JOURNAL OF ADVANCED ENGINEERING AND MODERN TECHNOLOGY

CSK SCIENTIFIC PRESS

Research Article

Volume 1 | issue 1

Hydrogeology and Aquifers Properties in the Area Around Almatama Town, River Nile State, Sudan

Afraa Abubker Abdelwhab Kaydon[1], Hassabelrasoul Elsidig Elhadi Ahmed[2], Sadam Hassan Mohmed Ahmed Eltayeb[1*], Braa Abdelwdood Ali Ahmed[3]

[1]*Department of Geology, Faculty of Sciences and Technology, Omdurman Islamic University, Sudan*

[2]*Department of Hydrology, Faculty of Minerals and Petroleum, International University of Africa, Sudan*

[3]*Ministry of Irrigation and Water Resources, Ground water and Wadies General Directorate, Sudan*

[*]**Corresponding Author:** Sadam Hassan Mohmed Ahmed Eltayeb, 1Department of Geology, Faculty of Sciences and Technology, Omdurman Islamic University, Sudan.

Submitted: 19 January 2026 **Accepted:** 23 January 2026 **Published:** 28 January 2026

Citation: Sadam Hassan Mohmed Ahmed Eltayeb (2026). Hydrogeology and Aquifers Properties in the Area Around Almatama Town, River Nile State, Sudan. J of Adv Eng & Modern Tech 1(1), 01-09.

Abstract

In the present study, an attempt has been made to evaluate hydrogeological properties of the Aquifers in the Area around Almatama, River Nile State, Sudan. Groundwater samples were collected from 24 locations within the study area. Based on hydrogeological studies there are two types of aquifers in the study area the alluvial (Unconfined) aquifer and Cretaceous sedimentary (Confined) aquifers. Upper aquifer is recent Water-bearing formation in the study area can be classified generally into two main aquifers Shallow or upper aquifer and Deep or lower aquifer. The two aquifers are separated by partial or completely impermeable layer of mudstone or clay. The thickness of the two aquifers varies between the 3 - 30 m (for the upper aquifer) and 13 – 55 m (for the lower aquifer). Pumping test technique is used to estimate the hydraulic properties of the Aquifer such as hydraulic conductivity (K), transmissivity (T) and storativity (S). The average values of hydraulic conductivity (K) are 1.86 and 188.75 m/min using Jackob and Thies methods respectively. The averages values of transmissivity (T) are 71.11 and 822.54 m2 /min using Jackob and Thies methods respectively. The average values of storativity (S) are 0.46 and 0.30 using Jackob and Thies methods respectively.

Key Words: Aquifer, Pumping Test, Hydraulic Properties, Conductivity, Transmissivity.

Introduction

Ground water Occurrence in Sudan Republic in four major aquifers. The Mesozoic Nubian aquifer system is the most important and most extensive water – Bearing. The other three main aquifer are the tertiary – quaternary retrial of the Gezira, Umm Rawaba and Alatshan formations, the tertiary basalt and the alluvial deposits. Minor amount of water are abstracted from weathered and highly fractured basement complex rocks.

The Nubian sandstone aquifer is the most important and the largest water-bearing formation in Sudan. It consists of sandy and gravely beds and characterized by high porosity and permeability. However, Nubian sandstone crops out in a vast area and is buried in some parts because they are too thin and always exist above the piezometric surface [1]. The aquifer covers about million square kilometers mostly in north and central of Sudan. It is generally overlain by Umm Ruwaba formation in central south in Sudan also it can be divided into sub basins such as Sahara basin, Umm Kaddada basin, the Nahoudbasin, Nile –Nubian basin and Elgadaref basin. The transmisivty coefficient of the aquifer is range from 35 to 1500 m2/daywhereas the permeability is ranging from 1 to 19 m2/day and the storage coefficient ranging from 10-4 to 25*10-2.The transition from confined to unconfined aquifer the well yield is between few m3/h to 400 m3/h so that these huge amounts of water can be used for irrigation.

Umm Ruwaba aquifers is second in order of importance it has lenticular water bearing strata of sand and pebbles which are mostly in hydrolic contact with each other the water in this aquifer is exploited mostly for domestic use and for life stock and occasionally for small scale of irrigation. It covers an area of about 800000 Km2 mostly predominant at the southern of the country. It may overlay altered formation of crystalline basement rocks (Bara Basin) or altered Nubian sandstone or other older formation (Atshan,Baggare, and Sudd basins). This basin can be sub divided into sub basins such as Bara basin, Baggara basin and Sudd basin.

