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APPLICATION OF TRANSIENT ELECTROMAGNETIC METHOD (TEM) FOR GROUNDWATER EXPLORATION IN EL-GALLABA PLAIN, WEST OF KOM OMBO, UPPER EGYPT

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تطبيق طريقة الكهرمغنطيسية لإستكشاف المياه الجوفية

بسهل الجلابة، غرب كوم أمبو – صعيد مصر

الخلاصة: تم اجراء عدد ٦٦ جسة كهرمغنطيسة بمنطقة سهل الجلابة، الواقعة على الضفة الغربية لنهر النيل، إلى الغرب من مدينة كوم أمبو في صعيد مصر، بهدف تحديد المقاومة النوعية الكهربية للتتابع الصخري التحتسطحى وتحديد الطبقة أو الطبقات الحاملة للمياه. وقد تم استخدام جهاز القياس TEM-Fast 48 فى القياسات الحقلية. ولتفسير القياسات الحقلية تم الاستعانة بالوصف الصخرى وتسجيلات الآبار المتواجده بالمنطقة لإنشاء النموذج الأولي لتحليل بيانات القياسات الكهرمغنطيسية. ومن تحليل وتفسير البيانات تم التوصل الي تحديد ست طبقات أساسية تقع في وسط السهل بما في ذلك المكون الحامل للمياه الجوفية بالإضافة الي أربع طبقات أقدم في العمر من السابقة والتي ظهرت علي السطح بفعل التراكيب الجيولوجية في الركن الشمالي الشرقي من السهل. وقد أوضحت القطاعات في اتجاهات شرق– غرب وشمال– جنوب التغيرات الأفقية والرأسية للمعاملات الجيوكهربائية للطبقات المستنتجة (السمك والمقاومة) وأمكن التعرف على التراكيب الجيولوجية التي تؤثر على المنطقة في الاتجاهات المختلفة. تم تمثيل منسوب سطح الطبقة والمقاومة الكهربائية والسمك لبعض الطبقات على هيئة خرائط كنتورية مثل منسوب السطح العلوى لطبقة الطين السفلى، منسوب سطح المياه بالمنطقة، توزيع المقاومة الكهربائية للطبقة الحاملة للمياه، توزيع سمك الطبقة الحاملة للمياه بالإضافة إلى خريطه للتراكيب الجيولوجية المستنتجة. وقد أوضحت خريطة منسوب سطح المياه أن إتجاه سريان المياه من الجنوب إلى الشمال مما يشير إلى إحتمالية تغذية خزان الرواسب الحديثة من الجنوب حيث خزان الحجر الرملى النوبى.

ABSTRACT: *Transient Electromagnetic (TEM) data were acquired at 66 stations in El- Gallaba Plain, which lies at the western bank of the River Nile, to the west of Kom Ombo town in Upper Egypt, in order to characterize the subsurface resistivity structure corresponding to lithological layering succession and water bearing formation/s. TEM data were collected using TEM-Fast 48 system with acquisition software. Lithologic logs and well logging records of some existing water wells have been used to develop the initial model for TEM data inversion. The inversion of the acquired data revealed a lithological succession consists of six major layers at the center of the plain including a water bearing formation and other uplifted four older layers at the northeastern periphery of the plain. The level, resistivity and thickness of some selected layers were displayed in the form of contour maps, such as level contour map of the upper surface of the lowermost detected shale layer, water table map, iso-resistivity contour map and isopach contour map for the water bearing formation as well as a map for the inferred structural elements in the investigated area. Cross sections in E-W and N-S directions enabled recognizing the vertical and horizontal variations in the geoelectrical parameters of the detected layers (thicknesses and resistivities) and their correlation in addition to revealing the structural elements that affect the area in different directions. The water table map derived from the TEM interpretation revealed that the groundwater flow is mainly toward the central part of the plain, with a clear flow direction from south toward north. The alluvial deposits aquifer is likely recharged from the Nubian Aquifer in the south.*

INTRODUCTION

Horizontal expansion in the new lands in the Egyptian desert has long been a key strategic target pursued by successive governments. However, there are still many questions about the possibility of providing water for the reclamation of new land without resorting to the Nile water, at a time when Egypt suffers from severe shortage of surface water resources. Therefore, water experts in Egypt save no efforts to search for new solutions to provide other water resources such as groundwater.

One of the targeted promising new lands for reclamation is El Gallaba Plain which lies in Upper Egypt at the western bank of the River Nile to the west of Kom Ombo town. It is a vast plain with an area of about 5500 km^2 (≈550,000 Hectare).

According to Gaber et al. (2011) the groundwater setting of El-Kubanyia basin (El Gallaba plain) which is located to the Northwest of Aswan City, is still not well understood and need more investigations, therefore, groundwater potentialities remain unknown. Accordingly, the present work is a geophysical attempt to delineate the subsurface geological setting and throw light on the groundwater occurrence in an area of about 2574 km^2 of the concerned plain between Latitudes 24.4^o and 25.0^o N and Longitudes 32.4^o and 32.9^o E with an average E-W width of about 39 km and N-S length of about 66 km (Fig. 1).

