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ASSESSMENT OF THE GROUNDWATER RESOURCES IN AYOUN MOUSA AND ADJACENT AREAS, WEST SINAI, EGYPT.

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The Ayoun Mousa and adjacent areas are classified into three main geomorphologic units: namely, structural plateau, alluvial plains and coastal plain. The main structural elements encountered in the area include E-W, NE, N-S and NW faulting systems; these elements exert strong control on the distribution of rock units and the drainage pattern.

There are three aquifer systems in the studied area namely; Quaternary, Miocene and Nubian Sandstone. The Quaternary System is unconfined to semi-confined and is restricted mainly in the alluvial fans and the tributaries of the main wadis with thickness varied from few meters to more than 60 m. It is recharged mainly from the eastern watershed areas. It can differentiate into Holocene and Pleistocene Aquifers. The Holocene Aquifer has shallow water table varied from +0.7 to +0.4 m with salinity ranges mostly from 570 to 9184 ppm. On the other hand, the water level of the Pleistocene Aquifer ranges from +23 to -8m with salinity varied essentially from 2414 to 27840 ppm.

The Miocene Aquifer System is formed mostly of sandstone with shale interbeds, where it located principally in the northern part of the studied area and classified into Ayoun Mousa and Nukhul Aquifers. Ayoun Mousa Aquifer is the upper unit and it's unconfined recharged largely from the eastern watershed area. The water level in this unit ranges from +21.7 to +212m and the salinity from 3520 to 7328 ppm. Nukhul Aquifer is the lower unit and it's confined recharged mainly from the deep Nubian Sandstone Aquifer through faults. It has groundwater salinity up to 4810 ppm.

The Nubian Sandstone System is extended allover the studied area and is divided into Lower Cretaceous and Jurassic as well as Paleozoic Aquifers. It is characterized by confined and flowing aquifer system. It is fossil water with no recent recharge from the eastern watershed area. The Lower Cretaceous Aquifer has piezometric head ranges from +15 to

+36 m and groundwater salinity ranges from 2413 to 2464 ppm with temperature reaches about 40 °C. However, the Jurassic Aquifer has piezometric head reaches +38 m and the groundwater salinity is about 2739 ppm with temperature around 45 °C. Lithologically, the Paleozoic formations are so thick (about 700 m) and have a good probability of groundwater occurrence, but not represented by any water points in the study area.

Keywords: Groundwater, Ayoun Mousa, South Sinai, Egypt.

Ayoun Mousa area is an attractive site for tourism and construction development, and therefore needs a significant water supply. It is located northeast of the Suez Gulf between latitude 29° 40' 00" to 29° 59' 00" and longitude 32° 35' 00" to 33° 00' 00" (Fig. 1). It is dissected by three main roads namely Suez - El Tor, Abu Soweir-El Tasa and Ayoun Mousa-El Nehyat (Fig. 1). It is also dissected by two main wadis: namely El-Reneiah and Lahata, in addition to some small wadis such as Marba. Three small villages: namely Ayoun Mousa, El Reneiah and El Nehyat El Gedeida, exist in the area. Topographically, the area varies from about +750 m in the eastern part to about -0.5 m near the Gulf of Suez. Climatically, the area is characterized by low rainfall (17.1 mm/year), high temperature (35 C°) and high evaporation rate in summer (3707 mm/year).

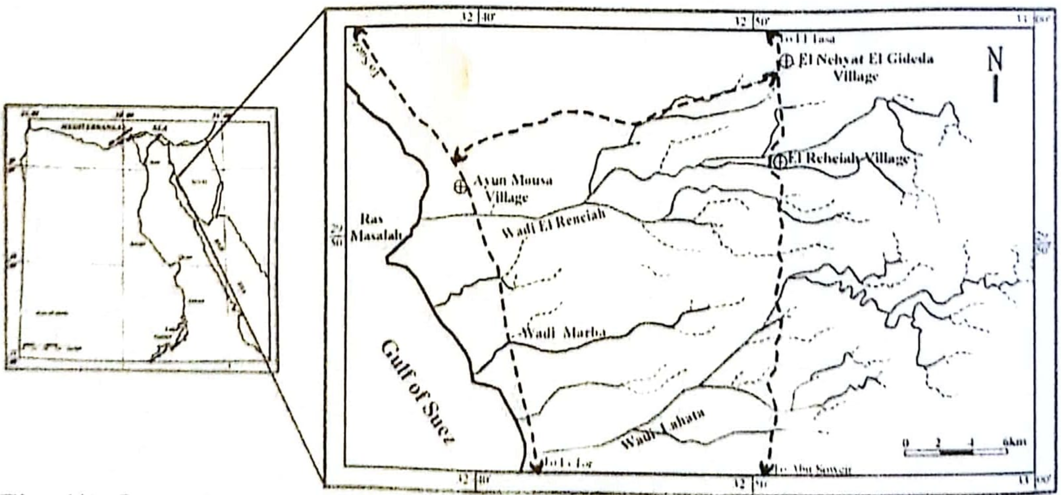

Fig. (1). Location map of Ayoun Mousa and adjacent areas.

The main objectives of this work are to re-evaluate the hydrogeological setting of the Ayoun Mousa area and to determine the geological controls on groundwater occurrence and quality. Moreover, the relationships between the shallow and deep aquifers and the evaluation of the groundwater for different purposes.

RESULTS AND DISCUSSION

1-Geomorphologic Aspects

Based on satellite image, topographic maps and field observations, the study area is classified into three main geomorphologic units (Fig. 2); namely; structural plateau, alluvial plains and coastal plain. They are discussed as follows from east to west:

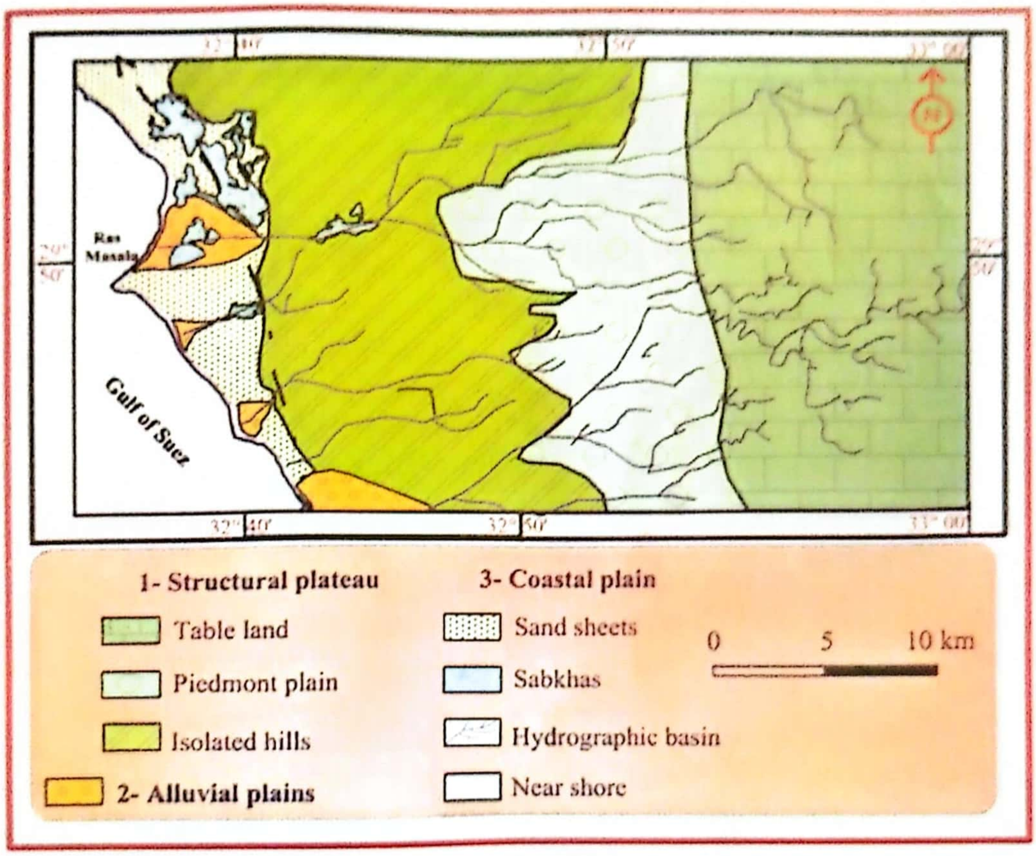

Fig. (2). Geomorphological map of Ayoun Mousa and adjacent areas.

