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DETECTING THE GROUND WATER ZONE OF THE QUATERNARY AQUIFER USING THE VERTICAL ELECTRICAL SOUNDING IN EL-QAA PLAIN, SAINAI, EGYPT.

By

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ABSTRACT

El- Qaa plain rises up to 200 m above mean sea level, sloping gently toward the south east of the Sinai Peninsula. It is characterized by young Tertiary and Quaternary alluvial sediments, sandstone, gypsum and limestone. Much of the alluvial sediments originated from the hills to the east, it covers an approximate surface of 6070 km2, which is estimated 10 % of the Sinai Peninsula, with a maximum length of 150 km approximately and a maximum width of 20 km. This research is aiming to detect the saline water bearing unit within the Quaternary aquifer in El-Qaa Plain area, using the vertical electrical sounding (VES) technique. This investigation based on measuring the electrical resistivity of the units with depth using the schlumberger array. In order to achieve the goal of this research, geological and geophysical studies have been executed, 30 VESes have been implemented with their processing and interpretation using Zohdy (1989) and WinSev (2004) programs. Several previous works have been collected and summarized. Hence four iso-resistivity contour maps, four cross sections, and top of saline water bearing unit contour map have been established. This study emphasizes the role of using the geoelectrical techniques in delineation of ground water quality in aquifers within such important areas.

Key words: Vertical electrical sounding, saline water zone, quaternary aquifer, El-Qaa plain, Sinai

INTRODUCTION

During the two last decades, there is a continuous demand for more and more water necessary in order to overcome the over-increasing populations and the land expansion projects in Egypt. At present, the reclamation of desert areas requires the exploration of new water resources, where the rainfall is scarce and the available surface water are limited So, the development of groundwater resource for desert reclamation projects are urgently needed in such areas which located along the eastern coast of the Gulf of Suez between 27° 43́ 44″ to 28° 54́ 55″ N and 33° 11́ 50″ to 34° 15́ 24″ E within the southwest Sinai rift zone (Fig. 1).

Many geological, hydrogeological and geophysical works have been carried out in parts of the study area (e.g., Geofizika 1963; Kamel and Fouad 1975; Webster and Riston 1992; Shendy 1984; Rizkalla 1985; Abdelrahman *et. al*. 1987; Tealeb and Riad 1987; Meshref and El-Kattan 1989; Ibrahim and Ghoneimi 1992; RIWR and JICA 1999; Gorski and Ghodeif 2000; El-Shayeb 2001; Sayed *et al*. 2004; Leppard and Gawthorpe 2006; El-Kelani *et al*. 1999 and 2003; Khalil 2009, M. S. Youssef 2013.

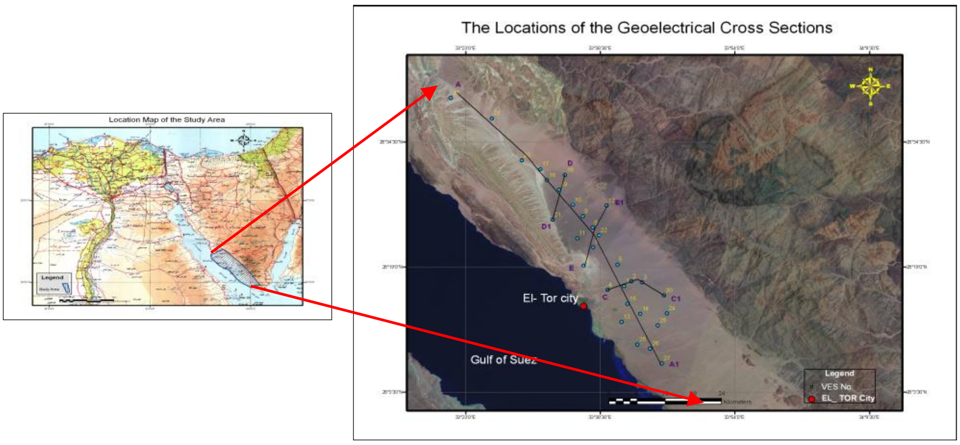


Fig. (1): Location Map of the Study Area

Geomorphologically, the study area can be subdivided into three main categories (Fig.2);
(1)The Eastern Mountain region, (2) the western Sedimentary Hill, and (3) the Central Plain. Geologically, the area ranges from Precambrian basement rocks to Quaternary deposits. According to the surface geologic map (Khalil 1998; McClay *et al*. 1998), the Quaternary deposits cover the Sahl El Qaa basin and the western side of the studied area. Miocene-Oligocene sediments outcrop in the northern and eastern parts of the basin, while Eocene-Cambrian sediments confine the valley at the east and west sides of the area. At the north-eastern part of the studied area Pre-Cambrian rocks outcrop, (Sultan *et al*, 2009) (Fig.3).

METHODOLOGY:

The vertical electrical resistivity sounding technique using Schlumberger array was used for determining the geoelectrical parameters, 30 VESes were carried out for the study area (Fig. 1) using Syscal R1. At each VES location, the distance between the potential electrodes increased from 1.5 m up to 200 m while the current electrode separation was increased from 1.5 m up to 400 m and to 800 m. By the beginning of the field survey, six vertical electrical soundings were carried out near to the available boreholes in the area of study for correlating the resistivity measurements with the lithological and hydrogeological information.