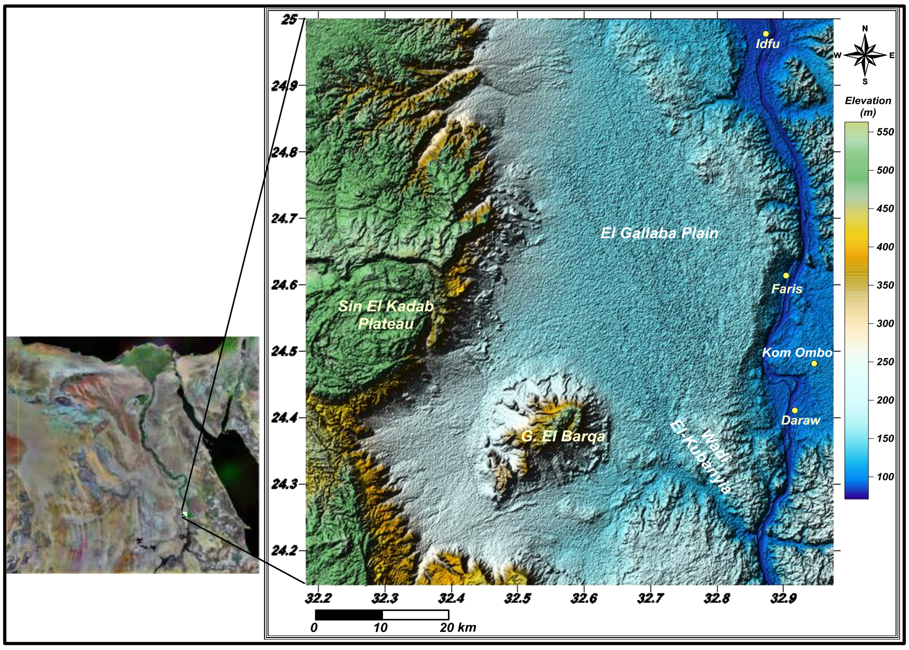

Fig. (1): Location map of the study area.

During the last few years Transient Electromagnetic (TEM) technique has become increasingly popular for hydrogeological purposes with very good findings, especially for mapping aquifer geometry because it is very sensitive to conductive bodies. Much has been published on the TEM geophysical technique, including applications in hydrogeological research (Meju, et al., 2000, Guérin et al., 2001, Danielsen, et al., 2003 and Metwaly et al., 2006). Accordingly, the present work depends on using Transient Electromagnetic (TEM) technique for groundwater exploration over El Gallaba Plain.

GEOMORPHOLOGICAL ASPECTS

Generally, the area belongs to the arid belt of North African which is characterized by arid climate conditions where rainfall is not significant throughout the year except for some rare and irregular storms which take place over different localities during the winter season.

According to Yousif (2019) two main geomorphic landforms are recognized in the study area:

1- Watershed highlands :

a- Plateau

The plateau (Sin ElKadab plateau) with its high elevation that exceed 500 m a.s.l. was formed through geologic structures represented by sets of faults affected its carbonate exposures

b- Isolated hills

The isolated hills are located in the center of El-Kubanyia basin (Gebel El Barqa). Its elevation reaches to 497 m a.s.l. and consists of succession of shale and limestone. Some small hills are noted in the vicinities of Gebel El Barqa forming butts and mesas landforms.

2- Collector lowlands :

a- Nubian and sandy silty plains

The Nubian plain are relatively flat and covered by sandstone and fluvial deposits with an elevation ranging between 170 and 235 m a.s.l. While the elevation of the sandy silty plain ranges between140 and 160 m a.s.l.

b- Drainage lines

The basin of Wadi El-Kubanya represents the main drainage line in the area.

c- Sand dunes

Sand sheet is noted along the scarp of the plateau filling the drainage lines and composed of fine to medium sand.

d- Alluvial fans

The alluvial fans are recorded around the scarp of the plateau where short drainage lines originate from the plateau and flow to the sandy plain. These alluvial fans composed of friable weathered products of the plateau (limestone and dolomite fragments), with elevation of about 160 m a.s.l.

e- Depressions

One depression is recorded between two blocks of the plateau with elevation reaches 450 m a.s.l. This depression is thought to be formed due to tectonic movements.

GEOLOGICAL SETTING

The general geologic setting in the study area and its vicinities has been investigated by many authors such as Said (1962); Zaghloul et al. (1983); Hewaidy and Soliman (1993); Issawi and Osman (1996); Issawi et al. (2009) and Yousif (2019). The stratigraphic sequence of the area, from Aswan to El Galaba plain, ranges in age from Pre-Cambrian to Quaternary (Fig. 2). The Pre-Cambrian rocks consist mainly of igneous and metamorphic rocks. A short distance to the north of Aswan the igneous rocks do not show above ground. The sedimentary section overlying the basement complex ranges in age from Paleozoic to Recent. According to the geologic map of Egypt (Luxor sheet), CONOCO (1987) (Fig. 2) and Yousif (2019), the exposed rock units in the study area from base to top include the following:

Upper Cretaceous: It is formed of the following geologic formations:

- *Abu Aggag* Formation (Nubian sandstone), that consists of coarse sandstone with mudstone intercalations.
- *Timsah* Formation (Nubian sandstone), which is made up of siltstone, sandstone, and shales with iron ore bed.
- *Um Barmil* Formation (Nubian sandstone), that is composed of medium sandstone with claystone intercalation.
- *Quseir* Formation, which consists of Varicolored shale, siltstone and sandstone.
- *Duwi* Formation, which consists of glauconitic sandstone with grey shale.
- Keseiba Formation, which consists of fine grained sandstone with shale and silt intercalations.