The structural plateau is divided into table land, piedmont plain and isolated hills. Table land is located in the eastern part of the studied area. It has variable ground elevation ranging from about +750 m (Gabal El Raha) to about +500 m above sea level. It is cut by a number of tributaries that debouch into the main wadis, El Reneiah and Lahata. The area is underlain mainly by Nummulitic limestone with marl and chert interbeds belonging to the Lower Miocene (Lower Middle Miocene). It was formed due to the effect of Pre-Middle Eocene tectonics that caused the uplift of the eastern part.

The piedmont plain has ground elevations ranging from about +240 to +180 m above sea level with relatively gentle slopes toward the west. It is dissected also by numerous tributaries that debouch into Wadis El Reneiah and Lahata. The area is composed mainly of fanglomerate near the foot slope of the high mountains, becoming limestone and marl intercalated with sandstone to the west. This area developed mainly due to the effect of tectonic orogeny during the Miocene, although the presence of fanglomerate is the result of water erosion during the rainy seasons.

The isolated hills have variable elevations between about +170 m to about +40 m above sea level. They are dissected also by a lot amount of tributaries that debouch in El Reneiah and Lahata main wadis, beside new small wadis such as Maraba. It is composed mainly of clays intercalated with sandstones and marls that belonging to Lower Middle Miocene Period. They were formed related to the variation of water resistance. It is characterized by the presence of small palm oases.

Alluvial plains are restricted in the downstreams of the main wadis. The larger fans are located in the downstreams of El Reneiah and Lahata Wadis. They take a triangular shape their base near the Gulf of Suez. They have mild topography and the low relief areas of the fans are occupied by inland sabkhas. They are composed of coarse sand in the eastern part and changed westward to become fine sand. They are partially covered by sand sheets. They were formed due to the effect of rainy seasons on the eastern high mountains and isolated hills.

The coastal plain unit is located parallel to the present shoreline and is composed of sand sheets, sabkhas, near shore and hydrographic basins. Sand sheets are occupying extended areas to the west of the study area. They are composed mainly of fine sand and are formed due to the effect of wind erosion.

There are two types of Sabkhas in the studied area namely inland and coastal ones. The inland sabkhas are located at the downstream of main wadis. They are characterized by low topography and dense natural vegetations. They are composed mainly of fine to medium sand that covered by thin salt crust and occasionally water ponds. They are formed due to the effect of rainy seasons and the seepage from the flowing water wells. On the other hand, the coastal sabkhas are located near the present shoreline. They are characterized by low topography (-0.50 m below sea level). They are composed mainly of fine sand that covered by thick salt crust. They are formed related to the tidal effect of the Gulf of Suez.

Near shore is relatively narrow around Ras Masalla and increase in width north and southward. The low relief areas are occupied by coastal sabkhas. It is composed mainly of medium to fine sand.

The studied area is dissected by main hydrographic basins namely, El Reneiah and Lahata beside some small wadis such as Marba. These hydrographic basins collect rainfall from the eastern high lands and debouch their water into the Gulf of Suez. They are covered mainly by boulders, cobbles and gravel sediments in the upstream that changed westward to become fine sand and silt in the downstream. They are formed due to the effect of rainy seasons.

2- Geologic Outline

In the study area, the surface geology is based on geologic map scale 1:250 000 (after EGSMA, 1994) and field observations, while the subsurface geology is based on the data derived from the available composite logs of coal project wells, some private shallow & deep wells and oil wells (Ayoun Mousa-1 & 2, Masalla-1, Masalla-3, Masalla-S-1, Masalla-E-1, Abu Qatifa-1 and N. Sudr-1).

The surface geology of the studied area (Fig. 3) is represented by Cretaceous-Paleocene, Eocene, Miocene and Quaternary sediments. The Cretaceous-Paleocene sediments are represented by Sudr Formation (chalk) in the southeastern part. The Eocene rocks occupy most of the eastern part and are represented by Thebes & Darat Formations (limestone with marl) and Samalut Formation (dolomitic limestone), while Miocene Rocks occupy most of the western portion and are represented by Sumar (marly limestone), Rudeis (marl and sandstone), Ayoun Mousa (clays intercalated with sandstone) and Karim (anhydrite) Formations. On the other hand, the Quaternary sediments are restricted mainly in the coastal plain and are represented by Pleistocene (fanglomerate, alluvial Hamadah deposits and coral reefs) and Holocene sediments (sabkhas, sand dunes and wadi deposits).

The subsurface geology of the area is well represented by the composite compiled columnar section shown in figure (4).

Based on MSS satellite image (ERSC 1990) and field observations, the structural lineament of Ayoun Mousa area was made (Fig. 5) where, the main structural elements of the studied area are E-W, NE, N-S and NW faulting systems. They much control the occurrence and distribution of rocks as well as the topography and characters of the hydrographic basins.

3- Hydrogeological Setting

Based on the available composite logs of the drilled wells (Fig. 6), hydrological parameters, hydrogeologic cross sections (Figs. 7 and 8), as well as the field and laboratory investigations (Table 1), Ayoun Mousa area can be differentiated into Quaternary, Miocene and Nubian Sandstone Aquifer systems (Fig. 4).

a- Quaternary Aquifer System

The Quaternary Aquifer System is restricted mainly in the alluvial fans and the deposits of the main wadis. The wadi fill water bearing layer is located in the upstreams of El Reneiah and Lahata wadis and is composed mainly of gravels and coarse sand that derived mainly from the eastern high lands. It is represented by three water sample nos. 1, 2 and 3. The water level ranges from +228 to +187.4 m with groundwater salinity ranges from 570 to 890 ppm. It is recharged mainly from the eastern watershed area.

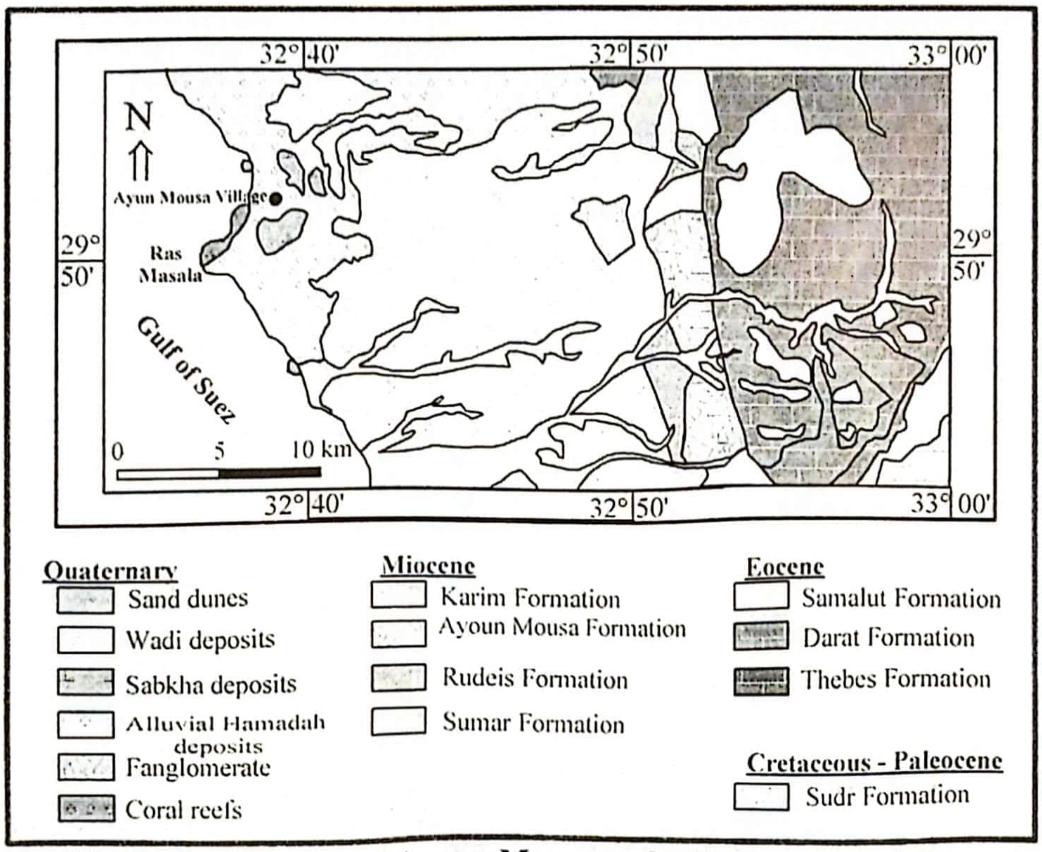

Fig. (3). Geological map of Ayoun Mousa and adjacent areas (after EGSMA, 1994).

