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STUDY OF GROUNDWATER OCCURRENCE AND THE IMPACT OF SALT WATER INTRUSION IN EAST BITTER LAKES AREA, NORTHWEST SINAI-EGYPT, BY USING THE GEOPHYSICAL TECHNIQUES

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دراسة وجود المياه الجوفية وتأثير تداخل المياه المالحة لمنطقة شرق البحيرات المرة- شمال غرب سيناء- مصر، باستخدام التقنيات الجيوفيزيقية

الخلاصــة: تقع منطقة الدراسة فى شرق قناة السويس بين طريق القنطرة شرق – العريش شمالا وطريق الأسماعيلية– الجفجافة جنوبا وهى تنحصر بين الشاطىء الشرقى لقناة السويس وطرق الطاسة– بالوظة شرقا و تبلغ مساحتها حوالى ١٢٠٠ كم٢. وتهدف هذه الدراسة إلى توضيح ظروف تواجد المياه الجوفية بالمنطقة وبيان مدى تأثير تداخل المياه المالحة على الخزان الجوفى بها. ومن أجل ذلك فقد تم عمل ٦٤ جسة جيوكهربية بتوزيع يغطى المنطقة وأربعة قطاعات للمقاومة النوعية ثنائية البعد.

تم تفسير البيانات الحقلية بأحدث برامج الحاسب الآلى، ومن نتائج التحليل وجد أن التتابع الجيوكهربى يتكون من ثلاث وحدات من الحصى والرمل والطين لرواسب العصر الرباعي. الطبقة الأولى وهى جافة ويزيد سمكها فى اتجاه الشرق من ٣ الى ١٤٧ متراً. الطبقة الثانية وهى مشبعة بمياه متوسطة الملوحة ويزيد سمكها أيضاً فى اتجاه الشرق من ٢,٥ إلى ٤٧,٥ متر. يزيد منسوب سطح الماء من ٢ الى ١٥٥ متراً. الطبقة الثالثة مشبعة بمياه مالحة من تداخل ماء البحر. ويزيد العمق إلى السطح الفاصل بين المياه المتوسطة الملوحة والمالحة باتجاه الشرق من ٤,٥ الى ٢٠٢,٥ متر. سمك الطبقة الحاملة للمياه المتوسطة الملوحة يزيد شرقاً. وقد أوضحت البروفيلات ثنائية البعد بوضوح تأثر المنطقة وخصوصاً الجانب الغربى منها بتداخل المياه المالحة.

طبقاً لمنسوب سطح الأرض بالمنطقة والعمق إلى سطح الماء والعمق حتى السطح الفاصل بين المياه المتوسطة الملوحة والمالحة تمت التوصية بحفر آبار يدوية بالجهة الغربية القريبة من قناة السويس، بينما يتم حفر آبار عميقة بالجزء الشرقى. يتم تحديد كمية السحب الآمن للمياه من الآبار إعتماداً على سمك الطبقة الحاملة للمياه المتوسطة الملوحة والعمق إلى السطح الفاصل بين المياه المتوسطة الملوحة والمالحة وكذلك معامل سريان المياه برواسب خزان العصر الرباعى.

ABSTRACT: *The study area lies between the Suez Canal from the west to El Tassa- Baloza Road to the east and between El Qantara Shark-Arish Road from the North and Ismailya-Gifgafa Road from the south, with an area of about 1200 km^2. Since the liberation of Sinai, the sustainable development has caused an overgrowing need for water resources of this important region. The concerned area has been geoelectrically studied applying the techniques of Vertical Electrical Sounding and Electrical Resistivity Imaging. The aim of this study is to evaluate the groundwater conditions. A total of 64 Vertical Electrical Soundings and four 2-D imaging electrical profiles were carried out.*

Geologically, the Quaternary deposits of northwestern Sinai area consists of gravel, sand and silt intercalated with clay. As a result, the upper part of the Quaternary deposits represents the shallow groundwater aquifer in this area, and can be distinguished into two zones. The upper zone is abrackish water, while the lower one is saline due to salt-water intrusion. The interface between brackish and saline water was distinguished along the interpreted W-E profiles. The geoelectrical succession reveals that aquifer is free type. The saline water intrusion was recoded in both the soundings and the electrical 2-D imaging profiles.

In the area under study, the depth to water increased towards the east, while the salinity of the brackish water decreases towards the east. The thickness of the brackish water zone increases towards the east as well as the depth to the brackish-saline water interface. Drilled wells are more suitable in the eastern parts of the studied area because the depth to water increases in the eastern direction, and the thickness of the brackish water increases towards the eastern direction from 8 m to 47.5 m. The proposed design for each well was tabulated and its safe yield was estimated in the area.

INTRODUCTION

In Egypt as one of the developing countries, some governmental and investment agricultural programs are now under execution.

Sinai Peninsula represents one of the most promising regions for development within the Egyptian territories. This is essentially due to its location where it possesses high quality of soils for cultivation, Trading and tourism potentials; besides it has a good system of paved roads and highways linking it with big cities and industrial centers along the Suez Canal and Delta. Unfortunately, the region is poor of its water resources; extensive groundwater evaluation for this region is the main objective of the present study.

The main water supply of the region comes through Al Salam Canal transferring water from the west of Suez Canal. However, few groundwater wells may enhance the water resources in this region. So, the exploration of groundwater resources in the region has a prime importance as well as the effect of the sea water intrusion.

The study area lies between the Suez Canal from the west to El Tassa-Baloza Road at the east and between El Qantara Shark-Arish Road from the North to Ismailya-Gifgafa road from the South. It is bounded by latitudes 31^o 33` and $31^o$ 00` N and longitudes 32^o 20` and $32^o$ 39` E, with an area of about 1200 km^2. (Fig.1). The surface of the area constitutes flat to slightly undulated plain with low ground elevation which ranges from 30m to 70 m. a. s. l. The area of study occupies a part of the arid belt, which dominates North Egypt and is locally affected by the Mediterranean climate.

GEOMORMPHOLOGICAL, GEOLOGICAL AND HYDROGEOLOGICAL FEATURES

Geomorphologically; the area belongs to the east Bitter Lakes and Gulf of Suez drainage basins, especially its lower part which is covered by gravel terraces, alluvial deposits and sand dunes. Generally, fluviatile plain deposit occupies the Northwestern part of Sinai, which is covered by aeolian sand and gravels with occasional clay interbeds of the Holocene and Pleistocene deposits (Ball, 1939 and Said, 1962). The area is mainly characterized by low relief of about 1.0 m above sea level in western parts, whereas the eastern and southeastern parts are relatively of high (more than 150 m). Few localities have very low relief reaching -1 m below sea level covered by sabkha deposits. The drainage lines are absent in the area of study, but they are recorded in Wadi El Meliz to the south (Youssef, 1998).

