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Hydrogeology and aquifer properties in the area around Shendi Town, River Nile State, Sudan

Alamin Dafaala Suliman[1], Adil B M Elkrail[2], Sadam H M A Eltayeb[3*]
[1] Department of Hydrology, Faculty of Minerals and Earth Sciences, Nile Valley University, Atbara, Sudan
[2] Department of hydrogeology, Faculty of Petroleum and Minerals, AlNeelain University, Kharoum, Sudan
[3] Department of Geology, Faculty of Sciences and Technology, Omdurman Islamic University, Sudan

Abstract
This paper emphasized on the hydrogeology and aquifers properties of ground water as it is vulnerable resources to many environmental risks and is essential to sustainable development. In the present study, an attempt has been made to evaluate hydrogeological properties of the Aquifers in the Area around Shendi Town, River Nile State, Sudan. The main objectives in this study are to appraise the groundwater resources, determine the hydrogeologic characteristics of the water-bearing formation and measure water level dynamic variations related to pumping. Generally, there are two types of water bearing formation in the study area namely; the alluvial deposits and Cretaceous sedimentary formation. The two aquifers are separated by partial or completely impermeable layer of mudstone or clay. The main water bearing formation in study area is the Nubian sand stone. Groundwater occurs in one main confined aquifer type. The main recharge source of groundwater in shallow aquifers in the study area is the infiltration from rainfall. The deep groundwater aquifers are recharged from the regional groundwater regime and from the river Nile. Pumping test technique is used to estimate the hydraulic properties of the Aquifer such as hydraulic conductivity (K), transmissivity (T) and storativity (S).The hydraulic conductivity (K) is ranging between 2.5 and 5.58 m/d, while Transmissivity (T) range is 50 and 390 m^2/d. In the study area the storage coefficient (S) ranges between 0.12- 0.15.

Keywords: Aquifer, Pumping test, Hydraulic properties, Conductivity, Transmissivity.

Introduction

Hydrogeology encompasses the inter relationships of geological materials and processes with water. Groundwater Basin, which is subsurface volume through which groundwater flows towards specific discharge zone. It is bounded by geological divides. The boundaries of a subsurface basin and groundwater basin may be coincides or not. Aquifers in the Sudan in order of importance are: the Nubian Sandstones Formations, Umm Ruwaba Formation, El Gezira Formation, the Alluvium deposits, and weathered and fractured Basement Complex rocks. The Nubian Sandstone Formations (Cretaceous Sedimentary rocks) occupies about 28% of the total surface area of the Sudan. Most of this formation is situated north of latitude 12°N. The Formation is either cropping out or covered by superficial deposits, Gezira Formation, Umm Ruwaba Formation or Tertiary Lavas (N.C.R. 1982). The thickness of the Nubian Sandstone Formation ranges from few meters near the Basement Complex to more than 2000 meters at its deep trough. The maximum thickness recorded from the borehole data of water wells is not exceeding 500 meters below land surface, but geophysical surveys carried out in the Nubian Sandstone Formation in different areas indicate that the thickness is more. postulated a thickness of 1680 meters at El Asal basin, which lies north of Jebel Aulia (N.C.R, 1982). Many boreholes were drilled in the Nubian Sandstone aquifer. The depths of these wells range from about 60 to about 600 meters. The water level in the Nubian Sandstone aquifer varies from basin to another, but generally ranges from few meters below the ground surface in the basins having sources of recharge (mainly in Nile and its tributaries) to more than 120 meters in the basins remote from or have no sources of recharge (N.C.R, 1982).Many researchers deal with hydrogeology of the study area. The most important of this work was carried by Kheiralla (1966), Saeed (1976), Sudanese- German Exploration project.