Alluvial aquifers is third in order of importance it has lenticular water bearing strata of the Nile silt and alluvial deposits of valleys are largest aquifers in Sudan most of them contain large quantities of water of good quality. The ground water of the alluvial is usually contained in unconfined aquifer at shallow depth (a few centimeters to 15 meters) below ground surface the ground water flow in some direction as the surface water flow downstream. The transsimisivity coefficient is range from 200 to 1500 m2/day and the storage coefficient is also high where 13 – 25 % is expected on unconfined aquifer.

Study Area

The study area lies in the River Nile State central Sudan on the western bank of the river Nile, between latitudes 16° 32´ 17 and 17° 07´ 17 N and longitudes 33° 04´ 44E and 33° 40´49E (Figure 1). The locality covers the south western part of river Nile state. It's bordered by Edamer Mhalia to the North, in Pagarose and ALmofraa Village in the west of the river Nile bank and the river Nile with the Shendi Mhalia to the east boundary and Khartoum locality in the south boundary at El Hogna (ALwefag) city. It's bordered by Northern state in the west. The study area covers an area about 904.9792 Km2. The area is characterized by tropical climate (dominated by semi desert conditions), In Matammah the mean maximum monthly temperatures range between 41 Cº to 43Cº in summer. The highest maximum temperature ever recorded was 45Cº in May and June; the minimum temperature is 19 ºC in January in winter. The rainy season extends from August to September with less than 100 mm per year rain fall. The land surface in general is largely a plain of low relief. Individual inselbergs (or jebels) occur sporadically. Sandy soils are common in most areas, except in the south, where clayey soils predominate. Wadis are mostly running ephemerally only during the rainy season. The Wadis mostly flow from N-NW to S-SE towards the river Nile. The River Nile is the important physiographic feature of the study area. Other drainage pattern in the study area is the Dendritic pattern which covers largely the area. Some other relatively big wadies flow towards the south direction to join Nile River. The main drainage in the study area is: River Nile, Wadi (ELNugoa), Wadi Hamra, Husra. The geological setting of the study is composed of Basement Complex (Pre-Cambrian), Nubian sandstone formation (upper Cretaceous), Hudi Chert (Oligocene) and superficial deposit (Quaternary) (look figure 3.1) in ascending chronological order [2]. The study area is entirely covered by Nubian Sandstone Formation [3]. Basement rocks have been exposed at Sabaloka igneous complex on the south, [4-6]. And low lying out crops at Nourth e.g. Wadi El Husra, Salawa , Abuzor and AlGerief) and encountered as subsurface geologic units west of Matammah, through the boreholes (e.g. Arkaweet – Alhajab – Alhobaje) [7]. Hudi Chert were observed north of Matammah at J.Kadakol. Sand dunes and superficial deposits cover most of the study area.In general the regional stratigraphic units in the area [8-10].

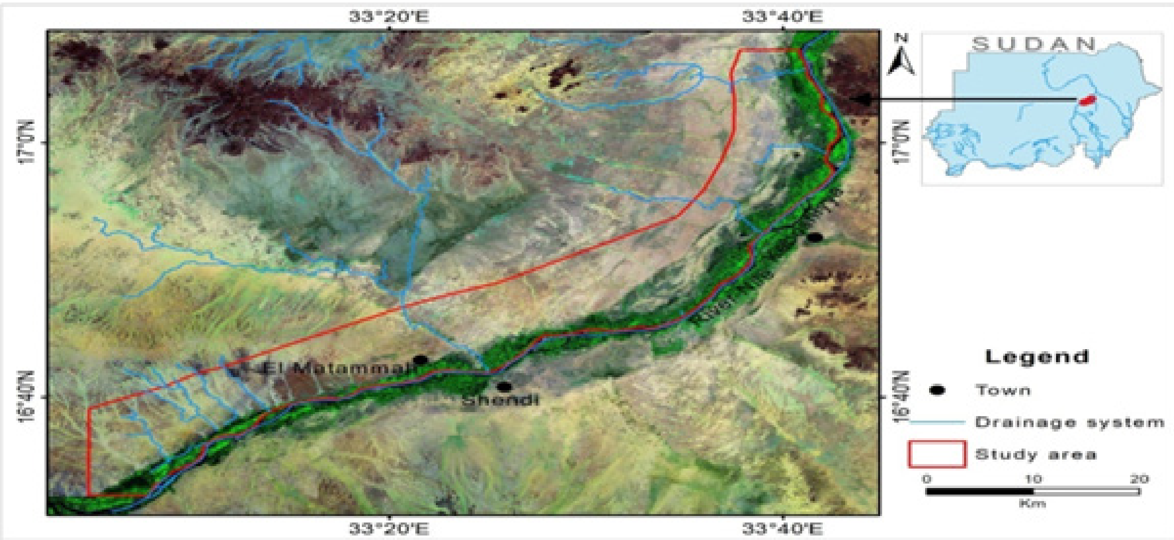


Figure 1: Location map of the study area.