The wetlands (sabkhas) water bearing is restricted in the low land in the western part of the studied area. They are composed mainly of silt and clay that covered by salt crust. They are represented by three water sample nos. 7, 8 and 9. The inland sabkhas recharged mainly from the flowing Nubian water wells as sample no. 8 that has groundwater salinity reach to 22850 ppm and in some parts recharged also from the drinking water line as sample no. 7 that has groundwater salinity reach to 820 ppm. On the other hand, the near shore sabkhas that are affected by Gulf of Suez are represented by sample no. 9 of groundwater salinity reach to 174000 ppm.

The Pleistocene Aquifer is located mainly in the alluvial fans of the studied area especially of Wadi Lahata. It is composed mainly of coarse and medium sand with thickness reach to about 60 m. It is unconfined to semi-confined aquifer and represented by 12 water samples (Fig. 6 and Table 1). This aquifer is recharged mainly from the eastern watershed area through faults and porous deposits.

Age (Said, 1962; Abdallah and Adindani, 1963; Eames, 1986; Zahran and Meshref, 1988; and Tewfik, 1988)			Lithology	Lithologic description (Zahran and Meshref, 1988)	Thickness	Aquifer System	Aquifer Type	Porosity % (Zahran and Meshref, 1988)	TDS (ppm)
Cenozoic	Quaternary			Sand with thin beds of clay	~10 to 80 m	*Quaternary Aquifer*	Unconfined to semi-confined		~370 - ~9200
	Miocene	Ayun Mousa Fm		Shale with thin beds of sand	~15 to 40 m	*Ayun Mousa Aquifer*	Unconfined		3520 - 7330
		Kareem & Rudeis Fm (Miocene)		Shale with thin beds of sandstone	~250 to ~400 m	Confining clay			
		Nukhul (L. Miocene)		Conglomeritic sandstone	10 to 60 m	*Nukhul Aquifer*	Confined	7% to 24%	4810
Mesozoic	Cretaceous	Kareem & Rudeis Fm		Limestone with thin beds of sandstone	~350 to ~700 m	Confining clay			
						Confining clay			
		Malha Fm		Sandstone with thin shale interbeds	~150 to ~230 m	*Nubian Sandstone Aquifer*	Confined	~25%	~2410 - ~2460
	Jurassic			shale		Confining clay			
				sandstone with shale interbeds	~700 to ~1000 m	*Jurassic Aquifer*	Confined	22%	~2740
						Confining clay			
	Triassic				~80 m				
Paleozoic	Premian ↓ Carboniferous					Confining clay			
				sandstone with shale and limestone interbeds	~700 m	*Probable Paleozoic Aquifer*	Confined	10% to 30%	
Pre-Cambrian				Basement Rocks					

Fig. (4). Combined geological and hydrogeological sequence of Ayoun Mousa and adjacent areas.

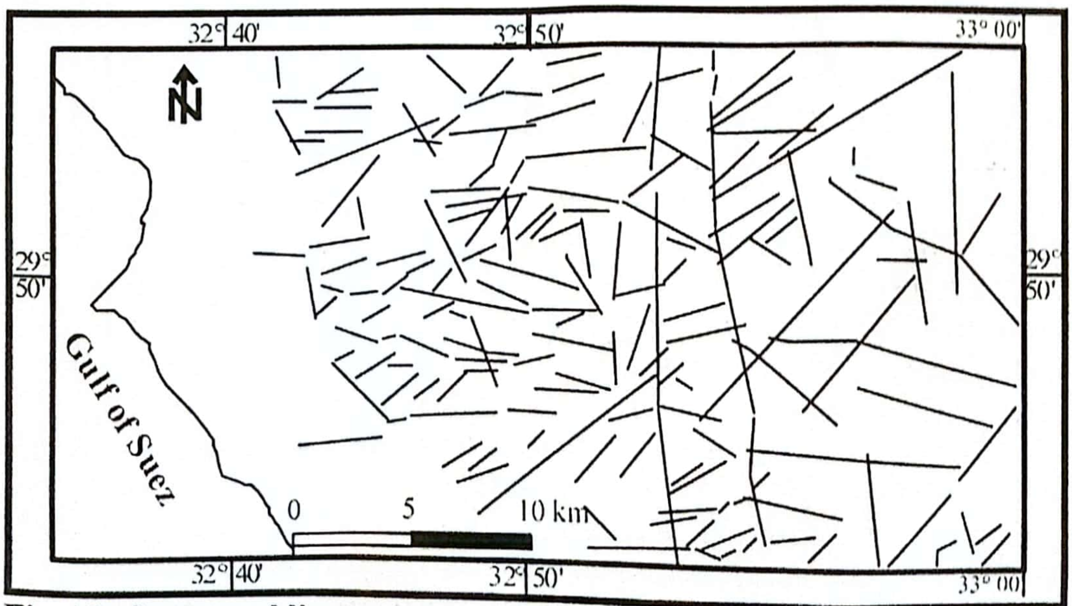

Fig. (5). Structural lineament systems of Ayoun Mousa and adjacent areas.