Tertiary: It is formed of the following geologic formations:

- *Dakhla* Formation (Paleocene- Eocene), which is made up of laminated shale.
- *Kurkur Formation* (Paleocene), that is mainly dolomitic and marly limestone.
- *Garra Formation* (Paleocene), that is made up of limestone, partly chalky and intercalations of marl and shale.
- *Thebes group* (Lower Eocene) which consists of earthy brown grading into greyish white limestone with chert.

Quaternary:

It represents the youngest deposits in the study area and consists mainly of alluvial sediments (mixture of gravels, sands, silts and mud).

Structurally, the study area is situated within the African Platform with its Pre-Cambrian folded basement, thus its tectonic framework is related to the Last African Orogenic belt (Said, 1962; Abd El-Razik and Razavaliaev, 1972). The study area is a part of the Nile Valley in Egypt which is, entirely, controlled by wrench faults that are generally parallel either to the Gulf of Suez or the Gulf of Aqaba directions (Youssef, 1968).

TEM DATA ACQUISITION

The TEM technique is a fast and cost effective method which can be performed in different types of configurations, no direct electrical contact with the ground is required and the obtained depth range from the top few meters to hundreds of meters. Theoretically, the transient electromagnetic method (TEM) is an inductive method that utilizes strong current which is passed through a rectangular loop commonly laid on the surface of the ground. The flow of this current in the surface loop will create a magnetic field that spreads out into the ground in the form of a primary magnetic field and induces eddy currents in the subsurface. When the current is abruptly terminated, this primary magnetic

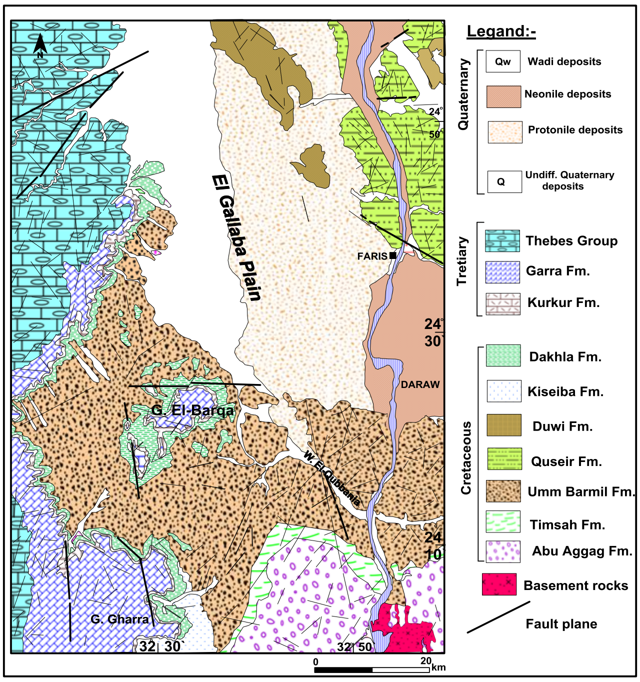

Fig. (2): Geological map of the study area (modified after CONOCO, 1987).

field is time varying and in accordance with Faraday's law, there will be an electromagnetic induction during this time. This electromagnetic induction in turn results in eddy current flow in the subsurface. The intensity of these currents depends on ground resistivity at a certain time and depth (Kaufman and Keller, 1983).

For acquiring the TEM data in the present work, the TEM-Fast 48 system from AEMR Ltd. was used. It is a robust geophysical tool providing efficient operation in several environmental noisy conditions. A total of 66 TEM soundings were acquired in 66 different locations in a detailed survey grid all over the study area (Fig. 3) using a single loop 200 *200 m (loop size). The measurements were acquired with setting the time range of measurement of transient characteristics to 7 or 9. This parameter is essential because high values correspond to distorted results and low values can result in loss of information about the late stages of transients. To improve quality of collected TEM measurements in case of noise existence, the induced current in the loop was set to 4A and the frequency of the filter was set to 50 Hz.

The acquired TEM data were filtered, smoothed and converted to apparent resistivities versus time (ρ and t) prior to inversion process. Examples of the field data is given in Figure (4).

RESULTS AND DICUSSION

Inversion of the field data was made by the computer software IX1D V.3.39 (2008), it is a software package for Windows which allows for forward and inverse (1-D) modeling of resistivity data, MT, Frequency EM and TEM data. The software allows data to be imported from generic ASCII or CSV files.