Objectives of the Study

The main objectives of this study are:

- To detect groundwater aquifers extent and geometry.
- To delineate potential Zones of groundwater occurrence.
- To determine hydrogeological characteristics of the aquifers.
- To study some aspects of the parameters that controls the existence of groundwater.

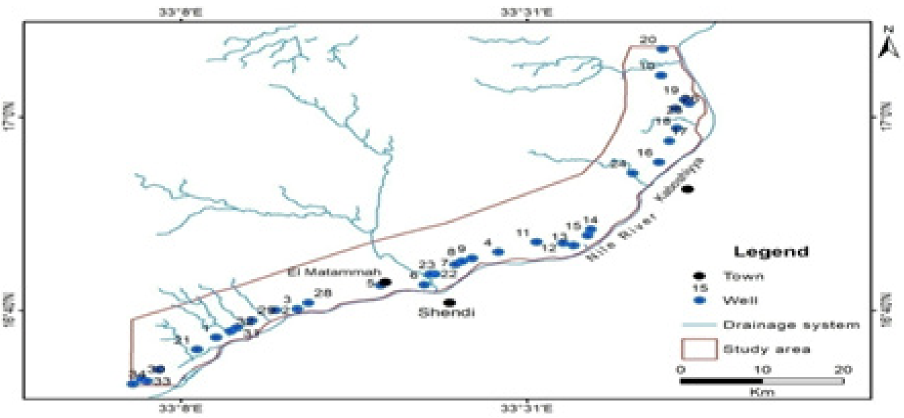
Methodology

The materials for this study include geological data (rocks and structures) [11-15]. 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 [16-18]. 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 [19-20]. 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, used for litholgical cross section in the study area [21,22].

Results and Dissection

Water Bearing Formation

The water bearing formation that acts as containers for groundwater are termeds aquifer, which is defined as any geological unit or structure that can store and transmits water in sufficient quantity to supply pumping wells or natural springs. The amount of groundwater that can be stored in a rock material and its yield depends on the porosity and permeability of that rock. The ability of the rock to yield water is determined by its permeability or ability to transmit water through the pore space of the rock material. The main sources of groundwater occurrences are the Nubian sand stone Formation aquifers. Groundwater samples were collected from 24 locations within the study area (Figure 2) [23-24].



3

Figure 2: The Well location distribution in the study area.

Aquifer Types in the Study Area

The study area is Hydro-geologically comprising of one main aquifer confined aquifer discussed below and other locally Perched water.

Confined Aquifers

Confined or artesian aquifer is that underlain and overlain by impervious layers. The main confined aquifers in the study area is within the sedimentary rocks of Nubian sandstone formation where the aquifer is covered by thick clay bed of about 20 m and the high depth to water table this encountered hydrostatic influence to confining system in elketteab and wadi Nogua. The basin lies North Matammah town from which water supply to the town is delivering; it is composed of sandstone that interbeded by compacted mudstone and overlain by Wadi fills deposits (Figure 3) [25-27].

Perched Water

It is unconfined separated from the main regional aquifer by localized clay or impervious materials in the zone of aeration, it is a source of limited water supply, and it is highly distinguishable by its sudden falls of water level in the borehole during drilling. A perched aquifer penetrated up to (13 m) within some pockets of shallow Nubian of mudstone intercalation observed down holding in Abugrain hand dug well (Figure 3) [28-30].

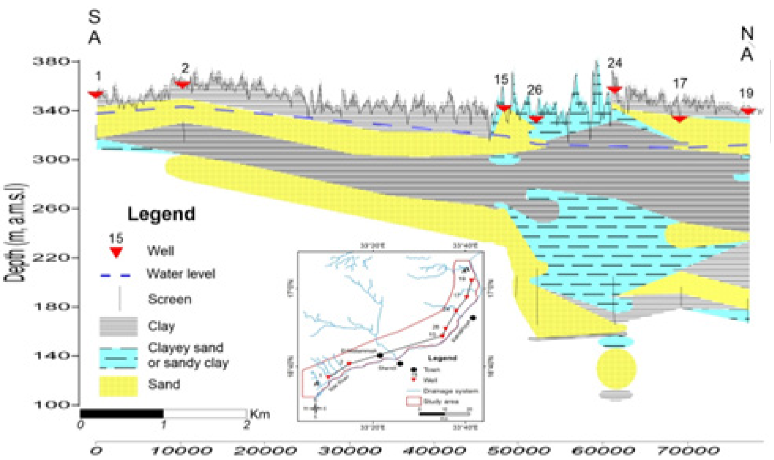


Figure 3: Confined and Unconfined Aquifers in the Study area

Aquifer Geometry (3D Model)

