GEOELECTRICAL INVESTIGATION FOR DELINEATING GROUNDWATER AQUIFER AND GEOTECHNICAL SITUATION AT EL SADAT CITY, EGYPT

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ABSTRACT

Geoelectrical tool is effective method for delineating groundwater and subsurface situation. Four dipole dipole sections have been measured by using electrode spacing of 10 m to delineate the subsurface stratigraphy and structures. Five vertical electrical soundings (VES) were measured by using Schlumberger configuration with AB/2 ranges from 1 to 500 m to estimate the groundwater aquifer in study area. Thegeoelectrical data processed and interpreted by using 1-D, 2-D and 3-D by using different software. This study aims to investigate the shallow and deeper section to delineate the groundwater aquifer and structural elements which dissect the study area. Also, aims to define the validity of construction on the study area. The results of interpretation revealed that the depth of the groundwater aquifer is ranging from 18 m to 150 m and the study area is suitable for any constructions.

ملخص

اداة جيوكتريكال هي طريقة فعالة لتحديد المياه الجوفية ووضع تحت سطح الأرض. وقد تم قياس أربعة أقسام ثنائي القطب ثنائي القطب باستخدام تباعد القطب من ١٠ م لتحديد طبقات وطبقات تحت سطح الأرض. تم قياس خمسة سبر كهربائي عمودي (فيس) باستخدام التكوين شلمبرجير مع أب / ٢ يتراوح من ١ إلى ٥٠٠ متر لتقدير المياه الجوفية في منطقة الدراسة. البيانات ثيغيولكتريكال معالجتها وتفسيرها باستخدام D-١، D-2و ٣ D-باستخدام برامج مختلفة. تهدف هذه الدراسة إلى التعرف على القسم الضحل والأعمق لتعيين طبقات المياه الجوفية والعناصر الهيكلية التي تشريح منطقة الدراسة. كما يهدف إلى تحديد صحة البناء في منطقة الدراسة. وأظهرت نتائج التفسير أن عمق طبقة المياه الجوفية يتراوح بين ١٨ م و ١٥٠ م ومنطقة الدراسة مناسبة لأي إنشاءات.

INTRODUCTION

In this study dipole–dipole resistivity and vertical electrical soundings (VES) investigations were carried out on El-Sadat area which lies west of the Nile Delta and the eastern side of the Cairo-Alexandria desert road. It is bounded by longitude 30º 21′ 64″ - 30º 39′ 55″ E and latitude 30º 18′ 57″ - 30º 38′ 19″ N (Fig. 1a) and (Fig.1).In the present work, the geoelectrical methods is used to delineate subsurface stratigraphy, structures, groundwater and geotechnical investigation to detect the validation of the study area for any constructions. Many authors used geoelectrical tools for delineating groundwater, mineral exploration, engineering geology, archaeological prospecting and subsurface structures such as Sultan et al ,2008, Fernando and Sultan, 2008, Sultan et al ; 2009, Sultan et al 2010, Sultan et al 2011, Mohamed, et al 2012, Araffa et al 2012, Salem et al 2013, Araffa and Pek 2013, and Araffa et al 2015. The present studies aim to use geophysical methods for hydrogeological studies where geophysics provides spatially distributed models of physical properties in regions that are difficult to sample by using conventional hydrological methods .The geophysical models often reveal more detail compared with models derived from hydrogeological data, such as pump tests and observations of hydraulic heads. Fattah, 2012 studied the hydro geochemical Evaluation of the Quaternary Aquifer in El Sadat City and concluded that the groundwater flow, recharge and geochemical evolution in the study area and associated aquifers of the region are complex. Using hydro geochemistry and geological knowledge, the groundwater flow pattern is schematized. Gad, 2005 and Shedid 1989 studied the geology and hydrogeology of the Sadat area.