The low inland and mobile elevated sand dunes form longitudinal sand hummocks mostly covered by dense natural vegetation. They generally cover vast area and are found in discontinuous pattern trending in the NW-SE direction especially in the eastern part of the studied area. Scattered palm tree communities due to shallow groundwater occupy the low-laying areas between the dunes. Moving of these active dunes, usually threatens the paved and unpaved roads in the study area.

Sandy inland sabkhas are situated in low areas between hummocky surface and sand dunes. They were formed as a result of high evaporation in low relief areas characterized by shallow groundwater and occasional rain fall water. They are represented by South El Qantara Sabkha, lying west of El Qantara-El Shat Road, which has elongated shape and is composed mainly of medium to coarse sands that are sometimes covered by salt crust.

Geologically; the area is entirely covered by Quaternary sediments of littoral, alluvial and Aeolian origin which show a variation in their texture and composition ranging from unconsolidated sands to sand and clay. The sand dune deposits are deflected and diverted from northwest to southeast direction, most likely due to local winds. To the west, near the Suez Canal, northeast trending linear dunes grade progressively into cresentic (transverse and barchan dunes) and complex cresentic dunes that are homogenous and continuous.

Hydrogeologically; the groundwater resource is represented by the unconfined aquifer of the Quaternary deposits. According to different authors such as: Said (1962), Shata et al. (1955) and El Shamy (1983), the Northwest Sinai area is covered by Quaternary deposits which are composed of sand, gravel, clay and sand dunes. Either clay or sand saturated with saline water underlies the aquifer.

FIELD WORK

1- Vertical Electrical Sounding (VES):

A reasonable coverage of the study area was reached by 64 ***Vertical Electrical Soundings (VES).*** The locations of the sounding stations (Fig. 2) were selected to cover the area under study as possible. The Schlumberger 4-electrode configuration was applied in the present investigation. The current electrode separation (AB) reached to 1000 meters. This electrode separation was found to be sufficient to reach reasonable depth range that fulfils the aim of the study.

Four of these soundings were conducted beside four drilled wells in order to parameterize and verify the geoelectrical interpretation. The direct current resistivity meter "Terrameter" model SAS 300 C was used for measuring the resistance "R" with high accuracy. The accurate locations of the sites of the geoelectrical measurements and their elevations relative to sea level were determined using the geographic positioning system (GPS) and topographic map scale 1:50,000. The locations of the VES stations, the geoelectrical cross section and 2D-imaging profiles are shown on figure (2).

2- Two-dimensional electrical resistivity imaging (electrical tomography):

Use was made of the direct current resistivity meters (Terrameter SAS 300C) to carry out these geoelectrical measurements using the Wenner electrode array. Four electrical 2-D imaging profiles were conducted in the western side of the study area, near the Suez Canal (Fig.2), with variable total lengths (630 m, 160 m, 160 m, 360 m respectively). The direction of all these 2-D imaging profiles is the west-east direction. The electrode spacing was 5m in the first profile, while it was 10 m in the other three profiles.

These profiles were conducted to study the effect of the seawater intrusion; three of them to the west of the Qantara-Shat Road and one to the east of that road.

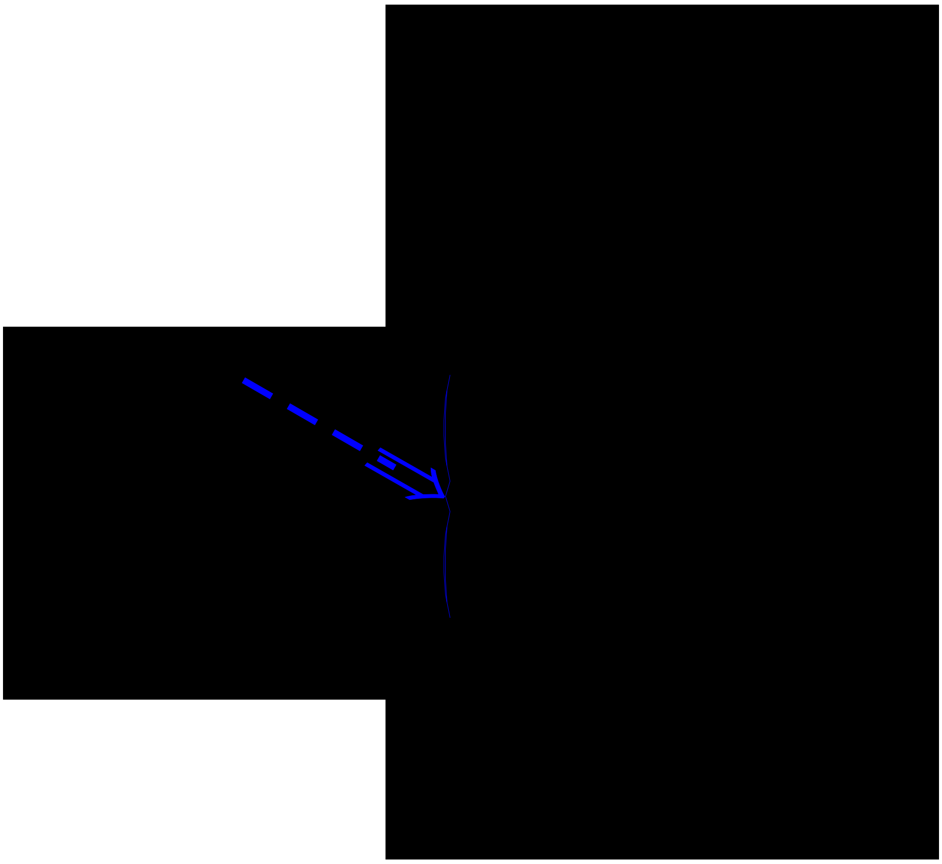

Fig. (1): Location map of the Study area.

