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Integrated geoelectrical and hydrogeological studies on Wadi Qena, Egypt

Ahmed G. Abd El_Hameed [a,*], Hassan M. El-Shayeb [b], Nahed A. El-Araby [c], Mostafa G. Hegab [d]

[a] Survey of Natural Resources Department, ESRI, University of El-Sadat City, Egypt
[b] Head of Geology Department, Faculty of Science, Menofiya University, Egypt
[c] National Water Research Center (NWRC), Egypt
[d] Research Institute for Groundwater (RIGW), National Water Research Center, Egypt

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ABSTRACT

The study of ground water resources in the arid regions has a great importance to the scarcity of water resources. So, the present work aims to identify the main aquifers in south Wadi Qana area. Wadi Qana is a wide valley in western desert and extending southwards for some 170 km from the South Galala Plateau to its broad fanning delta located on the Nile Valley plain east of Qena town. Fifty-four Vertical Electrical Soundings (VES) were measured in the study area by using AB/2 ranging from 1.5 to 1000 m. The quantitative interpretations of the field curves exhibited four geoelectrical successions and each succession is formed of seven geoelectrical units and there are two main water-bearing units act as aquifers, where the third geoelectrical unit appears in the south of the study area act as Quaternary aquifer and the sixth geoelectrical unit appears in the north of the study area act as Nubian aquifers. Ten water samples have been analyzed for different water quality parameters. The results reveal that TDS values are more than 1000 ppm where groundwater becomes unsuitable for drinking and other domestic uses and could be used for irrigation and some industrial activities under certain precautions.

1. Introduction

The population density in Egypt is concentrated in the Nile Valley and Delta, which represents 10% of the land of Egypt while it decreases in Desert parts of Egypt. The existence of groundwater potentialities permit to the execution of reclamation projects, Therefore, the study of groundwater resources in the arid regions of the western desert has a great importance to the scarcity of water resources.

Wadi Qena is a wide valley extending southwards for some 170 km from the South Galala Plateau to its broad fanning delta located on the Nile Valley plain, east of Qena town. The width of Wadi Qena ranges from 30 km to less than 5 km. The wadi is characterized by many ridges and high terraces with their longer axes parallel to the main course. These features represent several stages in the down-cutting of the wadi. They are mostly covered by fine silt and capped by dark desert-varnished gravels. A measure of the large sediment load carried by the Qena River during its active history is given by the area of its delta (600 km2), which may have extended also to the silt deposits west of the Nile there (Issawi, 1983).The studyarea lies in the southern part of wadi Qena between Latitudes 26°15′00″ and 27°14′00″N and Longitudes 32°41′00″ and 33°08′00″E (Fig. 1).

The present work deals with the use of geoelectrical and hydrogeological methods to study groundwater aquifer in the southern part of Wadi Qena area located in the Eastern Desert.

1.1. Geological setting

Several geologic, hydrogeological and geophysical studies were carried out by many authors such as Said (1981), Abu El-Ella (2004), Elewa et al. (2006), Elmalt (2008), El-,Shami (1988),

* Corresponding author.
E-mail address: ahmed.esri@gmail.com (Ahmed G. Abd El_Hameed).

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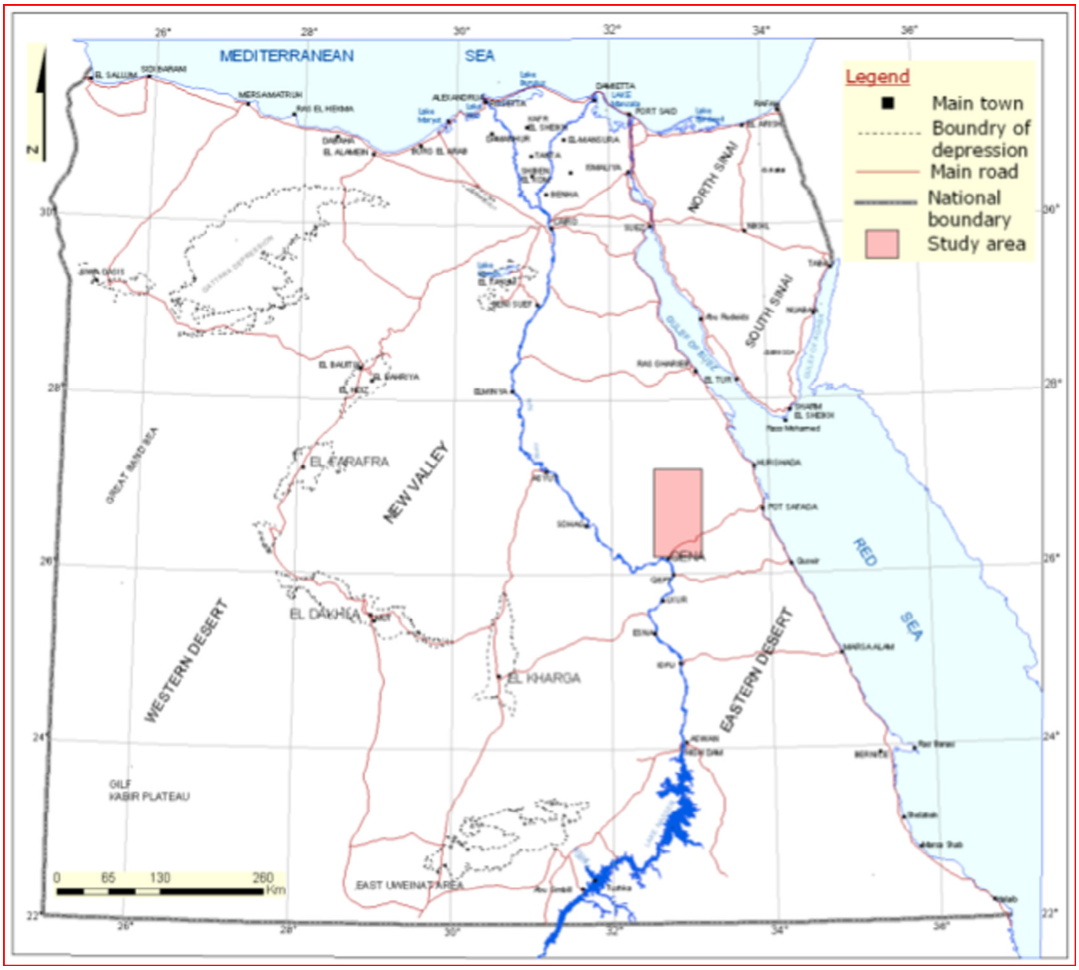

Fig. 1. The study area location map.

Aggour (1997) Hassan (1985) El-Hussaini et al. (1994), Galal (2005), Abdel Gowad (2010), Wilmsen et al., 2012, Seleem et al. (2013), Seleem (2014) and Abdel Moneim et al. (2015)

1.2. Geomorphology

Elewa et al. (2000) pointed out that the area of Wadi Qena basin divided into the following main landforms:

1. Platforms.
   (a) Limestone Plateau is dissected and consists mainly of beds of hard, jointed and fractured limestone. A flat-topped surface at Gebel Aras (524 m a.s.l.) represents a hard, massive, structurally controlled landform and provides a suitable catchment area.
   (b) Plateau of Nubian Sandstone is mainly composed of hard, massive sandstone beds forming dissected patches. These patches contain some beds of clay sand iron oxides that highly affect the groundwater conditions and quality. Also, This plateau is cut by few main faults.
2. At the northeast corner of the investigated area, Tors is appear as a small part and represents Precambrian basement rocks exposures. Also, they are highly weathered and represent a part of the groundwater aquifers catchment areas
3. Fault Scarps: The area is affected by structural disturbances that created major fault scarps with steep slopes (38° - 75°). These scarps moderate to trend NW-SE and N-S.
4. Alluvial Deposits
   (a) Alluvial Fans which are dispersed in the area of investigation due to the presence of fault scarps inducing topographic difference between the plateaus and the wadis. These fans are composed mainly of sands, clay and gravels.
   (b) Flood Plains which are nearly flat and completely cultivated. It belongs to the Pre-Nile and is of Quaternary age (Said, 1981) and is composed mainly of mud, silt and clay with some sands.

