MANAGEMENT OF GROUNDWATER RESOURCES IN WADI EL FARIGH AREA USING MATHEMATICAL MODELING TECHNIQUES

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ABSTRACT

Wadi El Farigh area is considered as one of the most important areas in the North of the Western Desert of Egypt. It depends on groundwater of Lower Miocene aquifer as a main source for agricultural and human resouces development. However due to an imbalance of groundwater regime in lower Miocene aquifer, the current study has been conducted. The main goal is the protection and management of groundwater in the Lower Miocene aquifer in the study area quantitatively and qualitatively and to prevent the lowering in the groundwater level which may lead to deterioration in groundwater quality. This goal is attained by developing a mathematical model that represents the hydrological conditions of the area through which four different scenarios for predicting the hydrological situation in the next ten years are conducted. The obtained results indicate that the hydraulic conductivity varies from 0.1 m/day to 25 m/day, the transmissivity coefficient varies between 1000 m^2/day to 7000 m^2/day and the specific yield varies from 0.011 to 0.32. It has been shown during the current study that the amount of groundwater extrated from the Lower Miocene aquifer in the studied area is about 57.07 Million cubic meters per year for the period from April 2013 to April 2014. Ten years of prediction from April 2014 to April 2024 reveal an expected drop in the groundwater level amounting to 7 meters. For the same period, the groundwater storage in the Lower Miocene aquifer in the study area is perdicted to be 7.72 million cubic meters per year. This means an expected loss in the amount of groundwater storage reaching about 49.35 million cubic meters through the ten years of perdiction if the current dicharge rate is maintained.

Keywords: Wadi El Farigh area, Western Desert of Egypt, Mathematical model West of the Nile Delta, Lower Miocene aquifer.

INTRODUCTION

The main purpose of the present study is to remanage groundwater resources of the Lower Miocene aquifer in Wadi El Farigh area, using the mathematical modeling techniques. Modeling is a basic approach for assessment of the external hydrological stresses on the groundwater aquifers, as well as identifying water balance in the time of modeling.

The studied area is located, at the Northeastern part of the Western Desert, West of the Nile Delta (Fig. 1). It is bounded by longitudes 30° 00” and 31° 00” E and latitudes 30° 00” and 30° 20” N. It occupies a total area of about 2165 km^2. The climate is characterized by desert conditions. The average annual rainfall depth ranges between 45 and 105. The contribution by rainfall to the groundwater in the area is very limited and can be neglected, where it lies within the zone of less than 200 mm/day percipitation (Lerner and Issar, 1990). The mean relative humidity ranges from 64.5% in winter season to 59.2% in summer season. The avergae seasonal evaporation ranges from 918.55 mm in winter season to 1512.27 mm in summer season. The studied area received the attention of some of researche workers in the field of geology, hydrogeology and geomorphology. Among them are; (Pavlov (1962), El Fayoumy (1964), Shata and El Fayoumy (1967), Sanad (1973), Attia (1975), El Shazly *et al.* (1975), Abdel Daiem (1976), El Ghazawi (1982), Abdel Baki (1983), El Ghazawi and Atwa (1994) and El Abd (2005).

An inventery of 213 water wells tapping the Lower Miocene aquifer in the Wadi El Farigh is conducted by the present authors. They are sampled and tested for hydrological and hydrogeological investigation (Fig. 2). The following geomorphologicl and geological conditions were stated in the last studies:

Geomorphologicaly, the studied area is characterized by the following three main geomorphological units of hydrologic importance (Fig. 3):

1- The alluvial plains:

They are distinguished into two different units as follow:

a) The old alluvial plain

It represents the main geomorphological unit in the studied area. It extends to the South of the young alluvial plain to the East of the Marbat depression and extends allover the study area at the North and East of Wadi El Natrun. Sandy deposits cover the surface in its northern part, while, in the southern part the gravels are dominant.

b) Young alluvial plain

It lies to the East of the study area and extends to El Nubariya canal. The surface is generally flat sloping gently northward with an average gradient of 0.1 m / Km. Its surface is built of sticky clay alternating with thin bands of silt containing shell fragments.

2- Structural landforms:

They consist of four alternating depressions and four ridges reflecting the impact of both the lithologic and the geologic structures. Structural depressions represent a distinctive land features in the study area. They represent negative hollows in the structural plain and are considered as good areas for the groundwater accumulations. Structural ridges comprise the folded ridges rising up to about +200 m above sea level.Such structural ridges reflect the impact of the lithologic and geologic structures.

3- The tablelands:

The tablelands in the area west of the Nile Delta are differentiated into Maryut tableland and the marginal tableland.

Geologicaly, the study area is built up of sedimentary rocks belonging to the Tertiary and Quaternary times. They are formed of different rock units composed of sands, gravels and clays. The Lower Miocene rocks are exposed in most of the studied area. While, the Pliocene rocks are exposed only in the northwest, east and southeast sides (Fig. 4).

Hydrogeologicaly, the lateral and vertical extensions of the Lower Miocene aquifer are illustrated through four Hydrogeological cross sections A – A', D –D’, C – C’ and B – B’ (Figs. 5, 8, inclusive). Such sections delineate the different hydrogeological rock units and their lateral and vertical relationships and facies changes. From the hydrogeological cross sections (Figs. 5, 8, inclusive) and saturated thickness map (Fig. 9), the following remarks can be identified:

1-The main water bearing formation in the studied area is the Lower Miocene aquifer. The groundwater exists under unconfined conditions.

2- The saturated thickness of the Lower Miocene aquifer ranges from 220 m to 330 m in the western part and from 110 m to 210 m in the eastern part. While it ranges from 110 m to 250 m in the middel area.

3-The Lower Miocene aquifer rests unconformably on the basalt sheets of the Oligocene age. Lowe Miocene deposits consist of sands intercalated with clay, while Oligocene deposits consist of gravel, sand and basalt.