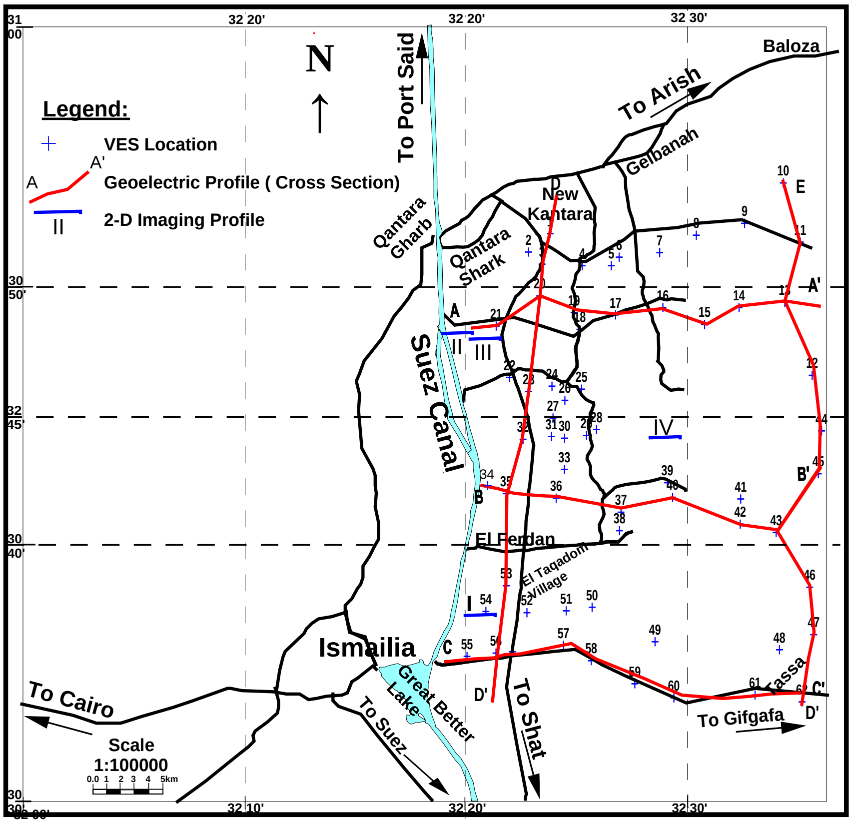

Fig. (2): Location map of the Vertical Electrical Sounding Stations, Geoelectrical cross sections and 2-Imaging Profiles.

INTERPRETATION AND DISCUSSION

1- Interpretation of the geoelectrical resistivity data (VES):

The interpretation of the geoelectrical resistivity data depends on determining and following up the geoelectrical parameters i.e. resistivities and thicknesses of a series of layers. The interpretation includes also correlation of similar layers or across zones where a layer or some layers may be absent because of lithologic variations. The product is a geological model that can be described and interpreted in terms of geological lithological variation and stratigraphy.

Use was made of the computer program (**Van Der Velpen, B.P.A., (1988), RESIST**), for the quantitative interpretation of the geoelectrical sounding curves. It is an interactive, graphically oriented, forward and inverse modeling program for interpreting the resistivity curves in terms of a layered earth model. An arbitrary initial model has been constructed in view of the overall shape of the sounding curves and refers to some deep drilled wells. The interpretation of the resistivity soundings led to the detection of four geoelectrical layers. Five geoelectrical cross sections were constructed, three of which were taken in the West-East (Figures 3, 4 and 5). While the other two sections take the north-south direction (Fig. No's. 6 & 7). The distribution of the resistivities and thicknesses of the encountered layers, from the surface downwards, were concluded.

The uppermost geoelectrical layer was found to consist of a group of thin layers attaining different resistivities. The resistivity of this compiled layer is expressed in terms of the average transverse resistivity. This layer shows its maximum resistivity value at VES No. 40 (2111 Ohm-m), whereas a minimum value of 31 Ohm-m is recorded at VES No. 51. The diversity of the resistivity values, characterizing this geoelectrical layer, is typically indicative of alluvial deposits or drift sands, which are formed of different deposits such as gravel, sand, and clayey sand. This layer reaches its maximum thickness at VES No's. 32 and 56 (3.7 m).

The second geoelectrical layer is characterized by relatively low resistivity values (4-288 Ohm-m). This resistivity values represent dry fine-grained materials such as silt, sandy clay or fine sand. The thickness of this layer differs greatly from one locality to another where its maximum thickness (97 m) has been recorded at VES 36 and its minimum thickness (1.6 m) has been found at VES 18.

The third geoelectrical layer extends allover the study area exhibiting resistivity values that range from 2.6 Ohm-m to 79 Ohm-m. The variation of the resistivity within this range indicates lateral lithologic change from fine sand to sand. The thickness of this layer varies from 5 m at VES 18 to 42.3 m at VES 28 showing a general eastward decrease.

The lowermost layer (fourth) extends along the area with very low resistivity values that do not exceed 7.6 Ohm-m. The resistivity range represents saline water saturated sand or clay layer.

The vertical and horizontal distribution of the detected geoelectrical layers have been illustrated as a geoelectrical cross sections (Figs. 3-7). From these cross sections, the following common features can be noticed:

- The first and second geoelectrical layers show a general decrease in their thicknesses westwards.
- The layers show regular regional thickness towards the west.
- Most of the layers extend along the cross sections with variable thickness due to variation in sand dune elevation.
- The thickness of saturated water-bearing layer is generally increases towards the southeast direction.
- The brackish-saline contact become deeper southeastwards the high lands.
- The groundwater is shallower towards the west due to low ground elevation but it becomes deeper towards the southeast direction.

2- Interpretation of the 2-D Imaging data:

For the interpretation of the imaging data, use was made of the computer program RES2DINV, ver 3.4 written by Loke (1998). It is a Windows-based computer program that automatically determines a two-dimensional (2-D) subsurface resistivity model for data obtained from electrical imaging surveys (Griffiths and Barker 1993).

Four 2-D Electrical profiles were carried out crossing the investigated area. These profiles were conducted in the W-E direction in a direction normal to the Suez Canal. Examination of these imaging profiles at the selected four sites in the study area indicates that deposits of high resistivity that corresponds to dry coarse grain sand and gravels dominate the upper parts. Some low resistivity zones were observed near the surface that may represent wet finer materials or marshes especially in the western side of the area. These images shows obvious downward resistivity decrease that represents saturated aeolian deposits. Discussion of the four imaging profiles is given below (Figs. 8, 11, 10 and 11):

1- The imaging profile No. 1

The first profile is located at the site of VES No.54, beside a well under drilling in the time of conduction (Fig. 8). Its length is 630 m along the W-E direction. The measured apparent resistivity pseudo-section is plotted down to datum level of n =10 in the upper image. Examination of this section indicates the domination of different low and high resistivity zones. At the shallow depth, a relatively high resistivity is detected, while at the deep horizon the lower resistivity is detected at the western side of that profile.