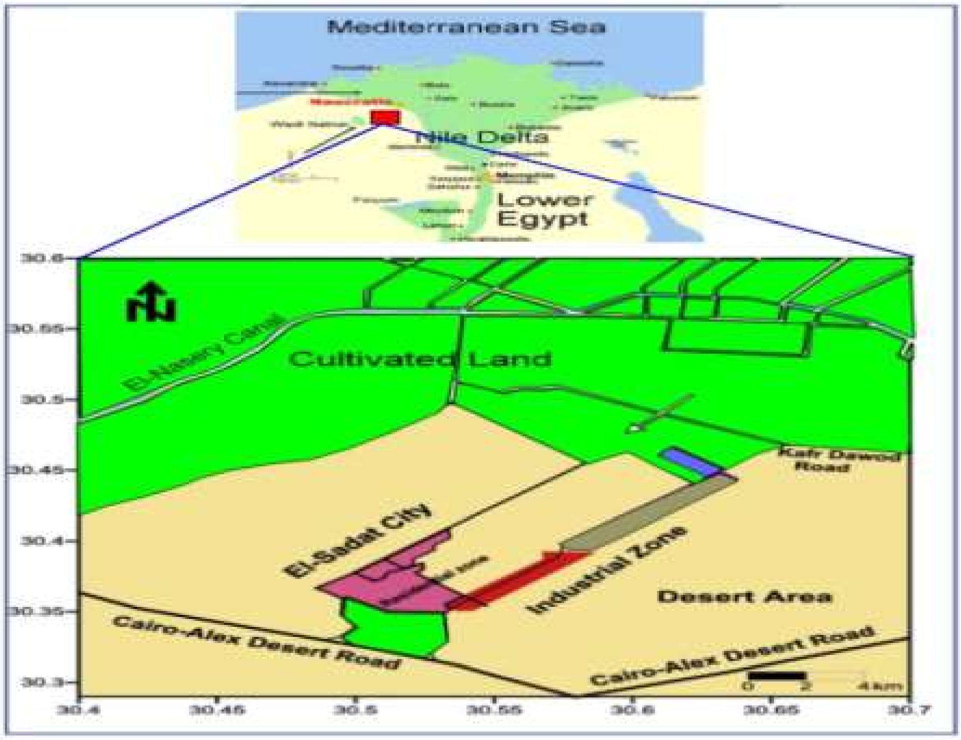

Fig. (1): Location map of the study area.

1.1 GEOLOGY OF THE AREA

The Sadat area is located in the eastern part of Western Desert where most of the surface is occupied by Late Cenozoic rocks (Said, 1962), which is classified into two periods, the Quaternary period and the Tertiary period. The Tertiary period includes the Pliocene, Miocene and Oligocene series. So, the stratigraphy according to the sequence of sedimentation from bottom to top (Fig. 2) as the following: Oligocene deposits, these sediments are represented by some horizons of red, violet and yellow ferruginous sandstone and sands, sometimes with gravels and occasionally indurate into quartzite. The Oligocene is represented by Gabel Ahmer Formation. Miocene deposits, these sediments are represented by Moghra formation, Qaret El Hemeimat Formation, Jaghbub formation, and Qaret El-Dib Formation. Pliocene deposits are represented by Gabel El Hadid Formation, Gabel Hamza Formation, Gar El-Muluk Formation and Alam El Khadem Formation. Pleistocene deposits are mainly distributed west of Rosetta branch and east of Wadi El Natrun. Pleistocene to Holocene this period is alluvial deposits derived from Miocene and Pliocene rocks, these deposits are Marshes and Sabkhas, Deltaic deposits, and Sand dunes and Lakes and water ponds (Abu Zeid, 1984). The stratigraphy of the area will be discussed according to the sequence of sedimentation from bottom to top as shown in table (1).