From one Hundred boreholes only nineteen data points are used in this study. From this data, the thickness of The sediments in the area range from a few meters in the north and northwest to more than 500 m in middle, in which the drilled boreholes struck the basement rocks (e.g: southwest Metemma from Salwa village and crop out in Alboaled, Hajer Alteer along the river Nile to Al hogna) [31-33]. Lithological information's are available from existing boreholes. They play a significant role to delineate the aquifers extensions and thickness (Figure 4). The dominant rocks, lithology of the study area characterized, by a grain size range from fine to very coarse sand. Some gravels are found inter bedded or mixed with sandy layers, also thick clay layers with average thickness of 50m were found at some boreholes [34,35]. The variability in lithology and structure of the rocks can be taken to characterize Nubian formation that pointed to rapid facies change while make very difficult to correlate the lithological units over long distances. Generally groundwater is found under different conditions. The saturated thickness changes from one place to another (Figure 4). The properties of the saturated zone are: range from 12m in the southwest to more than 25m in the northeast except in the northwest that part from the study area leach water table from the 50m to more than 90m from the groundsurface. Soil pores are filled with water and the moisture content is equal to porosity. The saturated thickness generally varies from 10m to more than 30 m (Figure 4) and (Figure 5).

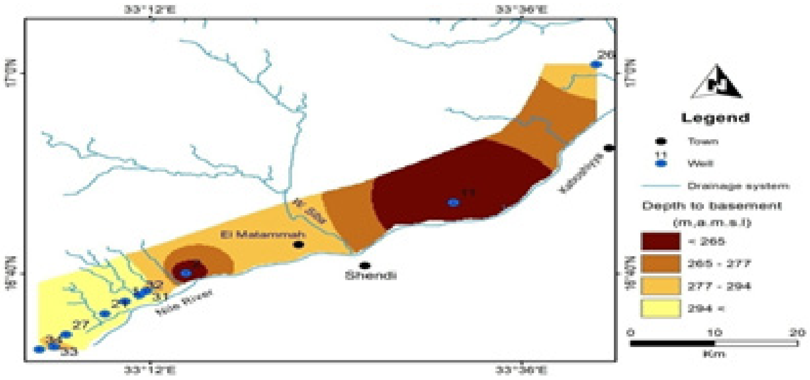


Figure 4: Depth to Basement Map in Study Area (Meter Below Ground Surface).

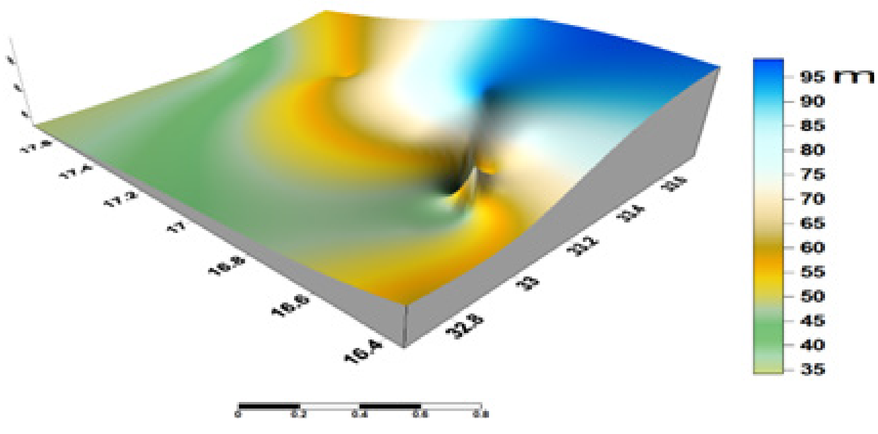


Figure 5: 3D Depth to Basement in Study Area (Meter Below Ground Surface).