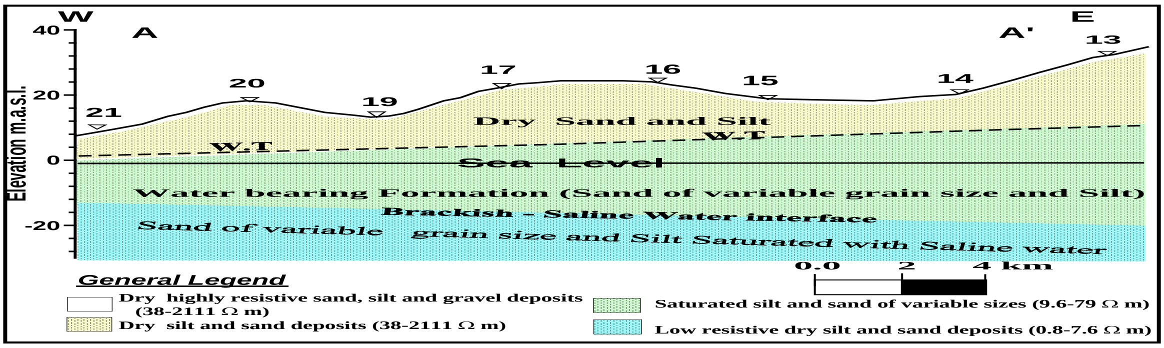

Fig. (3): The geoelectrical cross section AA'.

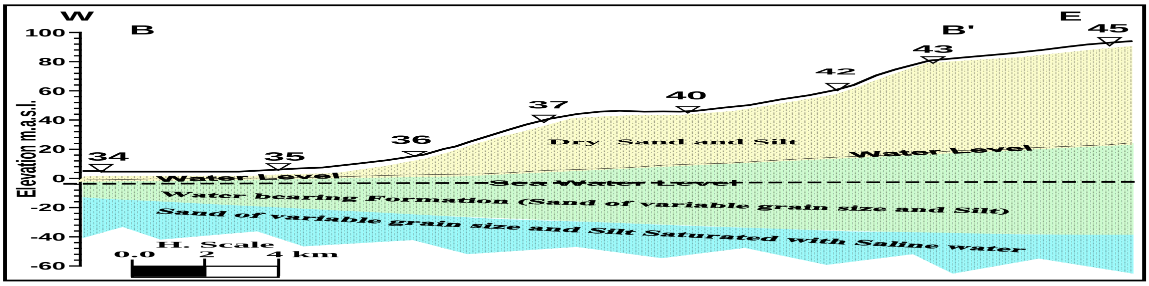

Fig. (4): The geoelectrical cross section BB'.

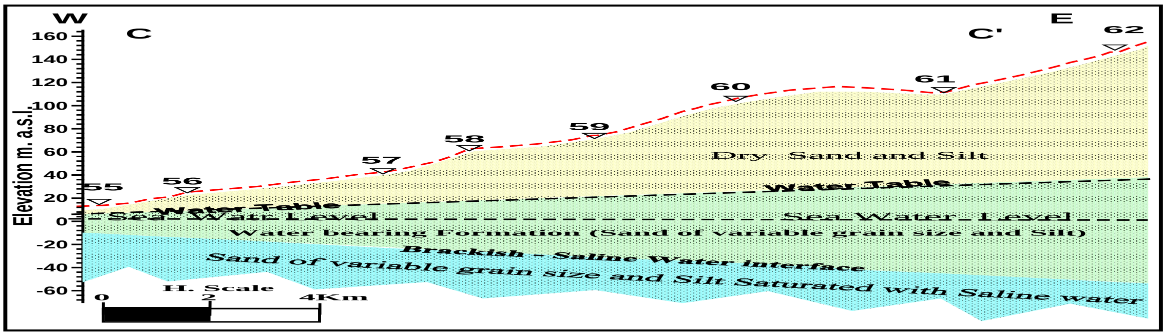

Fig. (5): The geoelectrical cross section CC'.

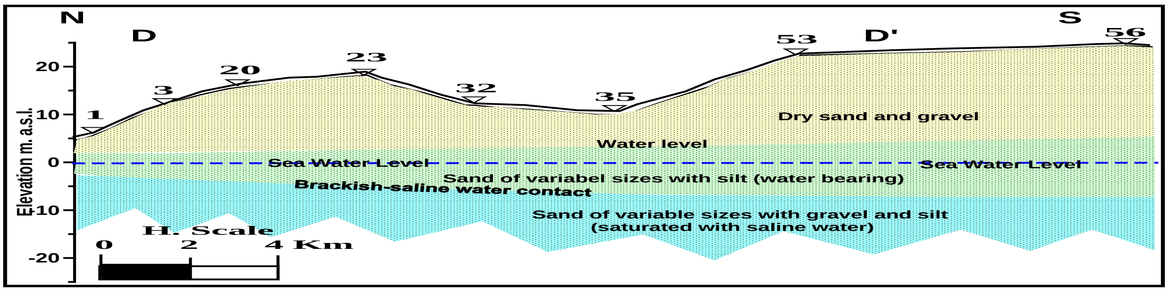

Fig. (6): The geoelectrical cross section DD'.

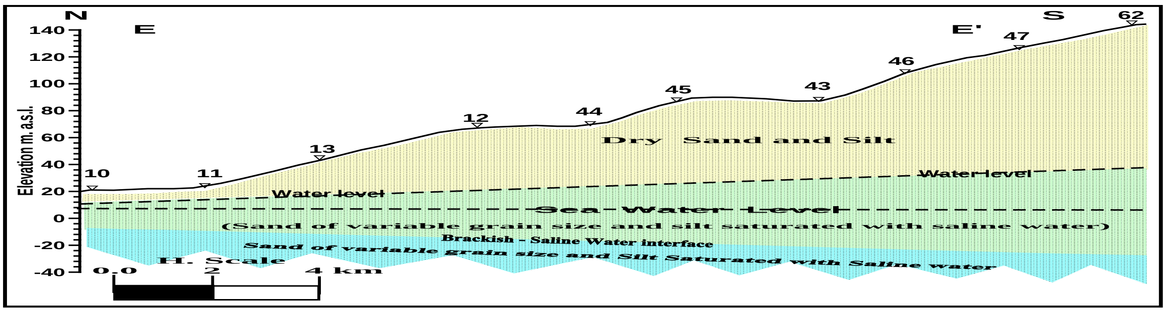

Fig. (7): The geoelectrical cross section EE'.