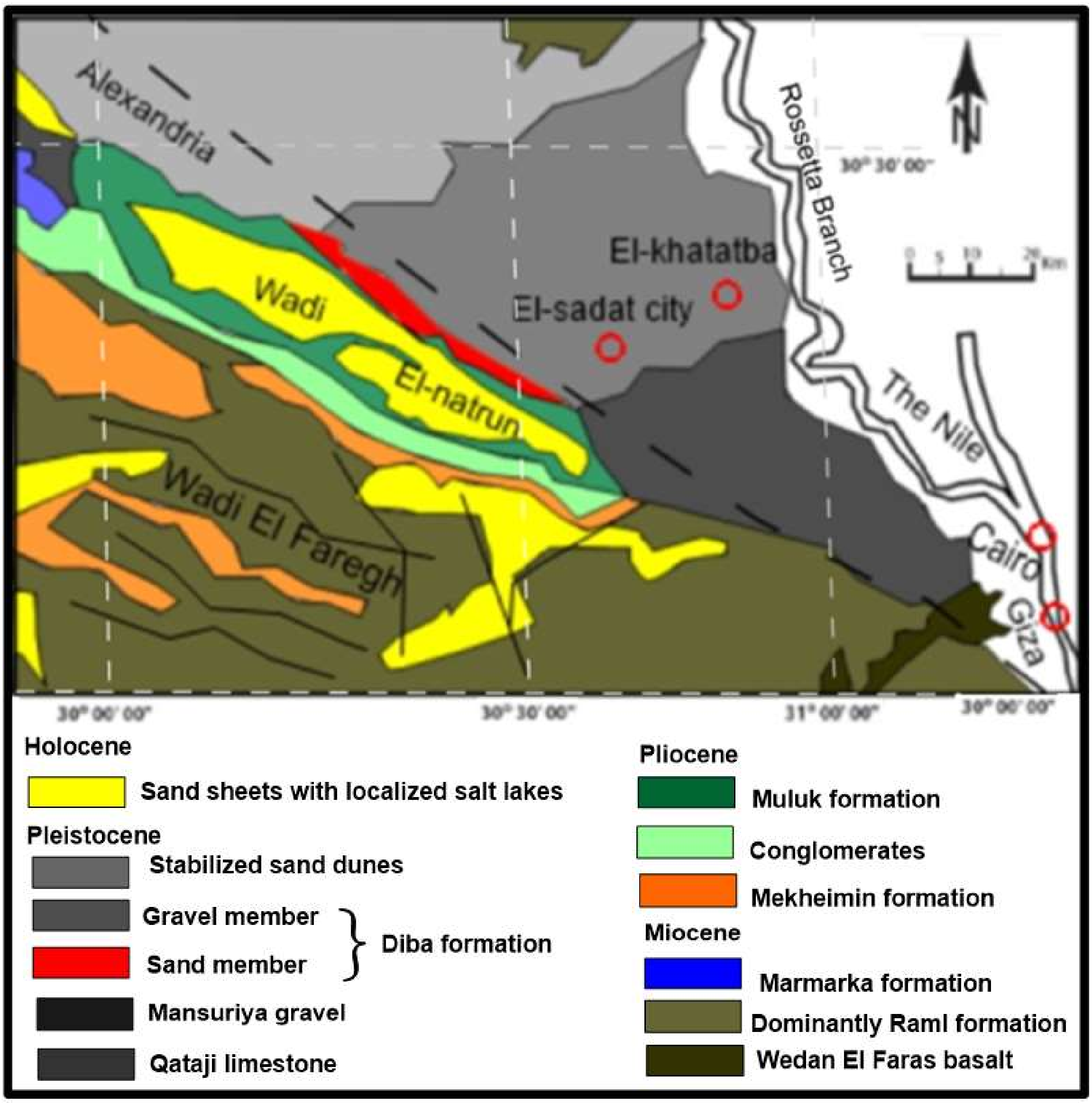

Fig. (2): Geological Map of the West Nile Delta Area modified from Abu Zeid, 1984.

2-METHODOLOGY

2.1 DEEP GEOELECTRICAL INVESTIGATION

The deep geoelectrical tool used in this work consists of measuring five Vertical Electrical Soundings (VES) of AB/2 spacing ranging from 1 to 500m using the Schlumberger configuration (Fig. 2). The data were acquired using a SYSCAL–R1 resistivity meter. The interpretation was carried out by using two methods, the first method is the manual method which depend on matching curve of two layers (Koefoed. 1979).

The interpreted model was used an initial model for the second method which represents the analytical method, in this method the authors are used IPI2WIN software for the calculating the final true resistivities and thickness for all subsurface layers.

The results of the quantitative interpretation of VES stations by using IPI2WIN software represents in figure 3. The results of interpretation reveals that the values of resistivities ranging from 9 ohm.m at VES station number 5 to 540 ohm at VES station number 2

Table (1) Generalized litho-stratigraphic succession in the study area (Modified afterE.A.Zaghloul, 1995 and RIGW-IWACO, 1990).

Age		Formation	Lithology	Description
Holocene		Alluvial&Deltaic Deposits&Sabkha&sand dunes		Silty Clay
Pleistocene	Prenile	Gabal El Basur fm.		Gravel & undifferentiated Sand
	Protonile			Sand & Clay/Oolitic limestone
Pliocene	Paleonile	Kom El Shelul fm		Sand & Clay with Pecten
	Lower	Gabal Hamza fm.		Limestone
Miocene	Upper	Qaret El Dib fm.		Sandstone with Evaporites
	Middle	Jaghbub&Hamimat fm.		Limestone with minor shale in bottom
	Lower	Moghra fm.		Sandstone / Shale
Oligocene		Gabal El Ahmar fm.		Sandstone & Basalt
Eocene	Upper	Kasr El Sagha fm.		Carboniferous Shale
	Middle	Mokatum fm.		Limestone
	Lower	Thebes fm.		Limestone
Paleocene		Abd Alla fm.		Limestone
	Upper	Tarawan fm.		Chalk
Cretaceous		Khoman fm.		Chalk
		Abu Roash fm.		Sandy L.S & Dolomitic L.S
		Bahariya fm.		Clayey Limestone with sand
	Lower	Kharita fm.		Clayey Sand
		Dahab fm.		Dolomitic Limestone
		Alamein fm.		Dolomite
Jurassic		Masajid fm.z		limestone
		Khattatba fm.		Shale
Triassic		Wadi El Natrun fm.		Sandy Limestone
		Ras Qattara		Sandstone
Paleozoic				
Pre-Cambrian		Basement complex		Basement complex