The geological information derived from the lithological description and well logging records of the existing wells in the study area were used to parameterise the initial interpretation model of the TEM data and to convert the resulting layer resitivity to its corresponding lithology. The lithological and well logging records of the existing water wells are shown in (Fig. 5).

The inversion of the TEM data revealed that there are two groups of layers have been detected in the study area. The first group (I) consists of a sequence of six layers which dominates most of El Gallaba plain, whereas, the second group (II) consists of a sequence of older four other layers forming an uplift in the north-eastern part of the study area. The resistivity range of the encountered layers, their corresponding lithology and the litho-stratigraphic formation to which the layer is, most probably, related are given, from top to base, in Table (1). Some anomalous resistivity values (2.7 Ohm.m in some localities and reach 36 Ohm.m in other localities) within the same layer have been detected at several localities. These anomalies can be attributed to lithological facies changes.

The results of the interpretation of the TEM soundings (resistivities and thicknesses) have been illustrated in the form of 2D visualization cross sections according to their corresponding geologic units. The depicted cross- sections A-A', B-B' C-C' and D-D' in Figure (6) show the lateral and vertical extension of the different layers in W - E direction and the cross section (E-E'), in the same figure, traverses the central part of El Gallaba plain in N – S direction.

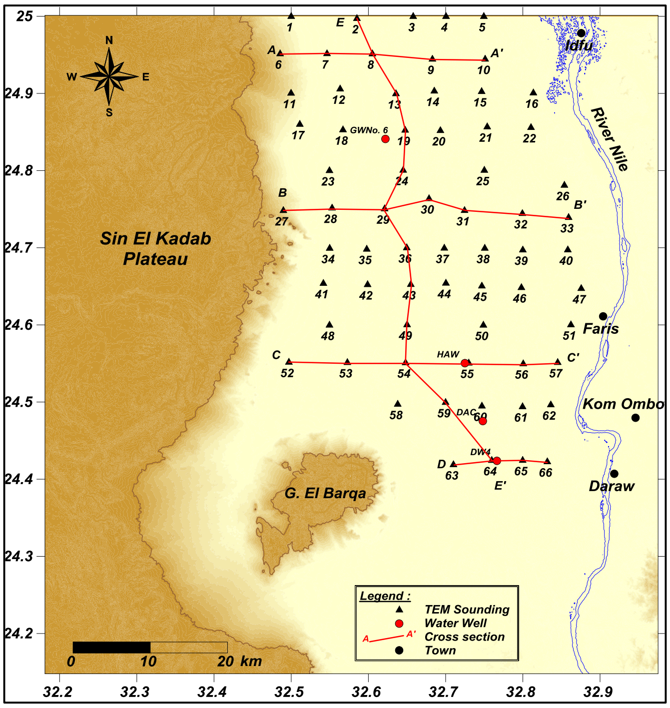

Fig. (3): Location map of TEM soundings, water wells and cross-sections.

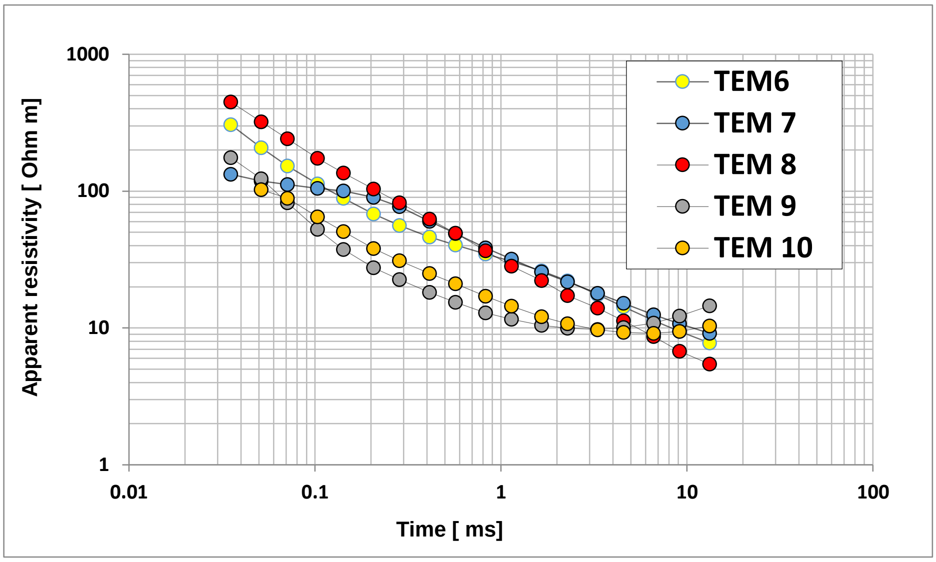

Fig. (4): Examples of some measured TEM data.