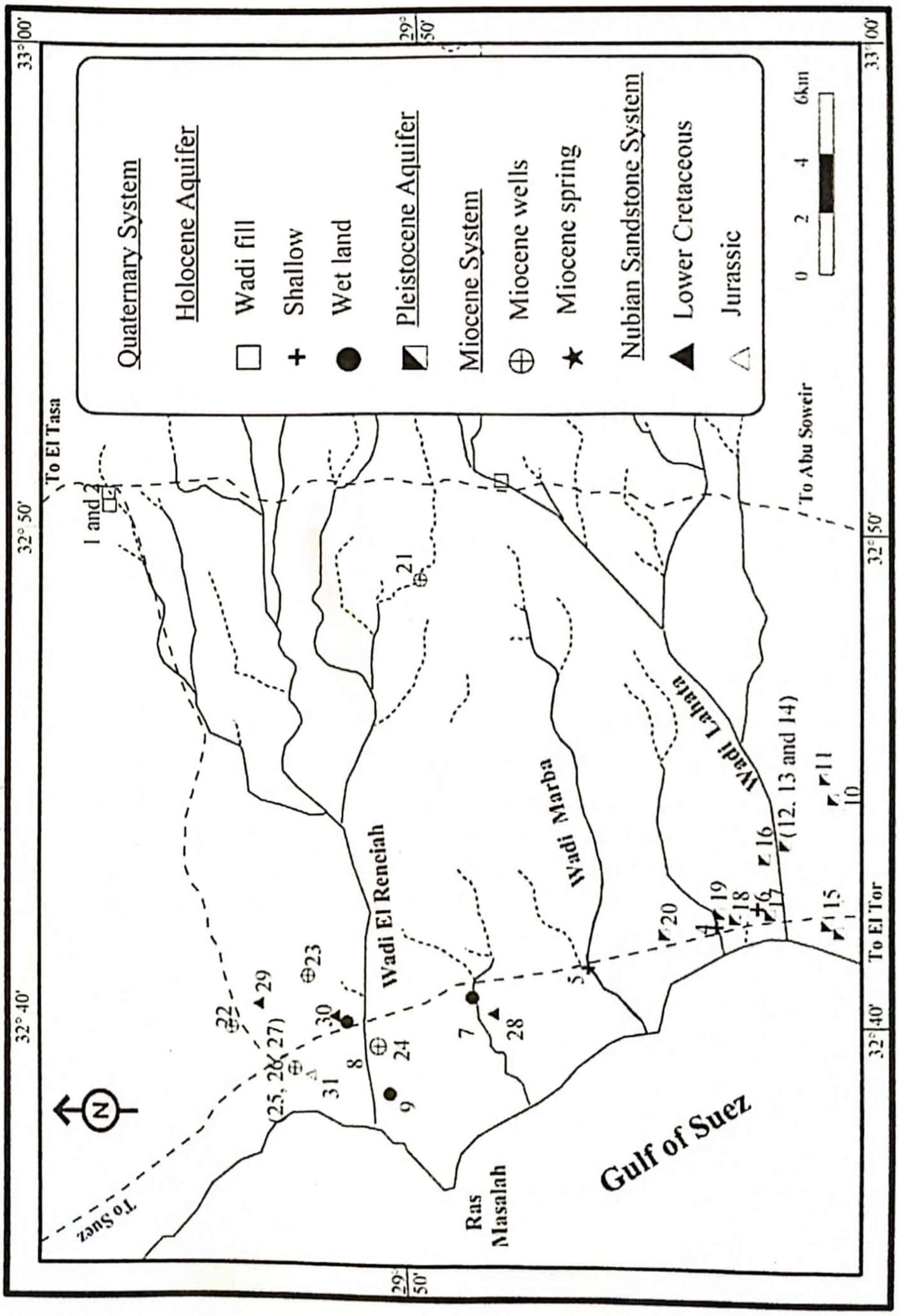

Fig. (6). Location map of selected wells in the area of study.

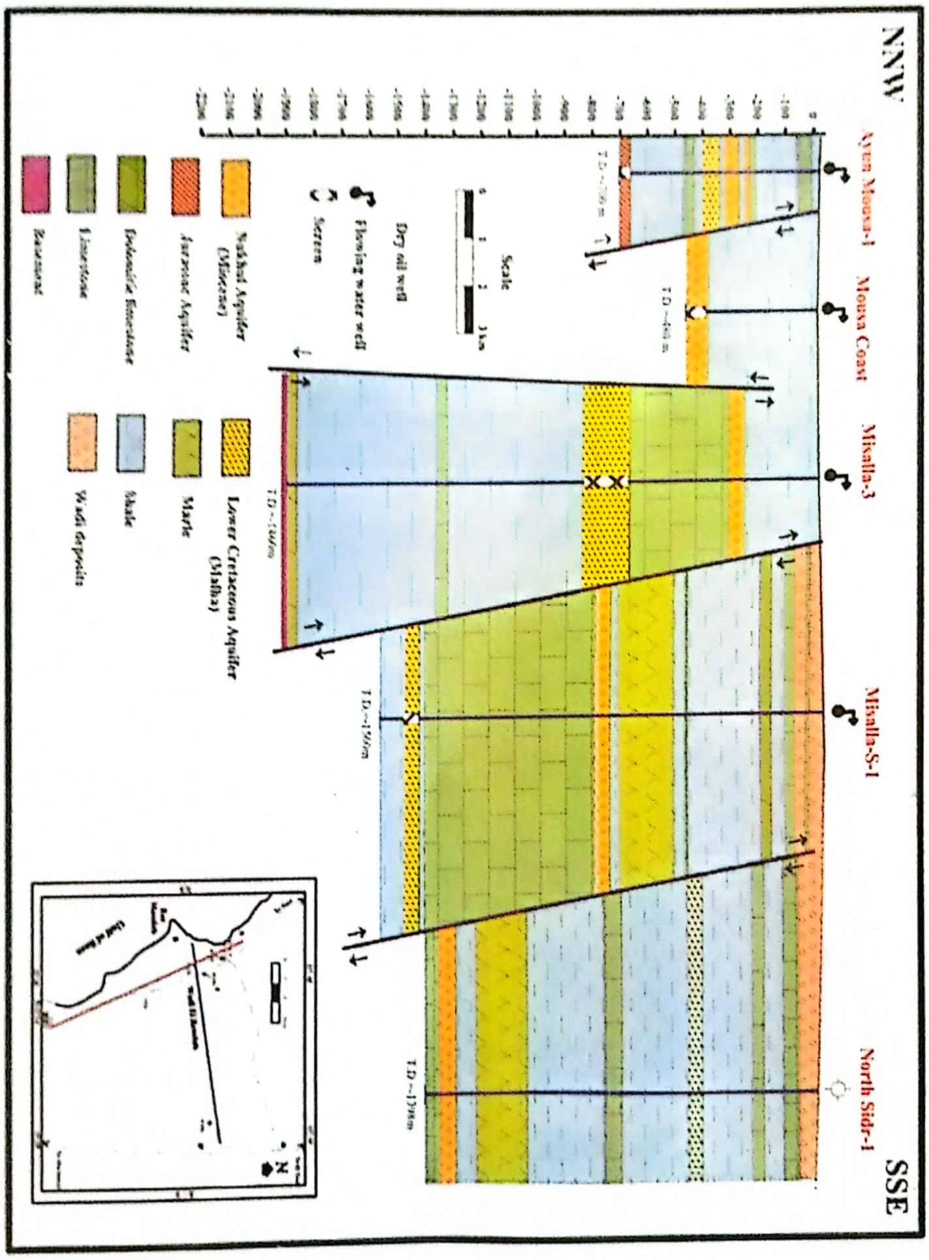

Fig. (7). N - S hydrogeological cross section in the coastal area from Ayoun Mousa southward.