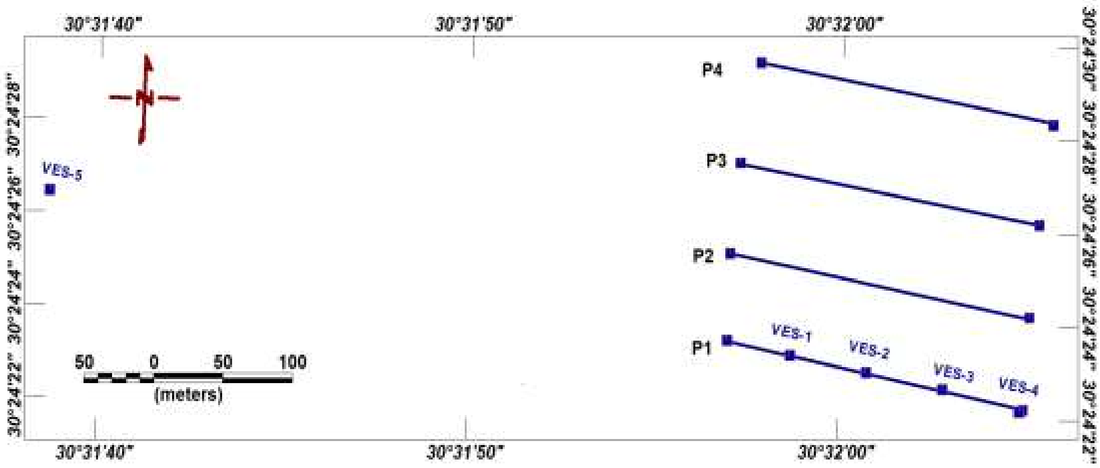

Fig. (2): Location map of ERT profiles and VES.

The results of interpretation of these VES station have been used to construct geoelectric cross section which is established to illustrate that the subsurface section which consists of four geoelectrical layers their descriptions can explained as follows (Fig. 4) :-

1- The top layer reflects high resistivty values with thickness about 18 m .This layer represents the surface layer which consists of sand and gravel sediments and silty sand sediments.

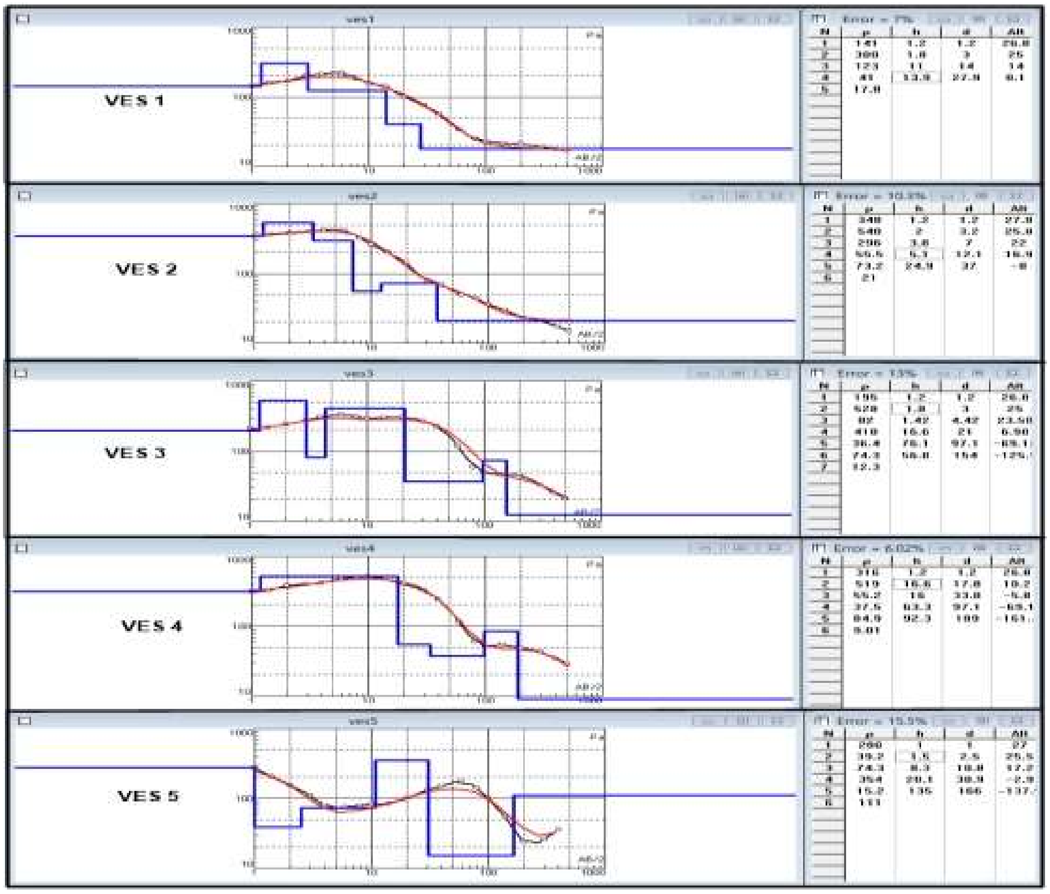

Fig. (3): the resistivity sounding curves for ves 1, ves 2, ves 3, and ves 4 and ves 5.