1.3. Stratigraphy

The area under investigation is formed of a sedimentary succession composed simply of Nubia Sandstone (at the base) overlain by a shaly sequence (Quseir Shale) intercalated in its lower part with two phosphorite horizons at Gabal Abu Had and by a phosphatic oyster bed in the southern part at Wadi Hamama. The Duwi Formation conformably overlies the Quseir Shale, and constituted of three phosphorite beds intercalated with shale, marl and sandstone. It is overlain by a succession of siliciclastics divided by the Tarawan Chalk (6 m thick) into Dakhla Shale (below) and Esna Shale (above). The Esna Shale is capped by Lower Eocene limestone which forms the surface of the plateau (Ahmed, 1983).

Dealing with the sedimentary succession present at Wadi Qena area, Ahmed (1983) established the following lithostratigraphic units which he compiled from the proposed lithostratigraphic classifications of Ghorab (1956), Youssef (1957), and said (1961, 1962):

Thebes Formation	Early Ypresian - Late Ypresian
Esna Shale Landenian	Early Ypresian
Tarawan Chalk	Landenian
Dakhla Shale	Maestrichtian - Landenian
Duwi Formation	Maestrichtian
Quseir Shale	Campanian - Maestrichtian
Nubia Sandstone	Pre - Campanian

The age of different lithostratigraphic units was assigned after Abdel Razik et al. (1972) and Faris (1974). The following is a brief description of the geologic units which appear in Wadi Qena (Figs. 2 and 3). Also, Fig. 3 shows Quaternary Deposits which consist of gravels, silt, and sand.

1.4. Structural setting

Wadi Qena represents a large wide and long drainage line that begins at the southern slopes of the southern Galala massif (upstream) and extends in N-S direction where, it drains into the Nile at Qena town (downstream). According to the EGSMA (1983), WadiQena can be considered as an anticlinal structure plunging due south. Several faults affect the wadi and its tributaries. These faults take trends N-S, NNW-SSE, NNE-SSW and NE-SW. The most effective trend is the NW-SE (Elewa et al., 2000).

2. Electrical resistivity prospecting

Groundwater investigation is very important processes to record the changes of subsurface in the study area and detect

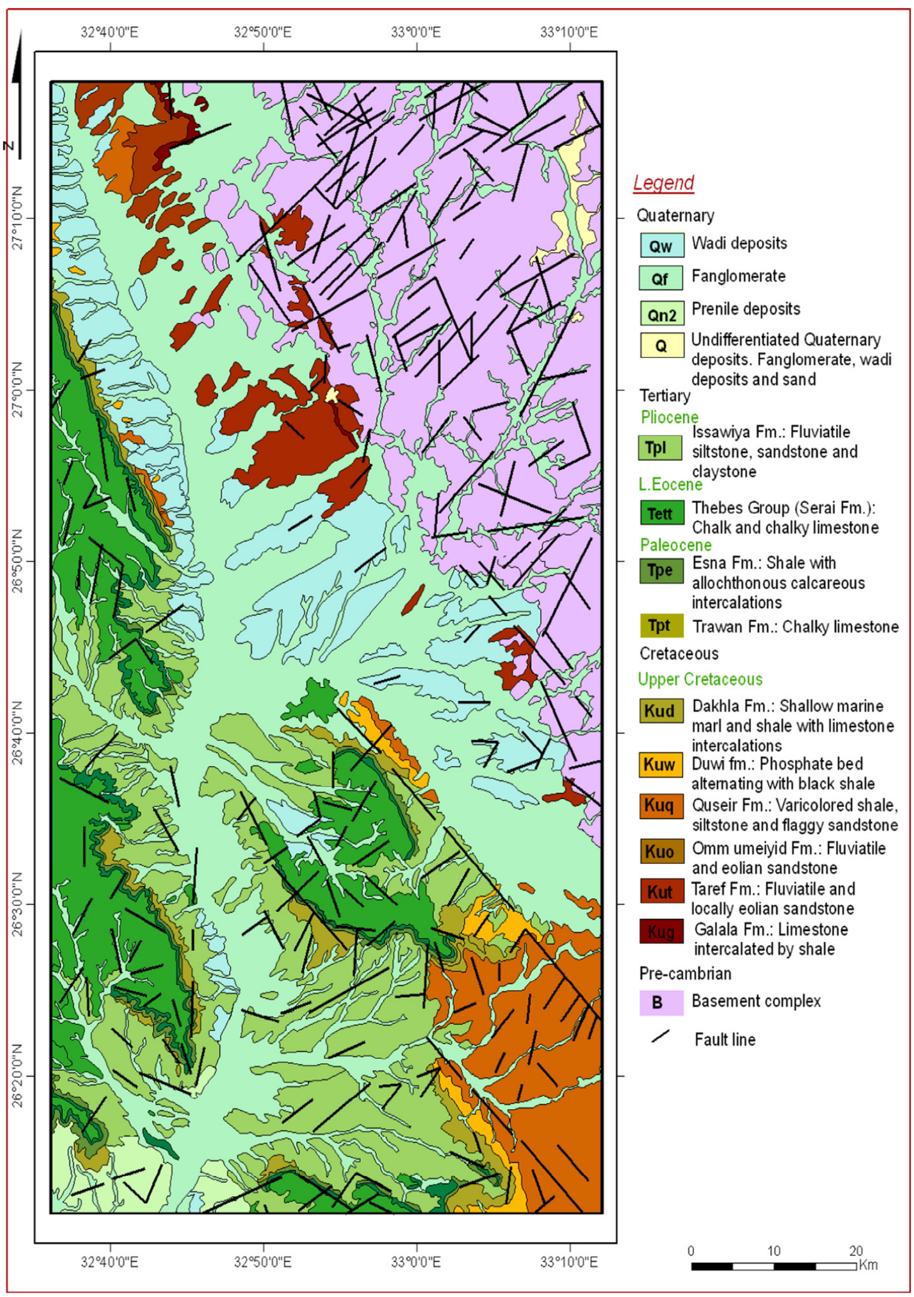

Fig. 2. Geologic map of the study area (After Conoco, 1987).