4- Steep faults have important effect on the thickness of the Lower Miocene aquifer. The Faults F_2, F_3, F_4 and F_5 have prominent effect on the hydrological regime and horizontal extension of the Lower Miocene aquifer in the study area. Moreover, another two proposed faults (F_7 and F_8) having the same effect.

5-The strcuatural faults are charcaterized by step, horst and graben blocks (Figs. 5, 8, inclusive).

CONCEPTUAL MODEL

The conceptual model (Fig. 10) is developed to define the hydrogeological and hydrological stresses and boundary conditions of the Lower Miocene aquifer in the studied area. Such model is designed to represent the following conditions and features;

1- The local recharge of the Lower Miocene aquifer takes place through lateral seepage from the West Nile Delta aquifer in the eastern part and lateral flow from the Oligocene aquifer in the western part. In the northern part, local recharge of the Lower Miocene aquifer in the studied area takes place from lateral leackage from the Pliocene aquifer, while in the southern part there is no source recharge.

2- The boundary conditions in the studied area can be reported as follows :

a) Vertical boundary:

The Lower Miocene aquifer extends downward from land surface and it rests on the basalt sheets of the Oligocene age.

b) Horizontal boundary:

A constant head boundary exists in the northern and western parts due to leteral leackage from the Pliocene aquifer at the north and a leteral leackage from the Oligocene aquifer at the west of the study area. A constant head boundary in the eastern part resulted from the lateral seepage from the Quaternary aquifer at West Nile Delta. A no flow boundary existed at the southern part where there is no recharge from the Pliocene aquifer (Fig. 11).

c) Permeable fault boundary,

Internal boundaries in the study area are represented by 6 permeable faults which are considered as general head boundaries.

ESIGN AND PREPARATION OF GROUNDWATER FLOW MODEL

The construction of the groundwater flow model was carried out by using MODFLOW software program (**Mc Donald and Harbough, 1988**). It is governed by three dimensional parabolic partial diferential equations for transient state (non equilibrium equation):

$$\frac{\partial}{\partial x}(Kxx\frac{\partial h}{\partial X})+\frac{\partial}{\partial y}(Kyy\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(Kzz\frac{\partial h}{\partial z})\pm W=Ss\frac{\partial h}{\partial t} \qquad (1)$$

Where:

Kxx, Kyy and Kzz are the values of hydraulic conductivities along the x, y and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (m/day).

h: is the potentiometric head (m).

W: is a volumetric flux per unit volume and represents sources and or sink of water (m^3/day).

Ss: is the specific storage of the porous material (dimensionless).

T: is the time (day).

The groundwater flow model is designed with regular square cells grid, where the dimensions of each cell is 500 m x 500 m for an area of 1703.25 km^2. The numerical model data for the studied area are collected from the field and previous works and are prepared as follows:

1- SURFER software is used for mapping and model input preparation.
2- MODFLOW software is used for modeling and running the numerical model.

CALIBARATION AND RUNNING GROUNDWATER FLOW MODEL

The groundwater flow model was calibrated for steady and transient time states. As for the steady state, data for groundwater levels during April, 2013 are utelized (Fig. 12). For the unsteady state calibration, data of groundwater levels for the period April, 2013 (as initial conditions) to April, 2014 (Fig. 13) (as final conditions) are considered. Different runs were carried out for adjusting the values of the hydrological parameters in order to approximate the calibrated data of groundwater levels of the water bearing formations in the study area to the field data (observation data). Ninteen water points are selected at different locations for the calibration of the model (Table 1) and (Fig. 14). The model was run using such data. It has been found that there are discrepancies between the field data and the computed ones for the water levels (April, 2014). Some changes in the values of the hydraulic conductivity and specific yield were performed in order to attain better coincidance of groundwater levels.

As a result of such calibaration, the hydraulic paramters of the Lower Miocene aquifer in the studied area were depicted as follows:-

1- Hydraulic conductivity (K):

Hydraulic conductivity distribution map (Fig. 15) is plotted based on the model calibrated data. It indicates that the value of hydraulic conductivity of the Lower Miocene aquifer in the studied area ranges from 0.1 m/day to 25 m/day.

2- Specific Yield (Sy):

The Specific Yield distribution map (Fig.16) is plotted based on the values obtained from the unsteady state calibrated run. The values range from 0.011 to 0.32.

3- Transmissivity coefficient (T):

The values of transmissivity coefficient (T) are also computed by multiplying the calibrated values of hydraulic conductivities by the values of the saturated thickness of the Lower Miocene aquifer for each cell. Fig.(17) shows the distribution map of the transmissivity coefficients of the Lower Miocene aquifer. They range from 1000 m^2/day to 7000 m^2/day. This gives an indication of the hydrogeological complexity and greate changes of facies of the Lower Miocene water bearing Formation in Wadi El Farigh area.

4- Diffusivity coefficient (A):

The diffusivity coefficient is computed as a function of the transmissivity and specific yield by the following equation;

$$A = T / Sy \qquad (2)$$

The values of the diffusivity coefficient are obtained from the unsteady state calibrated run. The values of this parameter range from 10000 m^2/day to300000 m^2/day (Fig. 18).