Study area

The study area lies at River Nile state around Shendi Town between latitudes 16˚30.618′ &17˚ 17′ 244″ N and longitudes 33˚ 25.200′ & 34˚02.92′ E, covering an Area of 11100.Km2. it’s located in the Southern part of the River Nile State, Northern Sudan. It lies on the Eastern bank of the river Nile and it bounded in east by Albotana peneplain (Fig.1). The area is easily accessible and can be reached by a paved road, passing through Shendi, to Atbara, following the River Nile on the Eastern bank. The Sudan railway line joining Khartoum Atbara, can also be used to reach the area. The distance from Khartoum to the study area is about 170 km. Topographically, the study areas are characterized by low relief, except the numerous occurrences of isolated sedimentary outcrops Southern Alnaggaa & Almoswrat and Bagrawia area at the north and a series to the East until Alhnafa mountain. From Bagrawia to the North a gap of flat layng area is crossed by local valleys e.g wady Alhwad,Altarbeel, Aldan, up to Umm Ali hill where high elevated isolated outcrop appear once again. A few kilometers to the North, these outcrops form flat lying and Northerly extended sedimentary plateau. at the Northern area they are characterized by flat lying tops. The area is dominated by arid to semi-arid condition. The rainfall is rare and vegetation is represented by thorny trees mainly lining the valleys. The winter season is from December to March with minimum temperature of 10ºC. The summer is characterized by maximum temperature of 45ºC extended from March up to mid-July where rainfall begins with an average between 50-100 mm/y. September and October are generally hot months during the day, warm at night with dust storm till November. The area is dominated by parallel to dendritic seasonal streams flow through sedimentary provinces and seems to be structurally controlled. The main direction of these streams is to the West and North West, towards the river Nile e.g. wadi Alawteeb, wadi alhreega, wadi alhwad wadi adan and wadi Gabaty. They are the main geomorphologic features which drain the water to the River.

The study area is entirely covered by Cretaceous Sedimentary Rocks, (Kherialla, 1966) surrounded and overlying the basement complex. The Basement rocks have been exposed at Sabaloka igneous complex on the south, Bayuda complex at the nourthwest, Butana basement rocks at the southeast, and Red Sea hills at the northeast forming an outlier (Vail, 1983, Almond, and Ahmed, 1993). Low lying out crops at North e.g. alzedab Alshreeg outcrop are encountered as subsurface geologic units north east and East of the study area of sand dunes and superficial deposits cover most of the study area.

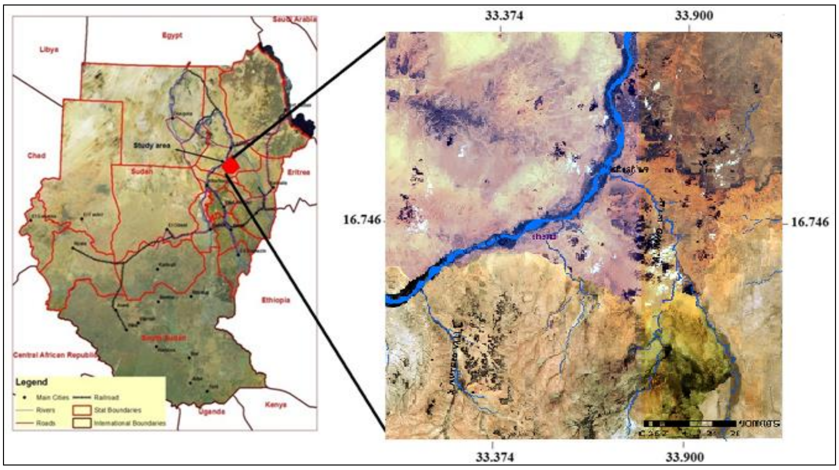


Fig 1: Location map of the study area.

3. Objectives of the study

The main objectives of this study are:

- To appraise the groundwater resources.
- To determine the hydrogeologic characteristics of the water-bearing formation.
- To measure water level dynamic variations related to pumping.

The overall objectives of the pumping test campaign were to further investigation the aquifer properties of the Shendi aquifer, in particular the hydraulic conductivity. In addition to, the well performance test allowed the determination of the laminar and turbulent head loss coefficients of the JACOB drawdown equation for each tested well.

Material and Methods

The materials for this study include geological data (rocks and structures). Hydro-geological work was conducted to obtain well locations, well design (filters and plain casing distribution), and lithology, depth to groundwater level was measured by using water level indicator. Elevations reference to mean sea level using Global Positioning System (GPS) device, to assure the Coordinates of the important features in the study area such as town, Hydrogeological outcrops Boreholes. Land sat imageries were enhanced and processed to detect the drainage pattern and structural features as a guide to define favorable sites for groundwater well locations. Pumping tests data was reanalyzed to obtain the aquifer parameters and the fluctuation of water level to evaluate hydrogeological conditions. Computer software included: aquitest, to evaluate the pumping test data. Rockwork, was used for litholgical cross section in the study area.