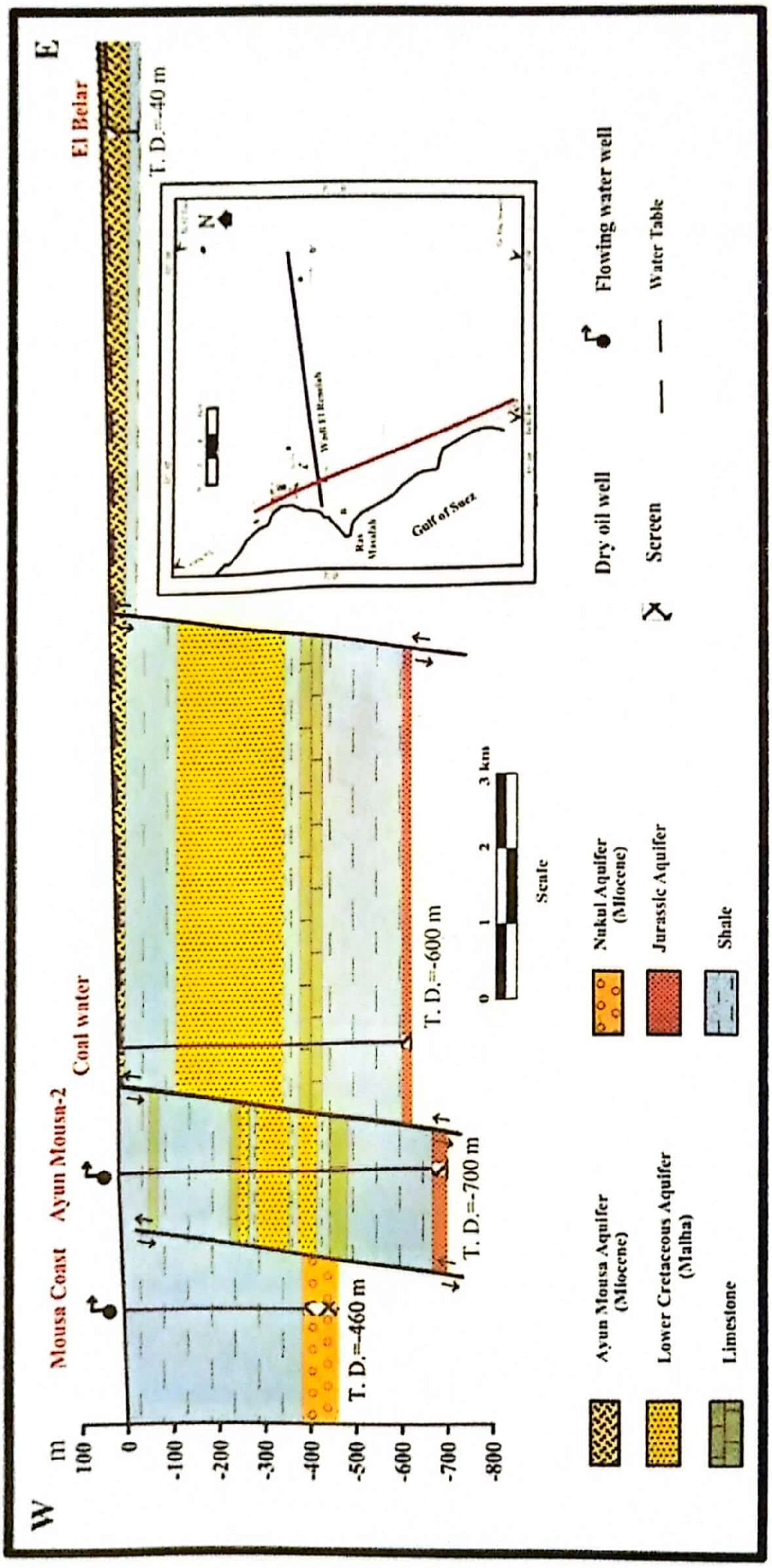

Fig. (8). W - E hydrogeological cross section between Ras Messalla and Ayoun Mousa.

Table (1). Chemical analyses of the groundwater samples collected from Ayoun Mousa and adjacent areas.

No.	Aquifer System		Well Name	Elevation(m)	Total Depth	Absolute Water level	Ec (mmohs/m)	TDS (ppm)	PH	Cations (ppm)				Anions (ppm)		
										K^+	Na^+	Mg^{++}	Ca^{++}	Cl^-	SO_4^-	HCO_3^-
1	Quaternary	Holocene	Um Maboug -1	200	13	+ 188.7	0.89	570	7.55	7.2	43	25	90	120	190	70
2			Um Maboug –2	199	13	+ 187.4	1.40	890	8.76	21.8	70	34	150	230	230	150
3			Um Kashtan	238	16	+ 228.0	1.12	717	8.46	8.5	55	45	90	145	242	100
4			Banana Beach	4	6.0	+ 0.7	3.65	2336	7.88	31.0	176	88	400	850	242	400
5			Nozha Beach	4	5.0	+ 0.4	8.90	5696	8.01	66.0	800	120	840	2500	440	490
6			Mohamed Shadad	5	8.5	+ 0.5	14.35	9184	7.51	29.2	1580	165	1140	4000	700	758
7			Um Gerdy Sabkha	5	-	-	1.28	819	8.07	7.1	63	28	145	280	55	193
8			Ayoun Mousa sabkha	11	-	-	35.70	22848	7.49	500.0	6600	225	700	10700	660	2200
9			Mousa Coast sabkha	1	-	-	272.00	174000	7.12	2500	22000	9100	19000	76000	19600	10100
10		Pleistocene	Said Sharaf	42	57	+ 15.0	3.77	2413	8.06	36.7	250	52	410	930	220	348
11			El Ahela Company	43	45	+ 23.0	9.25	5920	8.26	40.9	1100	174	580	2450	480	774
12			Mohamed Tag-3	41	35	+ 13.0	5.07	3245	7.93	24.0	600	90	320	1300	260	490
13			Mohamed Tag-2	39	45	+ 10.0	7.55	4832	7.70	25.3	874	166	460	2100	390	430
14			Mohamed Tag-1	38	45	+ 8.0	7.71	4934	7.84	23.4	950	148	460	2180	420	390
15			Bent Sultan	3	22	- 7.0	10.35	6624	7.86	33.1	1380	156	580	3010	580	347
16			Hag Abdel Haleem	13	38	- 2.0	10.45	6688	7.79	26.6	1058	410	460	2950	390	660
17			Golden Beach 2	3	20	- 7.0	12.65	8096	7.66	35.0	1565	297	650	3590	525	687
18			Temarcros	7	19	- 2.0	29.60	18 944	7.65	76.4	2530	1640	940	8400	1620	1395
19			Marina Sudr	9	50	- 3.0	36.50	23360	7.61	94.3	3220	1264	2360	10550	2000	1556
20			Holandeia	6	20	- 8.0	43.50	27840	7.55	108.0	5100	1050	2400	11750	3400	1755
21	Miocene		Wadi El Beiar group	218	11	+ 212.0	9.25	5920	8.26	40.9	900	394	360	2000	992	774
22			Adel Moneam Hegaz	30	30	+ 27.5	11.45	7328	7.80	64.2	1180	490	370	2400	1000	1369
23			Oasis well	22	10	+ 21.7	5.55	3520	7.80	46.9	600	96	320	1130	390	684
24			Mousa Coast well	18	460	Flowing	7.51	4806	7.82	45.9	990	58	520	1700	505	960
25			Ayoun Mousa Spring 2	21	4	+ 17.0	6.03	3859	7.84	46.9	500	32	680	1630	242	499
26			Ayoun Mousa Spring 3	15	3.5	+ 12.0	11.45	7328	7.80	85.7	1090	256	880	3150	520	797
27			El Sheikh Spring 1	17	5.5	+ 13.0	14.35	9184	7.93	95.5	1411	350	1010	4000	750	850
28	Cretaceous and Pre- Cretaceous		Masala-1	12		Flowing	3.77	2413	8.06	36.7	345	78	325	900	340	348
29			Masala-3	22	1860	Flowing	3.83	2464	8.05	22.9	433	116	180	860	293	458
30			Ayoun Mousa -2	34		Flowing	3.83	2451	7.63	44.6	260	258	90	740	480	439
31			Ayoun Mousa –1	19	700	Flowing	4.28	2739	7.80	35.0	475	98	250	950	280	573

b- Miocene Aquifer System

The Miocene Aquifer System is located mainly in the northern part of the studied area and can differentiate into Ayoun Mousa and Nukhul aquifer
as well as Miocene Springs. Ayoun Mousa aquifer is composed mainly of marine gypseous clays intercalated with sandstone and marl with thickness ranges from few meters in the eastern part to about 40 m in the western part. It is unconfined aquifer and is represented by El Beiar Group (sample no. 20) having salinity 5920 ppm in the eastern part and 3520 to 7328 ppm in the western part (samples 22 and 23). The water level ranges from +212 m in the eastern part to +21.7 m above sea level in the western part.

Nukhul water aquifer is recorded mainly in all the drilled oil wells with variable thickness that ranges from 10 m to about 60m (Fig. 6). It is composed mainly of conglomeritic sandstone It is represented only by one flowing water samples no. 24 with total salinity reaches 4810 ppm. It is recharged mainly from the deep Nubian Sandstone Aquifer System through faults.

Three Miocene Springs are recorded also in the northern part west Suez-El Tor Road (Fig. 6 and Table 1). The water level ranges from +12 to +17 m from the ground surface. The groundwater salinity ranges from about 3860 ppm to about 9180 ppm. They are recharged mainly from the deep Nubian Sandstone Aquifer System and Nukhul Aquifer through faults. The variation of salinity is probably due to the variation of the rate of recharge and the depth of recharge aquifer.

c- Nubian Sandstone Aquifer System

The Nubian Sandstone System is divided into Lower Cretaceous and Jurassic as well as Paleozoic Aquifers. The Lower Cretaceous Aquifer is extended allover the studied area and constitutes the main aquifer. It is composed mainly of sandstone intercalated with shale beds with thickness ranges from about 150 m to about 230 m (Figs. 7 and 8). It is overlain mainly by Upper Cretaceous shale in the northern part and limestone & shale in the southern part, while underlain by Jurassic shale. It is confined aquifer and represented by three flowing water well nos. 28, 29 and 30 (Fig. 6 and Table 1) namely; Misalla-3, Ayoun Mousa-2 and Masalla-1 with peizometric head ranges from +15 to +36 m above sea level. The groundwater salinity ranges from 2413 to 2464 ppm. They have relatively high temperatures reach about 40 °C.