The lower image is the true resistivity plot obtained after many iterations of the inversion program. Examination of this section indicates the domination of high resistivity zones (>100 Ohm.m) extending along the upper parts of the profile especially at the end (40m) of the profile. The high resistivities correspond to dry drift sand. Beneath the first datum, the image shows some low resistivity (<24 Ohm.m) zones that represent saturated sand deposits. The image shows zones of low resistivity downwards at the lower part of the profile that may be attributed to saline water saturated deposits.

2- The imaging profile No. 2:

This imaging profile located at the location of VES No.20 and its length is 240 m. This profile (Fig.9), shows that the succession is in agreement with the geoelectric cross section C C'. This succession began with a dry surface thin layer of drift sand followed by dry sand and silt and bottomed by saline water saturated sediments. The penetrated depth reaches about 30m.

3- The imaging profile No. 3:

This imaging profile is located at the location of VES No.21 and its length is 160 m along. It lies to the east of the 2-D profile No.2 and shows (Fig.10) an agreement with this VES and Imaging profile No.1.

4- The imaging profile No. 4:

This profile is located between the location of VES No.28 and VES No.38, its length is 300m (Fig. 11). It shows that the depth to the saturated zone is about 5m and the saturated thickness is about 10 m. This zone is followed downwards by dry sand, which is bottomed by sand saturated with saline water.

GROUNDWATER OCCURRENCES

In view of the little hydrogeological information in the investigated area, the applied geoelectrical methods were integrated to collect the common features that may suggest groundwater occurrence. The interpretation of the sounding data (VES) allover the studied area revealed that the resistivity of some layers changes from one locality to another.

According to the above discussions, all sites of the geoelectrical sounding stations seem to be favorable sites for the drilling of wells with variable depths according to each location. The geoelectrical succession revels that the aquifer is open where there is no confining layer, so this aquifer is unconfined (water table). The saline water intrusion from the west and north was detected in all soundings and the electrical 2-D imaging profiles. The suitable techniques for drilling can be both the hand-dug wells in western parts and drilled deeper wells in the east and southeast parts. Well logging of these boreholes is strongly recommended for proper development as production wells. Drilling at the western side is of less importance due to the expected high salinity due to the salt-water intrusion.

HYDROGEOLOGICAL ASPECTS

When an aquifer contains an underlying layer of saline water such as the area under study and is pumped by a well penetrating only the brackish water of the upper part of the aquifer, a local rise of the interface between the saline and brackish water below the well occurs. This phenomenon is known as up-coning, by pumping. This generally necessitates that the well has to be shutdown because of the influence of the saline water. Up-coning is a compiler phenomenon and only in recent years has significant headway been made in research to enable criteria to be formulated for the design and operation of wells for skimming brackish water from the saline water. An approximate analytical solution for up-coning directly beneath a well, based on the Depute assumptions and Ghyben-Herzberg relation (Todd, 1980), was given by:

$$Z = Q/[2\pi\, d^2\, K\, (\Delta\rho/\, \rho_b)]$$

Where $\Delta\rho = \rho_s - \rho_f$; ρ_s , ρ_f is the specific weight of saline and brackish water.

d = the distance between the end of the well and interface between saline and brackish water

K = Hydraulic conductivity and Z = the critical rise.

The map (Fig. 12) gives the recommended sites of water wells (drilled and hand dug). Table (2) shows the design of the drilled water wells in the eastern part of the area, such as total depth, casing length and screen length, also the safe well yield (Q) for every well, without reaching up-coning of the saline water, calculated by Ghyben-Herzberg relation.

If the up-coning exceeds a certain critical rise, it accelerates upwards to the well. Critical rise has been estimated to approximate Z/d = 0.3 to 0.5 . Thus, adopting an upper limit of Z/ d = 0.5 , it follows that the maximum permissible pumping rate without salt entering the well is : $Q_{max} \leq \pi\, d^2\, K\, (\Delta\rho/\, \rho_b)$

Where K is the hydraulic conductivity of the Quaternary aquifer from well No.41 at Shouhat is 1.64 m^3/day (dug well) and well No.41 at Shouhat El Masherif well is 9.2 m^3/day to 82 m^3.day (El Austa (2000).

According to this equation, the drilled well design and the corresponding Q max (safe well yield) are registered in table (1). If the hand dug wells lies half diameter r = 2 meters and will dug under water level (Z) by two meters. The safe well yield Q is calculated by equation $Q = \pi\, r^2\, Z$, then Q = 3.14 x 4 x 2 = 25.12 m^3 / day if the water is pumped ones every day. El Austa (2000). Safety yield (Q) for drilled wells varies from 82 to 6897.4 m^3/hour, and Safety yield for every hand dug well reach 25.12 m^3/ day.

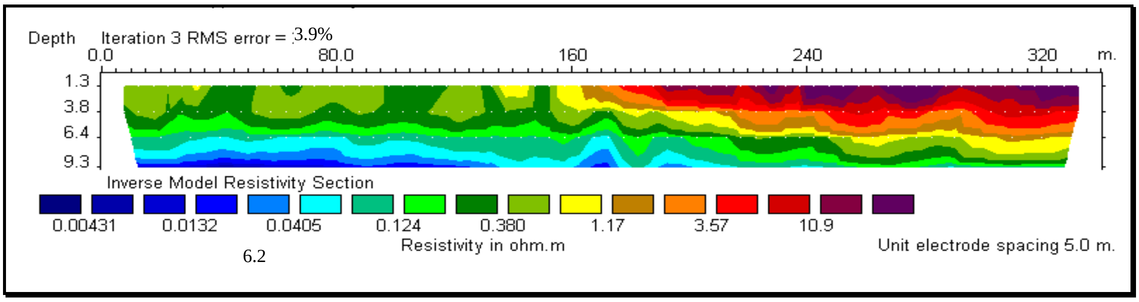

Fig. (8): The 2-D Imaging profile No. I.

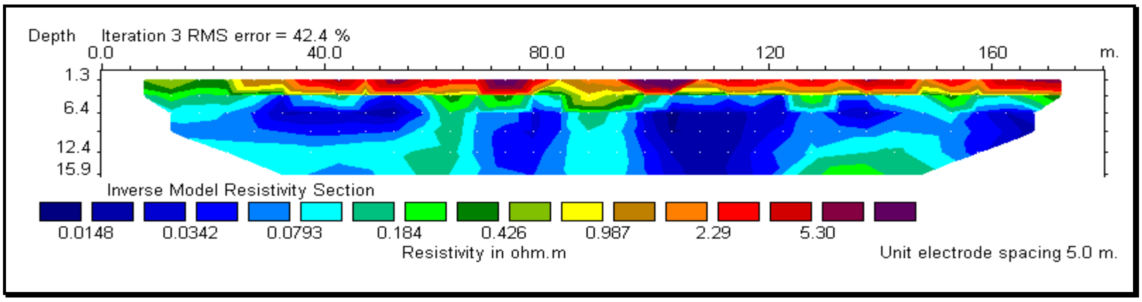

Fig. (9): The 2-D Imaging profile No. II.

