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Analytical Method for Determining the Parameters of the Nubian Aquifer, Farafra Oasis, Western Desert, Egypt

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ABSTRACT

The Farafra Oasis is located in Egypt's western desert, in the centre region of the country, covering an area of approximately 86,200 Km2. Groundwater extracted from the Nubian sandstone Aquifer System (NSAS) in the Farafra Oasis, and considered as the only source of water supply, As a result of the growing population, groundwater development in the oasis became of great necessity, especially because the soil is appropriate for agriculture in the area. For this reason, deep investigations have been carried out for the area under interest to assess the NSAS hydraulic parameters as an initial phase for a complete groundwater management scheme for the NSAS aquifer in Farafra Oasis.The NSAS in the Farafra Oasis is recognized as two aquifers; 1- Post Nubian or limestone Aquifer System, which consists of limestone and shale of Upper Cretaceous to Paleocene age. 2- The Nubian sandstone Aquifer system is composed of sandstone and little intercalation of shale and mud of an age ranges from Paleozoic to Cretaceous.The pumping test (constant discharge tests) followed by the recovery tests was done for the study area to calculate the transmissivity, storativity, and hydraulic conductivity of the aquifer using 2D analytical solutions. There are three productive zones in the area. The first one has a thickness range from 100- 140 m (a.s.1.). The calculated transmissivity values for this zone vary from 400 to 1,200 m2/day and the average value of the hydraulic conductivity was about 1.5 m/day. The average thickness of the second zone is 450 m. The transmissivity values for this zone vary from 1,600 to 3,000 m2/day and the hydraulic conductivity reaches 6 m/day. On the other hand, the third zone has an average penetrated thickness of 500 m. Its transmissivity values vary from 1,800 to 2,500 m2/day while the average hydraulic conductivity is about 8 m/day. The storage coefficient values for the NSAS in the area range from 4.7x10-4 to 2.5x10-3, as determined by the analysis of pumping tests. The hydraulic parameters indicate that the aquifer is still hydraulically promising, however, In order to ensure the long-term development of this aquifer in Farafra Oasis, more management studies must be completed.

INTRODUCTION

Farafra area lies in the heart of the Desert of Egypt at a distance of 600 km southwest of Cairo passing by Bahariya Oases. between latitudes 26º 00\ N, 27º 45\ N, and longitudes 26º 30\ E and 29º 00\ E , including an area of about 86,200 Km^2 as shown in Fig (1). It forms an irregular triangular shape with an apex to Bahariya Oasis and base towards Dakhla Oasis. In this remote area, groundwater is the only source of water. There are two main aquifers in the area; the shallow aquifer (Post Nubian aquifer) and the deep aquifer (Nubian Sandstone aquifer).

