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Assessment of Groundwater Potentiality in the West Wadi El Natrun- North Western Desert Region, Egypt

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***Abstract*:- Groundwater is considered as the main source of water for the desert development in Egypt. The North western desert region, especially the area located between Wadi El Natrun –Alamein road and El Dabaa road, in the vicinity of West Nile Delta Region is considered as one of promising desert areas for land reclamation activities in Egypt mainly based on groundwater. To achieve an integrated development plan for this area, adetailed hydrogeological investigations and evaluation groundwater potential of existing aquifer systems are required.**

The detailed hydrogeological investigations include geophysical survey, well inventory, groundwater sampling, implementation of pumping/recovery tests on some selected wells and integration assessment of these data to evaluate the groundwater potential of the existing aquifer. The interpretation of the geologic, geophysical and hydrogeological data revealed recognition of six geo-electrical (Hydrogeological units) with definite characteristics. Through GIS the collected and interpreted data were used to construct geoelectric cross sections and detailed specialized hydrogeological contour maps comprising depth to groundwater, groundwater level, salinity, as well as groundwater potentiality.

The present study concluded that, the existing aquifer within the study area belongs to the Moghra aquifer where its depth ranging from 106 m to 196 m from ground surface, depth to groundwater varies from 70 m to 170 m and the main flow direction is from northwest to southeast. Groundwater salinity varies from 1250 ppm to5000 ppm. The integration of processed data was used to evaluate the groundwater potentiality within the study area. Groundwater potential could be classified as high (at the southern east part) to low potential (at the northwest part) of the study area. The findings of this study could be considered as the base for formulating groundwater development plan for the study area.

1- INTRODUCTION

Egypt is located within the arid zone region; where about 97% of the population is living on approximately 4% of the total area of the country and all socio economic activities are mainly depend on the Nile water. In the desert fringes of the Nile Valley and Delta, groundwater is considered as the only available resource for interdisciplinary development (El Tahlawi et al., 2008). During the last three decades, intensive efforts were made to investigate the availability of groundwater occurrence and evaluate its potentiality all over the desert areas of Egypt.

The study area is located in the Northern part of the Western Desert, to the West of the Wadi El Natrun area and extended to El Dabaa Road. It is considered as an extension of the West Nile Delta Region, where extensive and large land reclamation activities are implemented by the private sector and concentrated in the eastern part of the study area. The existing aquifer systems and its lateral extension in these areas are not yet completely explored or evaluated regarding to groundwater occurrence and its

Hydrogeological studies of Moghra aquifer in north western desert area are scarce and the concerned study area is not included in those studies that had carried out by Yousef (2013), El Sabri et al. (2016) and Abdel wahab et al. (2018). So it was necessary to conduct out a detailed study in the concerned to evaluate the groundwater potential for developments.

The main objective of the research is to evaluate the groundwater occurrence conditions and detect the hydraulic parameters of the existing aquifer and its potentiality. To fulfil this objective, a detailed hydrogeological study has been conducted. The detailed hydrogeological study includes groundwater investigations, using electrical geophysical resistivity survey, well inventory, groundwater sampling, implementation of pumping/ recovery tests on some selected wells. Using GIS, the collected and interpreted data were used to construct geo-electric hydrogeological cross sections and detailed specialized maps including: depth to groundwater, Piezometric head and groundwater salinity contour map. The GIS will be used to analyse the integrated data and to classify the groundwater potential of the study area. The groundwater potential map will answer the question of how much groundwater can be extracted in a way to protect the groundwater sustainability and consequently propose the future suitable groundwater development plan for the study area.

2-PHYSICAL SETTING

2-1 Location

The study area is located in the northern part of the western desert to the west of the Wadi El Natrun area, between latitudes 30° 08' 43" and 30° 39' 30" North and longitudes 29° 29' 49" and 29° 57' 30" East. Its total area reaches about 2500 km². The area is bounded northwards by international road of El Alamein and southwards by El Dabaa road, which extends inside the area in a northwest direction with a length of about 45 km. Figure 1.The level of the ground surface varies from -2m to 150m (above mean sea level).

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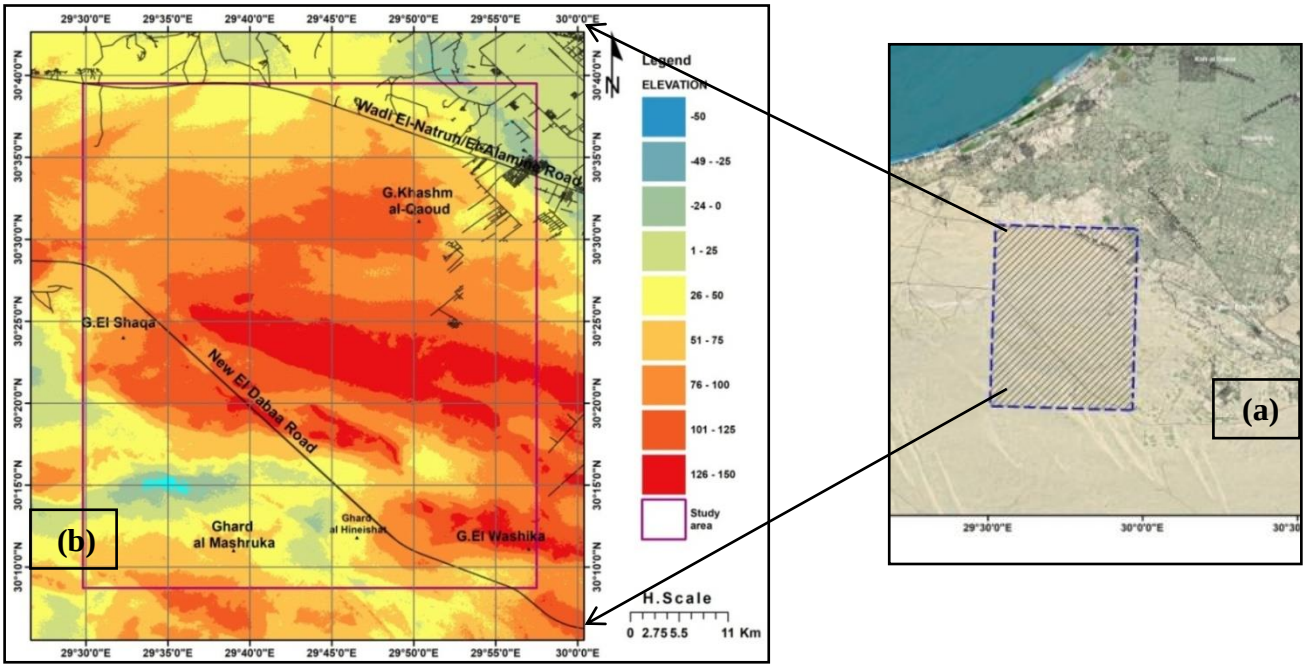