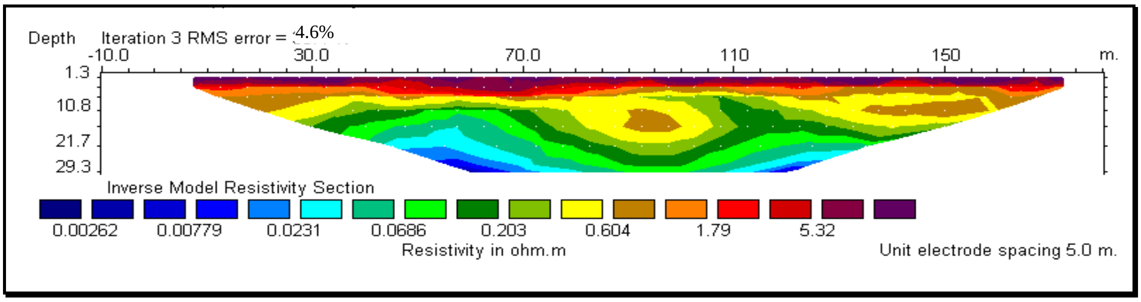

Fig. (10): The 2-D Imaging profile No. III.

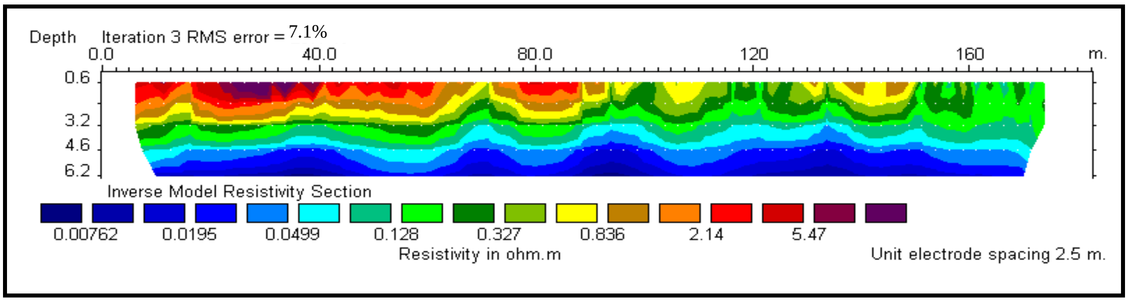

Fig. (11): The 2-D Imaging profile No. IV.

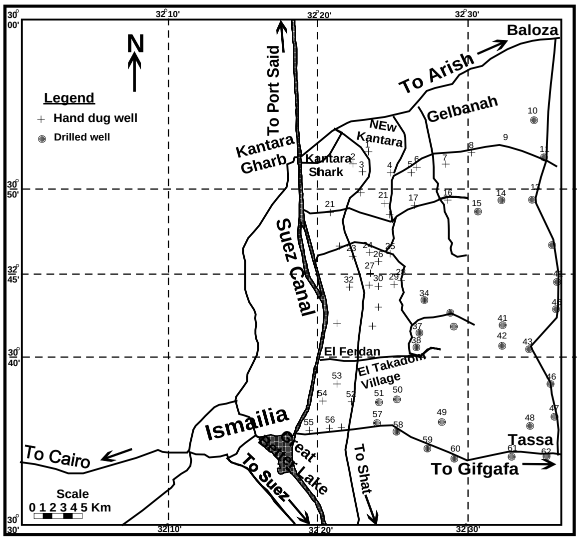

Fig. (12): Hand dug and Drilled wells.

- The Isopach map of brackish water bearing zone, which shown in figure 16 was drown by using the thickness of the third geoelectrical zone. It gives the direction of increase of the thickness. It is clear that the thickness increases generally towards the east in the study area (fig.13).

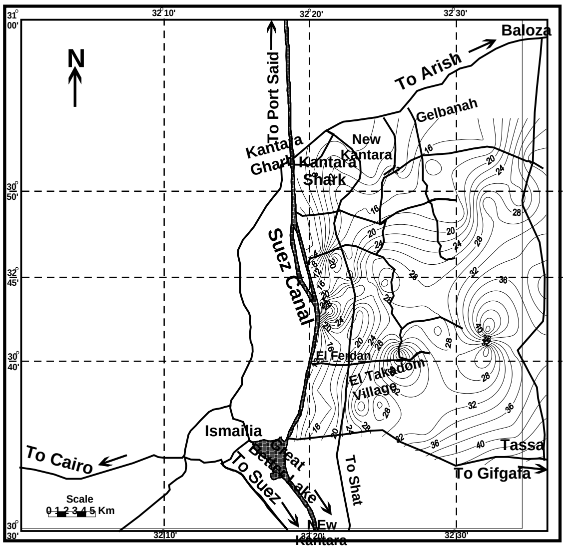

Fig. (13): Isopach map of brackish water formation layer (m).

- Depth to water contour map

For practical purposes, the depth to water contour maps (figs. 14 and 15) was constructed. The maps display just the interpreted depths to top of the brackish water-and the saline water bearing formations across the study area. The first map is useful in predicting the depth to water in the area where new water wells are intended to be drilled. This is quite necessary for the agricultural or industrial development of the area based on its groundwater resources.

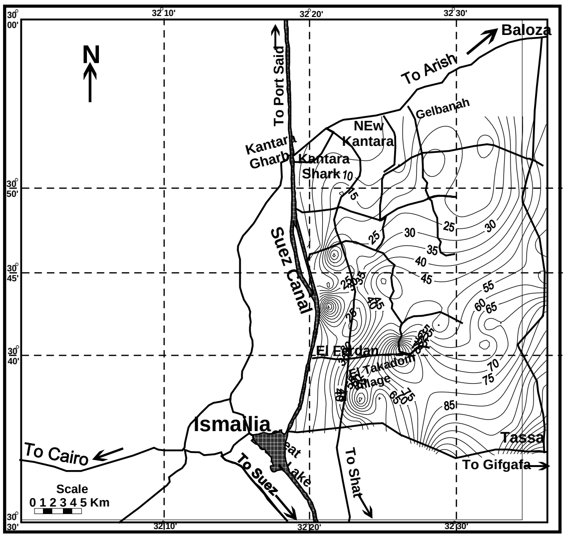

Fig. (14): Water table contour map (m.a.s.l.).