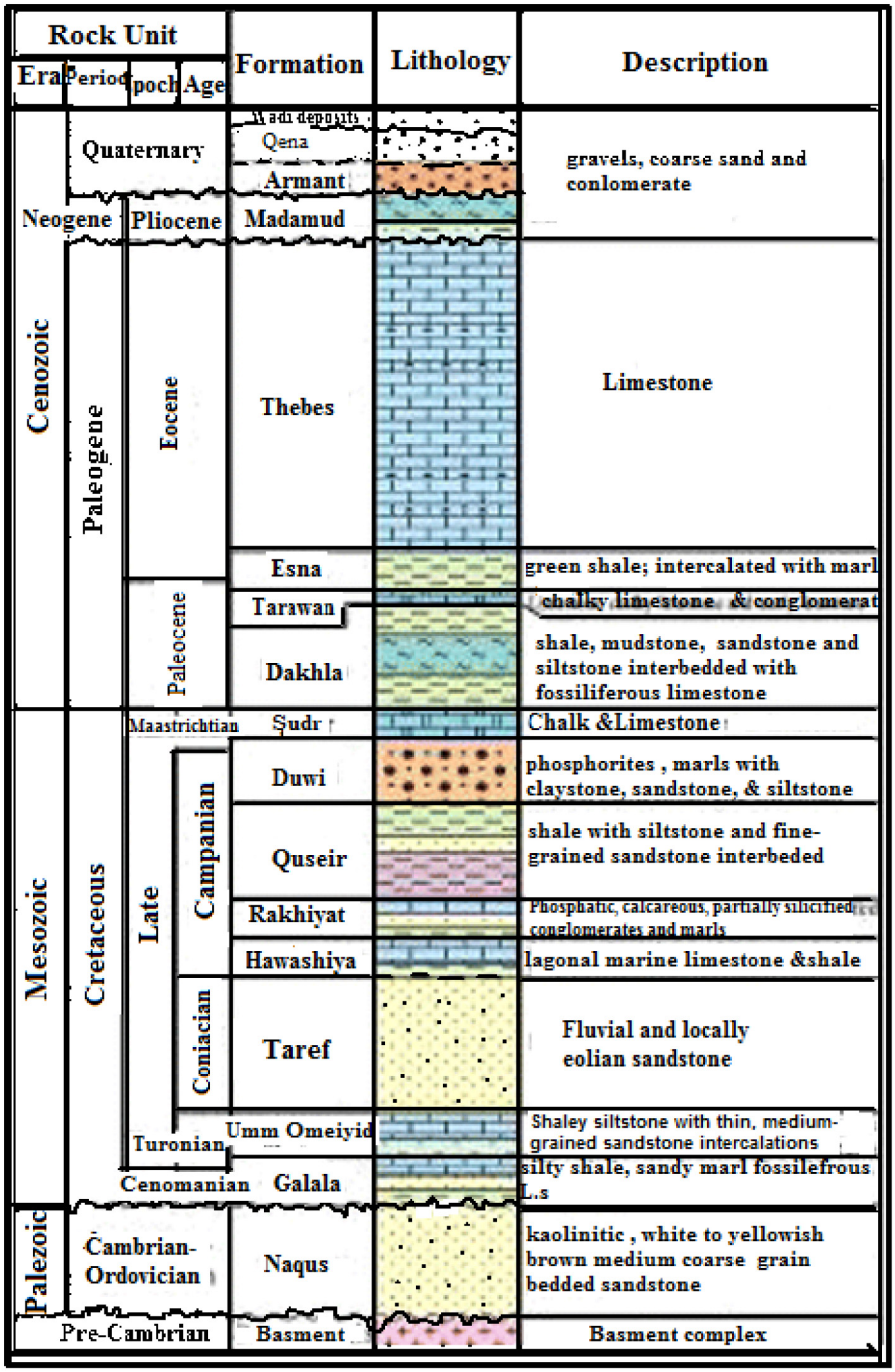

Fig. 3. Lithostratigraphic columnar section of Wadi Qena (modified after CONOCO, 1987; EGSMA,1983, 2006).

any probable influence on thickness of the sedimentary successions and on groundwater. Fifty-four Vertical Electrical Sounding stations of Schlumberger array have been carried out in the study area distributed on four cross-sections (Fig. 4). The current electrode spacing (AB) starts from 1.5 m. up to 1000 m. in successive steps. The "Terrameter SAS 300C" resistivity meter was used for measuring the apparent resistivity with high accuracy. Some of electrical sounding stations were measured close to the hand dug, drilled water wells to construct geoelectrical interpretation models based on the available geological and hydrogeological data of nearby wells.

2.1. Interpretation

The vertical electrical soundings were quantitatively interpreted using IPI2WIN (2005) program. The apparent resistivity sounding curve begins by defining the curve shape. This can be classified simply for three electric layers into one of four basic curve types which are H ($\rho1 < \rho2 > \rho3$), A ($\rho1 > \rho2 > \rho3$), K ($\rho1 > \rho2 < \rho3$) and Q ($\rho1 < \rho2 < \rho3$). These can also be combined to describe more complex field curves that may have several layers such as HK or KH types. The number of layers identified is equal to the number of turning points in the curve plus one (Renylods,

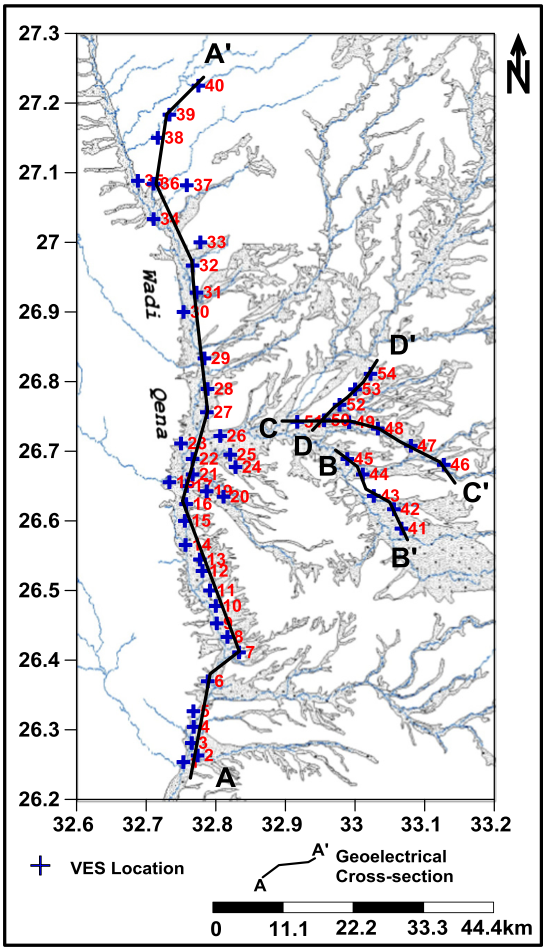

Fig. 4. The Location of both VESes and the Geoelectrical Cross-sections in the Study Area.

1997). Fig. 5) shows examples of field Vertical Electrical Sounding curves was measured along the area of study and Table 1 shows Results of interpretation of the vertical electrical soundings. The interpreted data was used for drawing four cross-sections named AA′, BB′, CC′ & DD′ take South-North direction, SW-NE direction, SE-NW direction and SW-NE direction, respectively. Each section shows the geoelectrical sequence, lateral and vertical resistivity variations that reflect the changes of lithology of the different layers and the impact of groundwater along the profile direction. Figs. 6–9 shows geoelectrical cross-sections AA′, BB′, CC′ and DD′ where the sequence of the study area can be divided into seven geoelectrical units.