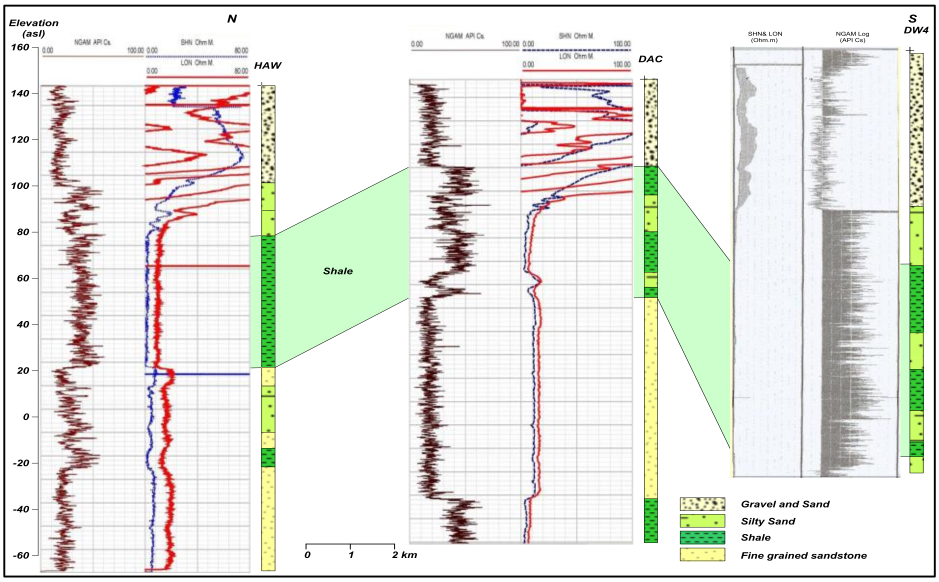

Fig. (5): Diagram showing the Lithologic logs and well logging records of some existing water wells in the study area.

Table (1): Resistivity range of the encountered layers, their corresponding lithology and the litho-stratigraphic Formations to which layers are, most probably, related (from top to base).

Group	Layer No.	Resistivity range	Corresponding lithology and Formation
I	1	400 – 1200 Ohm.m	Gravels and coarse sand (alluvial deposits, Quaternary)
	2	2 – 4 Ohm.m	Clay (alluvial deposits, Quaternary)
	3	100 – 300 Ohm.m	Sand (alluvial deposits, Quaternary)
	4 a	15 – 60 Ohm.m	Silty sand (alluvial deposits, Quaternary)
	4 b	5 – 12 Ohm.m	The lower part is a water bearing formation
	5	2 – 4 Ohm.m	Shale (Dakhla Shale)
	6	9.5 – 10.5 Ohm.m	Fine grained sandstone (Keseiba Formation)
II	1	90 – 240 Ohm.m	Sandstone (Duwi Formation)
	2	10 – 26 Ohm.m	Silty sandstone (Qusseir Formation)
	3	4 – 8 Ohm.m	Sandy siltstone (Qusseir Formation)
	4	34 – 52 Ohm.m	Sandstone (Umm Barmil Formation)