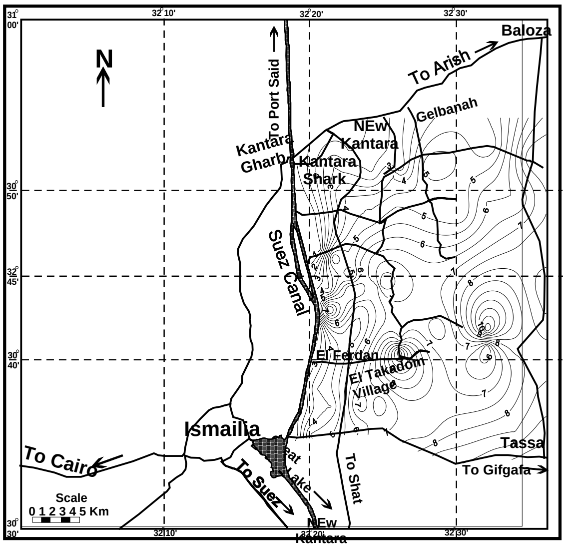

Fig. (15): Water table contour map (m. g.l.).

The map indicates that the western part of the area is the place where a minimal depth to water (3-124m) is expected. The depth to water increases gradually to reach 40-60m in the eastern edges of the area. This is of course, governed mainly with the change in surface topography of the area.

- Water contour table maps, The Water table contour maps shown in figures 16 and 17 was constructed using the interpreted depths to the top of the brackish water-bearing formation, referred to Sea Level and the depth to interface between the brackish and saline waters bearing formations. The brackish water-bearing formation contour map indicates that the average altitude of the water table is in the range of 2-10 m. and the change in water table takes place smoothly with an average hydraulic gradient of about 1.5 m/km. in the area. Consequently, it represents the parts of the area favorable for the drilling of new water wells.

Table (1): The depth to water, water table, depth to interface and interface level.

VES No.	Grou. Eleve. m.a.s.l	Water Depth m. g.l.	Water Depth m.a.s.l	Dep.to Interf. m.g. l.	Dep.to Interf. m.a.s.l.	Thick.of brackish w. b. f.	VES No	Groun Eleve. m.a.s.l	Water Depth m.g.l.	Water Depth m.a.s.l	Dep.to Interf. m.g.l	Dep.to Interf. m.a.s.l	Thick.of brackish w. b. f.
1	5	3	2	11	-6	8	33	30	25	5	42	-12	17
2	11	8	3	20	-9	12	34	80	71	9	109	-29	38
3	11	8	3	20	-9	12	35	9	7	2	15	-6	8
4	9	6.5	2.5	15.5	-6.5	9	36	19	14.5	4.5	30.5	-11.5	16
5	15	11	4	27	-12	16	37	59	52	7	80	-21	28
6	7	4.5	2.5	12.5	-5.5	10	38	120	109	11	154	-34	45
7	35	30	5.5	48.5	-13.5	19	39	60	53.5	6.5	81	-21	27.5
8	28	23	5	40	-12	17	40	50	44	6	69	-19	25
9	16	12	4	28	-12	16	41	85	73.5	11.5	121	-36	47.5
10	44	38	6	62	-48	24	42	64	57.5	5.5	81	-17	22.5
11	57	49	8	82	-25	33	43	80	72	8	99	-28	36
12	71	63	8	99	-28	36	44	59	52	7	82	-23	30
13	41	35	6	59	-18	24	45	92	84.5	7.5	118.5	-26.5	34
14	23	17	6	35	-18	32	46	117	108.5	8.5	147.5	-30.5	39
15	22	17.5	4.5	33.5	-11.5	16	47	119	110	9	152	-33	42
16	25	20.5	4.5	36.5	-11.5	16	48	105	97.5	8.5	135.5	-30.5	39
17	28	23	5	40	-12	17	49	89	81	7	112	-23	30
18	23	18.5	4.5	34.5	-11.5	16	50	55	49	6	74	-19	25
19	16	11.5	4.5	27.5	-11.5	16	51	92	84.5	7.5	118.5	-26.5	34
20	25	21	4	37	-12	16	52	33	29	4	45	-12	16
21	2.5	2	0.5	4.5	-2	2.5	53	21	19	4	33	-12	16
22	3	3	0.6	5.3	-2.3	2.8	54	15	12.5	2.5	22.5	-7.5	10
23	55	49	6	73	-18	24	55	11	9	2	18	-7	9
24	30	25	5	52	-12	17	56	23	18.5	4.5	34.5	-11.5	16
25	33	26.5	6.5	54	-21	27.5	57	40	36	6	59	-19	25
26	39	33	6	57	-18	24	58	60	53	7	83	-23	30
27	24	19.5	4.5	35.5	-11.5	16	59	70	62	8	99	-29	37
28	65	57	8	90	-25	33	60	133	124	9	166	-33	42
29	55	49	6	73	-18	24	61	109	99.5	9.5	145	-36	45.5
30	45	38	7	66	-21	28	62	165	155	10	202.5	-37.5	47.5
31	35	28	7	56	-21	28	63	112	103	9	136	-34	43
32	11	7	4	23	-12	18	64	123	114	9	156	-33	42

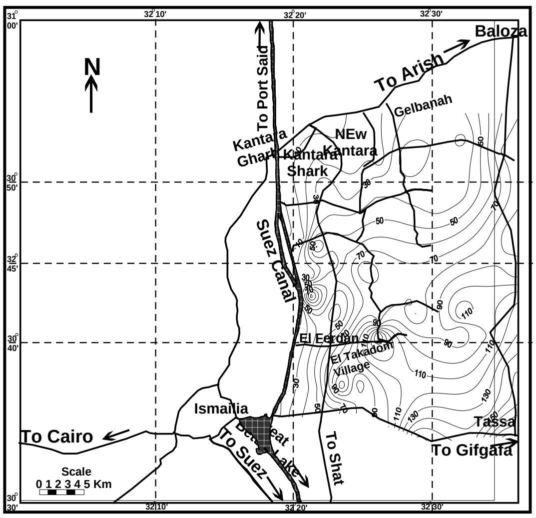

Fig. (16): Depth contour map to the interface between the brackish and saline water (m.g.l.).