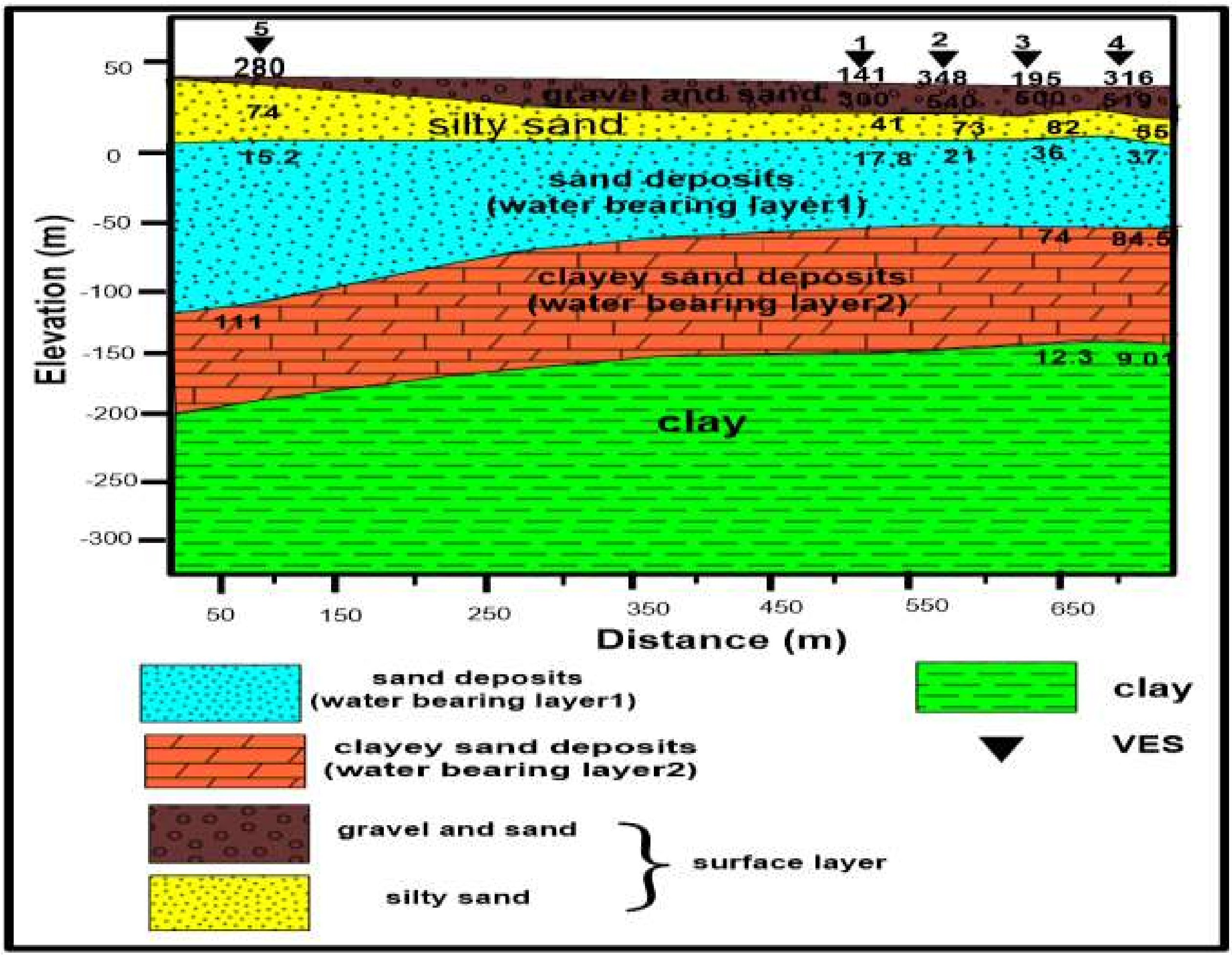

Fig. (4): Geoelectrical cross section.

2- The second geoelectrical layer is characterized by resistivity values ranging from 15.2 to 37 ohm.m, which corresponds to sand sediments (water bearing layer 1) with average thickness ranges from 20 to 25 m.

3- The third geoelectrical layer which exhibits medium resistivity values and corresponds to clayey sand sediments, this layer represents (water bearing layer 2) with thickness varied from 79 to 86m.

4-The fourth geoelectrical layer which reflects low resistivity values ranging from 9 to 12 ohm-m, which corresponds to clay layer.

2.2. SHALLOW GEOELECTRICAL INVESTIGATION, ELECTRICAL RESISITIVITY TOMOGRAPHY (ERT)

In this study, The ERT profiles are represented by dipole–dipole resistivity method. This method was used as a shallow investigation tool to acquire four ERT profile (Profile A-A′, Profile B-B′, Profile C-C′, and Profile D-D’) (Fig. 2). The length of each profile is about 200 m and the spacing between profiles is 50 m. The spacing between current electrodes and potential electrodes is (a), multiple n of the electrode spacing a = 10m and n = 7. The depth of current penetration is a function of electrode spacing and n value.