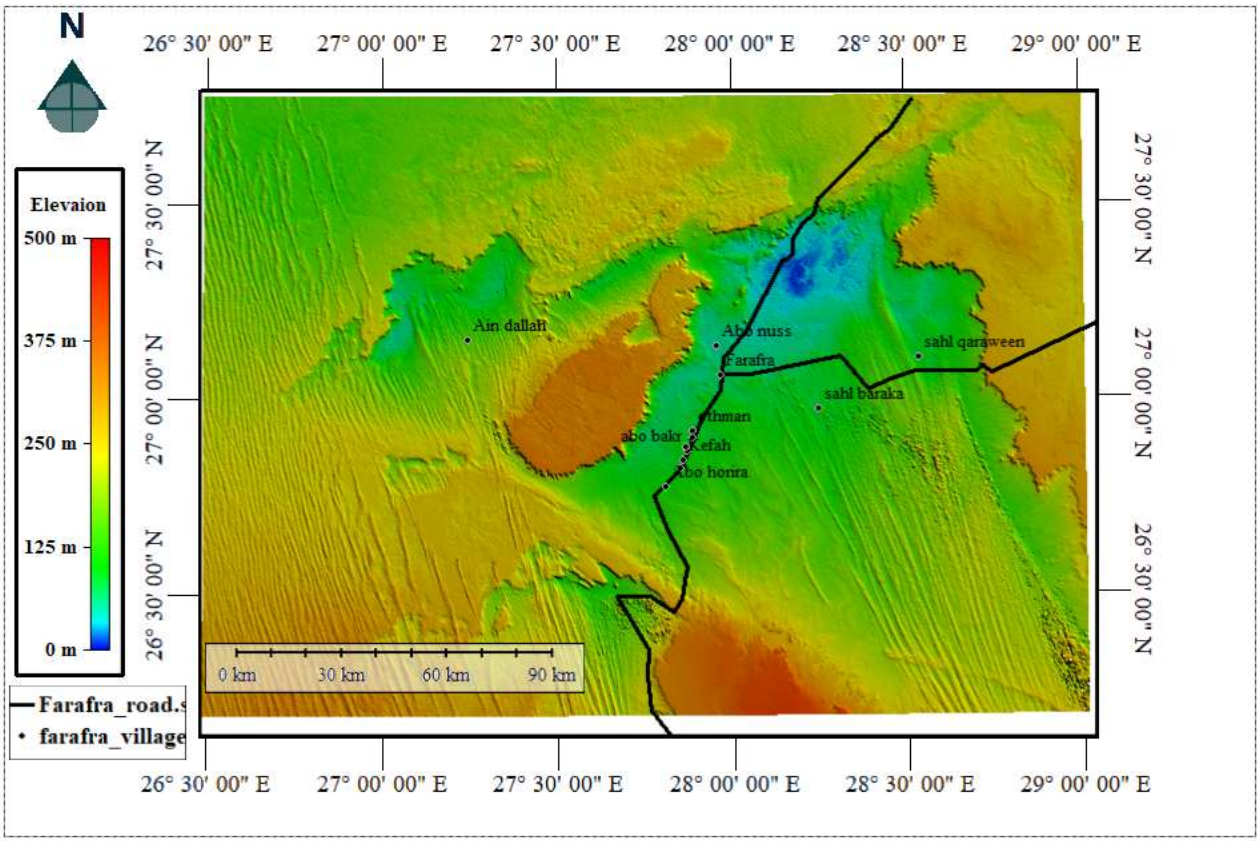

Figure 1. Location map of the study area**.**

2. GEOLOGICAL SETTING

Geologically, The age of the sedimentary succession ranges from the Upper Cretaceous to the Quaternary. (Ebraheem et al., 2002; Abdel Atti, 2002; Hamad, 2004; Ali, 2004; and El Sabri and El Sheikh, 2009).

- Dakhla Formation, Farafra Chalk Formation, and Hafhuf Formation are Upper Cretaceous rocks. (Fig. 2).

a) Dakhla Formation consists of shales with sand stone its repored thickness is about 130m . b) Farafra Chalk Formation covers the floor of the depression and the isolated hills. c) Hafhfuf Formation located at wadi Hennis in the north east of the study area .it is consists of dolomitic limestone with sandstoneand sandyclay interbeds and is considered as a marker boundary between the underlying Nubian clastics and the overlying upper Cretaceous non-clastics.

- Paleocene rocks are represented by Esna Shale Formation (125 m thick) and Tarawan Chalk Formation (74 m thick) (Fig. 2).

- Eocene rocks composed of grey limestone, hard, partly crystalline ,dolomitic at top and marly at base and exposed in north El Farafra Oasis (zaghloul,1983)

- Quaternary deposits: a) aeolian sand they form tha within the depression and on the plateau surface, b) Playa deposits are developed in the inland depressions these depositsare composed of fine sand ,silt and dark brown clay mixed with gypsum and halite (Fig. 2).