Figure (1): (a) General Location map & (b) Topographic map of the study area

2-2 Geological setting

The surface of the study area is covered by geological units ranging in age from Quaternary to Lower Miocene ages (El-Gezeery et al., 2007). Most of the area is covered by Quaternary sand sheets and sand dunes. According to different authors, the sedimentary sequence within the study area can be differentiated into the following main formations: Alexandria, Kalakh, Hagif, El-Solymania, Mikheimin, and Moghra formation, Figure 2. Regarding to the subsurface sequences, there are two main formations:

- **Moghra Formation:** belongs to the Lower Miocene, and consists of continental to shallow marine silica- clastic sequences including shale, siltstone, and white sandy carbonate beds, with abundant silicified wood. It is exposed on the surface at the southern part of the study area and disappears at the northern part of the area under younger formations.
- **Dabaa Formation**: belongs to Oligocene, and consists of argillaceous, carbonaceous shales with some inter bedding of glauconitic, sandy limestone. The maximum thickness of the Dabaa Formation in the present coastal area is around 650 m. In Oligocene time, basalt-diorite dykes and flows took place due to tensional movements in the rift zone (Said, 1990).

The study area is located in an unstable shelf, which is characterized by a northward thickening sedimentary section. This sedimentary section is underlain by high basement relief due to block faulting and affected by minor compressional folding (Said, 1990). According to Abdel Mogith et al. (2013), the study area is considered as part of the N.Abu Gharadig basin, which is a transitional basin between marine (Northern basin) and continental (Southern basin).

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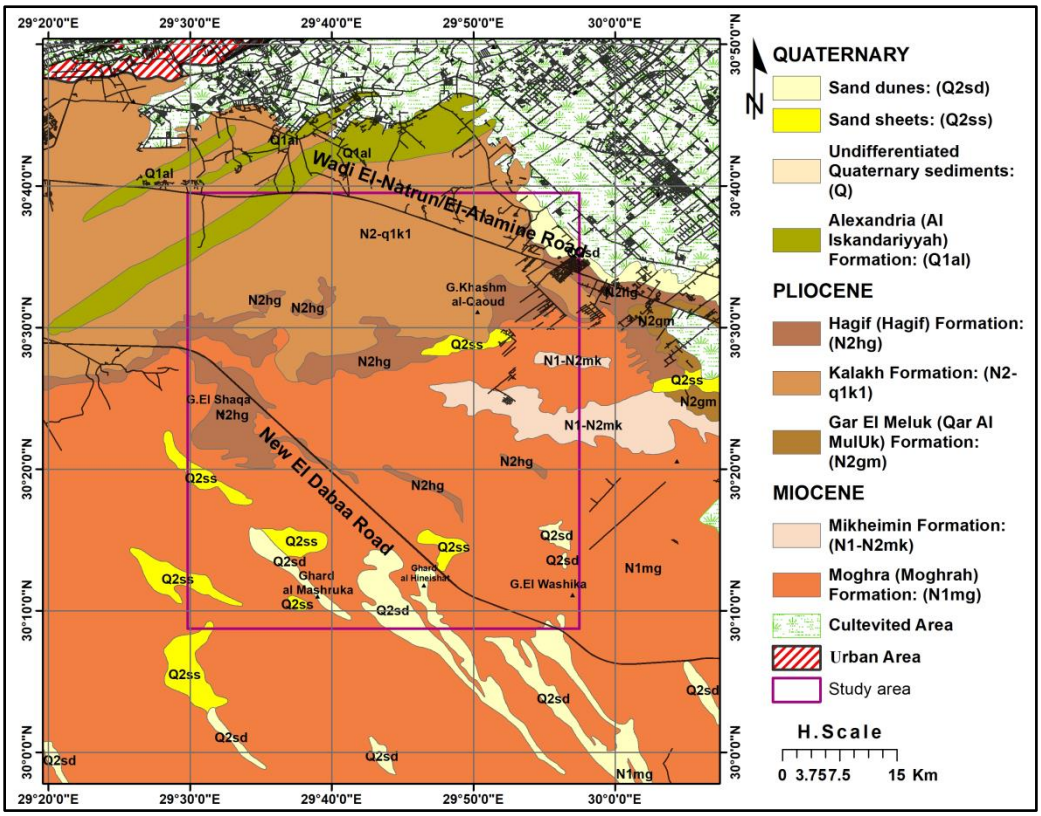

Figure (2): Geological map of the study area

3- MATERIAL AND METHODS

To achieve the research objectives in the study area, the following activities were conducted:

3-1 Assessment of Hydrogeological Properties

To determine the hydrogeological properties of the existing Moghra aquifer and in addition to the valuable data and results obtained from the interpretation of the geo-electrical survey, a well inventory for observation and productive wells were executed including locations, total drilling depths, groundwater depth, groundwater extraction, groundwater salinity and land use. Figure (3) illustrates the location of existing inventories wells in the study area. The collected data for about 290 existing wells were assessed and used to produce specialized water maps (groundwater depth, salinity, groundwater level).