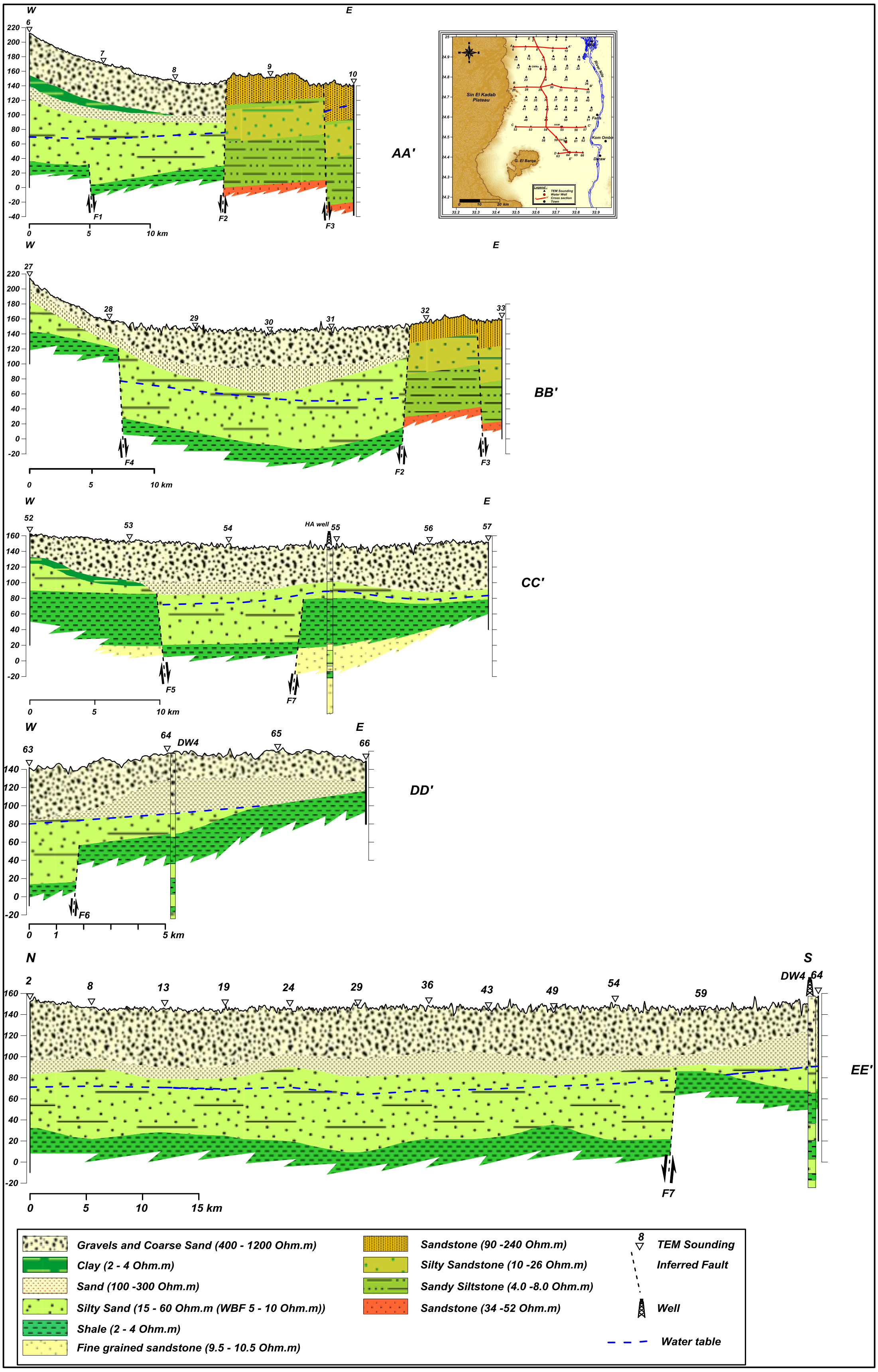

Fig. (6): Geo-electromagnetic Cross- sections (Cross- sections A-A', B-B', C-C' and DD' in W-E direction Cross- section E-E' in N-S direction).

The cross- sections show the horizontal and vertical extensions of the detected water bearing formation, the vertical relative displacement of layers due to faulting and the water table. The most important structural effect is represented (at the eastern side of the cross- sections A-A' and B-B') by the uplifted older layers of group II (layers 1, 2, 3 and 4) which, may, correspond to Duwi Formation and the underlying formations in front of the relatively younger Quaternary deposits. It is worth noting that, existence of these older formations is evidenced from the geologic map of the area (Fig. 2).

In order to provide clear insights into the structural configuration in the investigated area, the level of the upper surface of the shale layer (layer 5 in Group I) which corresponds to Dakhla Shale is selected to illustrate a level contour map (Fig. 7). This map delivered significant information concerning the structural elements that affect the study area and the groundwater occurrence within the overlying Quaternary deposits.

From the level contour map (Fig. 7), it is clear that the upper surface of the shale layer has not been detected along a North- West trending strip at the northeastern part of the area. As mentioned before, and evident on the cross- sections AA' and BB' this strip is occupied by the uplifted older group of layers (Group II). In the main plain, the shale layer shows a gradual, sometimes, abrupt decrease in level from the southeast and southwest of the area toward the central and northern part of the plain.

According to the abrupt changes in the level of the upper surface of the shale layer along with the correlation of the detected layers on the cross- sections, the structural elements have been inferred and depicted in Figure (8). From this map, it is obvious that the inferred group of normal faults throw down toward the center of the plain forming a graben- like structure.

As mentioned before, the relief of the shale layer surface and the structural elements control the groundwater occurrence in the study area. The shale layer represents the base of the alluvial deposits water bearing formation (layer 4 b). The faults contributed to existence of the shale layer at a higher or lower level and hence, forming the boundaries of the water bearing formation.

The water table map shown in Figure (9) indicates that there is a clear groundwater flow from the south (at Wadi El-Kubanyia) toward the central part of the plain in the north. The low level of the shale layer at that locality (as shown in Figure 7 and in cross section DD') along with the groundwater flow direction indicate that the alluvial deposits aquifer is likely recharged from the Nubian Aquifer in the south. Occurrence of groundwater at the northeastern part of the area is due, mainly, to seepage of irrigation water of the cultivated area at that location.

The water bearing formation has a resistivity ranges from 5 Ohm.m to 12 Ohm.m. The iso-resistivity contour map of the water bearing formation (Fig. 10) can give a preliminary qualitative perception about the relative preference of the water salinity throughout the water bearing formation. From this map, it is obvious that the groundwater salinity in the northern and southern parts of the area is less than central part. It has to be mentioned that, the electrical resistivity is also affected by the lithologic composition of the formation. The thickness of the water bearing formation varies from 4 to 66 m (Fig. 11). The water bearing formation attains its maximum thickness at the southern and the central parts of the plain.