2.2. The description of the geoelectrical units is as follows

1. The surfacial geoelectrical layer has resistivity values range from 35 Ohm.m to 740 Ohm.m. This layer is formed of rock fragments, with coarse sand which cover the surface. The thickness of this layer ranges from 4 m to 25 m. This geoelectrical layer is found at all VESes in the study area.
2. The second geoelectrical layer is found at all VESes in the study area except VESes. 52, 53 & 54 (Fig. 9). This layer has resistivity values range from 18 Ohm.m to 460 Ohm.m. This wide range in resistivity values is due to the expected intercalation of clay and silt with sand and gravel. This layer may consist of gravel, sand and some clay at some VESes. The thickness of this layer ranges from 6 m to 67 m.
3. The third geoelectrical layer has resistivity values range from 115 Ohm.m to 790 Ohm.m. This layer may form of gravels, boulders of limestone and some sand and silt. The thickness of this layer ranges from 50 m to 160 m. Fig. 6) shows that this layer is found at all VESes except VESes No. 34, 36, 38, 39 & 40, while this layer is not found at all VESes in Figs. 7–9.
4. The fourth geoelectrical layer is found at all VESes in the study area except VESes 21, 28, 29 & 30 (Fig. 6), VESes 41, 42, 43, 44 & 45 (Fig. 7), VESes 52, 53 & 54 (Fig. 8) and VESes 50, 52, 53 & 54 (Fig. 9). The resistivity values range from 10 Ohm.m to

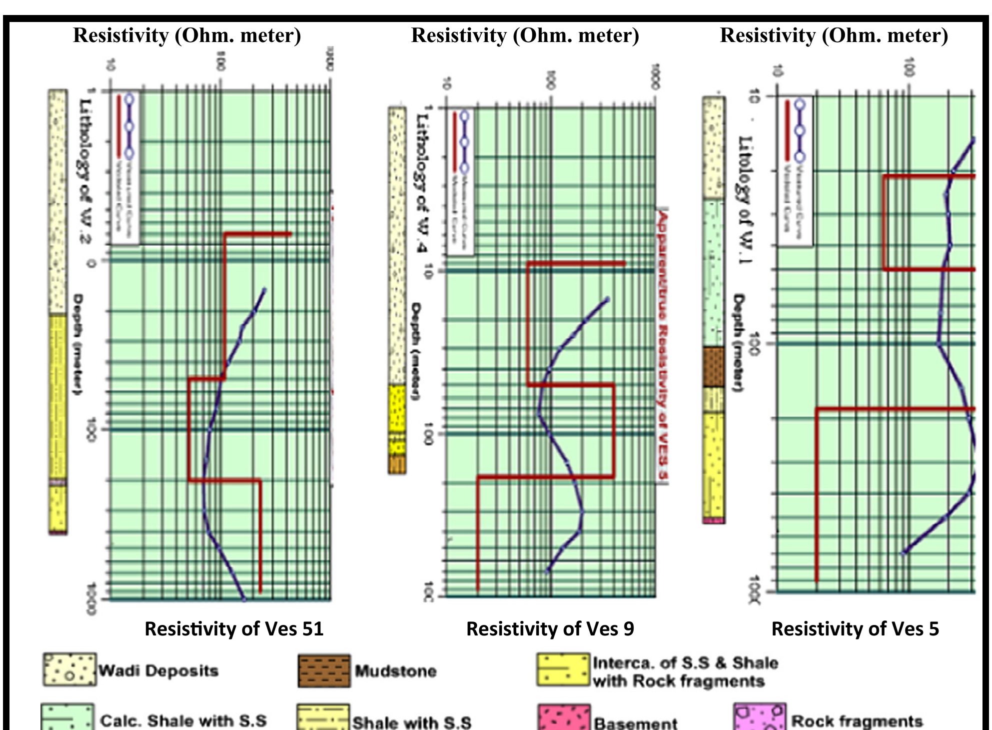

Fig. 5. Measured and interpreted data of VESes No. (5, 9, 51) and correlating them with drilling results of wells No. (4, 1, 2).

Table 1
Results of interpretation of the vertical electrical soundings.

VES No.	Resistivity (Ohm.m)					Thicknesses (m)			
	ρ1	ρ2	ρ3	ρ4	ρ5	Th1	Th2	Th3	Th4
1	362	460	150	45		16	29	150	
2	479	125	210	34		12.5	44	124	
3	520	113	385	24.3		13.2	38.8	126	
4	435	65	185	10		9.5	46.5	117	
5	510	60	400	20		9	41	135	
6	450	75	410	40		15.3	39.7	160	
7	295	43	437	20		14	35	101	
8	240	75	680	50		11	34	130	
9	330	65	550	20		21	29	133	
10	190	70	790	80		25	25	135	
11	285	41	620	135		18	45	127	
12	260	80	510	65		25	40	120	
13	360	65	770	140		15	43	122	
14	240	45	400	35		10	50	120	
15	260	105	620	75		15	35	125	
16	490	70	550	50		10.5	29.5	130	
17	380	145	130	1300		11	34	70	
18	160	18	310	15		7	21	82	
19	180	25	180	600		25	25	75	
20	220	45	720	165		22	23	130	
21	280	100	320	910		13	57	65	
22	590	130	360	1250		15	50	50	
23	435	80	345	110		11.5	58.5	140	
24	337	71	16	80		14	31	120	
25	4	45	160	1050		8	27	85	
26	60	95	45	195		4	21	125	
27	70	120	26	100		4	17	133	
28	210	18	195	1170		4	46	78	
29	401	48	115	750		6.5	48.5	70	
30	315	70	290	710		10	40	85	
31	298	65	568	25		15	40	110	
32	125	540	80	430	20	4	11	35	115
33	200	85	540	40		10	35	115	
34	660	70	50	370		8	67	115	
35	325	100	50	490		8	15	87	
36	740	80	62	165		11	34	105	
37	660	95	44	560		9.5	10.5	55	
38	53	90	24	2700		8	22	46	
39	35	260	43	4700		5	7	29	
40	38	230	65	3300		4	6	35	
41	190	370	80	5200		10	17	51	
42	290	72	5700			14	74		
43	187	115	225	1800		7	38	95	
44	70	160	5300			7.5	76.5		
45	200	90	180	6200		8	17	28	
46	4300	170	27	2500		7	37	136	
47	470	115	40	3300		6.5	16.5	105	
48	298	88	35	1900		8	8	119	
49	450	115	28	150		6	24	120	
50	390	130	75	330		7	33	105	
51	436	110	52	230		7	43	150	
52	300	141	1800			13	57		
53	270	100	3100			18	40		
54	480	73	5600			10	43		

165 Ohm.m. This layer may contain sand with some shale intercalated. The thickness of this layer ranges from 29 m to 150 m, while the lower surface cannot be reached by the used geometry of electrode configuration at some VESes.

5. The fifth geoelectrical layer is found only at some VESes as in Fig. 6) where, the layer reveals at VESes 28, 29 & 30. Resistivity values of this layer range from 430 Ohm.m to 1300 Ohm.m. This layer is a high resistance layer and may be of hard limestone. The upper surface of this layer has been pronounced at depths varying from 115 m to 135 m, while the lower surface cannot be reached by the used geometry of electrode configuration.
6. The Sixth geoelectrical layer is found only at VESes 34 & 36 (Fig. 6), VES 43 (Fig. 7), VESes 49, 50 & 51 (Fig. 8) and VESes 50, 52, 53 &54 (Fig. 9). Resistivity values of this layer range from 73 Ohm.m to 370 Ohm.m. This layer may form of coarse sand with some rock fragments. The upper surface of this layer has been pronounced at depths ranging from 45 m to 200 m. The thickness of this layer ranges from 40 m to 95 m, while the lower surface cannot be reached by the used geometry of electrode configuration at some VESes.
7. The seventh geoelectrical layer is found only at VESes 38, 39 & 40 (Fig. 6), VESes 41, 42, 43, 44 & 45 (Fig. 7), VESes 46, 47 & 48 (Fig. 8) and VESes 52, 53 & 54 (Fig. 9). Resistivity values of this