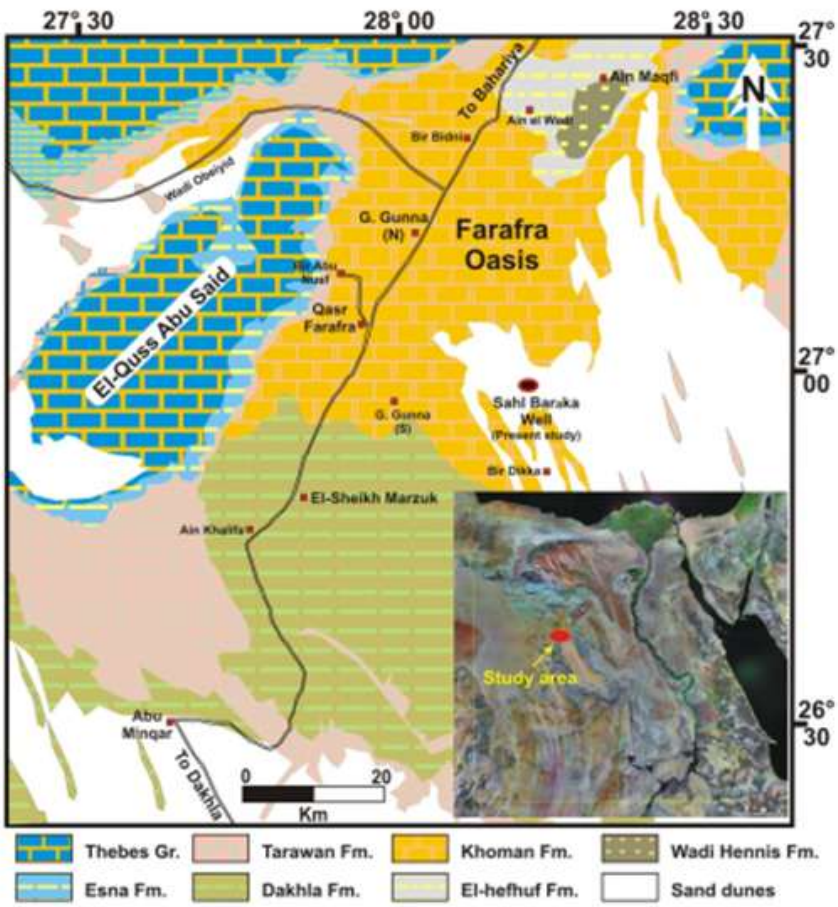

Figure 2. Modified geological map of the study area (after Conoco 1987).

Hydrogeologically, Deep wells drilled recently give important hydrogeologic data on the Nubian Sandstone Aquifer. (Fig. 3). The Post Nubian aquifer ranges 200 m thick while the Nubian Sandstone Aquifer is composed of alternating sand and clay units. These sand units forming three water-bearing horizons. The zone A which is equivalent to (Taref Formation) has a thickness of 155 m , while the zone B (Sabaya Formation), acting as the main groundwater resource, has a thickness of 400 m. The zone C (Six Hills Formation) is composed of sand stone medium to coarse scarcely cemented with fine lenses of. The Nubian aquifer's bottom level ranges between 1,700 and 2,300 metres (Thorweihe 1990).

A- Post-Nubian Sandstone sediments: These geologic rock units start with Quaternary deposits followed by Tertiary formations and Upper Cretaceous rocks units which are represented by Dakhla shale attaining a thickness about 58 meters. The Khoman chalk, underlain by the Dakhla shale (42 m) is followed by the Hefuf sandstone and limestone (110 m), Wadi Hennis sandstone and gravel is underline the Hefuf (25 m), finally El Heiz limestone Formation with a thickness (80 m).

B- Nubian sandstone complex: It is equivalent to Bahariya Formation has a thickness of sandstone of about 96 meters followed by Maghrabi Mudstone (first aquitard) with a thickness of about (85 m), Sabaya sandstone (225 m), Abu Ballas shale (second aquitard) is laid under the Sabaya Formation then Six Hills sandstone (250 m), the Six Hills Formation underlies Abu Ballas shale, (Euroconsult 1983).

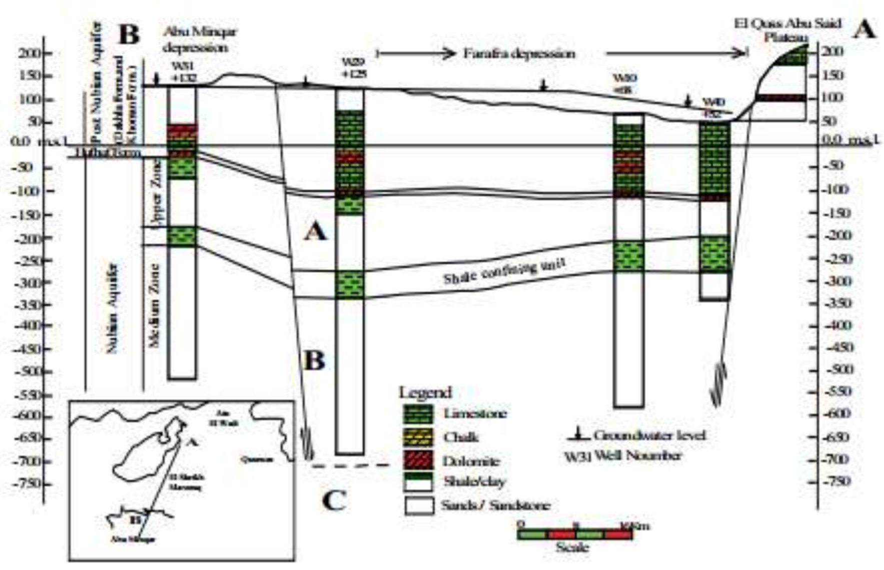

Figure 3. hydrological cross-section in Elfarafra depression (after Salem 2002).