The Jurassic Aquifer extends also allover the studied area and composed mainly of sandstone with some shale interbeds with thickness ranges from about 80 to 650 m. It is overlain and underlain mainly by shale layer i.e. confined aquifer. It is represented only by one flowing well namely Ayoun Mousa-1 (well no. 31) with peizometric head reaches +38 m and salinity of about 2739 ppm. It is characterized by groundwater temperature around 45 °C.

The Paleozoic Aquifer is recorded only in Ayoun Mousa-2 deep well with a thickness of about 700 m. It is overlying unconformably the basement rocks and overlain by Permian shale i.e. it is confined aquifer. It consists mainly of sandstone with shale and limestone interbeds but it is not represented by any samples.

d- Remarks on the changes in the groundwater occurrence.

In comparison of the hydrogeological setting in 2005 (present work) with the hydrogeological setting adopted by Himida *et al.* (1972) on the Ayoun Mousa area (Table 2), the following are the main remarks of the recorded changes:

Table (2). Comparison between the hydrogeochemical constituents in 1967 and in 2005.

Aquifer system			In 1967 (Himida *et al.*, 1972)	In 2005 (present work)
Quaternary	Holocene	No. of wells	Not recorded	3
		Piezometric head		+ 187 to + 228 m
		Salinity (ppm)		570 – 890
		Dominant salts		$CaSO_4$, NaCl, $MgCl_2$ and $Ca(HCO_3)_2$
		No. of wells	Not recorded	3
		Piezometric head		+ 0.4 m to + 0.7 m
		Salinity (ppm)		2336 – 9184
		Dominant salts		NaCL, $CaCL_2$ and $MgCL_2$
		Piezometric head	Not recorded	3
		Salinity (ppm)		-
		Dominant salts		NaCl and $MgCl_2$
	Pleistocene	No. of wells	Not recorded	12
		Piezometric head		- 8 m to + 23
		Salinity (ppm)		2413 – 27840
		Dominant salts		NaCL, $MgCL_2$ and $CaSO_4$
Miocene		No. of wells	4	4
		Salinity (ppm)	2694 – 7608	2520 – 7328
		Dominant salts	$CaCl_2$ and occasional Na_2SO_4	NaCl, $Ca(HCO_3)_2$ and $MgCl_2$
		No. of wells	12	3
		Salinity (ppm)	2386 – 6008	3859 – 9184
		Dominant salts	$CaCl_2$ and $MgCl_2$	NaCl, $MgCl_2$ and $CaCl_2$
Cretaceous and Pre- Cretaceous		No. of wells	3	3
		Piezometric head	+ 17 m to + 39 m	+15 m to +36 m
		Salinity (ppm)	5200 to 5840	2413 to 2464
		Dominant salts	NaCl, $CaCl_2$ and $CaSO_4$	NaCl, $Ca(HCO_3)_2$ and $MgCl_2$
		No. of wells	2	1
		Piezometric head	+ 40 m to + 50 m	+ 20 m
		Salinity (ppm)	4160 – 4187	2739
		Dominant salts	NaCl and $CaSO_4$	NaCl, $Ca(HCO_3)_2$ and $MgCl_2$

i- The new occurrence of the Quaternary Aquifer System especially in the southern part.

ii- The presence of new aquifer in the northern part namely Ayoun Mousa Aquifer.

iii- The disappearance of the Miocene wells in the coal Project due to the lowering of piezometric head with time and the low rate of upward leakage from the Nubian Sandstone Aquifer System through faults. This appear in the changes of the dominant salts from $CaCl_2$ in 1967 to NaCl, $Ca(HCO_3)_2$ and $MgCl_2$ in 2005.

iv- The disappearance of 9 Miocene Springs (six of them in the eastern part of the Suez – El Tor Road of the relatively high lands and the others west the road). This is due to the decrease of piezometric head with time and the low rate of upward leakage from deep Miocene Aquifer (Nukhul) and Nubian Sandstone Aquifer System through faults. This lead to the increase of salinity that ranges from 2386 - 6008 ppm in 1967 to 3859 – 9184 ppm in 2005. Also, lead to the changes of the dominant salts from $CaCl_2$ and $MgCl_2$ in 1967 to NaCl, $MgCl_2$ and $CaCl_2$ in 2005.

v- The decrease of the Lower Cretaceous piezometric head from +17 - +39m to +15 - +36m that lead to disappearance of coal project wells that debouch their water from the Aquifer. On the other hand, the groundwater salinity decreased from 5200-5840 ppm in 1967 to 2413-2464 ppm and the dominant salts changed from NaCl, $CaCl_2$ and $CaSO_4$ in 1967 to NaCl, $Ca(HCO_3)_2$ and $MgCl_2$ in 2005. The decrease of salinity and the change of main salts are due to the old Lower Cretaceous wells were restricted in the coal project of bad well design and of shallower depths, while the present wells were drilled by oil companies and of good well design as well as deeper.

vi- Also, the Jurassic piezometric head decreased from +40 - +50m to +38 m that lead to disappearance of coal project wells tapping this aquifer. On the other hand, the groundwater salinity decreased from 4160 - 4187 ppm in 1967 to 2739 ppm and the dominant salts changed from NaCl and $CaSO_4$ in 1967 to NaCl, $Ca(HCO_3)_2$ and $MgCl_2$ in 2005. The lessen of salinity and the change of main salts of the present wells than the older ones are due to the present wells were drilled by oil companies and of good well design as well as more deeper, while the older wells were restricted in the coal project of bad well design and shallower depths.

4- Hydrogeochemical Characteristics

From the chemical analyses of the collected water samples (Table 1) and the hypothetical salts percentages in the studied area (Table 3), the source of groundwater recharge and the aquifer sediments much control the geochemical properties of each aquifer. This appears in the following:

Quaternary water

i- All the Quaternary water samples are brackish water due to the effect of the leaching processes and the aquifer sediments are derived mainly from saline sediments, while the wadi fills water samples are fresh due to the low rate of leaching processes where they are located near the upstream.

Table (3). Hypothetical salts percentages of the collected water samples in Ayoun Mousa and adjacent areas.