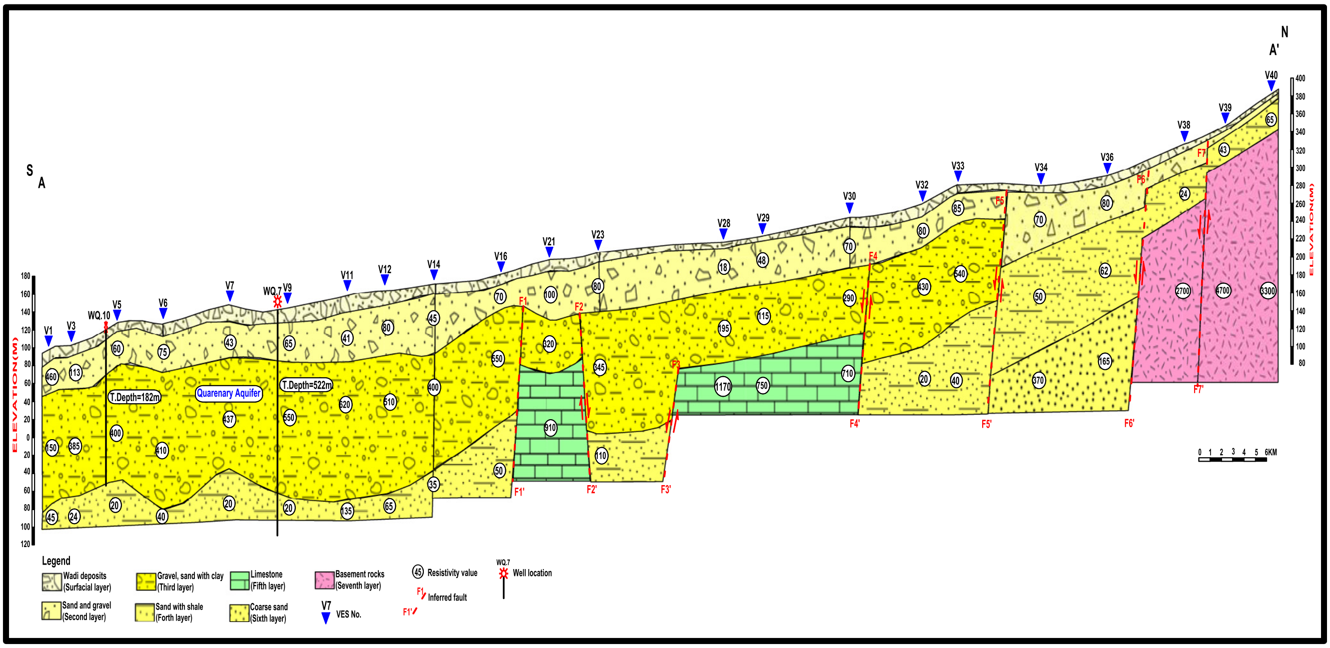

Fig. 6. Geoelectrical cross-section AA′ in the study area.

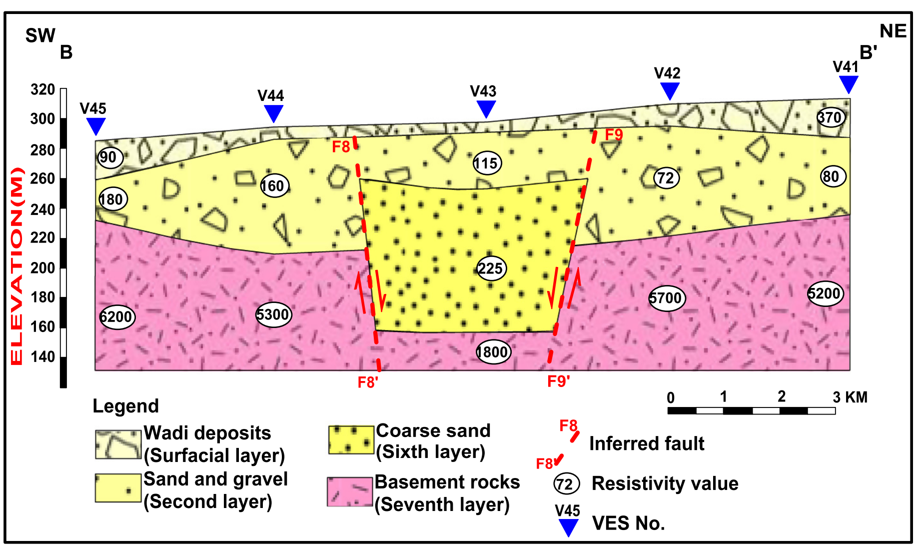

Fig. 7. Geoelectrical cross-section BB′ in the study area.

layer range from 1800 Ohm.m to 6200 Ohm.m. The upper surface of this layer has been pronounced at depths ranging from 41 m to 180 m. This layer may be the basement rocks.

Due to faults in the study area, some of layer appears in some VESes and cross sections and disappears in the other. The geoelectrical cross-sections showed that there are many inferred faults in the study area (Figs. 6–9). There are many faults showed in the geoelectrical cross-sections AA′ (Fig. 6). Also, two faults are showed in the geoelectrical cross-sections BB′ forming graben (Fig. 7). The first one located between VES 42 and VES 43 and the other located between VES 43 and VES 44. Fig. 8) reveals that there are two inferred faults in this cross-section CC′. The first one located between VES 48 and VES 49 and the other located between VES 50 and VES 51. Fig. 9) shows two inferred in this cross-section DD' where, the first one is located between VES 38 and VES 39 and the other one is located between VES 36 and VES 38.

By using this tool, it can be differentiated between two water-bearing layers act as Quaternary (the third geoelectrical layer) and Nubian aquifer (the sixth geoelectrical layer). The Quaternary aquifer appears at shallow depths at the mouth of the wadi as there is a large amount of recent sediments, while the Nubian aquifer appears in the cross-sections to the north and north east of the study area resting directly on basement rocks due to faults which resulted from the uplift movements.

3. Hydrogeological aspects

Groundwater in the Eastern Desert may be found in both shallow and deep formations. Shallow groundwater occurs in the alluvial deposits and shallow carbonate rocks and is discharged either naturally through springs, or through drilled wells of shallow depth. The deeper water-bearing formations, however, are more

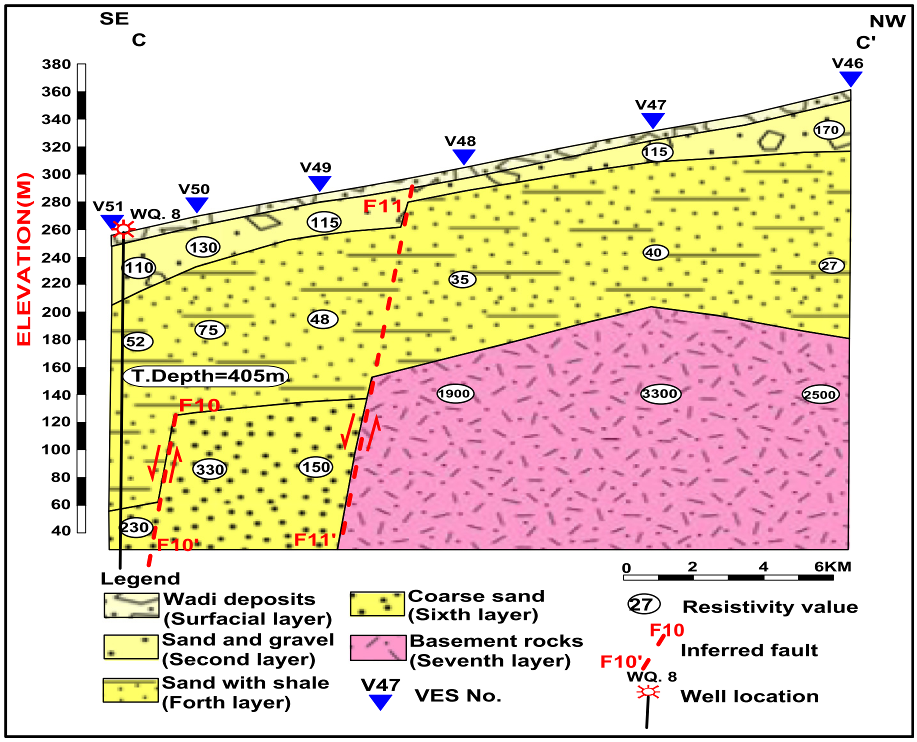

Fig. 8. Geoelectrical cross-section CC′ in the study area.