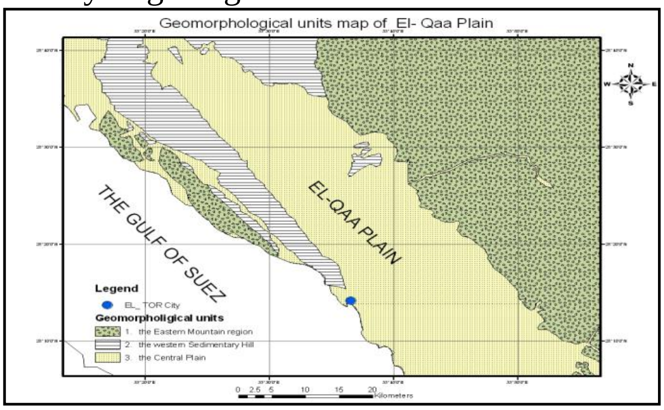


Fig.2: Geomorphological units of the study area

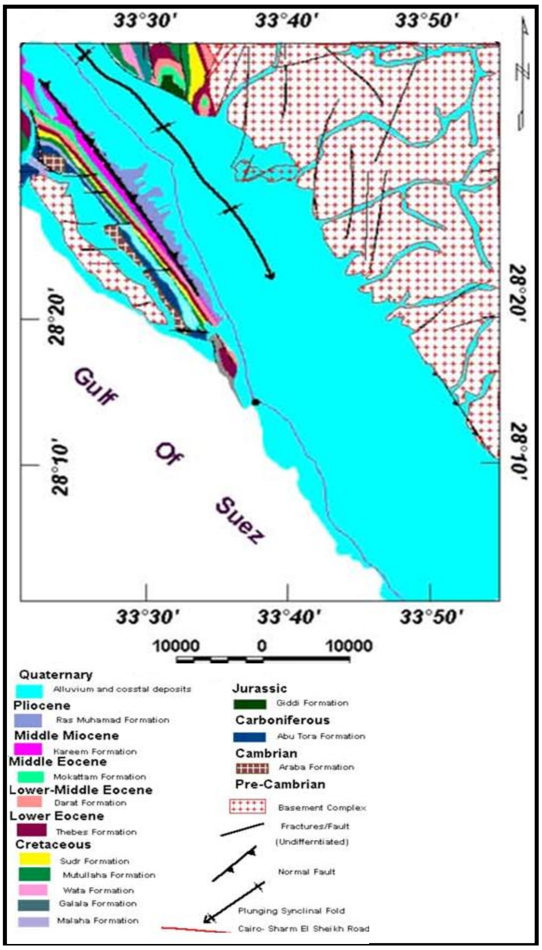


Fig.3: Geological units of the study area (After Sultan *et al*, 2009)

The main purpose of the qualitative interpretation of the geoelectrical resistivity soundings is to determine the number of geoelectrical units in terms of thicknesses (or depth) and relative resistivities. This is done by plotting the field measured apparent resistivity data "ρa" against half-current electrode spacing (AB/2) and construction of the field curves (VES curves), which guide the subsequent process of quantitative interpretation. This step using ZOHDY (1989) in the beginning to determine the multiunit model, and the results was used as a base to inter the result model in another program (Winsev6 2004). Winserv6 program has several Characteristics to relate between the geological data and the geoelectrical data (Fig. 4a & 4b).

RESULTS AND DISCUSSIONS

The results reached from the interpretation of the individual sounding curve, were utilized to recognize the subsurface setup of the area. This was accomplished through the construction of geoelectrical cross sections (Fig. 5a, 5b, 5c & 5d).

The cross sections illustrate that the study area has nine geoelectrical units their descriptions can explained as follows:-

1- The top geoelectrical unit has high average resistivity values ranges between 5000 Ohm.m. to 200 Ohm.m. With average thickness equal 3 m., it consists mainly of weathered materials.

2- The second geoelectrical unit has average resistivity values ranges between 75 to 100 Ohm.m. as a result of the intercalation of sand with clay with average thickness reachs 50 m., this unit is considered the top of the aquifer.

3- The third geoelectrical unit has average resistivity values ranges between 100-150 Ohm.m. and consists mainly of medium grained sand but this composition shows some variations such as the increasing in the clay percentage in some locations. This unit is one of the main aquifer units and has average thickness of 130m.

4- The fourth and fifth geoelectrical units which have average resistivity values range from 150 to 250 Ohm.m. and consists of medium to coarse grained sand and contain water, it considered the extension of the aquifer units, with thickness of 150 m.

5- The sixth geoelectrical unit which is the separation unit between the fourth and the fifth according to the increasing in the grain size which causes increasing in the resistivity values up to 700 Ohm.m. with thickness less than 50 m.

6- The seventh geoelectrical unit which has average resistivity values ranges from 25 to 75 Ohm.m. and consists of sand contains water relatively higher in salinity correlated with the upper aquifer units, with average thickness 150 m.