MATERIALS AND METHODS

This study aims to assess the hydrogeological characteristics of the existing main aquifers in the study area using the collected data from the wells. To achieve these goals, several sources were used including the geological map of El Farafra (CONOCO, 1987), the previous hydrogeological cross sections and pumping tests data.

the pumping tests results of wells were analysed using Aquifer Test software to estimate the hydraulic properties of the NSAS in the study area

The data for this study was collected in the farafra oasis, The pumping test procedures was carried out using the constant discharge test.

Data was collected and analyzed by the authers and general management for ground water of Elfarafra during and after the pumping test to determine the following hydraulic parameters:

1-Transmissivity (T)

2- Hydraulic Conductivity (K)

3- Storage Coefficient

it was employed in all these wells in the farfara oasis because there was no observation well was available. The data collected in such cases were used for the determination of the transmissivity of the aquifer. Theis method is used to calculate hydraulic parameters. Where the used Theis formula (1935) is:

$$T = \frac{Q}{4\pi s} W(u) \qquad (1)$$

$$S = \frac{4Tut}{r^2} \qquad (2)$$

where : T is the transmissivity of the aquifer (m^2/day)

Q is the pumping rate (m^3/day)

S is the aquifer storativity (dimensionless).

r distance from pumping well (m)

W(u) = Theis well function (dimensionless);

s = drawdown (m) at time (t) at distance (r) since the start of pumping

t = time after the start of pumping

$$W(u) = -0.5772 - \ln(u) + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} - \frac{u^4}{4.4!} + \ldots\ldots etc$$

calculating Hydraulic Conductivity which is also known as the permeability coefficient is computed with the use of a formula, as follows

$$K = \frac{T}{b}$$

where K is the hydraulic conductivity (m/d); T is the transmissivity (m2/d); b is the aquifer thickness (m).

The Theis Solution is based on the following assumptions:

- The aquifer is infinite
- the aquifer is isotropic and homogeneous
- control well is fully or partially penetrating
- the aquifer is horizontal and groundwater flow is horizontal
- flow is unsteady
- diameter of the pumping well is very small so that storage in the well can be neglected.

RESULTS

hydraulic parameters were calculated after analyzing the pumping test data. Using aquifer test pro software, which is analytical software for the graphical interpretation of pumping test data, it was possible to determine the hydraulic parameters and their distribution throughout the specified zones.