extensive and generally provide larger and more reliable well yields (Carr and Khafagi, 1981). The effective erosion of surface layers and the undulation of subsurface strata in other places in Wadi Qena causes the varying in the Quaternary alluvial deposits from place to place. Generally, the thickness increases in downstream area and reaches 100 m. (Seleem, 2013).The middle-downstream parts of Wadi Qena have groundwater reserves in Quaternary Aquifer System and Nubian Sandstone Aquifer System. The Quaternary Aquifer System is considered as an unconfined aquifer layer and Nubian Sandstone Aquifer System is treated as a confined aquifer layer.

In the study area, Figs. 6 and 8 show that geoelectrical cross-sections AA′ and CC′ where well No. (4) and well No. (1) are located in the cross-section AA′ while, well No. (2) is located in the cross-section CC′. From these cross-sections and the data information from three drilled wells by Research Institute for Ground Water (RIGW), the different expected water-bearing formations reveal the following important information:

1. Well No. 4 is drilled in the Quaternary aquifer which is composed of gravel, sand, silt with little clay, but wells No. 1 and 2 penetrates the Nubian aquifer, which is composed mainly of coarse sand and debris of basement rock origin with some intercalation of shale
2. Well No. 4 and 2 are of flowing type, but well No. 1 is non flowing one.
3. The Nubian Aquifer has different depths. Fig. 10) shows the depths to the Nubian aquifer in the study area through drilled wells, where the depth increases from north to south due to the increasing of Quaternary sediments at the entrance of wadi Qena beside the structural effect (faulting).
4. The water level in well No. 1 is nearly 105 m above mean sea level.
5. The fourth layer in cross-section AA′ act as the base of the Quaternary aquifer.
6. The amount of discharge from the shallow aquifer extracted through 22 shallow wells (of depth ranges from 12 to 70 m) is nearly 1.134.000 m^3/year considering each well operates 8 h/day for 150 day/year only, while the total amount of discharge from the deep aquifer reaches 0.4 million m^3/year.
7. The data of six wells drilled by General Authority for Rehabilitation Projects and Agricultural Developments (GARPAD, 1985) were used to study the groundwater in the southern part of Wadi Qena basin. The obtained data from these wells give us important information about the Nubia Sandstone aquifer in which the six wells were drilled. Table 2 shows the location of the exploratory wells and their basic hydrogeological data.

These data indicate that wells 1 and 2 are of artesian flowing type (well head pressures of 45 m and 4 m above ground surface, respectively), whereas the aquifer is unconfined in the other drilled wells with water table being encountered at 12 m (well No. 3), 28 m (well No. 4) and 43 m (wells No. 6 and 8) below ground level. The piezometric head in the Nubian Sandstone Aquifer System layer ranged from 232 m (above sea level) in the north to 148 m (a.s.l) in the south in 1985, which dropped to 207 m (a.s.l) in the north to 145 m (a.s.l) in the south in 2006. Fig. 11) shows the pizometric head in the study area using the data measured by NARSS, 2006.

From the above figure, we can get the information that the pizometric head in the study area increases to the north. The regional longitudinal hydraulic gradient is 1.3 m/km. The regional groundwater longitudinal flow direction is from NE to SW, controlled by the topography and structural setting of Wadi Qena.

3.1. Evaluation of groundwater quality in Wadi Qena area

Ten groundwater wells have been sampled to study groundwater quality. These water samples have been analyzed for different water quality parameters (Table 3). The measured parameters in

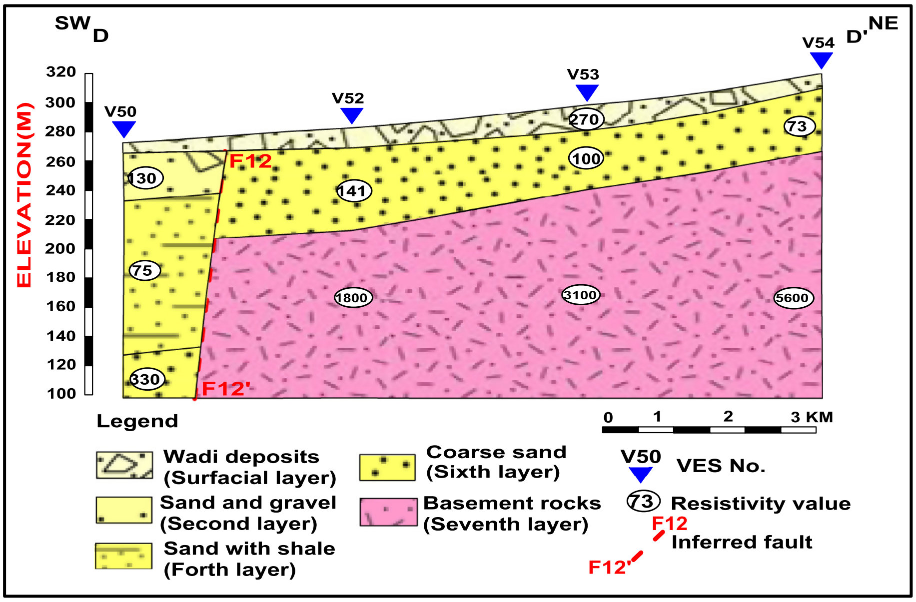

Fig. 9. Geoelectrical cross-section DD′ in the study area.

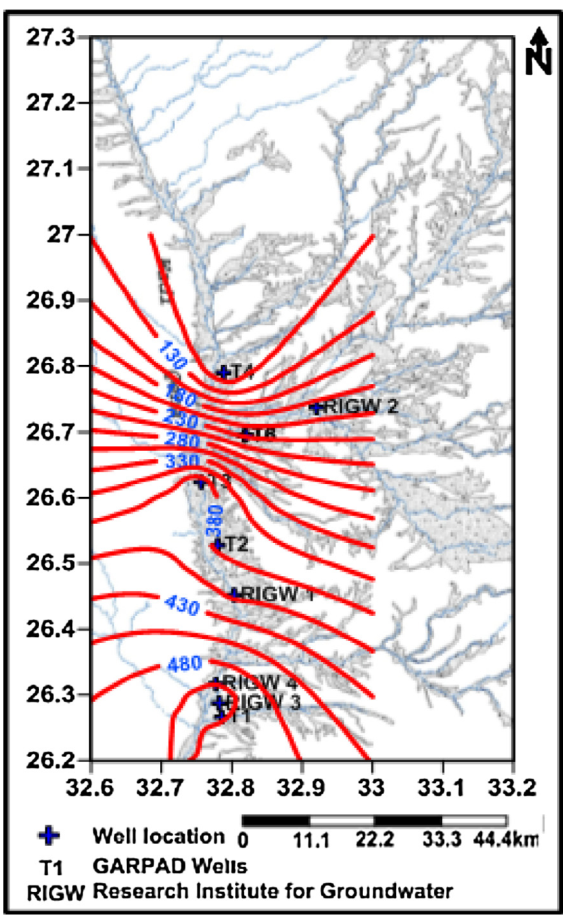

Fig. 10. The depth to Nubian aquifer in the study area.