7- The eighth geoelectrical unit has average resistivity values ranges from 5 to 25 Ohm.m. and its composition is mainly of silt and clay with average thickness reach 180 m.. This unit considered as the bottom of the aquifer.

8- The last and ninth geoelectrical unit which had the highest average values reached up to 5000 Ohm.m. and consists of the basement rocks. The resistivity values changed in some locations according to the percentage of the unconformity weathered surface.

By representing the resistivity measurements for AB/2= 400 m. the contour shows narrow intervals which reflect the limited change in the values which are relatively high and represent the fresh water bearing units (Fig.6).

The Iso-resistivity contour map at AB/2=800m. the map shows gradually decreasing towards the west which reflects the increasing of the thickness of the aquifer towards the east specially in the middle part in the plain (wells area) (Fig.7)

Fig. (8) shows that the El- Qaa plain can be subdivided into the north, middle and south areas, separated by faults that affecting the ground water flow and the ground water quality which can be realized from the contour map of the base of the aquifer. The map reveals that the most thickness of the aquifer appears in the middle part which refers to the highly productivity of the ground water (highly potential area).

By representing the values of the upper surface of the unit which contains the highly saline water (Fig.9), it is clear that the depth to the high saline water is 50m. at the south part area as it appears at Ves 26 but its thickness decreases outwards in the middle and the north part above the base rock of aquifer, and the flow is toward the north which may affects the ground water quality in the middle part to reach between 800 and 1200 ppm., especially in case of increasing the extraction from the wells and / or decreasing of the recharge which come from the wadies from the east mountains side.

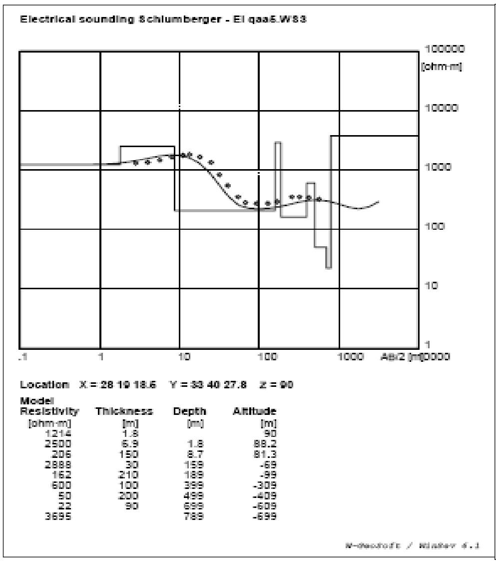


Fig.4a: Vertical Electrical Sounding curves

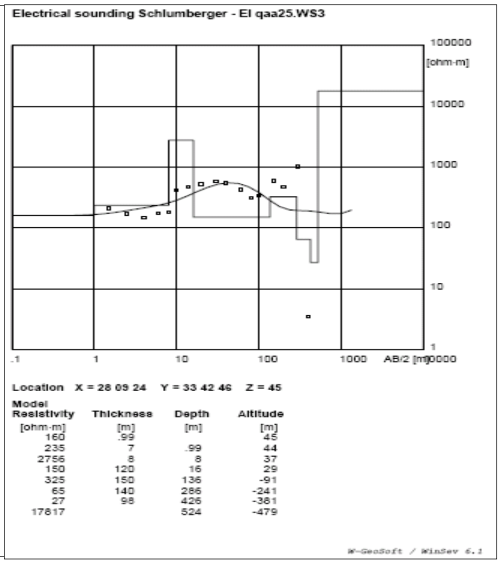


Fig.4b: Vertical Electrical Sounding curves

DRAINAGE BASINS AND QUATERNARY AQUIFER RECHARGE

Wadi Shadk and Wadi Maier are the main drainage basins which play the fundamental roles in the recharge process of the Quaternary aquifer in El-Qaa Plain, qualitative and quantitative analyses have been performed to indicate the contribution of these wadies in the recharge component to the ground water in El-Qaa Plain.

The size of the drainage basin affects on the amount of water yield. The length, shape and relief affect on the water rate and sediment yield while, the character and extent of the channels is effected by the sediment availability and the rate of water yield from the drainage basin.

Table : Morphometric parameters of Wadies Shadk and Maier

Morphometric parameter	Wadi Shadk	Wadi Maier
Area , km2	144.123	215.22
Basin Relief (gradient) "R" m.	2551	2336
Relief Ratio "Rr" m/km.	87.612	93.365
Basin Length "LB" ,km	29.117	25.02
main stream length "Vl" ,km	31.357	33.85
Basin slope , m/km	81.269	93.44
Max.stream slop m/km	76.384	69.01
perimeter , km	81.423	89.858
total.Nu	180	289
total length of streams ,km	261.576	384.767
Bifurcation ratio	3.414	3.900
Width of watershed ,km	4.59	6.358
Stream frequency"horton" , km-2 "F"	1.249	1.343
drainage density"horton" ,km-1"D"	1.815	1.788
Ruggedness number "Rg"	4.629	4.176
Circularity ratio "Rc"	0.273	0.335
Elongation Ratio "Re"	0.432	0.489
Form factor "Rf"	0.169	0.344
sinusity factor “Si”	1.077	1.35
length of over land flow "Lo" ,km	0.275	0.279