The dipole–dipole profiles were inverted using the RESINV2D software, which is based on a regularization algorithm (Loke & Barker 1996b). The inverted dipole–dipole section along profile A-A ′(Fig.5a) displays large variation in resistivities. The western half of the section is divided into upper and lower parts. The upper part demonstrates features at depth ranges from 2–15m of moderate resistivities corresponding to silty sand. The lower part at depth ranges from 22–28.4m exhibits low resistivities corresponding to sand deposits (water bearing layer). The eastern half of the section shows patches of moderate resistivities corresponding to silty sand and high resistivities corresponding to gravel and sand.

The dipole–dipole section along profile B-B′(Fig.5b) reveals moderate-to-high resistivities reflecting silty sand, and gravel and sand, respectively, while the bottom part of the section at depth ranges from 20–28.4m reveals low resistivities r corresponding to sand deposits(water bearing layer).

The dipole–dipole section along profile C-C′(Fig.5c) indicates moderate to high resistivities corresponding to gravel and sand, and silty sand, respectively, while the bottom part of the section at depth 17–28.4m reveals low resistivities corresponding to sand deposits (water bearing layer).

The dipole–dipole section along profile D-D’ (Fig.5d) indicates high resistivities corresponding to sand and gravel and shows patches of low resistivities corresponding to sand deposits (water bearing layer) at eastern and western part of the area. The intervening part at distances 50 to ~110 is divided into upper and lower parts. The upper part demonstrates features at depth ranges between 2 to 22m of moderate resistivities indicating silty sand, the lower part at depth ranges from 22–28.4m exhibits low resistivities corresponding to sand deposits (water bearing layer).

2.3. THREE-DIMENSIONAL INVERSION FOR DIPOLE–DIPOLE DATA.

the interpretation of dipole-dipole electrical data using RES3DINV program produced six slice at different depths (Fig. 6) .their depths are 0 - 3.5, 3.5 - 7.5, 7.5 - 12.2, 12.2 - 17.5, 17.5 - 23.6 and 23.6 - 30.6 m, respectively.

True resistivity map has been created by export the results into xyz format for depths ranging from 1.7 to 27.1 m. this file is reprocessed by using surfer software to clear the variation at different depths. It is divided into six files according to the calculated depths (1.7, 5.5, 9.8, 14.8, 20.5, 27.1m), each file containing x-coordinate, y-coordinate, and depth and resistivity columns. A base map is constructed using mapping and processing system of surfer program, then the resistivity values for all files at different depths were gridded using the same software. Finally each map contains a base and a gridded file to represent a true resistivity map at certain depth.

(Fig.7) show the resistivity depth slices (at depths 1.7, 5.5, 9.8, 14.8, 20.5, and 27.1 m) extracted from the 3-D inversion .The study area contains large variations in resistivities according to lithologic composition.The depth slice at 1.7m exhibits high resistivities corresponding to gravel and sand at the eastern part of the area, but the western part shows moderate resistivities reflecting silty sand. The depth slices at depth of 5.5 and 9.8 m exhibit high resistivities corresponding to gravel and sand at the northern and central part of the area, and the rest parts of the area shows moderate resistivities corresponding to silty sand.

The 3-D slice at depth of 14.8m exhibits patches of low resistivities revealing sand deposits (water bearing layer) at the bottom part of eastern half and central part of the area, while the moderate resistivities in the western part and the upper part of eastern half reflect silty sand deposits. The southern part of the area reveals relatively high resistivity corresponding to gravel and sand.

The depth slice at 20.5 m exhibits low resistivity revealing sand deposits (water bearing layer) at the northern part, central part, bottom part of eastern half, and bottom part of western half.

The southern part of the area reflects moderate and high resistivities corresponding to silty sand and gravel and sand

The last slice at depth of 27.1m indicates that the aquifer extends across the entire area and is composed of sand deposits except patches of moderate resistivities revealing silty sand at the upper part of eastern half and southern part of the area.