3-2 Geophysical Survey

Geo-electrical resistivity method was applied to determine vertical and lateral extension of the subsurface water bearing layers based on differentiation of their lithological and conductance (electric resistivity) characteristics.

Forty Vertical Electrical Soundings (VES) were conducted in the study area using ABEM-SAS 1000 equipment. The locations of the VES's were selected carefully to cover the study area(Figure 4).These measurements method were conducted applying Schlumberger array with a maximum electrode spacing (AB/2) reaching 700 m. The field data are interpreted by IPI2WIN 2005program. Available subsurface lithological and hydrogeologic data of wells were used for calibrating geo-electrical results

3-3 Groundwater Quality Assessment

Groundwater samples were collected from selected observation and production wells of the study area and chemically analyzed regarding pH, EC, soluble cations as well as soluble anions and heavy metals, in addition to calculate of Sodium Adsorption Ratio (SAR) from the measured results .Figure 3 shows location map for the production and monitoring wells.

3-4 Hydraulic Parameters Calculations

Hydraulic parameters of the existing aquifer area are considered very important to evaluate groundwater resource through prediction of drawdown in aquifer under proposed pumping scenarios. To determine the hydraulic parameters of El-Moghra aquifer in the study area four long duration pumping tests were carried out for some selected production wells (Figure 3), the measured data were analyzed using specialized programs through different methods according to some factors: aquifer type, isotropy, discharge and well penetration. So, the analysis methods Theis (1935) and Hantush-Jacob (1955) were used to reach more representative solutions. Aquifer productivity was calculated for each well based on the groundwater discharge (m^3/h) and the corresponding drawdown.

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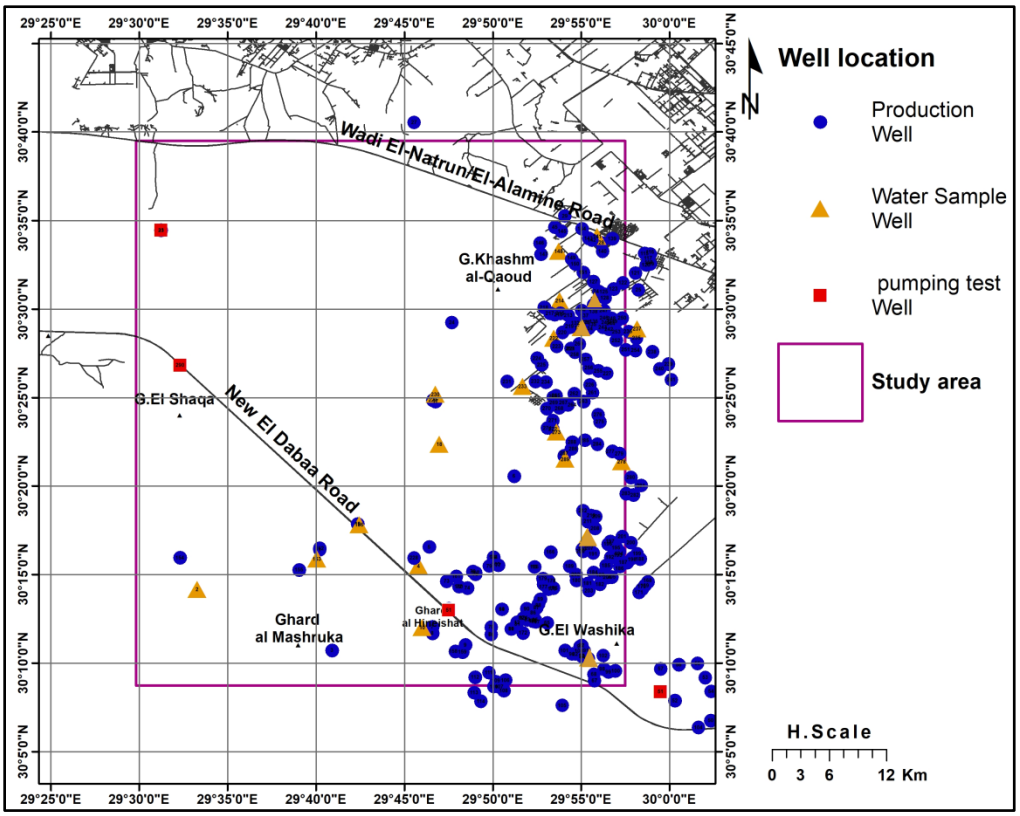

Figure (3): Location Map for the existing wells (production/monitoring)

3-5 EVALUATION OF GROUNDWATER POTENTIALITY

The potentiality of the Moghra aquifer, in the study area, will be estimated based on the measured and interpreted hydrogeological data which are represented in the following major parameters; i) the type and the thickness of the aquifer; ii)the groundwater depth; iii) groundwater salinity iv) groundwater productivity and v) the existing groundwater extraction.

4- Results and Discussions

4-1Geophysical survey results

The obtained results from the quantitative interpretation are illustrated in three geo-electrical cross-sections (AA'– BB'– CC'), where six geo-electrical units can be differentiated according to their electrical resistivity. The interpreted data were verified through the available lithological data from the existing wells, taking into consideration the prevailing geological and hydrogeological conditions of the area. The cross sections also indicate that there is a noticeable lateral and vertical electrical resistivity (lithological) variation in the study area, in addition to the inferred faults which greatly affect the hydrogeological regime of the area (Figure 4). In the following a brief will be given about the detailed characteristics of the recognized geo-electrical units:

a) **The first geo-electrical unit;** with resistivity values range from 11 to 100Ohm.m, this unit is formed from gravel, with fine to coarse grained sand which covers the whole surface. Its thickness ranges from 0.8 to 2 m.
b) **The second geo-electrical unit;** has resistivity values range between 55 and 382 Ohm.m which indicates sand, gravel and rock fragment components. This unit intercalates sometimes with silt and fine sand which cause decreasing in resistivity values under some VES stations. The thickness of this unit ranges from 2 to 25 m.
c) **The third geo-electrical unit;** with resistivity values range from 30 to 123 Ohm.m. This unit may consist of limestone with some clay intercalation under some VES stations. The thickness of this unit ranges from 2 to 14 m. This unit appears only at the northern part of the study area.
d) **The fourth geo-electrical unit**; has resistivity values range from 4 to 113 Ohm.m. This unit may contain fine to medium dry sand with shale intercalation which increases to be the dominant component at some VES stations (5, 6, 23, 24, 25, 30 and 31). The thickness of this unit ranges from 5 to 47 m.
e) **The fifth geo-electrical unit**; has a resistivity values ranges from 47 to 180 Ohm.m. This unit has a relatively high resistance and may be composed of coarse sandstone. The thickness of this unit ranges from 76 to 158 m.
f) **The sixth geo-electrical unit;** has a resistivity values range from 8 to 50 Ohm.m. This unit may consist of shaly sand. The upper surface of this unit has been detected at depths ranging from 106 m to 196 m, while the lower surface cannot be reached by the used geometry of electrode configuration. The resistivity values of this unit give an indication to the probability of constituting groundwater bearing layer.

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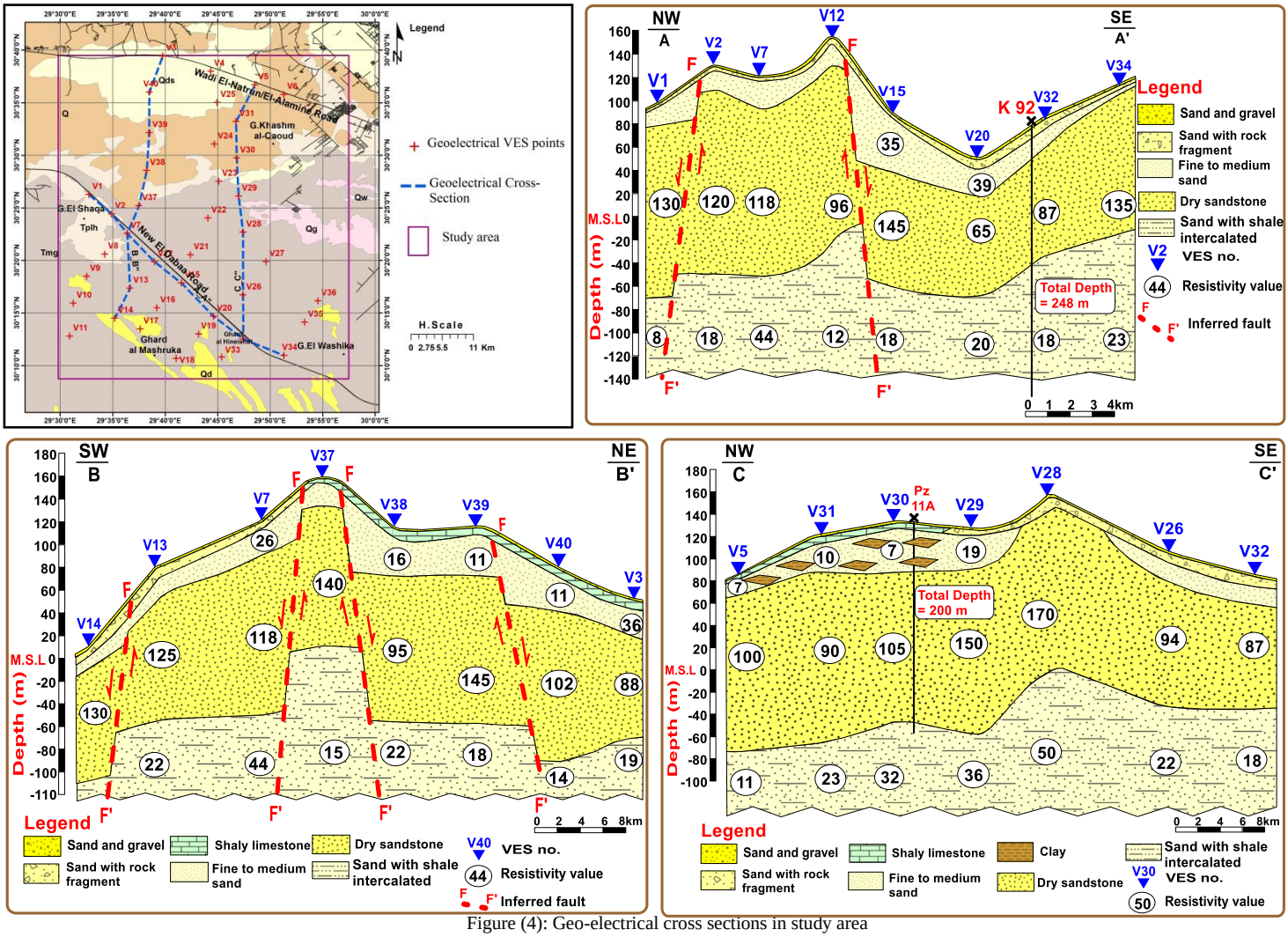

Figure (4): Geo-electrical cross sections in study area

4-2 Groundwater level and flow of El Moghra aquifer

The measured data indicated that the depth to groundwater in the study area varies from 70m to 170m. These data also helped to identify the general and local groundwater flow and produce different specific water maps. Figure (5) shows depth to groundwater contour map. Figure (6) shows the groundwater level map (related to mean sea level), which indicates that the groundwater levels varies from a maximum of -10 m in the middle part of the study area and decreases to -40m and -30m in the eastern and western directions respectively. Also, from the groundwater level contour map (Figure 6), the groundwater flow directions can be detected as follow:

- The regional direction of groundwater flow is occurred from the northwest to the southeast, while the local direction of groundwater flow is from the middle part of study area to both east and west direction of El Dabaa road.
- The local fluctuation of the groundwater levels is controlled by the intensity of groundwater extraction rates from the existing production wells.