5. Results and Dissection

5.1 Aquifer lithology and thickness

Lithological information's are available from existing boreholes. They play significant role in delineating the aquifers extensions and thickness. The dominant rocks, in the study area are characterized by grain size range from fine to very coarse sand. Some gravel are found interbeded or mixed with sandy layers. Thick clay layers with average thickness of 40 m were found at some boreholes. The variability in lithology and structure of the rocks can be taken to characterize Nubian Sandstone formation that pointed to rapid facies changes that make to correlation of lithological units over long distances very difficult. In general groundwater found under different conditions. The thickness of saturated zone changing from one place to another. The saturated thickness generally varies from 15 m to about 70 m. (Figure 2, 3,4).

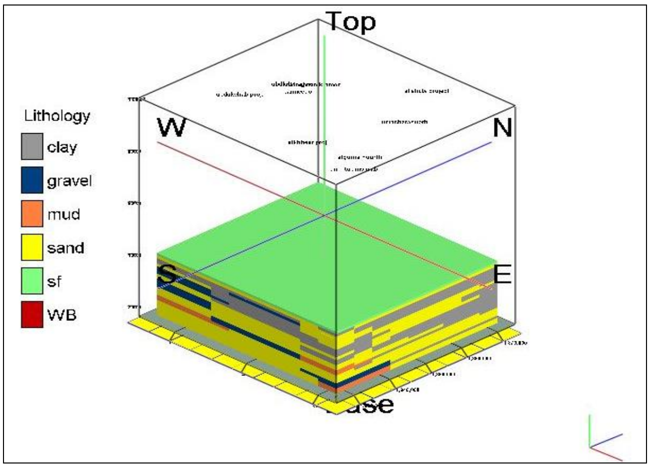
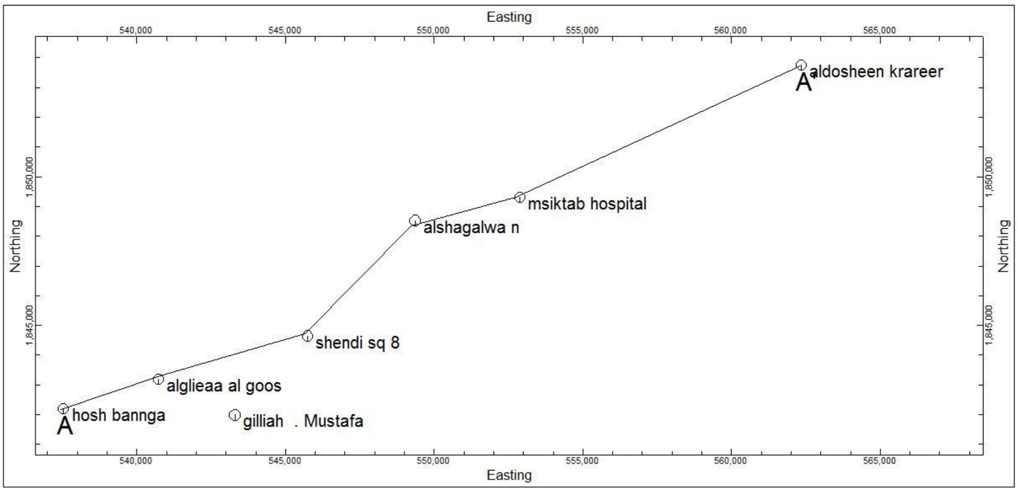


Fig 2: 3D model of the study area.