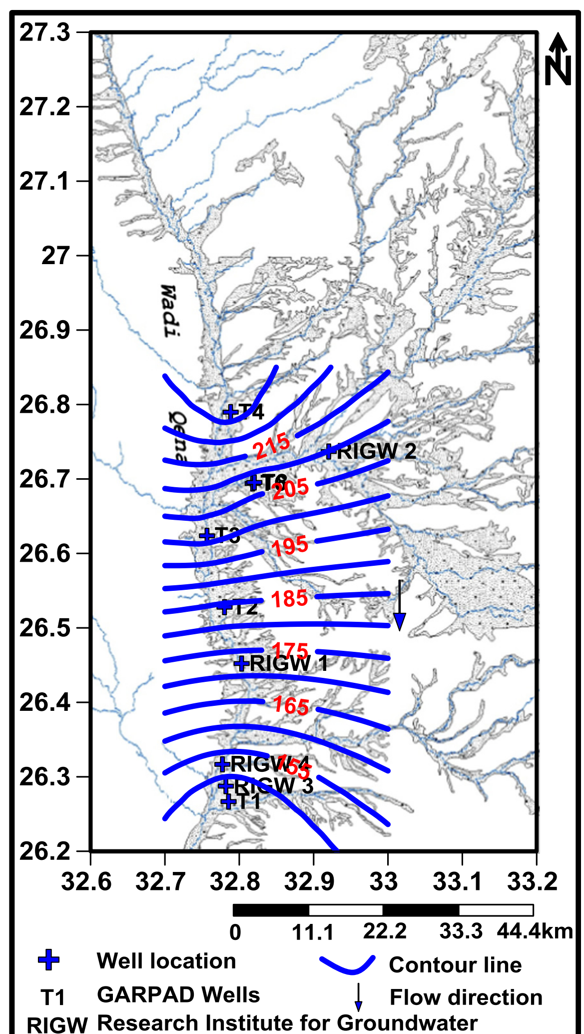

Fig. 11. The piesometer head in the study area.

water samples have been compared with the standard drinking water quality guideline values issued by WHO (2004), and Egyptian Ministry of Health and population (2007) and those for

Table 2
Location of the exploratory wells and their basic hydrogeological data (After Elewa and Abu El Ella, 2011).

W. No.	Type of well	Lat. (North)	Long. (East)	Total depth (m)	Ground level (m)	Water depth (±m)	Piezometric head (m) GARPAD, 1985	Piezometric head (m) NARSS, 2006	Flow rate (m^3/d)
1	Obs.	26°16′00.4″	32°47′08.2″	656	100	+45	148	145	3240
2	Prod	26°31′40.6″	32°46′48.3″	548	180	+4	185	184	748
3	Obs.	26°37′25.5″	32°45′ 23.9″	646	214	−12	204	202	680
4	Prod	26°47′22.8″	32°47′17.8″	439	256	−28	229	228	645
6	Obs.	26°41′42.4″	32°49′06.8″	626	250	−43	232	207	450
8	Prod	26°41′42.8″	32°49′12.7″	618	250	−43	232	207	445

Table 3
Sampled groundwater wells for the studied Wadi Qena Area (Units in ppm).

Serial	Code	X	Y	pH	EC)mmohs/cm	TDS)ppm(	K+	Na+	Mg++	Ca++	Cl^-	SO_4^-	HCO_3^-	NO_3^-
1	WQ1	32.785611	26.266722	7.88	3	1893.3	9	465	19.2	160	700	310	228	2.1
2	WQ2	32.780167	26.527750	7.27	2.76	1640	10	410	18	135	630	270	163	4
3	WQ3	32.788389	26.789722	7.83	2.59	2206.4	19	540	26.4	185	800	400	232	4
4	WQ4	32.820278	26.695333	7.83	2.59	1584.1	9	400	16.12	115	590	210	209	35
5	WQ5	Shallow well	7.2	7.07	3131.8	11	900	64.8	480	1380	0	265	31	
6	WQ6	Surface water pole	6.95	14.45	8469.7	15	1950	167.7	900	3700	1500	87	150	
7	WQ7	32.803167	26.452111	8.11	2.83	1811	8	482	19.8	125	680	290	260	1.7
8	WQ8	32.920306	26.736917	7.31	3.36	2150	12	530	26.8	161	765	380	212	4.80
9	WQ9	32.781972	26.287444	8.1	2.8	1797	8.0	550	3.8	90	730	220	214	3
10	WQ10	32.77733	26.31669	7.9	2.6	1500	15	200	150	200	600	400	300	–

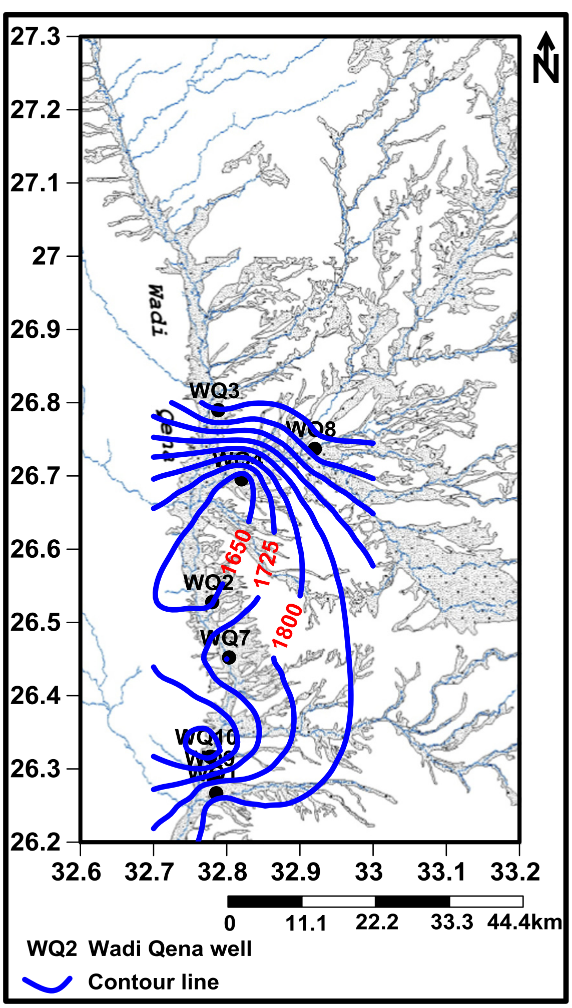

Fig. 12. Isolines of Salinity contour map in the study area.

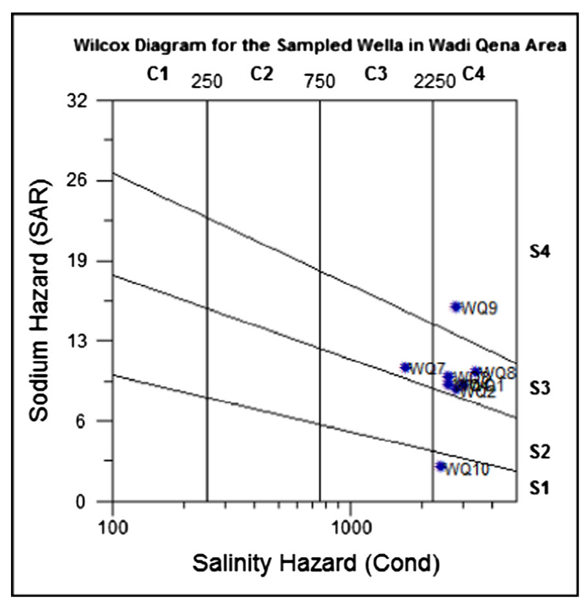

Fig. 13. Wilcox diagram of the water samples of the studied area.