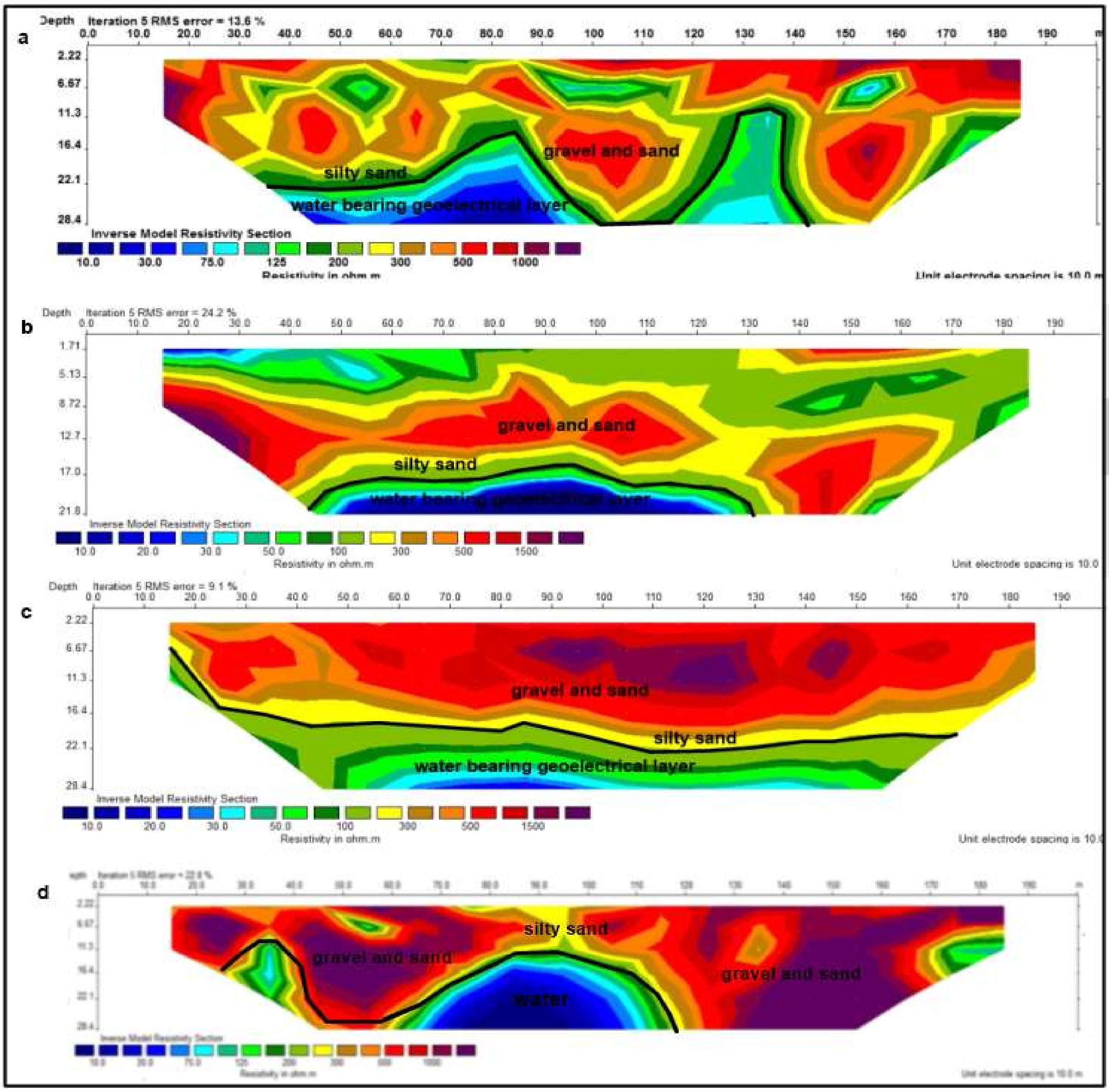

Fig. (5): Inverted Dipole-dipole Section (a) for Profile A-A′, (b) for Profile B-B′, (c) for Profile CC′, and (d) for Profile D-D'.