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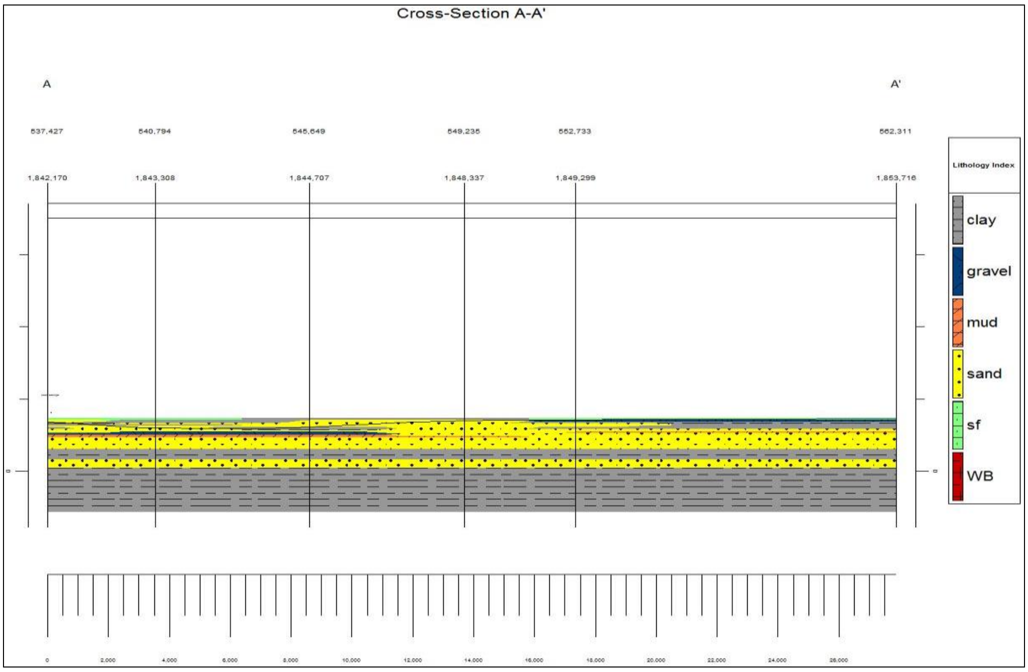

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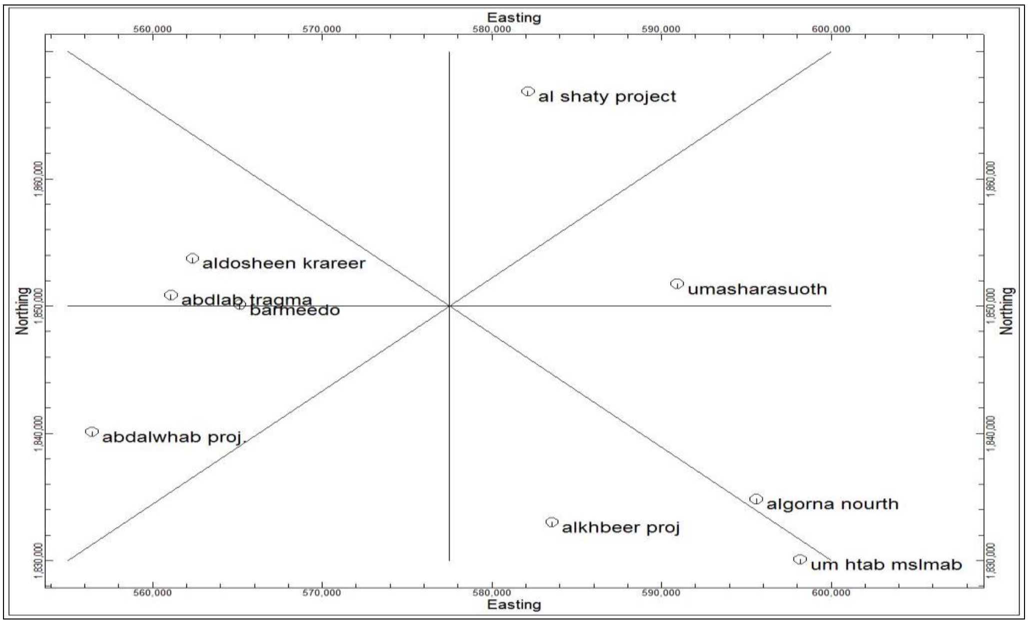
Fig 3: Maps showing cross section of the study area.



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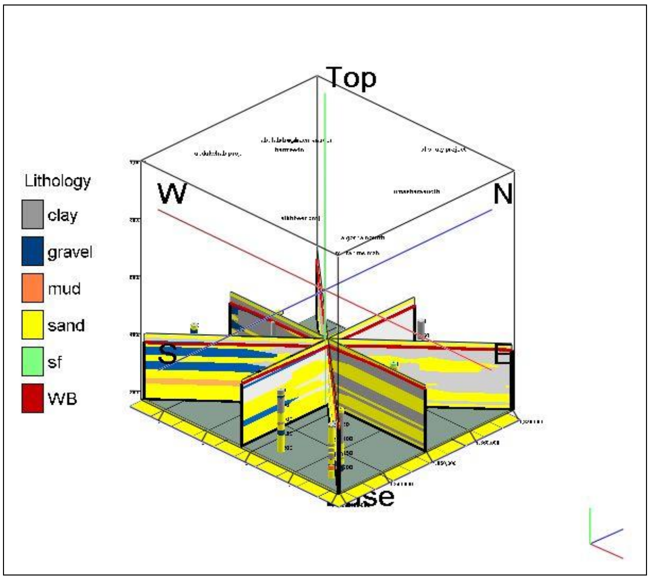

B

Fig 4: Maps showing 3D fence diagrams of the study area.