The match between the model responses and field observations may be examined qualitatively in the preliminary stages of the calibration processing using contour maps of calculated head and observed head. However, after the initial runs are completed, some statistical measure of goodness of fit should in general be used for more quantitative comparision and assessment. Several basic statistical meausures of goodness of the fit are used such as the following measures (**Zheng and Bennett, 2002**):

1- The mean absolute residual error (MA) is defined as

$$\mathrm{MA} = \frac{1}{N}\sum_{L=1}^{N}[\mathrm{CaLi} - \mathrm{Obsi}] \qquad (3)$$

Where, N is the total number of observation; Cali and Obsi are the calculated and observed values of the model dependant variables, which may be hydraulic heads, drawdown, travel time, concentrations, flow rates, solute mass fluxes or some combination of these. MA value near zero is indicative of an overall agreement between the calculated and observed vlues. The mean absolute residual error (MA) is a more robust esimator of goodness of fit. In the current study, the mean absolute residual error (Ma) equals 0.1

2- The linear correlation coefficient (r), is defined by the following equation:-

$$r = \frac{\sum_{L=1}^{N}\left(\text{Cali} - \overline{\text{Cal}}\right)(\text{Obsi} - \overline{\text{Obs}})}{\sqrt{\sum_{1=1}^{N}(Cali - \overline{Cal})2}\sqrt{\sum_{1=1}^{N}(Obsi - \overline{obs})2}} \qquad (4)$$

Where, $\overline{\text{Cal}}$ & $\overline{\text{Obs}}$ are the means of calculated and observed values respectively. The values of r lie between -1 and 1. In the currrent study, the linear correlation cofficient (r) equals 0.99, while better calibrated model tends to have r values close to 1, which means a strong significant correlation.

3- The observed and calculated values can also be plotted as a scatter diagram with the observed values on one axis and the calculated values on the other axis and plot a fitting line. The narrower the area of scatter around the 45° line, in this type of plot, the better is the match between observed and calculated values. If the observed and calculated values were to match perfectly, all data points would fall on the straight line. The scatter diagram for the present study is shown in Fig.(19).

GROUNDWATER MANGEMENT

The mathematical model is used for determining possible management policies of the Lower Miocene aquifer.

1- Present Situation: There are three cases:

First case: a number of 600 wells are recorded in the studied area. They were visited during the current study. The total amounts of groundwater extracted from those wells are estimated for about 147.9 Milloin cubic meters per year.

Second case: the total amounts of groundwater extracted from these wells are doubled to be about 294.1 Million cubic meters per year.

Third case: the total amounts of groundwater extracted from those wells are decrease to about 98 Million cubic meters per year.

2- Prediction of the Hydrological Situation:

Four scinarios were assumed for the previous three cases of the present situation.

a) **First Scinario:** from the period of April 2013 to April 2014 using the actual data of 600 wells collected through a visit to the study area. About 57.07 Million cubic meters per year in the groundwater storage is recorded as gain while an amount of about 147.8 Million cubic meters per year of groundwater is extracted. The total amount of recharge in this area reaches about 204.57 Million cubic meters per year (Table 2).

b) **Second Scenario:** the groundwater flow model, which have been built for the studied area was operated yearly for ten years predication period in order to detect the future hydrological situation for the first case. Table (2) and Fig.(20) represent the results of the perdiction. The result of ten years perdiction indicate a gain in the groundwater storage of about 7.72 Million cubic meters per year with an amount of groundwater extracted equals 147.8 Million cubic meters per year. A drop of groundwater levels reaching 7 meters through these ten years from April 2014 to April 2024 is recorded (Fig. 21).

c) **Third Scenario:** where the amounts of groundwater extrated from wells are doubled to about 294.1 Million cubic meters per year. A loss of the groundwater storage in the studied area, by about 61.65 Million cubic meters per year is recorded (Table 3).

d) **Fourth Scenario:** where decreasing the amount of groundwater extrated to about 98.83 Million cubic meters per year is assumed, a gain of the groundwater storage amounting 97.73 Million cubic meters per year in the studied area is recorded (Table 3).

CONCLUSION

Wadi El Farigh area is built up of sedimentary rocks belonging to the Tertiary and Quaternary times. They are formed of different rock units composed of sands, gravels and clays. The Lower Miocene rocks are exposed in most of the studied area. The main water bearing formation in the studied area is the Lower Miocene aquifer. The groundwater exists under unconfined conditions. The Lower Miocene aquifer rests unconformably on the basalt sheets of the Oligocene age and the saturated thickness ranges from 110 m to 330 m. The local recharge of the Lower Miocene aquifer takes place through lateral seepage from the West Nile Delta aquifer in the eastern part and lateral flow from the Oligocene aquifer in the western part. In the northern part, local recharge of the Lower Miocene aquifer in the studied area takes place from lateral leackage from the Pliocene aquifer, while in the southern part there is no source of recharge. The obtained results from the groundwater flow model indicate that the hydraulic conductivity varies from 0.1 m/day to 25 m/day, the transmissivity coefficient varies between 1000 m^2/day to 7000 m^2/day and the specific yield varies from 0.011 to 0.32. Four scenarios were built using the groundwater flow model. The fourth one was chosen as the best among of, where the amount of groundwater extracted is managed to be (98.83 $(10)^6$ m^3/year). It nearly equals the safe yield of the groundwater extraction (97.73 $(10)^6$ m^3/year).

RECOMMENDATIONS

1- No more wells be drilled in the studied area.
2- Reducing the discharge rate from the operated wells and keeping the constant rate arounds 35 ^{m3}/h for each well.
3- Growing low-water comsuming plants.
4- Using the groundwater for the agricultural activities only.
5- Reusing the treated drainage water for irrigation.
6- Suggesting a mathematical model for salt transportation in the area in order to depict the deterioration in the groundwater quality in the area.

ACKNOWLEDGMENT

Praise to GOD, lord of the world, by the grace of whom implementation of this world was possible.

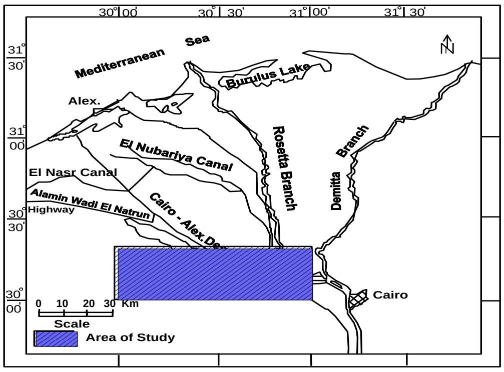


Fig. (1): Location map of Wadi El Farigh area, North of the Western Desert, Egypt.