The results of these analyses are shown in the above table, the catchments of wadi Shadk and wadi Maier were identified from two topographic sheet of scale 1:100.000, it controlled mainly by the structures (faulting) of the Basement mountains rocks, and elongated in the direction perpendicular to the El- Qaa Plain; it drains rainfall water from high mountains of the Sinai ring in the east to the Gulf plain in the west. It is involving many different kinds of Igneous and Metamorphic rocks distributed in the area, the basin of wadi Maier lies on basement rocks but wadi Shadk has an extension in the sediment of El-Qaa Plain and the sedimentary materials in both wadies present along the streams until it reaches the pediment plan as Quaternary deposits toward the west part. The network is well developed, high dens, and it cover almost the whole area. The drainage pattern along the high lands is coarse dendritic to sub-dendritic and parallel to sub-parallel. And in the relatively low plains the dominant types are sub-parallel, braided and dichotomic.

Generally, stream network of wadi Shadk and wadi Maier are mainly dendritic, sub-parallel and braided which may generate and maximize the runoff volumes, also affected by the sediment transport and the total time of concentration. (Fig.10).

From a hydrogeological point of view and based on the hydro-morphometric parameters, wadi Shadk and Wadi Maier are considered as moderately risk basins.

The estimated losses from the two mentioned wadies which may contribute from the rain fall precipitated on the catchments areas of the wadies can be calculated   using the Soil Conservation Services (SCS equation) as follows:

The SCS-CN method is based on the water balance equation (Mishra and Singh 2003). The method is based on the following three equations:

$$P = Ia + F + Q \qquad (1)$$

$$Q/ P - Ia = F/ S \qquad (2)$$

$$Ia = \lambda S \qquad (3)$$

Where P = total rainfall; Ia = initial abstraction; Q = direct runoff; F = cumulative infiltration excluding Ia; S = potential maximum retention after runoff begins; and λ= 0.2 (a standard value). Equation (2) uses the proportionality concept and equates the ratio of the actual direct surface runoff (Q) to potential maximum surface runoff (P) (or total rainfall) to the ratio of the actual retention (F) (or infiltration) to potential maximum retention (S). Coupling of Eq. (1) with Eq. (2) leads to the popular expression of the SCS-CN method:

$$Q = (P - Ia) 2 / (P - Ia) + S \qquad (4)$$

The potential maximum retention after runoff begins, S, is related to the soil and land use/vegetative cover characteristics of the watershed by the equation:

$$S = (1000/CN) - 10 \qquad (5)$$

Where S is in inch and CN is non-dimensional. The value of CN is derived from the tables given in the National Engineering Handbook, section-4 (NEH-4; SCS 1956) for the catchment characteristics such as soil type, land use, hydrologic conditions, and antecedent soil moisture conditions. By CN value estimation, Calculation of the Maximum retention after runoff begins (S) and the initial abstraction (Ia) which are considered the main component of the losses includes water captured by vegetation, depression storage, evaporation, and infiltration. For any P, this abstraction must be satisfied before any runoff is possible.

CN for wadi shadk equal 65 but for wadi Maier equal 80 by substitution of these values in the equation no.5 the value of S will be 13.76 mm. for wadi Shadk and 6.35 mm. for wadi Maier, which yield 1983132 m3 for wadi Shadk and 1366647 m3 for wadi Maier. These huge quantities of water have a respectable refraction of the infiltration to the ground water which can explain the salinity changes and the iso-apparent resistivity contour maps.

CONCLUSION

According to the above mentioned discussion of the results reached from the interpretation of the resistivity sounding measurements, it can be concluded that:

1- The surface geoelectrical unit is mainly consists of weathered materials and the second geoelectrical unit consists of intercalation of sand with clay with average thickness reach 50m., this unit considered the top of the aquifer while, the third geoelectrical unit consists of medium grained sand with some variations like increasing in the clay percentage in some locations. This unit is one of the main aquifer units and has average thickness of 130m.

2- The fourth and fifth geoelectrical units consist of medium to coarse grained sand containing water, it considered the extension of the aquifer units, with thickness of 150 m. while, the sixth geoelectrical unit is the separation unit between the fourth and the fifth units and according to the increasing in the grain size which causes increasing in the resistivity values up to 700 Ohm.-m with thickness less than 50m.

3- The seventh geoelectrical unit consists of sand and contains water relatively higher in salinity correlated with the upper aquifer units, with average thickness 150m., while the eighth geoelectrical unit is consisted mainly of silt and clay and is considered the bottom of the aquifer. The last and ninth geoelectrical unit consists of the basement rocks and these values changed in some locations according to the percentage of the unconformity weathered surface.

4- The El- Qaa plain can be subdivided into the north, middle and south areas, separated by faults that affecting the ground water flow and the ground water quality, also the most thickness of the aquifer appears in the middle part (the highly potential area).

5- The maps depth to the high saline water is 50 m. in the near the southern part of the Gulf region, but its thickness decreases outwards in the middle and the north part as a result of the feed that comes from the valleys of the eastern mountains.