No.	Aquifer system	Well Name	KCL	NaCL	$MgSO_4$	$CaSO_4$	$Ca(HCO_3)_2$	$MgCL_2$	$CaCL_2$
1	Holocene	Um Maboug –1	2.14	21.71	7.90	38.74	13.52	15.98	0.00
2		Um Maboug –2	4.02	21.90	0.00	34.90	17.91	20.12	1.15
3		Um Kashtan	2.02	22.12	20.4	26.40	15.23	13.80	0.00
4		Banana Beach	2.23	21.44	0.00	14.18	18.45	20.28	23.41
5		Nozha Beach	1.92	39.37	0.00	10.46	9.17	11.17	27.91
6		Mohamed Shadad	0.53	49.06	0.00	10.44	8.90	9.69	21.37
7		Um Gerdy Sabkha	1.46	21.96	0.00	0.00	25.94	18.46	22.79
8		Ayoun Mousa sabkha	3.63	81.23	0.00	3.91	9.91	0.96	0.00
9		Mousa Coast sabkha	2.36	35.18	0.00	0.00	6.13	27.52	14.16
10	Pleistocene	Said Sharaf	2.57	29.71	0.00	12.56	15.64	11.69	27.83
11		El Ahela Company	1.14	51.88	0.00	10.90	13.84	15.52	6.72
12		Mohamed Tag-3	1.23	52.07	0.00	10.82	16.04	14.77	5.07
13		Mohamed Tag-2	0.86	50.46	0.00	10.93	9.48	18.13	10.13
14		Mohamed Tag-1	0.78	53.59	0.00	11.35	8.30	15.79	9.51
15		*Bent Sultan*	0.83	58.44	0.00	11.78	5.55	12.49	10.92
16		Hag Abdel Haleem	0.66	44.49	0.00	7.96	10.60	32.61	3.68
17		Golden Beach 2	0.71	54.06	0.00	8.87	9.13	19.41	7.82
18		Temareros	0.67	37.44	3.31	8.20	7.80	42.59	0.00
19		Marina Sudr	0.66	38.42	0.00	11.44	7.00	28.53	13.95
20		Holandeia	0.64	51.46	0.00	16.45	6.68	20.04	4.72
21	Miocene	Wadi El Beiar group	1.16	43.20	17.32	5.73	14.15	18.45	0.00
22		Adel Hegazy	1.47	45.91	0.00	1.27	4.26	36.06	11.02
23		Oasis well	2.35	50.97	6.53	9.35	21.91	8.89	0.00
24		Mousa Coast deep	1.57	57.40	0.74	13.45	21.23	5.62	0.00
25		Ayoun Mousa Spring 2	2.02	36.49	0.00	8.53	13.83	4.42	34.71
26		Ayoun Mousa Spring 3	1.92	41.34	0.00	9.62	11.60	18.36	17.16
27		El Sheikh Spring 1	1.71	42.88	0.00	10.99	9.80	20.12	14.51
28	Cretaceous and Pre- Cretaceous	Masala-1	2.44	38.85	0.00	18.57	14.96	16.62	8.56
29		Masala-3	1.55	49.60	12.26	3.87	19.84	12.87	0.00
30		Ayoun Mousa -2	3.00	29.62	26.29	0.00	11.79	22.18	0.00
31		Ayoun Mousa –1	2.13	49.04	6.58	7.31	22.37	12.56	0.00

ii- The pH ranges mainly from 7.12 in the eastern part to 8.76 in the western part due to the effect of leaching processes.

iii- The main salts of Holocene Aquifer changed from NaCl, $MgCl_2$, $CaSO_4$ and $Ca(HCO_3)_2$ of in the eastern part (wadi fill) to NaCl, $CaCl_2$ and $MgCl_2$ in the western part (shallow) due to the effect of leaching processes. On the other hand, the main hypothetical salts of the Pleistocene Aquifer are mainly NaCl, $MgCl_2$ and $CaSO_4$. due to the aquifer sediments derived mainly from the saline sediments and salt water intrusion from the Gulf of Suez.

iv- The dominant sequence changed from Ca^{++}>Mg^{++}>Na^{+} – $SO_4^{=}$>Cl^{-} >HCO_3^{-} near the upstream (wadi fill) to Ca^{++}>Na^{+}> Mg^{++} – Cl^{-}> $SO_4^{=}$>HCO_3^{-} in the down stream due to the effect of leaching processes. On the other hand, the effect of salt water intrusion and leaching processes make the dominant sequence of Pleistocene Aquifer to become mainly Na^{+}> Ca^{++}>Mg^{++} – Cl^{-}> $SO_4^{=}$>HCO_3^{-}.

b- Miocene water

i- All the Miocene water samples are brackish water due to the effect of leaching processes and the marine nature of the aquifer sediments.

ii- The pH ranges mainly from 7.8 and 8.26 due to the effect of leaching processes.

iii- The main hypothetical salts of Ayoun Mousa Aquifer are NaCl, $MgCl_2$, $MgSO_4$ and $Ca(HCO_3)_2$ due to the aquifer is recharge mainly from the eastern watershed area that characterized by marine sediments. On the other hand, the main hypothetical salts in the other Miocene Aquifers (Nukhul and Miocene Springs) that are recharged mainly from the deep Nubian Sandstone Aquifer System varied mainly from NaCl, $CaSO_4$ and $Ca(HCO_3)_2$; and to NaCl, $CaCl_2$ and $Ca(HCO_3)_2$ due to the variation of rate of leaching processes.

iv- The dominant sequence of Nukhul Aquifer and Miocene Springs of the same source of recharge (deep Nubian Sandstone Aquifer System) are Na^{+}> Ca^{++}> Mg^{++}- Cl^{-}> HCO_3^{-}> $SO_4^{=}$, while the dominant sequence of Ayoun Mousa Aquifer that recharged from the eastern watershed area are mainly Na^{+}> Mg^{++}> Ca^{++}– Cl^{-}> $SO_4^{=}$> HCO_3^{-}.

c- Nubian Sandstone Water

i- All the Nubian Sandstone Water samples are brackish water due to the marine nature of the aquifer sediments.

ii- The pH ranges mainly from 7.63 and 8.06 due to the effect of leaching processes.

iii- The main salt combinations in Lower Cretaceous aquifer are NaCL, $MgCL_2$ and $Ca(HCO_3)_2$, due to the effect of shale layers, while the main salt combinations in Jurassic Aquifer are NaCl, $MgCL_2$ and $Ca(HCO_3)_2$ due to the small thickness of shale layers.

iv- Also, the variation of the thickness of shale layers causes the changes of the dominant sequence from Na^{+}> Mg^{++}>Ca^{++} –Cl^{-}> $SO_4^{=}$> HCO_3^{-} in Lower Cretaceous Aquifer to Na^{+}> Ca^{++} > Mg^{++}- Cl^{-}> HCO_3^{-}>$SO_4^{=}$. in Jurassic Aquifer.

5- Genesis of Groundwater

From the above mentioned hydrogeological and hydrochemical analyses that plotted on Piper Diagram (1944) and Sulin's Diagram (1948) (Figs. 9 and 10) in the studied area, most of the groundwater samples of the different aquifers refers to meteoric type. However, the chemical composition of the Quaternary Aquifer system reflects the influence of both marine environment and aquifer sediments, while the other aquifer system reflects the role of aquifer sediments only. Observation of the water static head in the deeper aquifer system indicates its increase with depth which necessitates a connection of the groundwater aquifers from deeper to shallower.

The Quaternary Aquifer System and Ayoun Mousa Aquifer (Upper Miocene) are recharged mainly from the eastern watershed areas, while the deeper aquifer systems are fossil water. This appears from the isotope analyses of the Nubian Sandstone water that carried by El Abd (2000) and Tantawy (2003). Where, the oxygen^{18} ranges from –5.93 to –6.12% and the deuterium ranges from –39.8 to –43.2% that reflecting paleo-meteoric water and less active recharge from recent meteoric water. Also, the age determination of the Miocene Springs by Munnich and Vogel (1962) is >30 900 YBP based on C14 and the water mainly of Nubian Sandstone. On the other hand, the disappearance of coal project water and most of the Miocene Springs as well as the decrease of the piezometric head of the Nubian Sandstone Aquifer System.