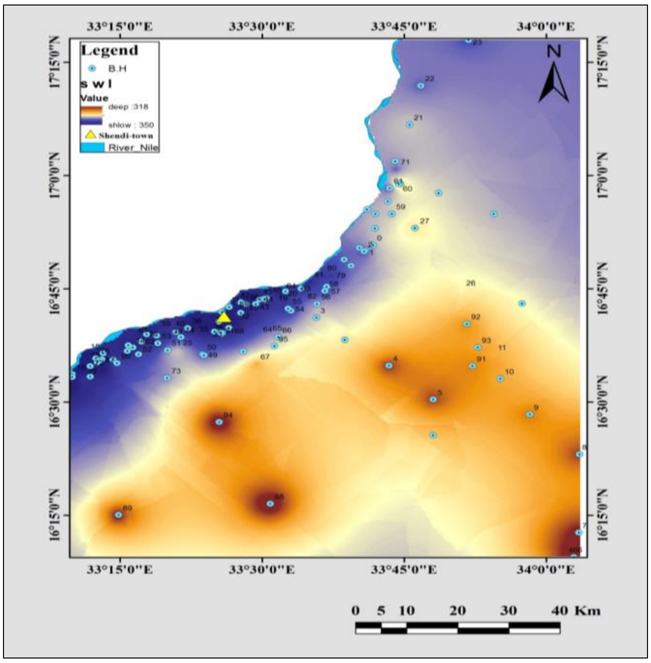

Fig 5: Distribution of hydraulic head in the study area.

Aquifers Types in Study Area

Crteaceous sedimentary (Nubian sandstone) formation

It is the main aquifer in the study area consists of sandstone, clay and silt. The total depth of water level tapped by the drilled wells ranges from 50 meters to 300 meters, and the depth of the water varies in those wells from a few meters to 100 meters.

Recent sediment

They are represented as superficial deposits (Nile & valleys Sediments). It is one of the most important shallow aquifers. Their depths are about 20 m and characterized by high permeability and porosity and yield fresh waters.

Aquifer Characteristics

In the study area four layers with two aquifers were considered namely upper and lower aquifers separated by impermeable geological formations. The lower aquifer was assumed to be confined, unconfined with thickness varies from 15 to 70 m. The upper aquifer thickness (second layer) varies from 5 to 30 m. The Nubian Sandstone Formation is the predominant geological formation in the study area. This Formation composes of Sandstones, Mudstones and conglomerates covered by recent deposits. Most of the Sandstones are poorly cemented. The grains are coarse and moderately to poorly sorted giving the rock the property of relatively good porosity. Due to the existence of mudstones and clays intercalations, more than one aquifer is encountered (Fig, 2). The artesian conditions are prevailing in the area under investigation that as a result of presence of thick mudstones and clay beds confining the poorly cemented sandstones. The later constitutes the main water bearing horizon with thickness increases to the west of the study area.

Hydraulic head in the study area

The hydraulic head reaches from 315 m to 359 m at the average level of 339.8 meters (a.m.s.l). Head variation is depicted that hydraulic gradient decreases gradually with distance from south east to east, (figure 3, 4).

Aquifer Properties

The purpose of groundwater observation wells network to monitor the quantity of groundwater reservoir. Keeping in view the regional and local requirements, the planning and design of such a net work should depend on hydrogeological situations, purpose of investigations, stage of development as well as political and social demands (Fetter, 1994). In order to determine the hydrogeologic characteristics of the aquifer, pumping test has been carried out at several localities. Pumping test data used in this part are collected from the Almewal Alzahapy company activities in the area. The following methods were used to the interpretation of the collected data:

Thies, (1935), Cooper and Jacob methods were applied for the unsteady- state flow in confined aquifer methods for estimating the coefficient of tramnmissivity (T) and the storage (S). Hydraulic conductivity (K), transmissivity (T), and storartivity (S), are the most important properties of aquifer in relation to its ability to store and transport the groundwater.

