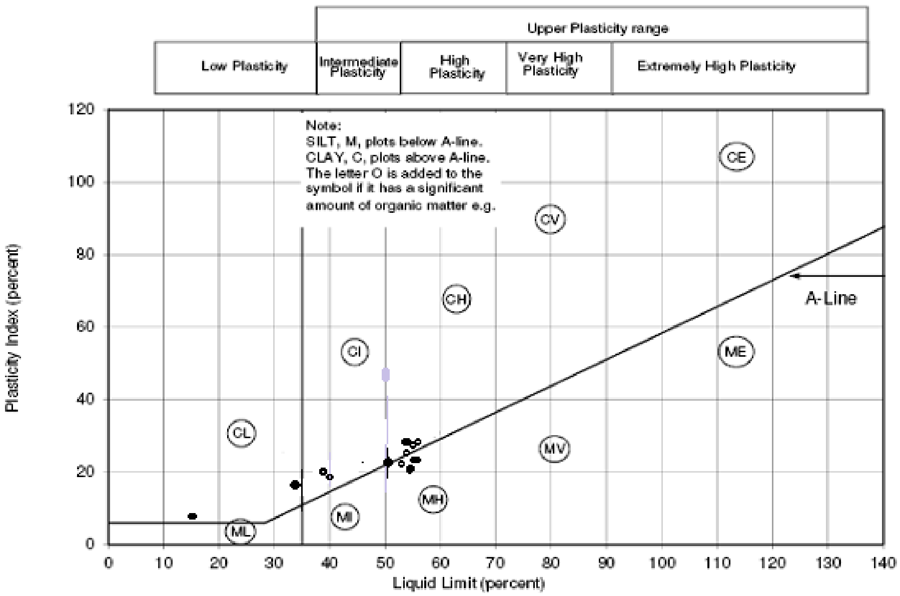



Figure (8) Isopach Map of the Topsoil.




.Figure (9) Plasticity chart for soil samples at the study area

# التقييم الجيوكهربائي والجيوتكنيكي للتربة التحت سطحية في موقع هندسي مقترح شمال شرق مدينة بغداد

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**الخلاصة**

تم تطبيق طرق المسح الجيوكهربائي والجيوتكنيكي لتقييم التربة التحت سطحية ضمن الموقع المقترح كمنشأ هندسي. الهدف من الدراسة الحالية هو الحصول على معلومات عن سمك وطبيعة التتابع الرسوبي وكفاءة الطبقات التحت سطحية. تم انجاز ثمانية عشر نقطة مسح كهربائي عمودي باستخدام ترتيب شلمبرجر كما تم جمع ثمانية عشر نموذج تربة عند كل نقطة مسح كهربائي وباعماق لاتتجاوز المتر الواحد لغرض اجراء التحاليل الجيوتكنيكية. اظهرت نتائج تفسير المسح الجيوكهربائي اربعة انطقة جيوكهربائية رئيسية تشتمل على التربة السطحية , خليط من الرمل والطين , الرمل الحصوي , الحصى الرملي .طبقة التربة السطحية تمتاز بقلة سمكها (اقل من 2 متر) وتتكون بصورة رئيسية من السلت الطيني , الطين السلتي , الرمل الطيني , الطين الرملي و/او مواد الدفن. تتراوح قيمة المقاومة النوعية الكهربائية للطبقة السطحية بين 0.75-19.6 اوم.م. وبين 1.71-6.7 اوم.م لخليط الرمل والطين. وبين 0.01-2.69 اوم.م لطبقة الرمل الحصوي المشبعة بالمياه الجوفية وبين 4.23- 4.61 اوم.م لطبقة الحصى الرملي المشبعة . سبب القيم المنخفضة للمقاومة النوعية يعود الى محتوى الرطوبة والمحتوى الطيني لرواسب منطقة الدراسة. اظهرت النتائج الجيوتكنيكية بان التربة السطحية ذات محتوى طيني عالي ومحتوى رطوبي متوسط الى عالي بالاضافة الى لدونتها العالية . نستنتج من نتائج الطرق اعلاه بان التربة السطحية لمنطقة الدراسة ذات كفاءة قليلة ولاتعتبر جيدة لتشييد الاسس للمنشأ الهندسب لذلك فان استخدام الاسس الضحلة في البناء يكون غير ملائم في منطقة الدراسة.

**الكلمات المفتاحية** :- جيوكهربائية , المقاومة النوعية , المسح العمودي , منشأ هندسي , المسح الجيوتكنيكي