6- Groundwater quality in the middle part reach between 800 and 1200 ppm. and the quality decreased especially in case of increasing the extraction from the wells and / or decreasing of the recharge which come from the wadies from the east mountains side.

RECOMMENDATIONS

From the present study the following recommendations can be given:

1- Stop drilling any Groundwater productive wells in the wells' field in the central part, with implementing of highly effective management of the aquifer in order to conserve the resource.

2- Increasing the possible recharge amount coming from the wadies in the study area establishing the artificial structures in order to increase the time of concentration of the runoff which lead directly to permit the water to percolate towards the ground water.

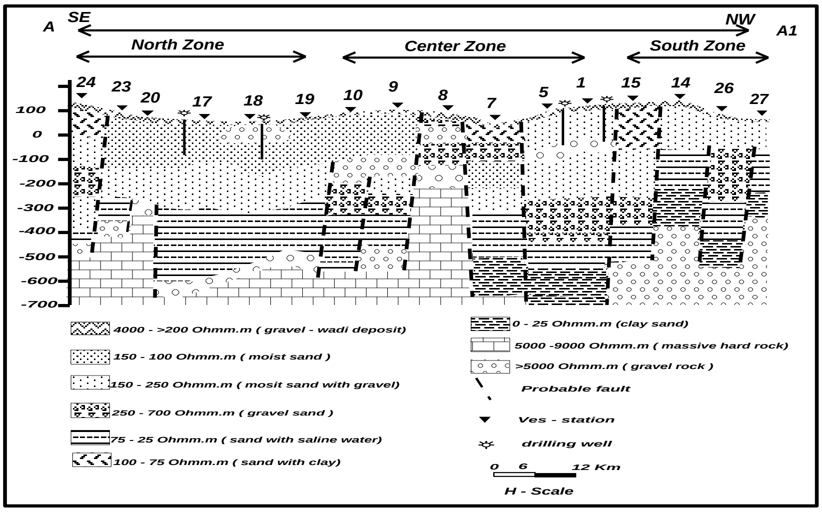


Fig. 5a: Geoelectrical cross section A-A$_1$

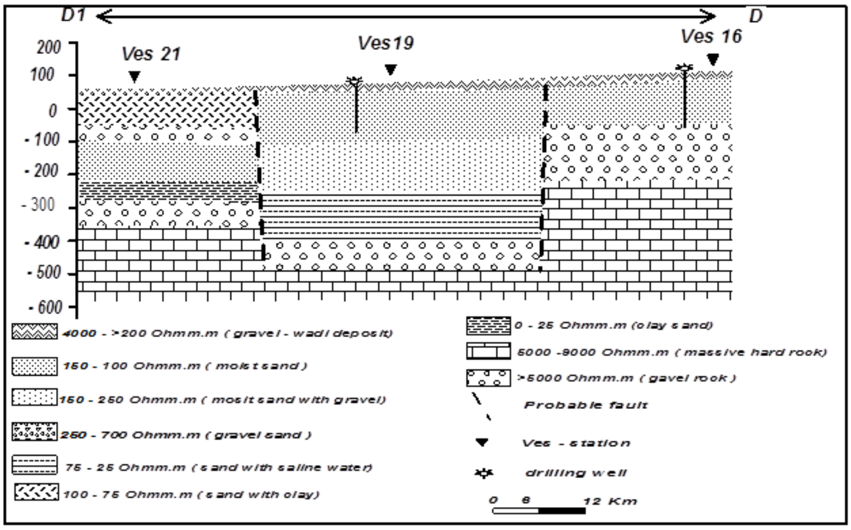


Fig. 5b: Geoelectrical cross section D$_1$-D

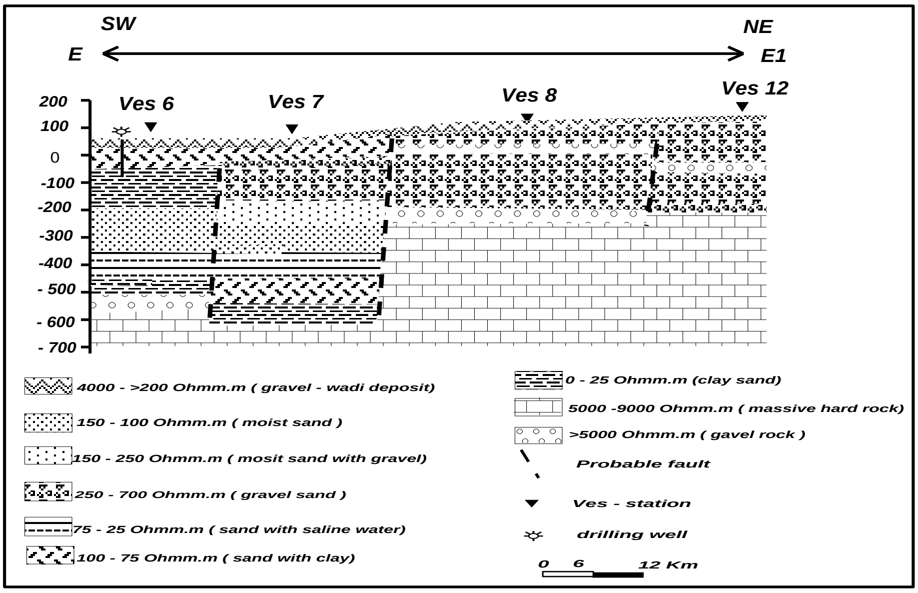


Fig. 5c: Geoelectrical cross section E - E_1

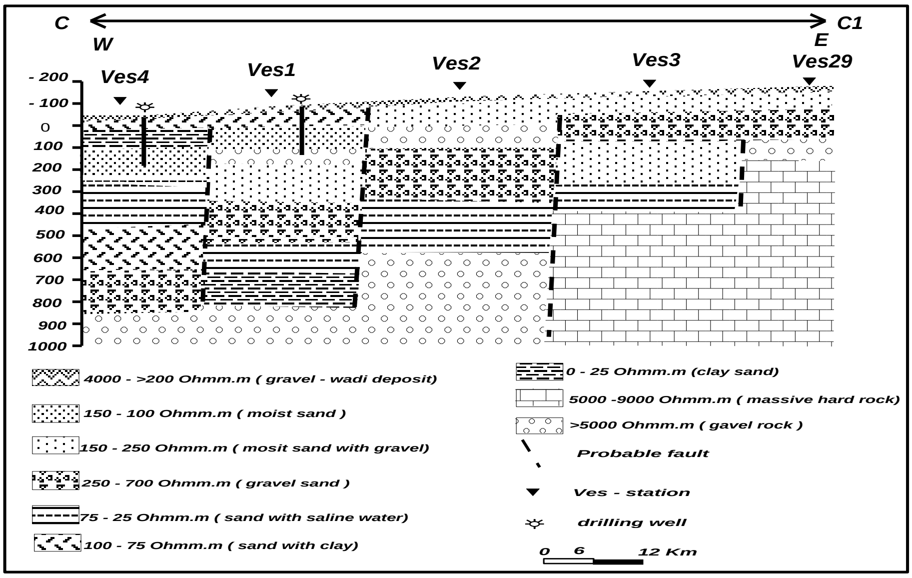
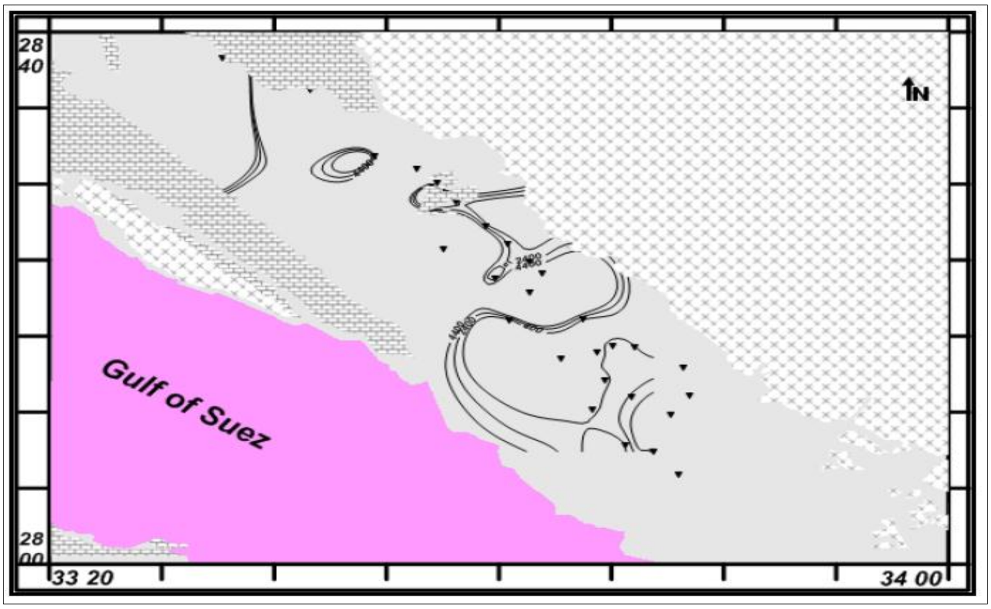
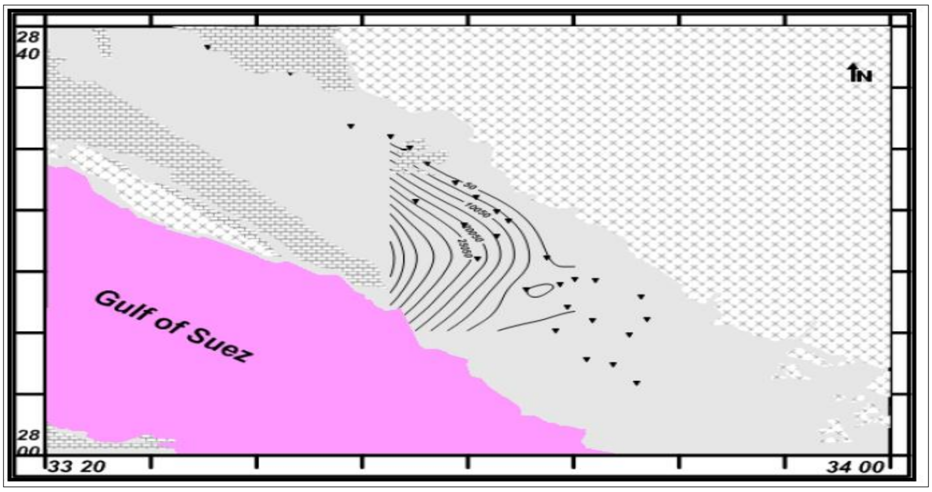