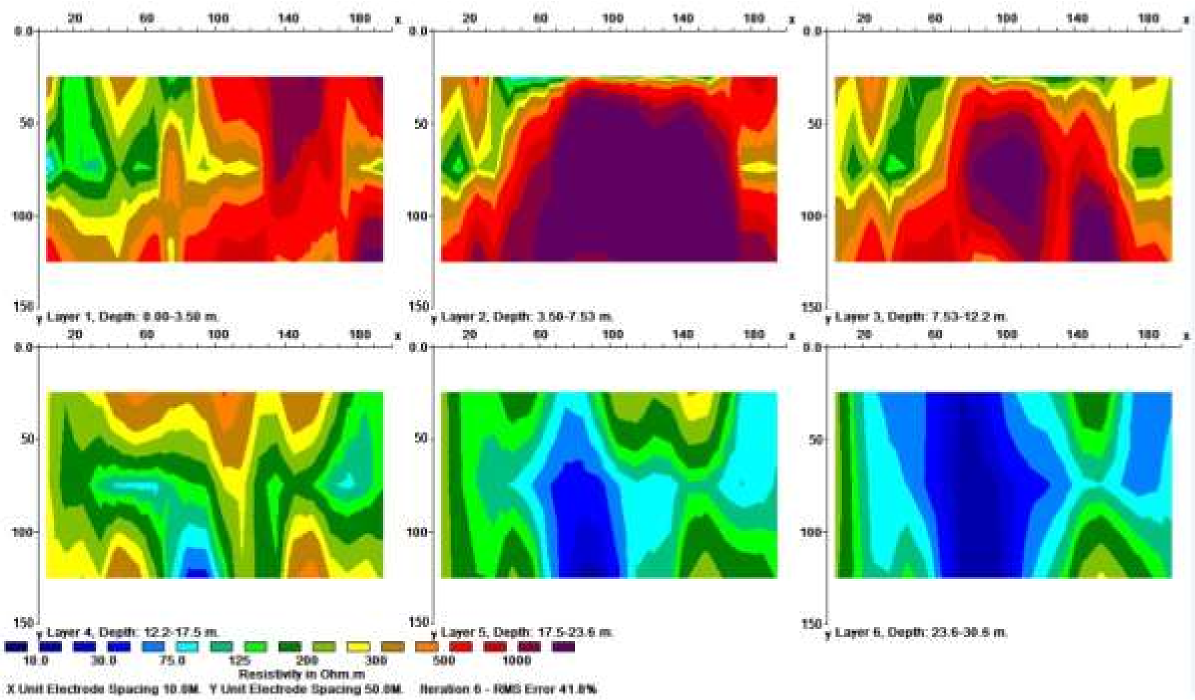

Fig. (6): three-dimensional resistivity image slices using RES3DINV program.

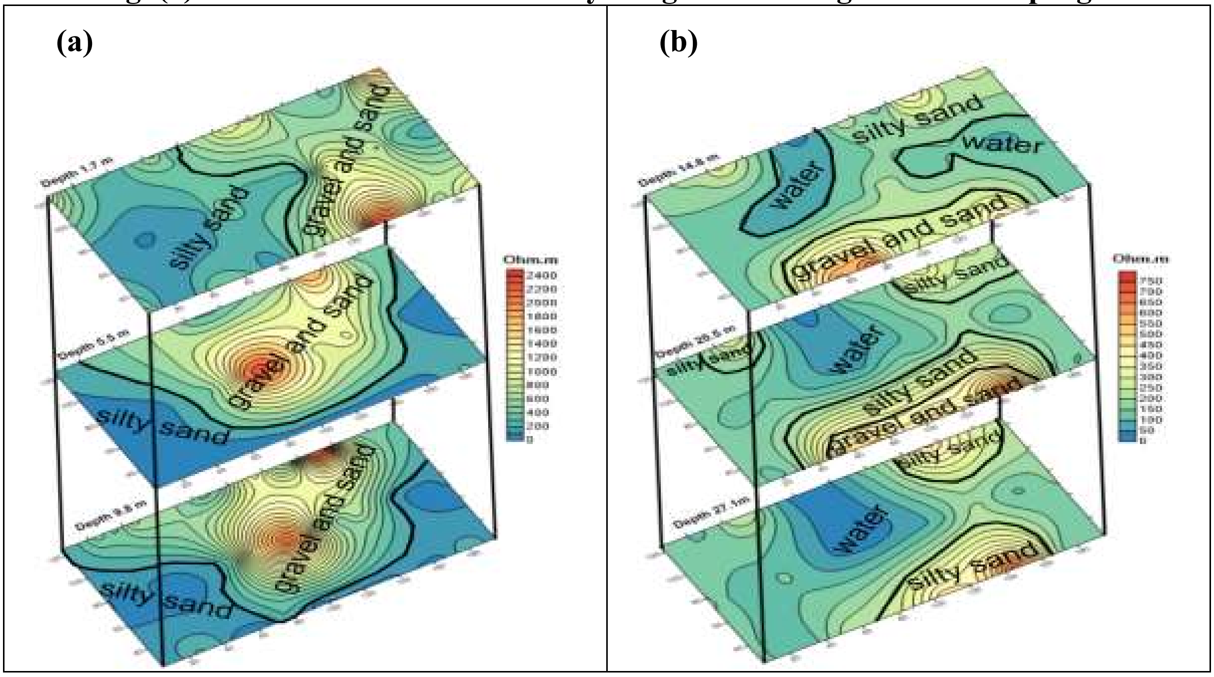

Fig. (7): True Resistivity Map (a)at Depth 1.7 m, 5.5m, 9.8m,and (b)at Depth 14.8m, 20.5m, and 27.1m.

3 DISCUSSION

This study aims to investigate the shallow section for geotechnical purposes and the deeper section for groundwater exploration.

The 2D and 3D geoelectrical resistivity imaging as well as the VES revealed the general pattern of resistivity variations within the study area. The results from 2D and 3D inversion and the result of 1-D inversion (VES) are compatible and show a decrease in resistivity with depth

,where the surface layer consist of moderate resistivity values corresponds to silty sand deposits and high resistivity corresponds to gravel and sand. The second layer has low resistivity values corresponds to the upper surface of sand deposits (water bearing geoelectrical layer) at depth of18 m.

CONCLUSION

Through the interpretation of the geoelectrical data we can conclude that the shallow part of the study area consists of silt sand, gravel and sand and water bearing geological layer

The water bearing layer consists of two zones, the first exhibits low resistivities revealing to brackish water while the second zone is more fresh where the its resistivities are more or less high. The area are suitable for constructions where the clay layer at high depth but sand layers at shallow depths.

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