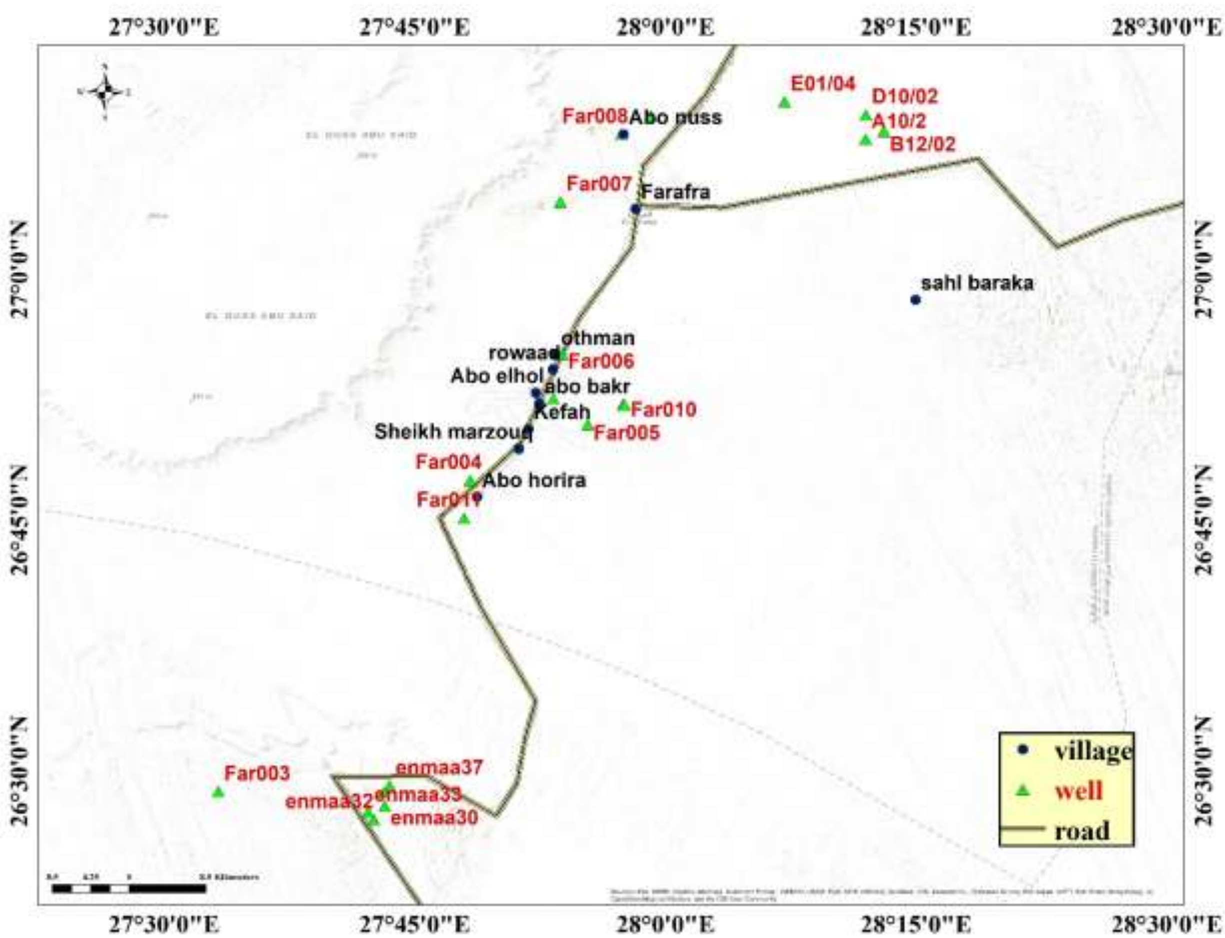

Figure 4. location map of the pump wells in the farafra oasis**.**

In this study, analysis of 20 pumping test data representing three productive zone. fig (4) (constant rate tests) was used to evaluate the hydraulic characteristics of the Nubian aquifer (transmissivity, storage coefficient, and hydraulic conductivity) using the aquifer test pro software programme and Theis's method.

Nubian sandstone aquifer system in the farafra oasis is divided to three zones A, B, and C. At present; zone B (second productive zone) is considered a high extracted zone and zone A(first productive zone) is considered a weak extracted zone, because its heads fall down, and most of it's wells not flowing now. In the present, the zone C(third productive zone) of the Nubian aquifer is considered the promising zone where penetrated by many wells with depth more than 1000 meter, this aquifer has high water head pressure and gives big artesian

The analysis of the results of the pumping test (constant discharge test) which included transmissivity, storage coefficient, and hydraulic conductivity using are summarized in Tables 1, 2 and 3

(i)- The First Productive zone

It is composed of fine to coarse-grained sandstone with less shaped clay intercalations. Its thickness ranges from 95 m in the north at Farafra area to 225 m, The average thickness is 140 m. This zone indicates transmissivity of 400 m2/day with a permeability value of 1.3 m/day northwest Farafra . It has values of transmissivity as 560 m^2/day and permeability as 1.9 m/day at the eastern part of El Sheikh Marzouk sub-area. These results reflect a poor transmissivity of the water from the investigated zone, the lateral facies changes and the difference in thickness within the same zone.

Table 1. showing The results of interpretation of the pumping tests data in the first productive zone in the study area (Theis method)

no	Well name	coordinate		Total Well depth. (m)	Transmissivity (m^2/day)	Hydraulic Conductivity (m/day)	Storage Coefficient
		N	E				
1	Far001	27 09 10.5	27 59 06.3	380	400	2	9.8×10^{-3}
2	Far002	26 51 55.7	27 57 28.3	395	560	1.9	7.6×10^{-3}
3	Far003	26 28 45.6	27 33 14.5	325	680	1.3	1.21×10^{-4}

(ii)- The second productive zone

this zone consists of medium-grained sandstone with intercalations of lens-shaped shale. The penetrated thickness of this aquifer ranges from 200 m to 460 m. There are many wells tapping this zone. The scattering of the wells in the study area gave the chance to evaluate the transmissivity and hydraulic conductivity at different places. The area of the study recorded 1500 m2/day as the minimum value and 3500 m^2/day as the maximum value for the transmissivity while 2.13 m/day and 10.33 m/day for the hydraulic conductivity. and examples of the plot which result analysis of the pump test were shown in fig 4 and 5