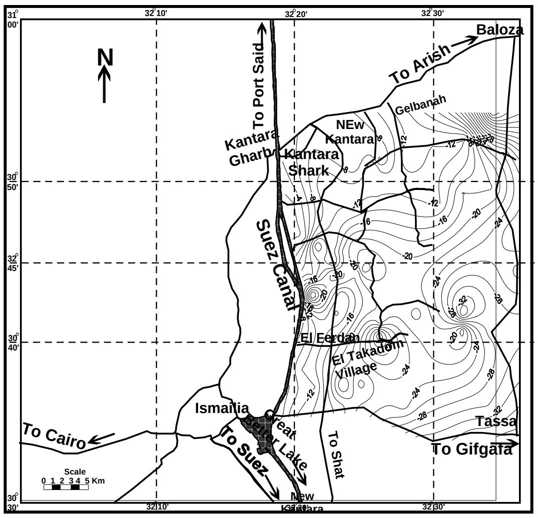

Fig. (17): Elevation contour map of the interface betwen the brackish and saline water (m a.s.l.).

From the tables No. (2), hand dug wells is suitable in the western part of the study area due to low ground level, shallow water level and effect of the salt water intrusion.

Drilled wells are more suitable in the eastern and southeastern parts of the area due to the increase in depth to water in the eastern direction, and the thickness of the brackish water increases in the eastern direction (8 to 47.5 m).

Table (2): Design and safety yield of water wells.

Q max=3.14 x d^2 x 1.64 x 0.025 = 0.12874 m^3/day , K = 9.12 m^3/ day , $\Delta\rho$ = 0.025

VES No.	Design T.D.	Len. of Casing	Well Screen	Dm	D^2m^3	Q m^3/day	VES No.	Design T.D.	Len. of Casing	Well Screen	Dm	D^2m^3	Q m^3/day
1	11	3					33	42	25	20			
2	20	8					34	109	71	20	18	324	2954.9
3	20	8					35	15	7				
4	15.5	6.5					36	30.5	14.5				
5	27	11					37	80	52	20	8	64	583.7
6	12.5	4.5					38	154	109	20	25	625	5700
7	48.5	30					39	81	53.5	20	7.5	57	519.8
8	40	23					40	69	44	20	5	25	224
9	28	12					41	121	73.5	20	27.5	756.3	6897.4
10	62	38	20	5	25	224	42	81	57.5	20	3.5	12.3	112.2
11	82	49	20	13	169	1541.3	43	99	72	20	7	49	446.9
12	99	63	20	7	49	446.9	44	82	52	20	10	100	912
13	59	35	20	4	16	145.9	45	118.5	84.5	20	14	156	1422.7
14	35	17					46	147.5	108.5	20	19	361	3292.3
15	33.5	17.5					47	152	110	20	22	484	4414
16	36.5	20.5					48	135.5	97.5	20	20	400	3648
17	40	23					49	112	81	20	11	121	1103.5
18	34.5	18.5					50	74	49	20	5	25	224
19	27.5	11.5					51	118.5	84.5	20	14	156	1422.7
20	37	21					52	45	29				
21	4.5	2					53	33	19				
22	5.3	3					54	22.5	12.5				
23	73	49	20	4	16	145.9	55	18	9				
24	52	25	20	7	49	446.9	56	34.5	18.5				
25	54	26.5	20	7.5	57	519.8	57	59	36	20	3	9	82
26	57	33	20	4	16	145.9	58	83	53	20	10	100	912
27	35.5	19.5	20				59	99	62	20	17	289	2635.7
28	90	57	20	13	169	1541.3	60	166	124	20	22	484	4414
29	73	49	20	4	16	145.9	61	145	99.5	20	23.5	552.3	5037
30	66	38	20	8	64	583.7	62	202.5	155	20	27.5	400	3648
31	56	28	20	8	64	583.7	63	136	103	20	23	529	4824.5
32	23	7					64	156	114	20	22	484	4414

SUMMARY, CONCLUSION AND RECOMMENDATIONS

The study area lies between the Suez Canal from the west to El Tassa- Baloza Road at the east and between El Qantara Shark-Arish Road from the North and Ismailya-Gifgafa road from the South, with an area of about 1200 km^2. 64 Vertical Electrical Soundings (VES) were conducted, applying the Schlumberger array and AB/2 spacing of 300-1000m. The results of the interpreted geoelectrical data were represented by contour maps, iso-pach maps and geoelectrical cross sections. The hydrogeological part of the study in the present work depends on different sources of information as collecting the previous hydrogeological data and the data of the water wells by natives and governmental authorities for agricultural activities. Five geoelectrical cross sections, are constructed from the interpreted geoelectrical data, three of which are in W-E direction and the other two in the W-E direction, to illustrate the horizontal and vertical variations along these directions. This led to the conclusion that the succession in the area consists of four main geoelectrical layers of gravel, sand and clay of Quaternary deposits.

It was concluded that the locations of all geoelectrical soundings are suitable for drilling groundwater production wells. At these sounding stations the groundwater exists at a depth ranging from 2 to 155 m. Drilling at the western location may be of less important, although groundwater exists, due to higher groundwater salinity (salt water intrusion), and small thickness of the water-bearing formation. Sand deposits mainly dominate the whole section with high porosity that facilitates infiltration of surface water. From the dug, drilled wells in this area the groundwater is fresh to brackish with the salinity increasing with depth and become highly saline due to the saline water intrusion. The water can be used for domestic purposes and irrigation on a large scale. The aquifer is recharged by runoff from the adjacent upland area.

From these geoelectrical and hydrogeological studies, the authors recommendations are:

1- The depth to water-bearing zone is about 2 m from the ground surface at western side of the study area, while it reaches about 155 m from the ground surface at the southeastern parts of the area. The eastern part of the study area is the best site for drilling new groundwater wells, because it has a suitable thickness of the water-bearing formation.

2- The thickness of water bearing bed ranges from 2.5 in the western part to about 47.5 m in the southeastern side of the investigated area.

3- The most suitable location for drilling new productive wells is the location of the sounding stations at the east and southeastern sites where the depth of the well ranges from 120 to 205 m. While in the western region, the hand dug well type is suitable for to water extraction.

4- Due to the saline water intrusion, more drilling depth than the brackish-saline water contact at each location is not recommended.

5- Well logging of these wells is strongly recommended to the proper design as production wells and also the pumping tests are highly important to determine the safe yield at every location to avoid the over pumping or the depletion of the aquifer.

6- The potentiality of the study area could be regarded as a fair aquifer with good water quality.

7- Detailed hydrogeological and hydrogeochemical studies are highly recommended in the whole area.

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