4-3 Aquifer recharges and discharge

The recharge of the aquifer in the study area is limited and its source mainly from the lateral recharge from Quaternary aquifer especially in the southeastern part of the study area, in addition to the direct recharge through the rainfall in some parts of the area where the aquifer is unconfined. The Groundwater discharge is mainly taking place by groundwater extraction form existing production wells concentrated in the south and east part of the study area, where the average rate of well discharge varies from 40-60m^3/h. Current groundwater extraction considered to be small as the development in the study area still in its early stage.

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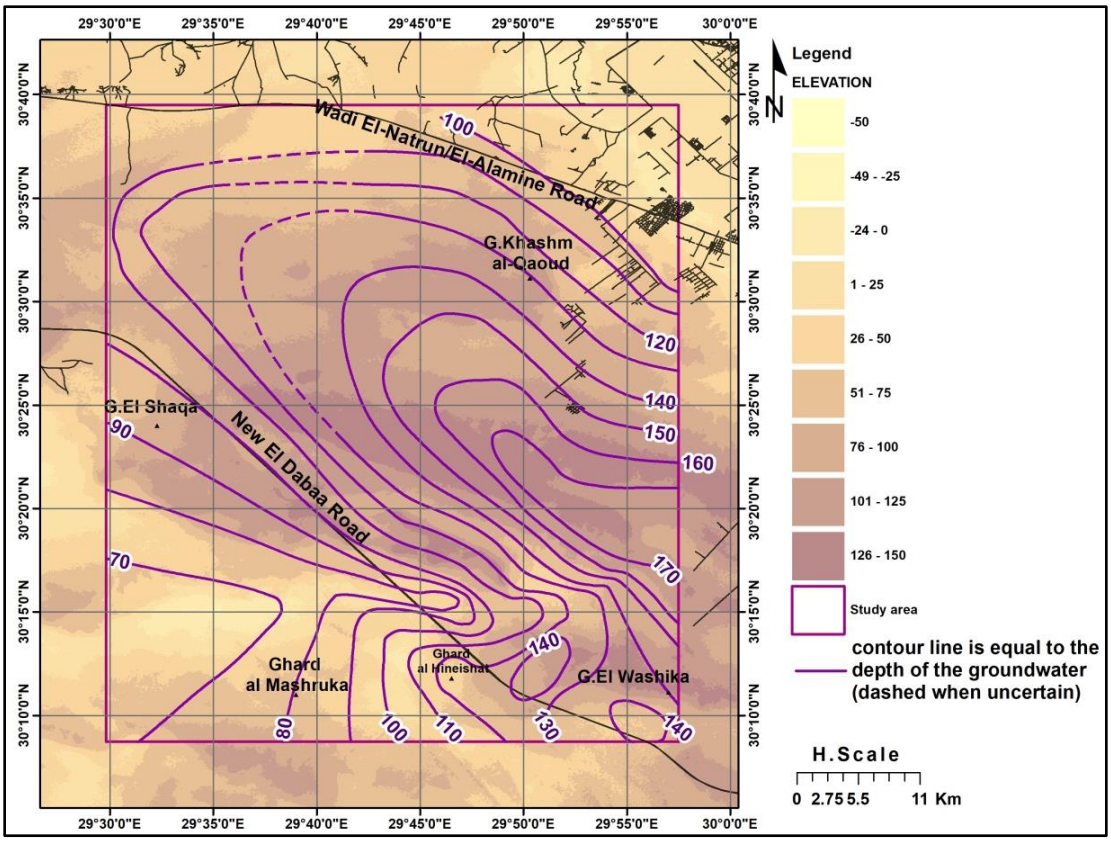