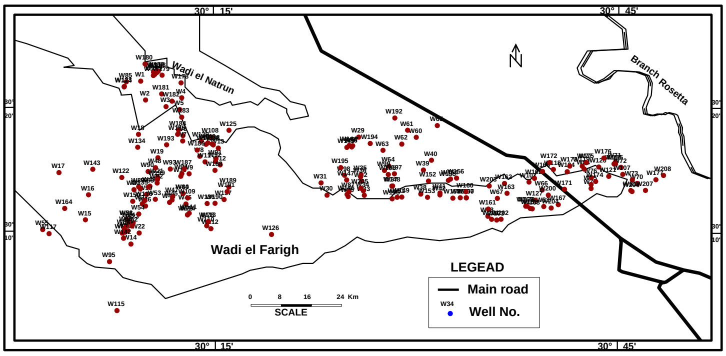


Fig.(2): Well location Map of Wadi El Farigh area, Egypt.

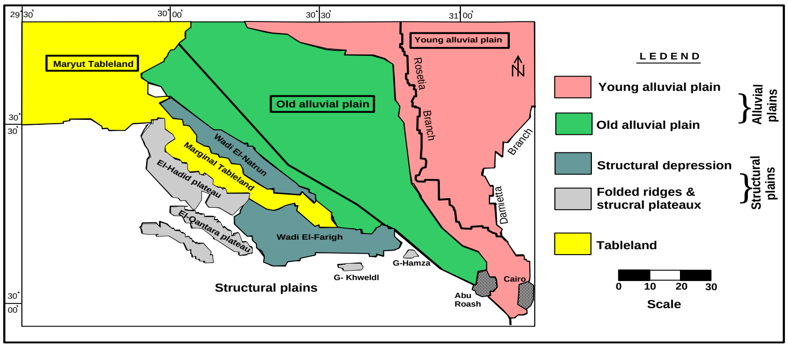


Fig. (3): Geomorphological map of the studied area, (Compiled after different authors).

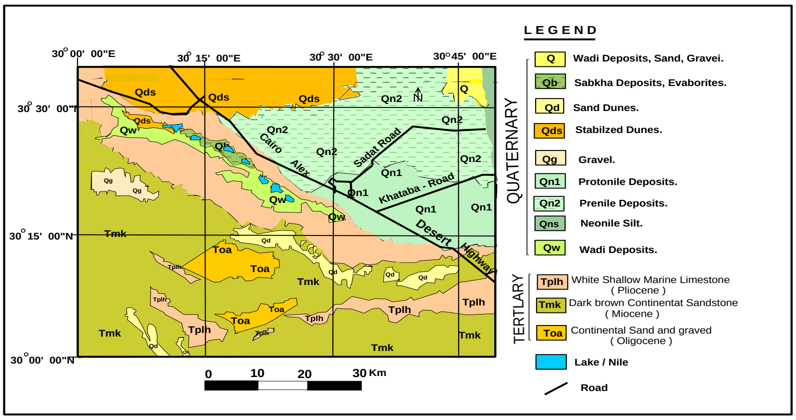
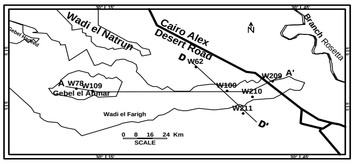
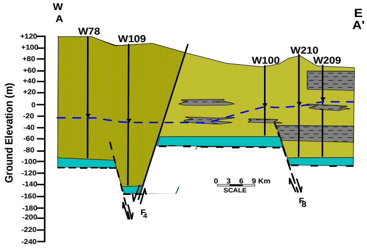
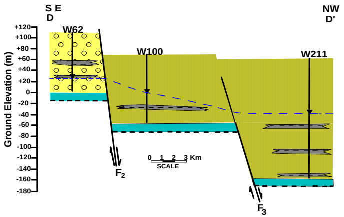


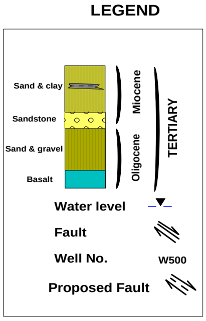
Fig. (4):. Geological map of the studied area, (Conoco Coral, Egypt 1987).



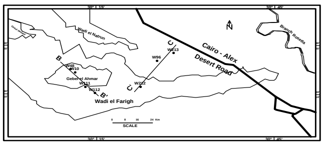


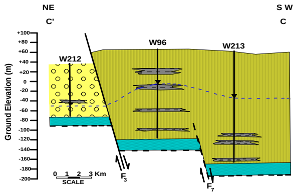
Fig(5): Hydrogeological Cross Section A - A',
Wadi El Farigh area, Egypt.



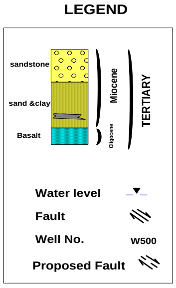


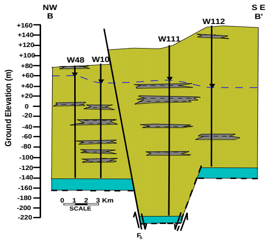
Fig(6): Hydrogeological Cross Section D- D',
Wadi El Farigh area, Egypt.





Fig(7): Hydroeological Cross Section C - C',
Wadi El Farigh area, Egypt.





Fig(8): Hydroeological Cross Section B -B',
Wadi El Farigh area, Egypt.