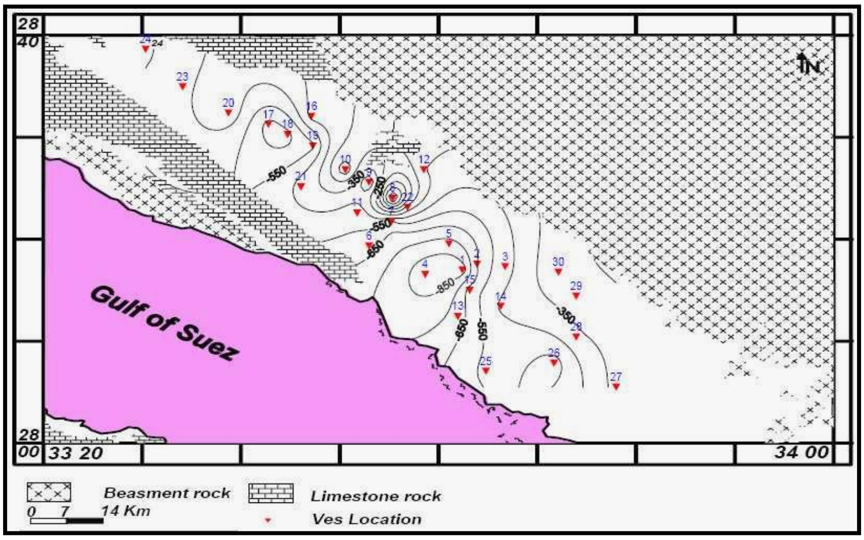
Fig. 5d: Geoelectrical cross section C- C_1



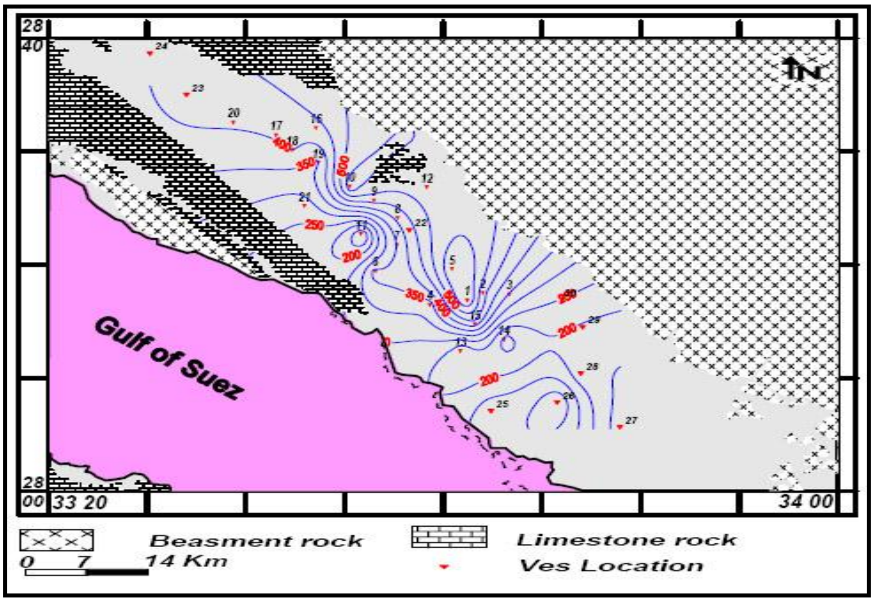
(Fig.6): Iso-Resistivity Contour Map of the AB/2=400m



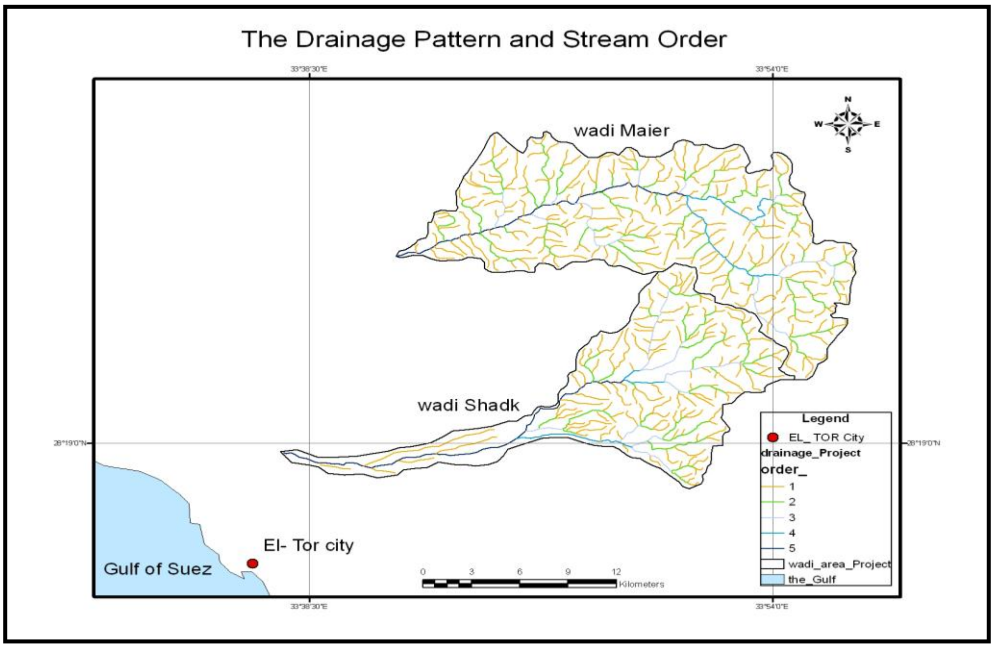
(Fig.7): Iso-Resistivity Contour Map of the AB/2=800m