Figure (5): Depth to groundwater contour map-Year 2021

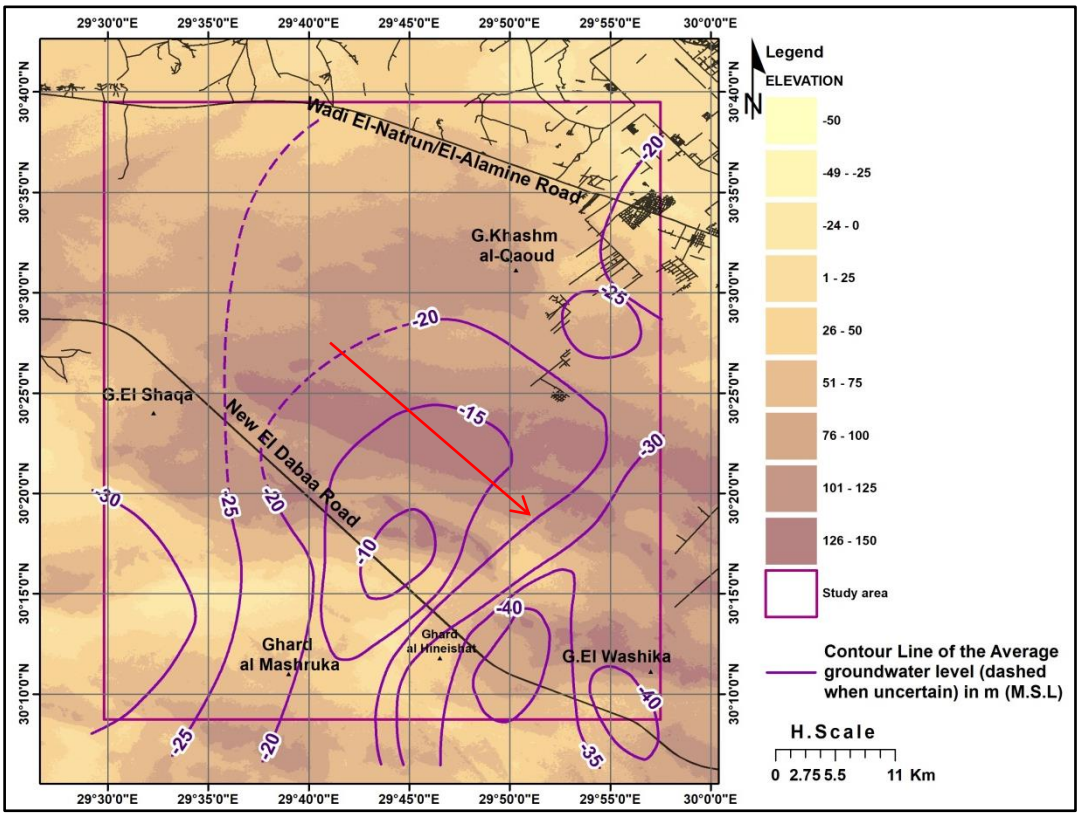

Figure (6): Groundwater level contour map-Year 2021

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4-4 Groundwater Quality

Based on the measured field data and results of the chemical analysis (pH, TDS, major Cations and Anions as well as for heavy metals) of the collected groundwater samples, groundwater salinity map was prepared using GIS (Figure 7). The results of the representative groundwater samples are presented in Table 2, where:

- The values of pH ranged between 7.27 and 8.5 with an average of 7.64 and this means that pH of the collected samples were neutral.
- EC ranged between 5.46 and 2.28 m mhos/cm with an average of 3.545mmhos/cm and these values violated the allowable limit of irrigation FAO (1985).
- The values of TDS ranged between 5500 and 1485ppm with an average of 2570 ppm.
- The data of soluble cations and anions clear that Na was dominated compared to other cations while Cl and So_4 were dominant compared to the other anions. This means that the dominant salts were Sodium Chloride (NaCl) and Sodium Sulphate (Na_2So_4).
- The Values of Sodium Adsorption Ratio (SAR) ranged between 8.04 and 17.09 with an average of 11.3. The average violated the permissible limit that recommended by FAO (1985) for irrigation.
- The data of heavy metals clear that all the metals below the permissible limit except manganese in some locations where its concentrations violated the allowable limits. This may attributed to the fertilizers application of manganese

From the results , it is clear that the data of some wells are available to use in irrigating some crops that are semi tolerant and tolerant to salinity, considering the system of drip irrigation and the time of irrigation application which should be before the sun set.

Table (2): Chemical Analysis of Groundwater Samples

Element	Unit	Max.	Min.	Average
pH		8.19	7.27	7.643125
Electrical Conductivity (EC)	mmhos/cm	5.46	2.28	3.545
Total Dissolved Solids(TDS)	mg/l	5500	1485	2570.063
HCO_3	mg/l	326.9	131.5	200.28
Calcium Ca	mg/l	222.2	88.6	143.3356
Magnesium Mg	mg/l	92.96	35	53.9625
Sodium Na	mg/l	1100.32	381	599.0713
SAR	Ratio	17.09	8.04	11.300
Chloride Cl	mg/l	1516.56	527	855.355
Nitrate NO_3	mg/l	8.7	<0.2	2.580625
Sulfate SO_4	mg/l	1002.24	221	456.6
Aluminum Al	mg/l	0.06	<0.006	0.017813
Copper Cu	mg/l	0.039	0.013	0.026438
Iron Fe	mg/l	0.083	0.005	0.05625
Lead Pb	mg/l	0.014	<0.003	0.006375
Manganese Mn	mg/l	0.331	<0.005	0.080188

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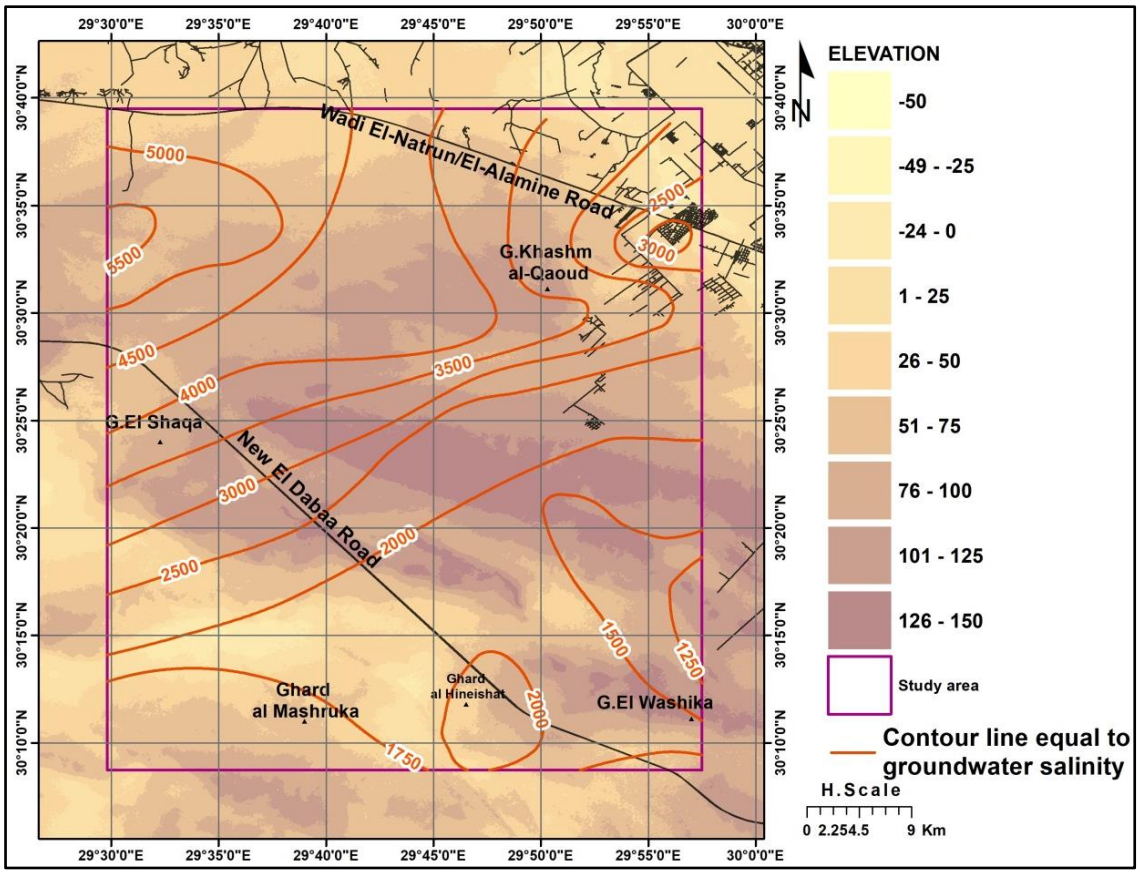