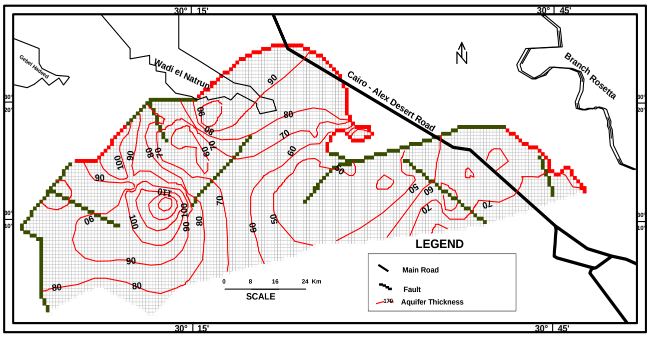


Fig.(9): Isopach Map of the Lower Miocene Water Bearing Rock Uint,Wadi El Farigh area, Egypt.

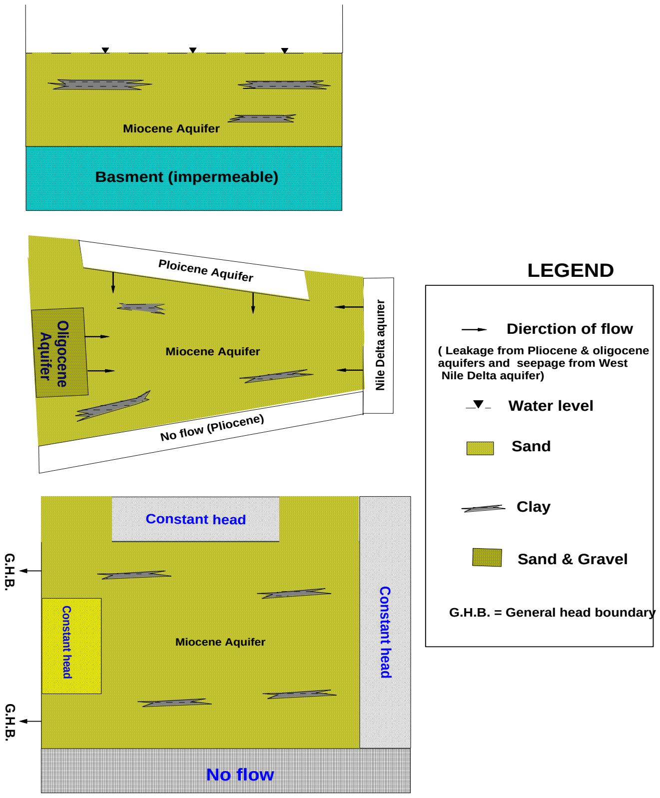


Fig.(10): Conceptual Model for the Lower Miocene Aqufifer, Wadi El Farigh area, Egypt.

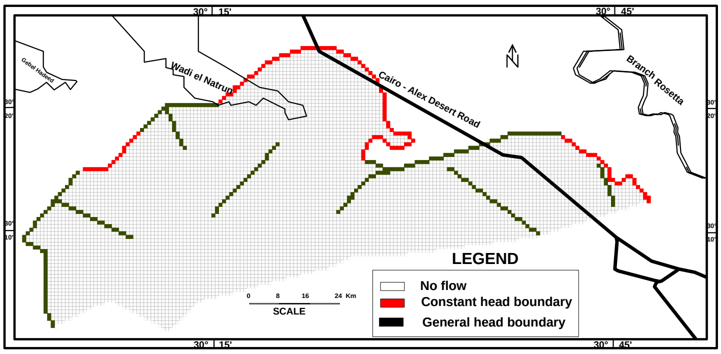


Fig.(11): Boundary Conditions and Mathematical Model Network of Lower Miocene aquifer, Wadi El Farigh area, Egypt.

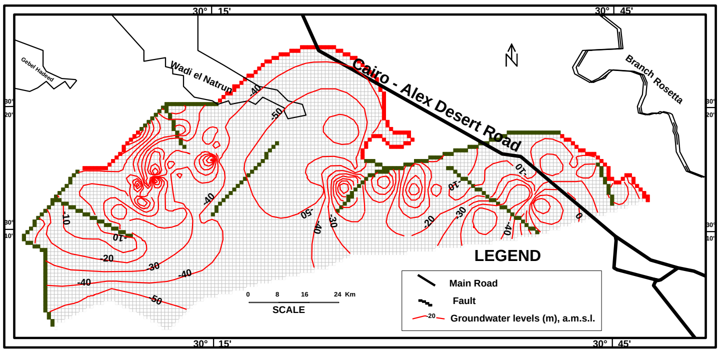


Fig.(12): Water Table Contour Map of the Lower Miocene aquifer (April 2013), Wadi El Farigh area, Egypt.

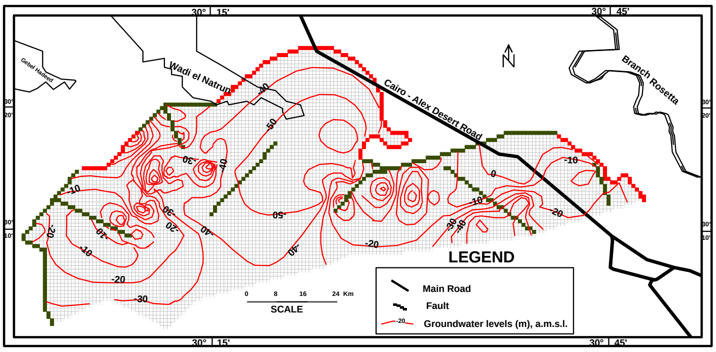


Fig.(13): Water Table Map of the Lower Miocene aquifer (April 2014), Wadi El Farigh area, Egypt.