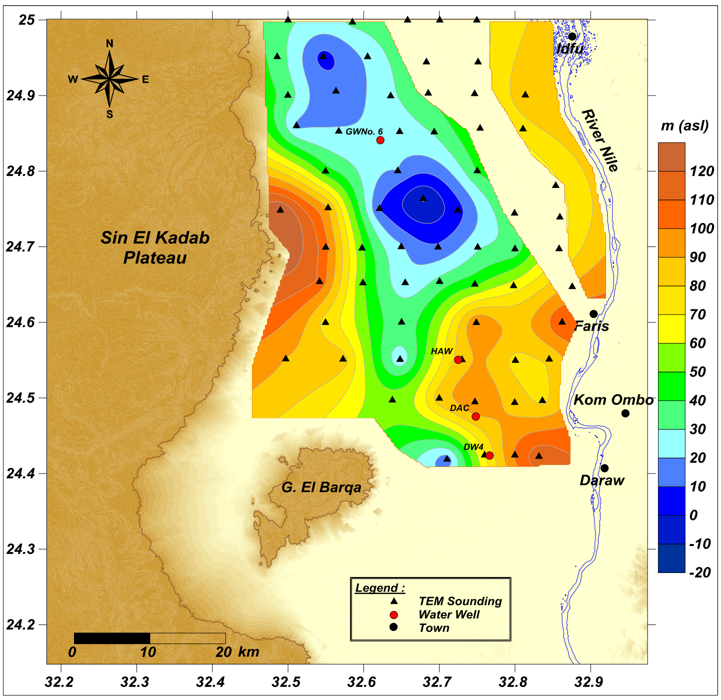

Fig. (7): Level contour map of the upper surface of the shale layer (Dakhla Shale).

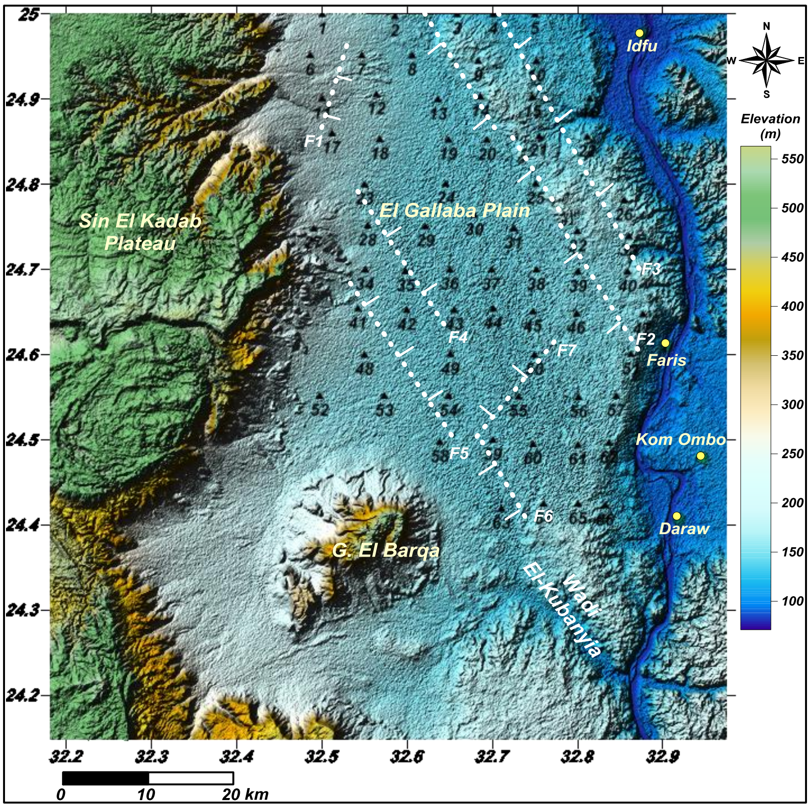

Fig. (8): Inferred structural elements in the study area.

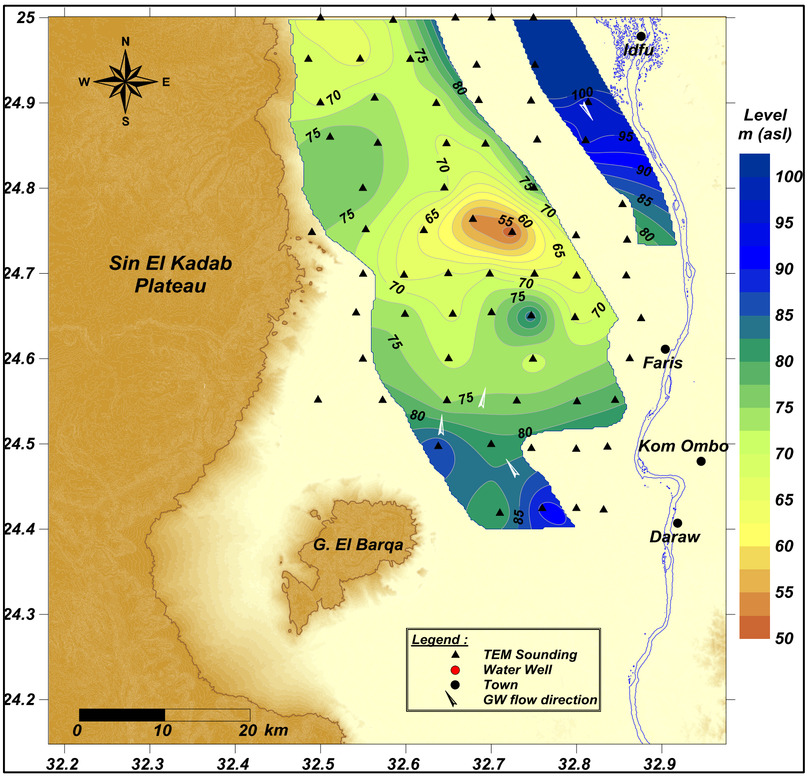

Fig. (9): Water table contour map in the study area.