Table 2. showing The results of interpretation of the pumping tests data in the second productive zone in the study area (Theis method)

no	**Well name**	**coordinate**		**Total Well depth.**	**Transmissivity (m^2/day)**	**Hydraulic Conductivity (m/day)**	**Storage Coefficient**
		N	E				
1	enmaa37	26 29 06.6	27 43 29.2	762	2100	4.6	5.8×10^{-3}
2	enmaa32	26 27 05.5	27 42 32.9	714	5200	8.9	4.9×10^{-3}
3	enmaa30	26 27 53.4	27 43 11.6	696	3300	8.2	4.95×10^{-4}
4	B 12/02	27 08 15.1	28 13 03.2	848	1900	4.7	3.47×10^{-4}
5	D 10/02	27 09 14.0	28 11 58.9	880	3200	7	3.45×10^{-4}
6	E 01/04	27 10 01.1	28 07 07.1	885	1800	4.5	5.22×10^{-4}
7	Far004	26 47 22.4	27 48 17.7	750	1850	4.6	1.24×10^{-4}
8	Far005	26 50 42.6	27 55 20.1	800	2400	6	2.54×10^{-4}
9	Far006	26 54 56.8	27 53 49.03	820	1800	4	4.5×10^{-4}
10	Far007	27 04 01	27 53 42	850	2500	6.2	4.7×10^{-4}
11	Far008	27 08 05	27 57 22.3	800	2800	7.3	3.54×10^{-4}

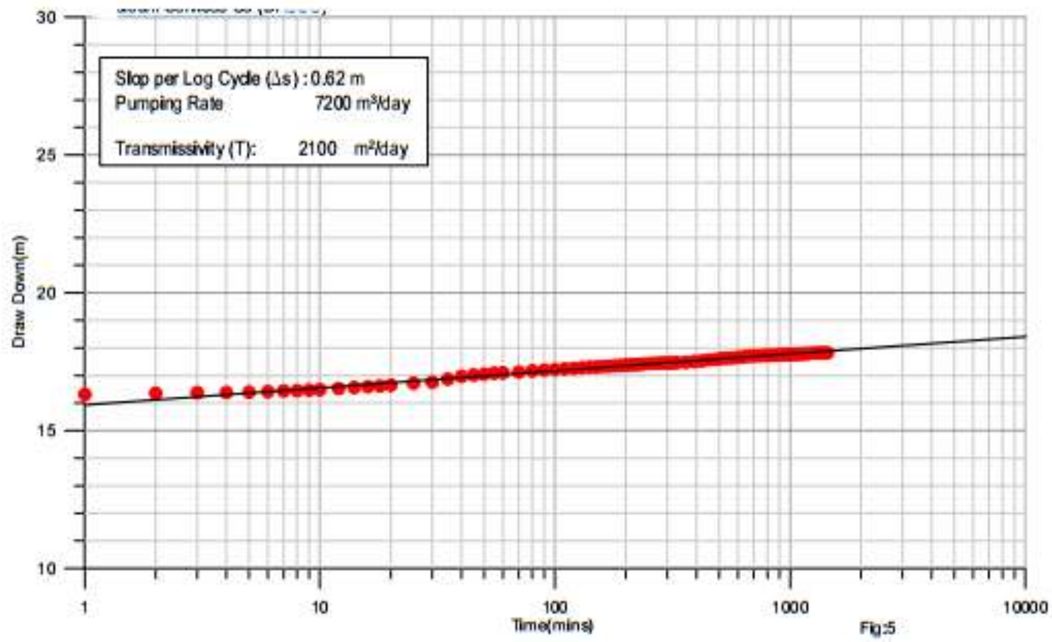

Figure 5. pumping test analysis in the enmaa 37 well.

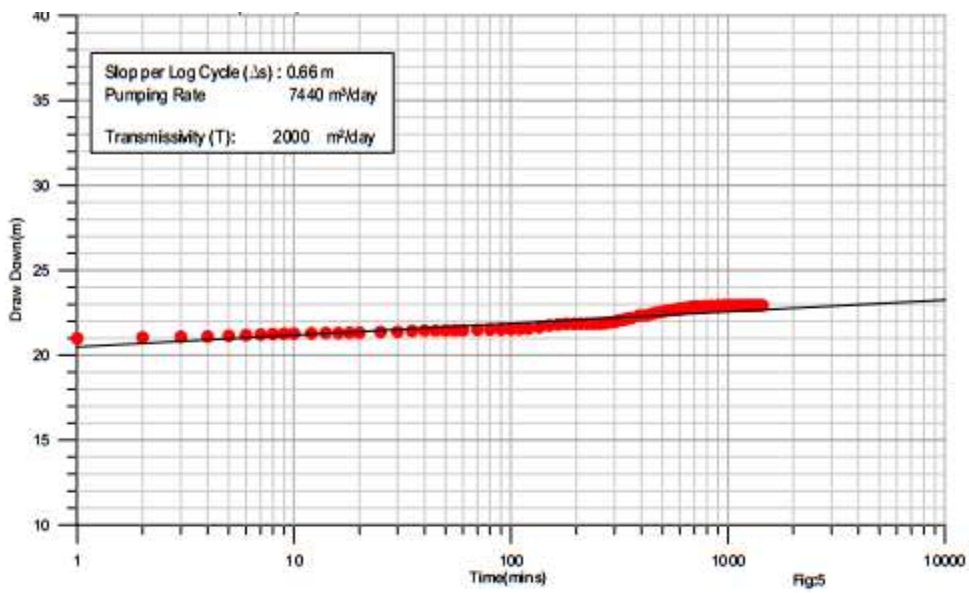

Figure 6. pumping test analysis in the enmaa 33 well.