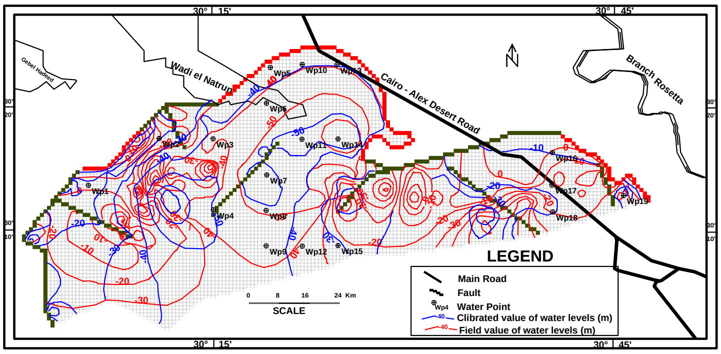


Fig.(14): Groundwater Level Contour Map of the Lower Miocene aquifer (April 2014), unsteady State Calibrated Run, Wadi El Farigh area, Egypt.

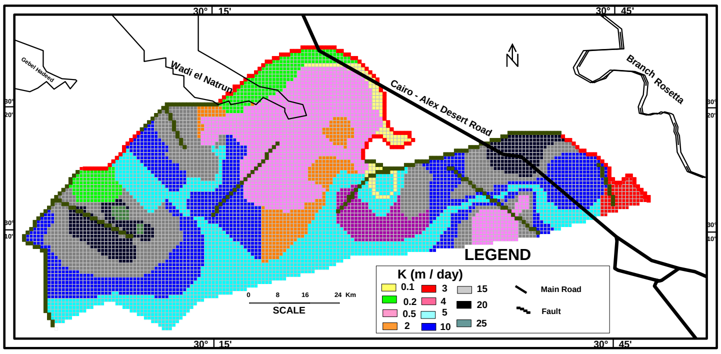


Fig.(15): Hydraulic Conductivity Coefficient Distribution Map of the Lower Miocene aquifer, (Unsteady State Calibrated Run), Wadi El Farigh area, Egypt.

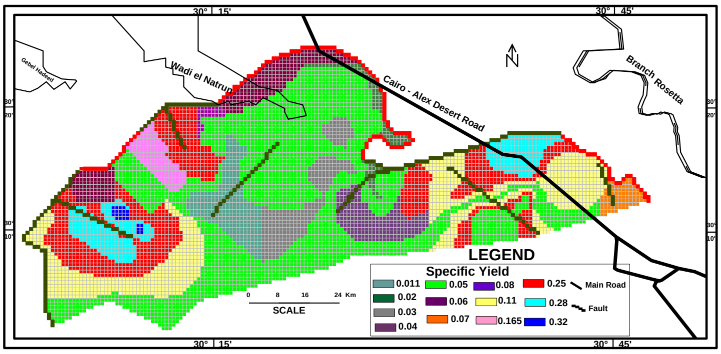


Fig.(16): Specific Yield Distribution Map of the Lower Miocene aquifer, (Unsteady State Calibrated Run), Wadi El Farigh area, Egypt.

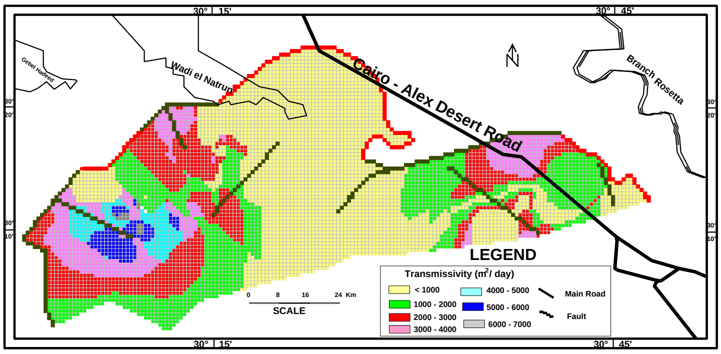


Fig.(17): Transmissivity Distribution Map of the Lower Miocene aquifer, (Unsteady State Calibrated Run), Wadi El Farigh area, Egypt.

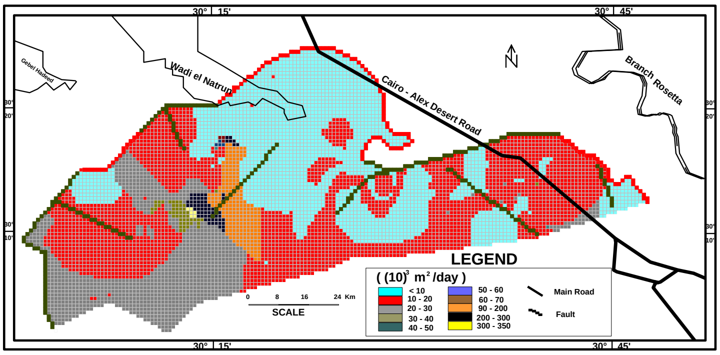


Fig.(18): Diffusivity Coefficient Distribution Map of the Lower Miocene aquifer (unsteady state, Calibrated Run), Wadi El Farigh area, Egypt.

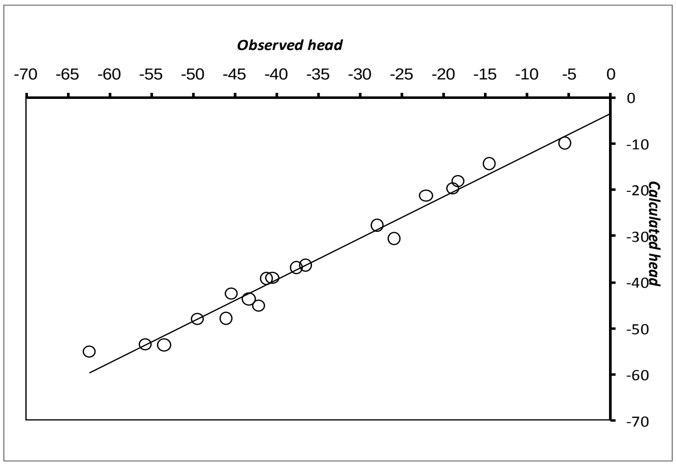


Fig. (19): scatter diagram between observed heads and calculated heads, for the period (April 2013 – April 2014), Lower Miocene aquifer, Wadi El Farigh area, Egypt.