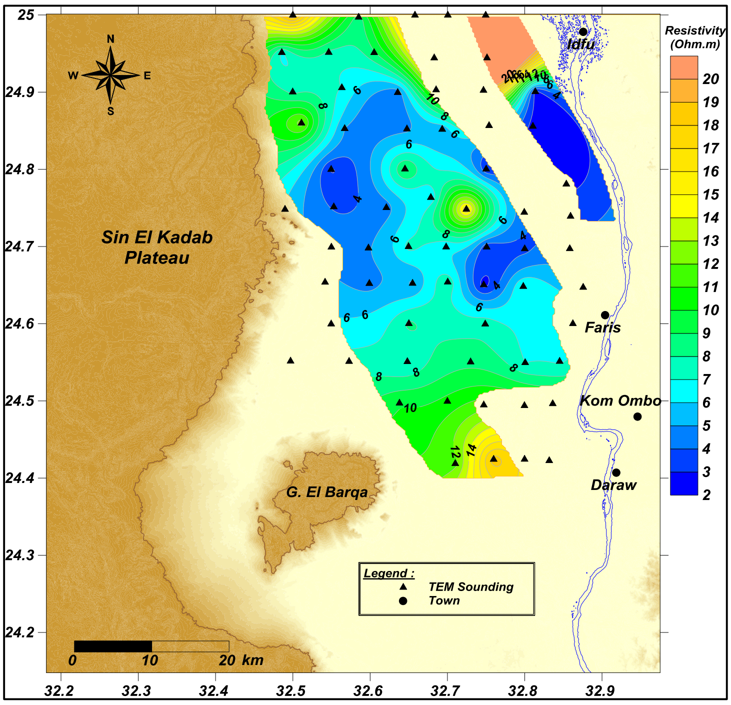

Fig. (10): Iso-resistivity contour map of the water bearing formation in the study area.

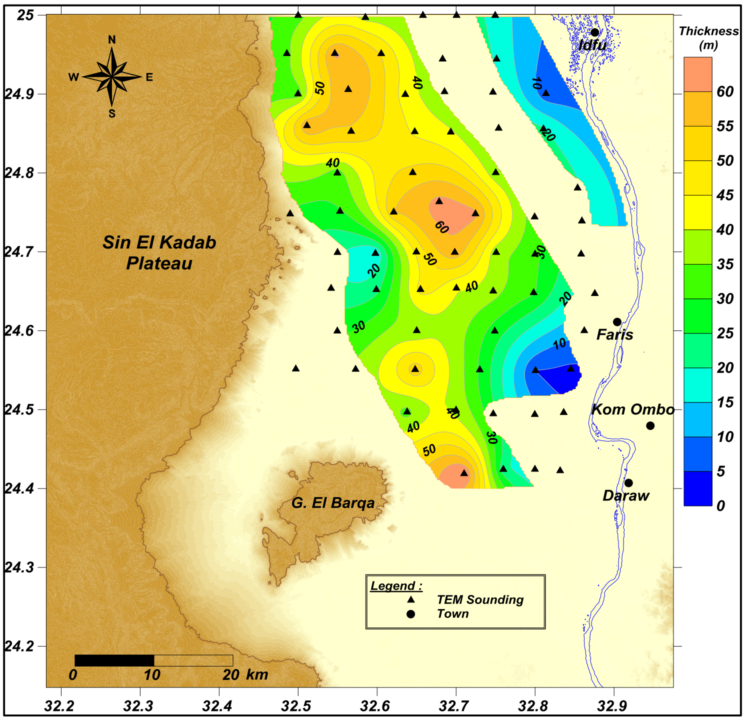

Fig. (11): Isopach contour map of the water bearing formation.

CONCLUSIONS

Application of the Transient Electromagnetic method (TEM) to groundwater exploration in El-Gallaba Plain, West of Kom Ombo, Upper Egypt lead to the identification of the subsurface layering succession including the water bearing formation and delineation of the conditions that contribute to groundwater recharge and occurrence in the study area. The results indicated that groundwater exists in the lower zone of the Quaternary alluvial deposits. The shale layer which is likely to be El-Dakhla Shale forms the base of the aquifer. The water table map indicates that there is a clear groundwater flow from the south (at Wadi El-Kubanyia) toward the central part of the plain in the north. The low level of the shale layer at that locality along with the groundwater flow direction indicate that the alluvial deposits aquifer is likely recharged from the Nubian aquifer in the south. Occurrence of groundwater at the northeastern part of the area is due, mainly, to seepage of irrigation water of the cultivated area at that location.

From the distribution of the resistivity and thickness of the water bearing formation, sites for drilling productive water wells can be located at the southern and northern parts of the study area.

The investigated area with its groundwater potential can be considered as a promising area for reclamation.

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