(iii)- The third productive zone

It consists of sandstone medium to coarse, scarcely cemented, with fine lenses of shale .The maximum penetrated thickness of this aquifer is about 450 m . Their transmissivities are 1815, to 2500 m^2/day. The hydraulic conductivity values are 8.6, 9.5, and 10.4 m/day). It is noticed that the transmissivities at the locations of these wells are in parallel with the hydraulic conductivities. The difference between the results of the two hydrologic parameters is an indication on lateral facies changes, different penetrated net pay thicknesses and varied hydraulic gradients in these locations

Table 3. showing The results of interpretation of the pumping tests data in the third productive zone in the study area (Theis method)

no	**Well name**	**coordinate**		**Total Well depth. (m)**	**Transmissivity (m2/day)**	**Hydraulic Conductivity (m/day)**	**Storage Coefficient**
		N	E				
1	enmaa36	26 28 42.6	27 43 10.2	1000	2100	6	2.2×10^{-4}
2	Enmaa 33	26 27 30.6	27 42 12.1	1200	2000	5	1.2×10^{-4}
3	A 10/2	27 07 46.1	28 11 58.1	900	1800	8.4	8.15×10^{-4}
4	Far009	26 52 15.7	27 53 17.7	850	1815	4	3.5×10^{-4}
5	Far010	26 51 53.1	27 57 32.6	960	2250	9.5	9.5×10^{-4}
6	Far011	26 45 07.03	27 47 56.8	1100	2505	6.2	3.6×10^{-4}

DISCUSSION

Generally, the averages of both the transmissivity and hydraulic conductivity for the Nubian Sandstone aquifer increase with the average of depth. This means that the aquifer has also vertical facies changes and its sand/shale ratio increases downwards resulting in better hydrologic parameters. The aquifer has a high to moderate potentiality, according to Gheorhg (1979) classification Table (4).

Table 4. Classification of the aquifer potentiality according to transmissibility values (after Gheorhg, 1979).

Potentiality of the aquifer	**Transmissivity (m2/day)**
Highly potential	>500
Moderate potential	500-50
Low potential	50-5
Very low potential	5-0.5
Negligible potential	<0.5

The storage coefficients have values ranging from $1.04x10^{-4}$ to $5.22x10^{-3}$, according to the classification of Kruseman and DeRidder, (1970), According to the results of the study's pumping tests, the Nubian sandstone aquifer is in s emi-confined to confined conditions.

Table 5. Varying types of aquifers have different orders of magnitude of storativity. (Kruseman and DeRidder, 1970).

storage coefficient	**Type of aquifer**
Confined aquifer	From 10^{-4} to 10^{-6}
Semiconfined aquifer	From 10^{-2} to 10^{-4}
Unconfined aquifer	From 0.1 to 0.01

CONCLUSION

Bsed on the analysis of the constant discharge test carried for the aquifer in of El Farafra area, the main hydrogeologic characteristic of El Farafra area can be summarized as follows: -

1) The second productive zone has depth varies from 600 m to 900 m, high extraction and high pressures. The extraction is about 7000 m^3/day and the pressure of water heads varying from 3 to 4 bar, The transmissivity values for this zone vary from 1,800 to 3,300 m2/day and the hydraulic conductivity reaches 6 m/day
2) Recently, most production well drilled in the deep Nubian aquifer. In the present, this zone has high pressure but the pressure will drop gradually and the discharge will decrease.
3) These hydraulic parameters are useful in case of subjecting the area to groundwater numerical modeling

4) as determined by the results of pumping tests analysis. The hydraulic parameters show that the aquifer is still hydraulically promising

however, further management studies have to be accomplished to ensure the sustainable development of this aquifer in Farafra Oasis.

REFERENCES

1. Ali MT (2004). Evaluation of groundwater resources of El Sheikh Marzouq area at Farafra Oasis in the Desert of Egypt (Doctoral dissertation, PH. D. Thesis,Geol. Dep. Fac. of Sci. Menoufya Univ., Egypt).