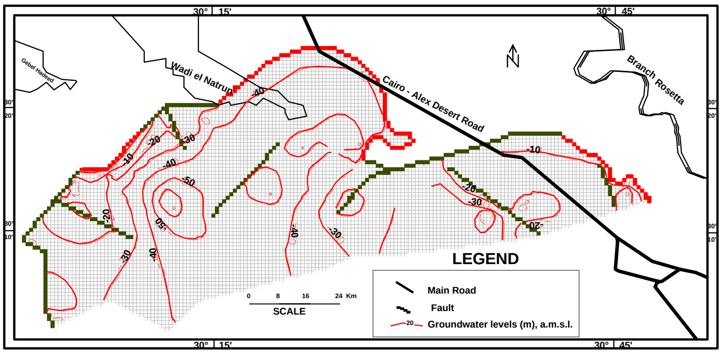


Fig.(20): Water Table Map of the Lower Miocene aquifer (April 2024), Wadi El Farigh area, Egypt.

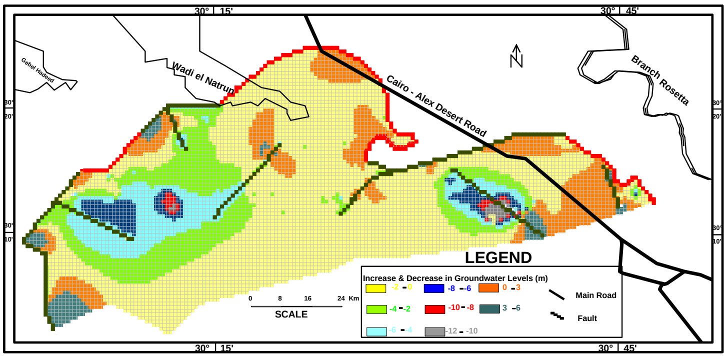
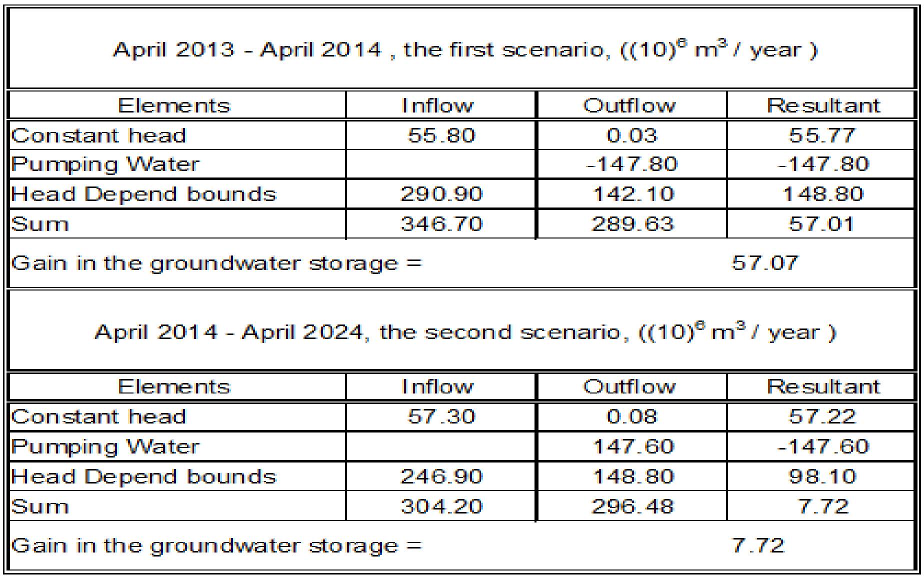


Fig. (21); Increase and Decrease in Groundwater Levels of the Lower Miocene Aquifer from April 2014 to April 2024 (Unsteady State Prediction), Wadi El Farigh area, Egypt.

Table (1): Field measurements and predicated groundwater level, for the period (April 2013 - April 2014), Wadi El Farigh area, Egypt.

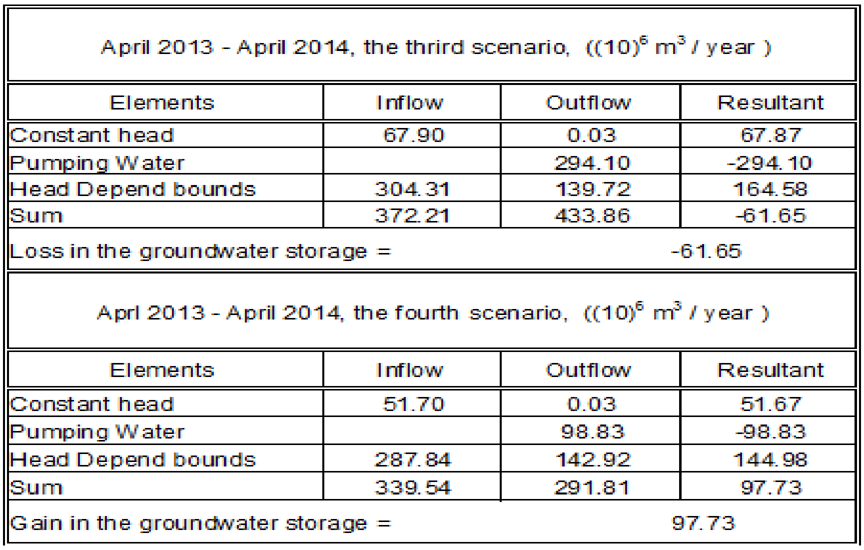
Water Points	Model Row	Model Column	Observed head (H_0)	Calculated head (H_c)	Residual (H_0 - H_c)
Wp1	21	49	-14.4	-14.4	**0**
Wp2	41	36	-18.78	-19.83	**1.05**
Wp3	59	36	-43.27	-43.78	**0.51**
Wp4	56	56	-46.03	-47.97	**1.94**
Wp5	72	16	-36.46	-36.44	**-0.02**
Wp6	71	28	-45.38	-42.56	**-2.82**
Wp7	71	46	-53.43	-53.72	**0.29**
Wp8	71	56	-49.44	-48.08	**-1.36**
Wp9	71	66	-42.09	-45.16	**3.07**
Wp10	81	15	-40.44	-39.11	**-1.33**
Wp11	81	36	-55.65	-53.55	**-2.1**
Wp12	81	66	-37.51	-36.9	**-0.61**
Wp13	91	15	-41.12	-39.26	**-1.86**
Wp14	91	36	-62.41	-55.11	**-7.3**
Wp15	91	66	-25.85	-30.65	**4.8**
Wp16	151	40	-5.36	-9.92	**4.56**
Wp17	151	49	-18.21	-18.15	**-0.06**
Wp18	151	56	-21.99	-21.25	**-0.74**
Wp19	171	52	-27.9	-27.71	**-0.19**