Table 4
watertypes and salt combination in the water samples of the study area.

Sample No.	Code No.	Watertype
1	WQ1	Na-Ca-Cl-SO_4
2	WQ2	Mg-Ca-Na-Cl-SO_4
3	WQ3	Na-Ca-Cl-SO_4
4	WQ4	Na-Ca-Cl
5	WQ5	Na-Ca-Cl
6	WQ6	Na-Ca-Cl-SO_4
7	WQ7	Na-Ca-Cl-SO_4
8	WQ8	Na-Ca-Cl-SO_4
9	WQ9	Na-Cl
10	WQ10	Mg-Ca-Na-Cl-SO_4

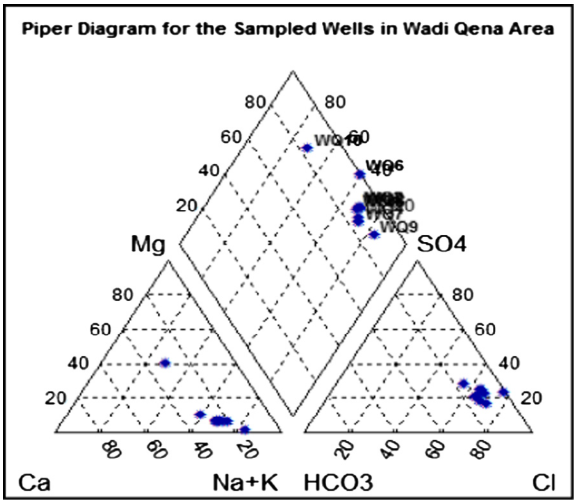

Fig. 14. Piper diagram of the water samples of the study area.

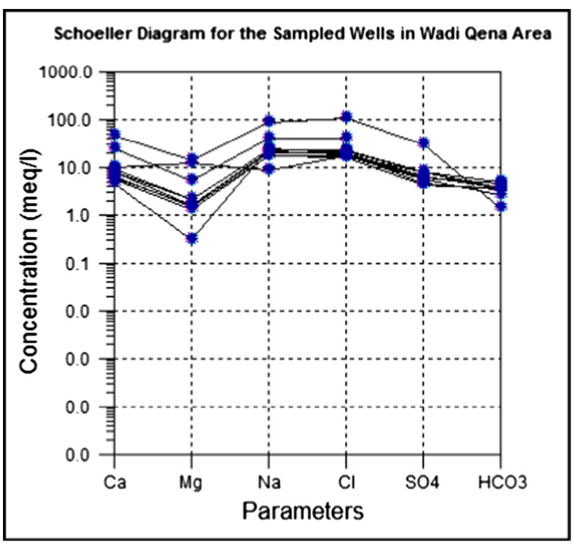

Fig. 15. Schoeller diagram of the water samples of the studied wells.

irrigation issued by FAO (1985) as shown in Table 3. Fig. 12 shows that the total Dissolved Solids (TDS) ranges between 1500 ppm (the deep well (10) to 2206 ppm (the deep well 3), while, in the shallow well and surface water pole (Samples 5 and 6), very high TDS values are found and could be referred to dissolution of salts from the formation and due to evaporation near the surface. In all the (10) groundwater samples, TDS values are more than 1000 ppm and groundwater becomes unsuitable for drinking and other domestic uses. TDS values of samples 1, 2, 4, 7, 9, and 10 are in the range of brackish water and could be used for irrigation and some industrial activities under certain precautions, while TDS of the other samples are very high and could be used for irrigation of certain crops that are tolerant for very high water salinity. The water types, Piper Diagram, and Schoeller Diagram are determined using the AQUACHEM which is a software developed by Waterloo Hydrogeologic Inc. (2003) for graphical representation and hydrochemical analysis of water quality data. According to U.S. salinity laboratory and Wilcox Diagrams (USSL, 1954 and Wilcox, 1955), (Fig. 13) show that the Sodium content is very high in the groundwater of most studied wells and the water type are classified as C4-S4, C3-S3 and C4-S3 indicating unsuitable groundwater for irrigation under ordinary conditions but requires some reservations for types of crops, methods of irrigation, and soil type.

Table 4 reveals that the most of the water samples indicate sodium, calcium, chloride, sulfate water type, this means that groundwater of deep origin reserved for a long time in the aquifer formation giving chance for the halite and gypsum salts to dissolve in the groundwater. The medium salinity or brackish groundwater in the area could be referred to mixing from other sources recharging groundwater in the area especially in wells (2, 4, 7, 9, and 10). Piper diagram of the studied wells (Fig. 14) shows that all the (10) groundwater samples of the studied wells lie in the right part of the diamond shape of the diagram. This indicates that groundwater in these wells is dominated by sodium and chloride due to dissolution of salts, especially halite and gypsum, from the sediments through which groundwater flows. This may be reflected on the future withdraw from all groundwater wells in the area where lower salinity is expected after a time due to upward seepage of the deep groundwater from the Nubian sandstone aquifer or from the near Nile Quaternary aquifer with lower salinity. The Schoeller (1969) diagram Fig. 15) shows that the results specify that lines of similar slope connecting concentrations of different parameters are indicative of water from a similar source. It is shown that there is one trend of lines indicating dominance and increase of sodium (Na) and chloride (Cl) contents in all the five wells. This is indicative of sodium chloride watertype due to dissolution of salts as halite and gypsum in groundwater and mixing between upward seeped deep groundwater with water from the Nile Quaternary aquifer.

4. Conclusion and recommendations

4.1. Conclusion

1. Two aquifers systems are present in the Wadi Qena, the shallow aquifer which decreases in thickness northward and disappears close to latitude 26°40′N and the Nubian sandstone aquifer which is considered the main aquifer at wadi Qena and composed of sand, gravels with thin clayey limestone layers.
2. The Nubian sandstone aquifer is present under confined conditions at southern part and unconfined conditions at the northern part of the Wadi and having a thickness varying from 120 m. to 320 m. and generally decreases south wards. This also confirmed by the results obtained from the drilled test/productive wells.
3. The groundwater in wadi Qena is mainly fossil water (paleo water) and the Nubian aquifer receives a little recharge comes from the rainfall and local recharge is also expected from dissecting faults of eastern and western plateaus that pounded the Wadi Qena rather than the recharge from the deep seated faults of basement complex underlying the Nubian aquifer.
4. The discharging area occurs mainly at southern and middle parts of the wadi through three wells and the total discharged groundwater reaches about 400,000 m^3/year. and the aquifer is considered generally as low productive aquifer.
5. The water in Nubian sandstone aquifer is generally brackish (TDS about 1600–2000 ppm) which is suitable only for irrigation of salt tolerant plants and desalinization process is recommended in drinking purposes.

4.2. Recommendations

1. Nubian sandstone aquifer at Wadi Qena area can be taking into consideration in future for sustainable development:
2. Due to low potential of the water resources at Wadi Qena area the highly economic and salt tolerant plants should be selected.

3. Because scarcity of water resources at Wadi Qena, agricultural development on groundwater should be phased and evaluate the potential of the aquifer at the end of each stage.

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