Hydraulic conductivity (K)

Hydraulic conductivity K is the ratio of flow velocity to the driving force of water under saturated conditions in porous medium. Also it is defined as the quantity of water flowing in one unit time through a face of unit area, under a driving force of one unit of hydraulic head change per unit length. It’s express by meter/day. In the study area (K) is ranging between to 2.5 and 5.58 m/d.

Transmissivity (T)

Transmissivity (T) is the rate of flow of water through avertical strip of aquifer one unit wide, and extending the full saturated thickness of the aquifer. Transmissivity is equal to the product of hydraulic conductivity and formation saturated thickness. It,s express by meter square / day. Transmissivity values obtained by recovery test are more accurate compared to those obtained by draw down tests, in the study area (T) is ranging between 50 and 390 m^2/d.

Storativty

Storatvity (S) is the volume of water that an aquifer releases or intakes into storage per unit surface area of the aquifer under unit change in hydraulic head normal to that surface. In the study area the storage coefficient (S) ranges between 0.12- 0.15. The results of pumping tests data are shown in (Table 1). The magnitude and spatial distribution of the aquifer parameters is described as follow:

Table 1: The result of pumping test daa.

Well Name	Method	Theis			Cooper& Jacob		
	Parameter	T	K	S	T	K	S
Seef project	1	$1.86x10^2$	$6.54x10^0$	$5.23x10^{-4}$	$2.56x10^2$	$8.54x10^0$	$9.11x10^{-5}$
Alaang project	2	$3.08x10^1$	$1.03x10^0$	$1.14x10^{-4}$	3.08x10	$1.03x10^0$	$1.2x10^{-4}$
Shaty prject	3	$1.56x10^1$	$6.2x10^{-1}$	$1.45x10^{-4}$	$3.89x10^1$	$3.56x10^0$	$5.0x10^{-1}$
Shendi b24	4	$4.83x10^0$	$1.3x10^{-1}$	$5.0x10^{-1}$	$1.95x10^2$	$7.82x10^0$	$5.x10^{-1}$
Banat alahamda	5	$2.08x10^1$	$8.30x10^{-1}$	$1.20x10^{-4}$	$1.73x10^3$	$6.91x10^1$	$5.0x10^{-1}$
Umeshair north	6	$1.86x10^1$	$7.43x10^{-1}$	$5.00x10^{-1}$	$6.50x10^2$	$2.6x10^1$	$5.0x10^{-1}$
Glleaa mostafa	7	$2.93x10^1$	$7.33x10^{-1}$	$1.17x10^{-1}$	$1.27x10^3$	$3.17x10^1$	$5.0x10^{-1}$
Alshekhab	8	$1.99x10^2$	$4.97x10^0$	$1.00x10^{-6}$	$3.44x10^3$	$8.60x10^1$	$5.0x10^{-1}$
Mesaiktab oshara	9	$2.78x10^1$	$5.51x10^{-1}$	$5.0x10^{-1}$	$8.84x10^2$	$1.77x10^1$	$5.0x10^{-1}$
Algyada	10	$1.82x^1$	$4.56x10^{-1}$	$5.0x10^{-1}$	$2.2x10^2$	$5.67x10^0$	$5.0x10^{-1}$

Conclusion

The dominant aquifers, in the study area are characterized by grain size range from fine to very coarse sand. Some gravel are found interbeded or mixed with sandy layers. Thick clay layers with average thickness of 40 m were found at some boreholes. The saturated thickness generally varies from 15 m to about 70 m. Crteaceous sedimentary (Nubian sandstone) formation it is the main aquifer in the study area consists of sandstone, clay and silt. The total depth of water level tapped by the drilled wells ranges from 50 meters to 300 meters, and the depth of the water varies in those wells from a few meters to 100 meters. In the study area four layers with two aquifers were considered namely upper and lower aquifers separated by impermeable geological formations. The lower aquifer was assumed to be confined, unconfined with thickness varies from 15 to 70 m. The upper aquifer thickness (second layer) varies from 5 to 30 m. The hydraulic conductivity (K) is ranging between 2.5 and 5.58 m/d, while Transmissivity (T) range is 50 and 390 m2/d. In the study area the storage coefficient (S) ranges between 0.12- 0.15.

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