Table(2) : The Water Balance of the Lower Miocene Aquifer



April 2013 - April 2014 , the first scenario, $((10)^6\ m^3$ / year)			
Elements	Inflow	Outflow	Resultant
Constant head	55.80	0.03	55.77
Pumping Water		-147.80	-147.80
Head Depend bounds	290.90	142.10	148.80
Sum	346.70	289.63	57.01
Gain in the groundwater storage =			57.07
April 2014 - April 2024, the second scenario, $((10)^6\ m^3$ / year)			
Elements	Inflow	Outflow	Resultant
Constant head	57.30	0.08	57.22
Pumping Water		147.60	-147.60
Head Depend bounds	246.90	148.80	98.10
Sum	304.20	296.48	7.72
Gain in the groundwater storage =			7.72

Table(3) : The Water Balance of the Lower Miocene Aquifer



April 2013 - April 2014, the thrird scenario, $((10)^6\ m^3$ / year)			
Elements	Inflow	Outflow	Resultant
Constant head	67.90	0.03	67.87
Pumping Water		294.10	-294.10
Head Depend bounds	304.31	139.72	164.58
Sum	372.21	433.86	-61.65
Loss in the groundwater storage =			-61.65
Aprl 2013 - April 2014, the fourth scenario, $((10)^6\ m^3$ / year)			
Elements	Inflow	Outflow	Resultant
Constant head	51.70	0.03	51.67
Pumping Water		98.83	-98.83
Head Depend bounds	287.84	142.92	144.98
Sum	339.54	291.81	97.73
Gain in the groundwater storage =			97.73

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إدارة مصادر المياه الجوفية بمنطقة وادى الفارغ باستخدام النمذجة الرياضية

[٤]

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المستخلص

تعتبر منطقة وادى الفارغ من المناطق الهامه فى غرب الدلتا وشمال الصحراء الغربية وتعتمد على المياه الجوفية كمصدر رئيسى للتنمية الزراعية والبشرية والمتاحة بخزان الميوسين السفلى ونظرا لعدم توازن نظام المياه الجوفية سواء فى كمية التغذية للخزان الجوفى ونوعية المياه من حيث الملوحة، فإن الدراسة الحالية تهدف إلى حماية وادراة مصادر المياه الجوفية كما ونوعا بهذا الخزان الجوفى بمنطقة وادى الفارغ وذلك للحد من هبوط منسوب المياه الجوفية الذى يؤدى إلى تدهور نوعيتها ويتم ذلك من خلال عمل نموذج رياضى يمثل الظروف الهيدرولوجية لمنطقة الدراسة واقتراح عدة سيناريوهات للتنبؤ الهيدرولوجى خلال العشر سنوات القادمة. وقد اعتمدت الدراسة الحالية إلى البيانات التالية معامل التوصيل الهيدروليكية للخزان الجوفى تتفاوت بين ٠,١ م / يوم إلى ٢٥ م / يوم وأن معامل الانتقالية يتراوح بين ١٠٠٠ م^{٢} / يوم إلى ٧٠٠٠ م^{٢} / يوم. وقد تم بناء النموذج الرياضى على الأسس التالية:

١-الحدود الهيدروليكيا للخزان الجوفى.
٢-عدد الآبار التى تم إدخالها فى النموذج الرياضى هى ٦٠٠ بئر.
٣-معايرة النموذج الرياضى.

وقد توصلت الدراسة الحالية إلى النتائج التالية وجود مخزون فى كمية المياه الجوفية فى خزان الميوسين السفلى بمنطفة الدراسة فى الفترة أبريل ٢٠١٣ – أبريل ٢٠١٤ بحوالى ٥٧,٠٧ مليون متر مكعب فى السنة وباستخدام النموذج فى التنبؤ لمدة عشر سنوات من أبريل ٢٠١٤ إلى أبريل ٢٠٢٤ من خلال سيناريوهات التشغيل الآربعة وجد أنه سوف يحدث هبوط فى منسوب المياه يقدر بحوالى ٧ متر خلال العشر سنوات القادمة وأن مخزون المياه الجوفية بخزان الميوسين السفلى بمنطقة الدراسة سوف يصبح ٧,٧٢ مليون متر مكعب أى أنه سوف يحدث فقد فى المخزون الجوفى بمقدار ٤٩,٣٥ مليون متر خلال العشر سنوات القادمة اذا ظل السحب كما هو عليه الآن.

الكلمات الدالة: منطقة وادى الفارغ، الصحراء الغربية، غرب دلتا النيل، النمذجة الرياضية، خزان الميوسين السفلى.