(fig. 8): contour map of the bottom of the aquifer



(Fig.9): Iso-Resistivity Contour Map of the Upper Surface of the Saline Unit



(Fig.10): the drainage net work of wadi shadk and wadi maier

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تحديد نطاق المياه الجوفية فى الخزان الحديث مستخدما الجسات الجيوكهربية الرأسية بسهل القاع – سيناء - مصر

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تم اجراء عدد ٣٠ جسة جيوكهربية لتغطية منطقة سهل القاع و خضعت تلك القياسات للتحليل الكيفى والكمى واسفرت النتائج عن وجود تسع وحدات جيوكهربية، الاولى سطحية تتكون من الحصى والرمل بقيم مقاومه تتراوح بين ٢٠٠ – ٥٠٠٠ اوم/ متر وسمك يزيد عن ٣متر، تليها وحدة تتكون من الرمل المتداخل مع الطين بقيم مقاومة تتراوح بين ٧٥ الى ١٠٠ اوم/متر وتعتبر الجزء العلوى من الخزان الجوفى، اما الوحدة الثالثة التى تتكون من الرمال المتوسطة الحجم بقيم مقاومة ما بين ١٠٠ - ١٥٠ أوم/متر وسمك يتراوح بين ١٠٠ إلى ١٥٠ متر وتحتوى تلك الوحدة على مياه قليلة الملوحة، تتكون الوحدتان الرابعة والخامسة من حبيبات من الرمل بمقاومات كهربية تتراوح بين ١٥٠ إلى ٧٥٠ اوم/متر وتعتبر هذه الطبقات هى طبقات الخزان الجوفى المحتوي على مياه قليلة الملوحة و يبلغ سمك الطبقتين أكثر من ١٥٠ متر تحتوى الوحدة الجيوكهربية السادسة على حبيبات كبيرة من الرمال بمقاومة كهربية ٧٠٠ اوم/متر وهذه الوحدة غير ممثلة فى كل المنطقة وتتكون الوحدة الجيوكهربية السابعة من الرمل المحتوى على مياه مالحة نسبيا بمقاومة كهربية تتراوح بين ٢٥ الى ٧٥ اوم/متر، اما الوحدة الجيوكهربية الثامنة فتتكون من السلت والطين بمقاومة كهربية تتراوح بين ٥ إلى ٢٥ أوم/متر، تأتي بعد ذلك الوحدة الجيوكهربية الاخيرة لتعطي قراءات عالية أكبر من المقاومة ٥٠٠٠ أوم/متر مما يدل على تكونها من صخور القاعدة.

اكدت الدراسات المورفومترية مساهمة احواض صرف وادى شدق ووادى ميعر في عملية إعادة تغذية المياه للخزان الجوفي الحديث بسهل القاع واوضحت خرائط تساوى المقاومة للخزان الجوفى بمنطقة الدراسة ان الخزان الجوفى بسهل القاع تم تقسيمه الى ثلاث مناطق شمال ووسط وجنوب وذلك بسبب الفوالق بالمنطقة، كما ان المقاومة تناقص تدريجيا نحو الغرب وتقل نحو الشرق وخاصة في الجزء الأوسط في (منطقة الآبار) وان اكبر سمك لطبقة المياه الجوفية يظهر في الجزء الأوسط الذي يتميز بإنتاجية عالية من المياه الجوفية.

تتراوح نسبة الاملاح الذائبة بالمياه الجوفية في الجزء الأوسط لتصل إلى ما بين ٨٠٠ و ١٢٠٠ جزء في المليون. وتزداد فى حالة زيادة الانتاج من الآبار او فى حالة قلة التغذية التي تأتي من الأودية من جهة الجبال الشرقية، لذلك نوصى بإيقاف حفر الآبار الإنتاجية للمياه الجوفية في الجزء الأوسط، مع تنفيذ إدارة فعالة للغاية لطبقة المياه الجوفية من أجل الحفاظ على الموارد، كذلك لابد زيادة كمية التغذية الممكنة القادمة من الوديان في منطقة الدراسة عن طريق إنشاء الحواجزالاصطناعية التى تعيق حركة المياه وتعمل على زيادة الترشح نحو المياه الجوفية.