2. Bear J (1979) “Hydraulics of groundwater” (New York: Mc-Graw Hill). Anderson MP,

3. CEDARE, (2001): “Regional Strategy for the Utilization of the Nubian Sandstone Aquifer System”.

4. CONOCO (1987): Geologic map of Egypt. Egyptian General Authority for Petroleum
   [5] (UNESCO Joint Map Project). Scale (1:500,000), NG 35 NE Farafra sheet.

5. EUROCONSULT, (1983): “Determination and Evaluation of Long Period Economic Exploitation of Groundwater Resources in Dakhla – Kharga – Farafra, for Agricultural Development”.

6. El Sabri MA, El Sheikh AE (2009) Groundwater sustainability of the post nubian sandstone aquifer in Farafra Oasis, Western Desert, Egypt. Journal of Science, Faculty of Science, Assiut University

7. Ebraheem AM, Riad S, Wycisk P, Seif El-Nasr AM (2002) Simulation of impact of present and future groundwater extraction from the non-replenished Nubian Sandstone aquifer in southeast Egypt. Journal of Env Geology 43: 188-196.

8. Gheorhge, A. (1979) Processing and synthesis of hydrogeological data. Abacus press, 390 Jacob, C.E., (1964): Drawdown test to determine effective radius of artesian well. Proc. Am. Soc. Civil Engrs. Vol. 79, No. 5.

9. Hamad MHM (2004) "Subsurface geological hydrological and hydrochemical studies on the Inter-stratal waters in Farafra Oasis, Western Desert, Egypt. M.Sc. Thesis, Geology Dep., Fac. of Sci., Cairo Univ, Egypt, pp. 277.

10. Himida IH (1970) The Nubian artesian basin, its regional hydrogeology aspects and palaeohydrogeological reconstruction. Journal of Hydrology 9: 89-116.

11. Idris H (1996)" Springs in Egypt" Jornal of Env Geology 27: 99-104.

12. Khalaf S, Abdalla MG (2014) Groundwater Modeling of Multi-Aquifer Systems Using GMS. Hydrol Current Res 6: 184

13. Kruseman GP, DeRidder NA (1970) Analysis and evaluation of pumping test data. International Institute for Land Reclamation and Improvement, Wageningen, p 200

14. Mawlood D K and Mustafa J S 2016 Performing Pumping Test Data Analysis Applying Cooper-Jacob's Method for Estimating of The Aquifer Parameters Mathematical Modelling in Civil Engineering pp. 9-20.

15. Moharram SH, Gad MI, Saafan TA and Khalaf S (2011) "Optimal Groundwater Management Using Genetic Algorithm in El-Farafra Oasis, Western Desert,Egypt" Water Resour Manage pp. 9865-3.

16. NOUVO CASTORO, (1985): "Technical and economical feasibility study for the reclamation of 50 000 feddans in Farafra oasis". Report submitted to the General Authority for Reclamation projects and Agricultural Development (GARPAD) v. 4, 250 pp.

17. Parson M (1962) "Bahariya and Farafra area, New Valley Project, Western Desert, Egypt, Final Report" A report submitted to GDDO, Parson Eng. C,California, USA pp. 150. Research Institute for Groundwater (2005): "Groundwater Management and utilization of the Nubian sandstone aquifer of El Farafra Oasis". Status report

18. Salem AAA (2002) "Hydrogeological studies on the Nubian sandstone aquifer in Bahariya and Farafra depressions, Western Desert Egypt" PH. D. Thesis,Geol Dep Fac of Sci. Ain Shams Univ Egypt, pp. 157.

19. Shata AA (1982) "Hydrogeology of the great Nubian Sandstone basin, Egypt"Jornal of Eng. Geol., London 15: 127-133. Thorweihe U (1990) "Das Groundwsser der Ostsahara" Die Geowissenschaten 8: 211-219.
    [20] Thabit, M., (2004): "Evaluation of Groundwater Resources of El Sheikh Marzouq Area at El Farafra Oasis in the Western Desert of Egypt". Ph. D. Thesis Submitted to Menofia Univ.

20. Theis, C.V., 1935: The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.transport" Academic Press, San Diego, New York Boston pp. 318.

21. Il Novo Castro (INC) (1985) "Technical and economic feasibility study for the reclamation of 50,000 feddans in Farafra oasis, Report submitted to the General Authority for Reclamation Projects and Agriculture Development (GARPAD) 4: 250.

22. Woessner WW (1992) “Applied groundwater modeling:Simulation of flow and Advection

23. Zaghloul,E. A.,Issawi, B. and Abdalla,A.(1983): geology of Abo Monqar Farafra-Ain Dalla stretch,Western Desert ,Egypt,ph.D.thesis submitted to fac.Sci.Cairo Uni.,pp. 186.