Figure (7): Groundwater salinity contour map-Year 2021

4-5 Hydraulic Parameters of El-Moghra Aquifer

Table 3 and Figure 8 illustrate the results of analysis of long pumping tests data for selected production and monitoring wells in the study area. From these results it can be observed that:

- The transmissivity of Moghra Aquifer varies from 107 to 3100 m^2/day (at wells no Pz15, K92 respectively, where the low value of transmissivity can be attributed to the decrease of the saturated thickness (less than 50 m) and the presence of thick intercalated clay layers in the aquifer.
- The productivity of aquifer (specific capacity values, (Q/s) ranges between 1.6 to 19m^3/h/m in wells K92 and K126 respectively. The decrease in Q/s values is mainly due to the increase in drawdown (s) for constant discharge rate (Q), and this resulted from the low of transmissivity value of the aquifer within these areas..
- According to well productivity classification (Sen, 1995), the tested wells of El-Moghra Aquifer can be classified as highly productive (Q/s more than 18 m^3/h/m), moderately productive (Q/s from 18-1.8 m^3/h/m) and low productive (Q/s from 1.8-0.18 m^3/h/m).

Table 3: Hydrogeological characteristics of the Moghra Aquifer

Well	coordinates		Transmissivity (T) (m^2/day)		Pumping rate (m^3/h)	Draw down (m)	Productivity (m^3/h/m)
	N	E	Pump/recover	Value			
K126	30.44	29.54	Pumping	1390	31	1.6	19 (H)
			Recovery	378			
K 92	30.21	29.99	Pumping	107	48	29.51	1.6 (L)
			Recovery	97.1			
D32b	30.14	29.99	Pumping	1060	137	13.7	10 (M)
			Recovery	1010			
Pz15	30.57	29.52	Pumping	3100	33	10.7	3 (M)
			Recovery	1700			

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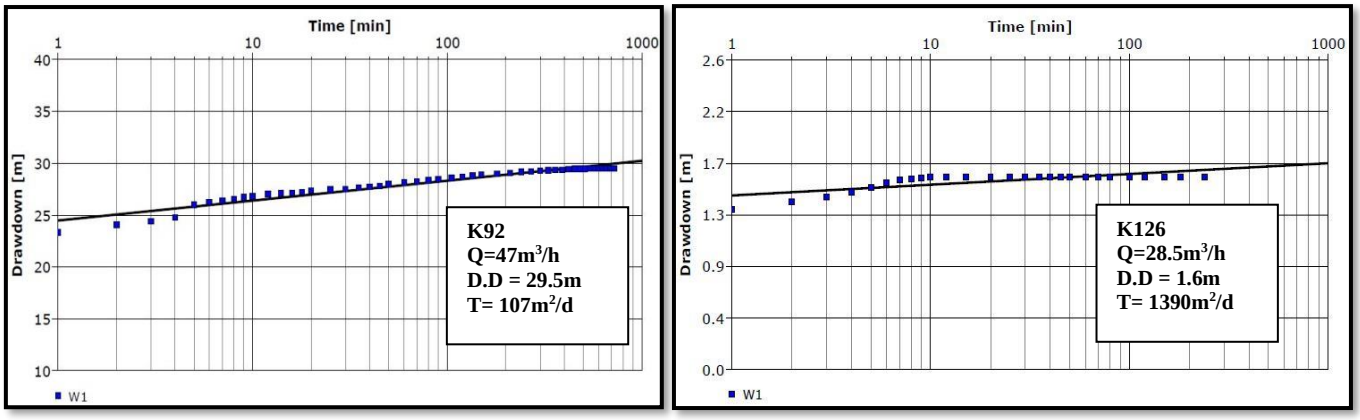

Figure (8): Pumping test data analysis for wells K92, K126

4-6 Groundwater potentiality

Aquifer potential may be defined as its ability to supply water with good quality and suitable rate at a certain time and place for sustainable development. The main factor affect groundwater potential represented in the continuity of the source in termsof both quality and quantity. Quantity refers to the availability of the source, while qualityrefers to its suitability for a specific use (RIGW, 1992).

The potentiality of the Moghra aquifer, in the study area, will be evaluated based on the following major parameters; i) the type and the thickness of the aquifer; ii) the groundwater depth; iii) groundwater salinity iv) groundwater productivity and v) the existing groundwater extraction. The present study revealed that the transmissivity of the aquifer ranges between 97(the middle part of study area closed to El Dabaa road) and 3100 m²/day (in northwest direction of study area). Groundwater level is deep where it reaches to 150m from ground surface with groundwater salinity ranges from 1250 to 5000ppm. While the calculated productivity of El Moghra aquifer varies from Low to high, and the aquifer is under semi confined condition. Current groundwater extraction considered to be small as the development still in its early stage.