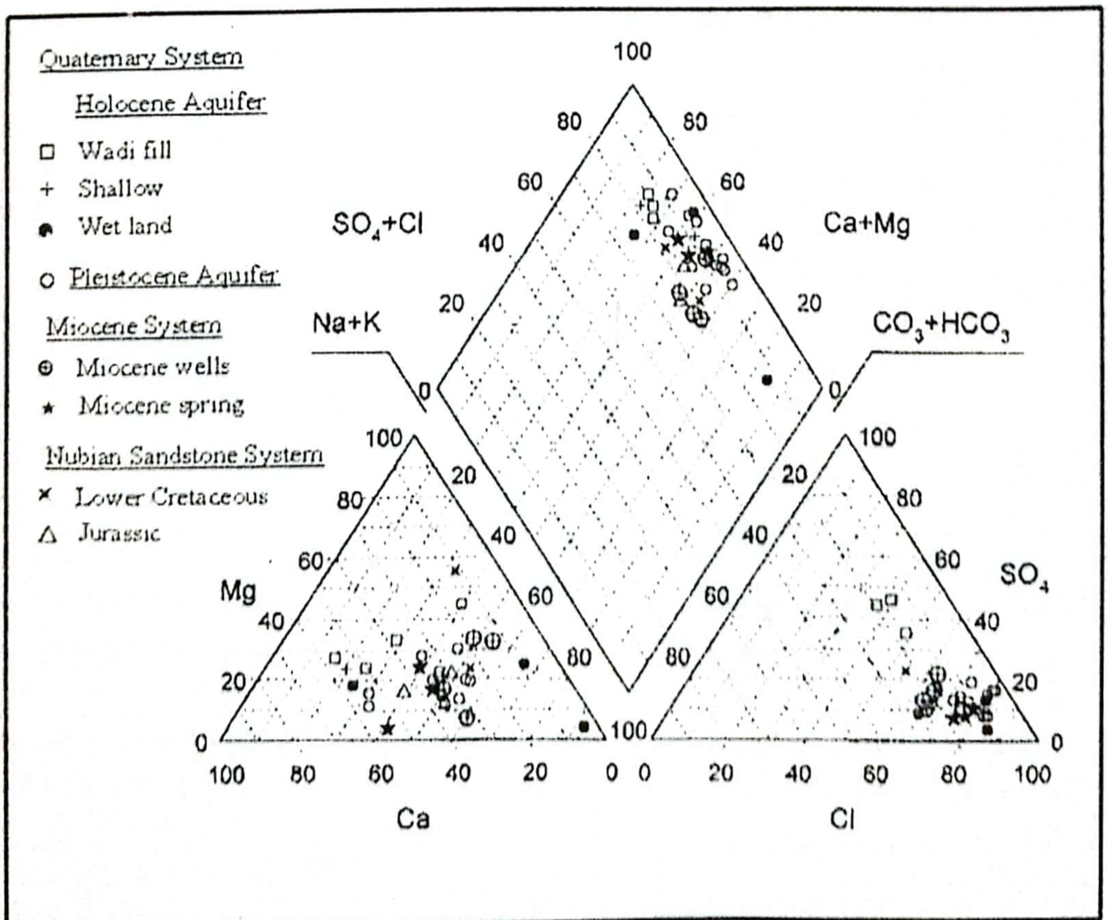

Fig. (9). Genetic classification of water points in the study area.

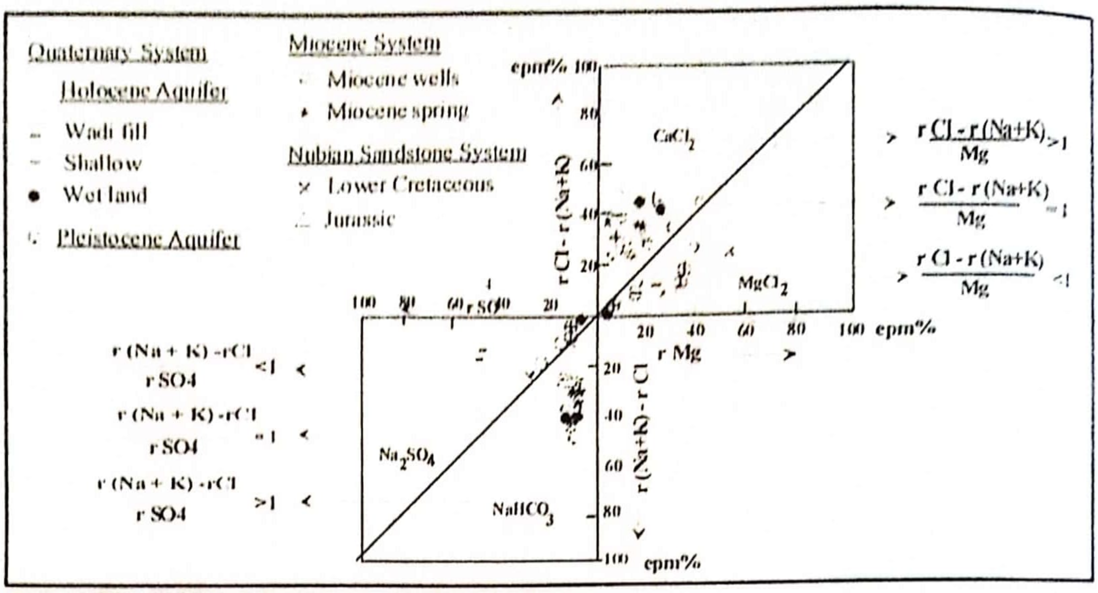

Fig. (10). Sulin Diagram of the study area.

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تقييم مصادر المياه الجوفية لعيون موسى والمناطق المتاخمة لها، غرب سيناء، مصر.

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تم تقسيم منطقة عيون موسى والمناطق المتاخمة لها جيومورفولوجيا إلى ٣ وحدات جيومورفولوجية رئيسية هي الهضبة التركيبية، السهول الفيضية والسهل الساحلي. أما أهم العناصر التركيبية الرئيسية بالمنطقة هي أنظمة الفوالق ذات الاتجاهات شرق-غرب ، شمال شرق ، شمال جنوب و شمال غرب وهى تتحكم في توزيع الصخور ومسارات أنظمة الصرف.

يتواجد بالمنطقة ثلاثة أنظمة للخزانات الجوفية هي الرباعي ، الميوسين و الحجر الرملي النوبي. نظام الخزان الرباعي هو عبارة عن خزان حر إلى شبه محبوس وينحصر في الغالب في المراوح الفيضية ومجارى الوديان وبسمك يتراوح بين عدة أمتار إلى اكثر من ٦٠ متر. يتغذى في الغالب من أحواض المياه في الشرق. وتم تقسيمه إلى خزان الهالوسين وخزان البليستوسين. خزان الهالوسين يتميز بمستوى ماء أرضي ضحل بين +٠,٧ متر و +٠,٤ متر وبملوحة تتراوح بين ٥٧٠ جزء في المليون و ٩١٨٤ جزء في المليون. من ناحية أخرى منسوب المياه في خزان البليستوسن يتراوح بين +٢٣ متر و –٨ متر و ملوحة مياهه أيضا تتراوح بين ٢٤١٤ و ٢٧٨٤٠ جزء في المليون.

نظام خزان الميوسين يتكون غالبا من الحجر الرملي به طبقات رقيقة من الطفلة ويتواجد في الجزء الشمالي من منطقة الدراسة وتم تقسيمه إلى خزانات عيون موسى ونخل. خزان عيون موسى عبارة عن خزان ضحل وحر يتغذى أساسا من أحواض الصرف في الشرق. منسوب المياه به يتراوح بين +٢١٢ و +٢١٧ متر وملوحة مياهه تتراوح بين ٣٥٢٠ و٧٣٢٨ جزء في المليون. أما خزان نخل عبارة عن خزان عميق و محبوس يتغذى أساسا من خزان الحجر الرملي النوبي العميق من خلال الفوالق و ملوحة المياه تصل إلى ٤٨١٠ جزء في المليون.

أما نظام خزان الحجر الرملي يمتد في كل منطقة الدراسة وتم تقسيمه إلى خزانات الكريتاسى السفلي و الجوراسى والباليوزوى. وتتميز بأنها عبارة عن خزانات محبوسه وفواره ومياهها متحفرة مع عدم وجود تغذية من أحواض الصرف الشرقية. خزان الكريتاسى السفلي ذو ضغط بيزومترى يتراوح بين +١٥ متر و +٣٦ متر وملوحة المياه تتراوح بين ٢٤١٣ و ٢٤٦٤ جزء في المليون ودرجة الحرارة تصل إلى حوالي ٤٠ درجة مئوية. بينما خزان الجوراسى يتواجد أيضا تحت ضغط بيزومترى +٣٨ متر وملوحة مياهه حوالي ٢٧٣٩ جزء في المليون ودرجة الحرارة تصل إلى ٤٥ درجة مئوية. من الناحية الليثولوجية تكاوين الباليوزوى سميكة (حوالي ٧٠٠ متر) ولها احتمالية عالية لتواجد المياه ولكن غير ممثلة بأي آبار.