Based on assessment and integration of all above mentioned measured and calculated data, and according to the criteria for classification different potential parameters in desert fringes of the Nile Delta (RIGW, 1992), presented in Table 3, Groundwater potentiality of the study area was estimated. Figure 9, represents a groundwater potentiality map for the study area.

Table (4): Criteria for Qualitative Classification of the Potential parameter in Desert fringes (RIGW, 1992)

Classification	Saturated Thickness (m)	Depth to G.W (m)	Suitability for Irrigation TDS (ppm)
High (blue)	*	<15	<1500
Moderate (Green)	*	15-40	1500-3000
Low (Red)	*	40-80	3000-5000
None (Black)		>80	>5000

* is included in classification of productivity and depth to groundwater

According to Figure 8, the groundwater potentiality of the study area can be differentiated into the following categories:

High potential: It covers the south and southeast parts of the study area where the aquifer is characterized by high productivity, high groundwater suitability (>1500ppm) and medium to low groundwater depth.

Moderate Potential: It covers the middle part of the study area where the aquifer is characterized by moderate productivity, moderate groundwater suitability (1500- 3000ppm) and low groundwater depth (>80m).

Low potential: It cover the north part of the study area where the high productivity, low groundwater suitability (>3000 ppm) with low depth to groundwater (>80m).

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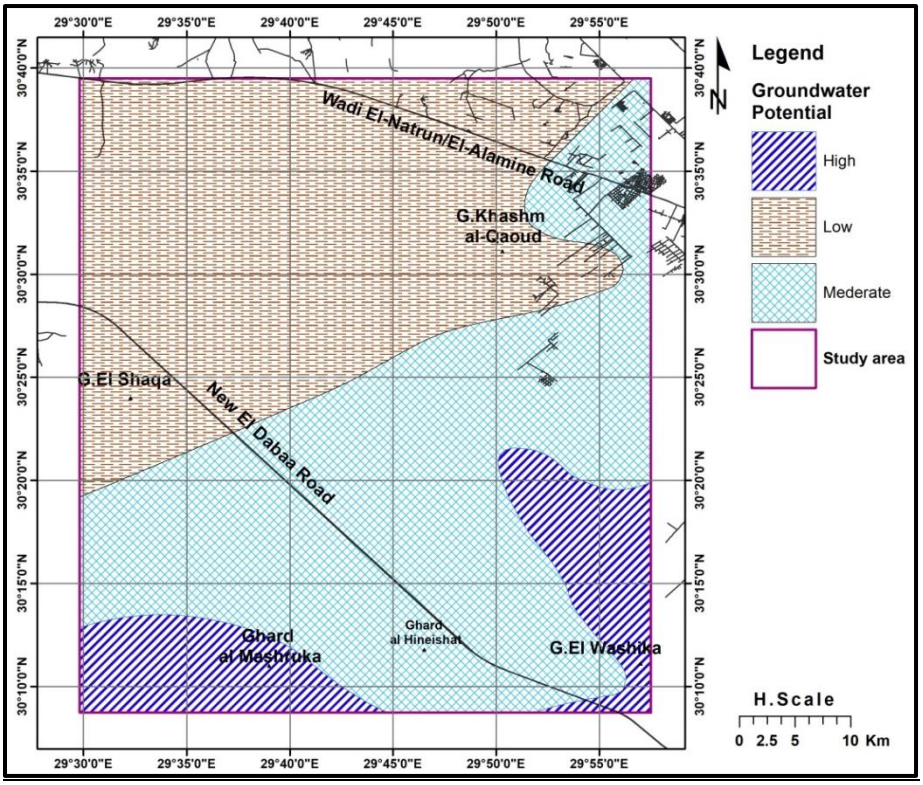

Figure (9): Classification of groundwater potentiality year-2021

4- CONCLUSIONS

The study area is located west wadi El natrun between Wadi El Natrun –Alameen road and El Dabaa road, considered as one of promising desert areas for land reclamation activities based on groundwater. Development in that area has been started since few years. The existing aquifer system and its lateral extension in these areas are not yet completely explored or evaluated regarding to groundwater occurrence and its potentiality.

Geophysical investigations detected the occurrence of six Geo-electrical units, mainly composed of clastic sediments except the third unit, which composed of limestone and clayey limestone. Verification of the geophysical results with the available well data indicated that the six geo-electric unit, which consists of sand with some intercalation of shale, represents the main groundwater bearing layer within the study area (Moghra aquifer).The depth of the aquifer varies from 106 to 196 m from the ground surface, and it is considered as semi confined aquifer.

Assessment of the hydrogeological data indicated that the new development in the study area are implemented by the private sector and concentrated in the south and eastern part of the study area where groundwater salinity less than 2000ppm.The depth to groundwater varies from 70m to 170m and a groundwater level varies from -10 m in the middle part of the study area and decrease to -40m and -30m in the eastern and western directions respectively. The regional direction of groundwater flow is from the northwest to the southeast.

The major discharge component is through groundwater drilled wells which located in the eastern parts of the study area. The average well discharge rate varies from 30- 40m^3/h. Generally current groundwater extraction is considered to be small as the development still in its early stage. The aquifer is considered generally as medium productive aquifer and groundwater salinity varies from 1250 ppm to 5000ppm which indicates its suitability only for irrigation of semi tolerant and salt tolerant crops.

The transmissivity of the aquifer ranges between 97 (the middle part of study area closed to El Dabaa road) and 3100 m^2/day (North West direction of study area). Groundwater level is deep where it reaches to 150m from ground surface. Groundwater potentiality within the study area was classified into three categories from high potential to low potential based on the main effective parameters: groundwater depth, saturated thickness, productivity and suitability of groundwater.

This research gives good insight for the hydrogeological conditions and groundwater potential for study area. Continuous monitoring for present and future development highly recommended before any additional extractions. Periodical evaluation and updating of the groundwater potentiality is a most. The water users should follow the wells licensing system and instructions of the related authorities regarding to groundwater protection.

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