Depth to Groundwater Level

Water level measurements an important for any type of pumping test [36,37]. The depth to water level is measured reference to earth surface. Water level is variable according to the topography, structural geology, distance from the sources of recharge and the variations of permeability(Table 1). However, water tables from 25 wells were used to detect the flow pattern (Figure 6). Groundwater table varies from 9.8 m to 80 m with the average level of 20 meters from the ground surface. That variation is ascribed to hydraulic gradient decreases directly with distance from south west to northeast. In the study area groundwater flow pattern had been deduced from the water table subtraction from elevation above mean sea level map that is explaining the elevation of the hydraulic head. In the sedimentary area contour lines interval is five meters. The depths to the rest water level show a wide range of variation from 10 to 38 m below the ground surface. Deeper depths characterize the west boundary area with static water level approximately ranging from 60m to 80m from ground surface in the western zone, while the shallower depths are found near the river Nile zone, with static water level approximately ranging from 9m to 30 m from ground surface, while the hypapesal depths are found middle of the area.

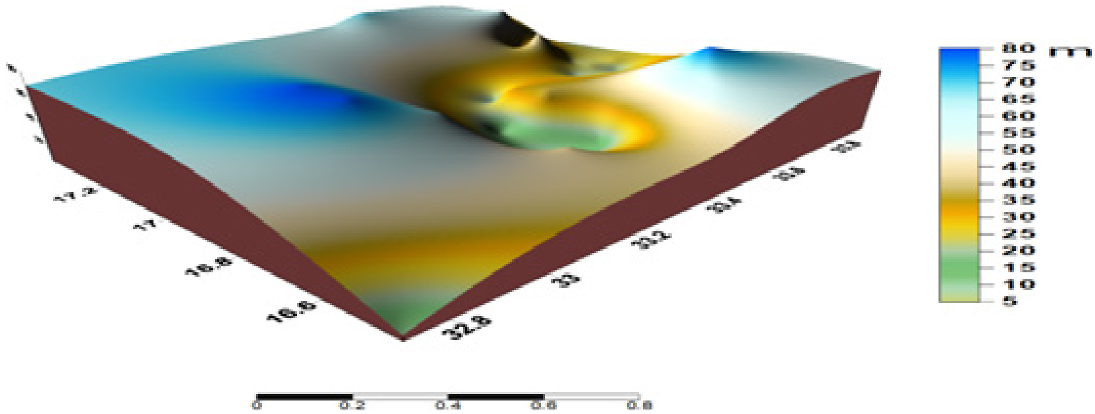


Figure 6: 3D Water Level in Study Area (Meter Below Ground Surface)

Table 1. Showing Elevation, Static Water Level (S.W.L) and Water Head

Well No.	Longitude	Latitude	Elevation (m)	S.W.L (m)	Head (m)
1	33.45611	17.36667	403	69.5	333.5
2	33.37917	17.37917	379	63	316
3	33.47667	16.87167	356	37	319
4	33.3025	16.73167	355	4.4	350.6
5	33	16.98111	417	80	337
6	33.13583	16.79917	373	64	309
7	33.00556	16.8675	407	80.3	332
8	33.26722	16.63361	373	41	332
9	33.68	16.65944	401	79	322
10	32.7144	16.4311	390	9.3	380.7
11	33.73028	17.21972	356	63	293
12	33.77167	17.05556	366	22	344
13	33.72833	17.16722	370	16	354
14	33.70523	16.99111	364	20	344
15	33.80722	16.95639	352	19	333
16	33.8375	16.98833	371	25	346
17	33.77444	17.00056	366	23	343
18	33.34278	16.90278	365	19	346
19	33.375	16.88583	367	10	357
20	33.73361	17.12167	352	50	302
21	33.91583	17.24583	354	15	339
22	33.47444	16.96083	365	33	332
23	33.44972	16.70083	372	14.3	357.7
24	33.46361	16.98917	357	17.3	339.7

Pumping Tests Analysis

Pumping test technique is used to estimate the hydraulic properties of the Aquifer such as transmissibility and storativity. Various formulas were applied to analyze the pumping test data. According to the available data, calculations of transmissivity and hydraulic conductivity of the aquifer were accomplished by application of various methods for the unsteady state flow condition for both pumping and recovery tests , transmissivity T, and stortativity S, are the most important properties of aquifer in relation to its ability to store and transport groundwater. The pumping tests where conducted from pumped wells without observation wells. In this case, draw-down must be measured in the pumping well which carried out by companies. The methods used in this study include;(A) Cooper-Jacob (1946) method, (B)

Theis (1935) method. Each method is being applicable under a certain hydrogeological boundary condition [38-40].

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 expressed by meter/min. At borehole in the study area the hydraulic conductivity (K) values range between 0.000305 to 11.1 m /min and average is 1.86 m /min using Jackob method. Also the hydraulic conductivity (K) values range between 0.000895 to 1720 m / min and average is 188.75 m /min using Thies method (Figure 7), (Table 2).

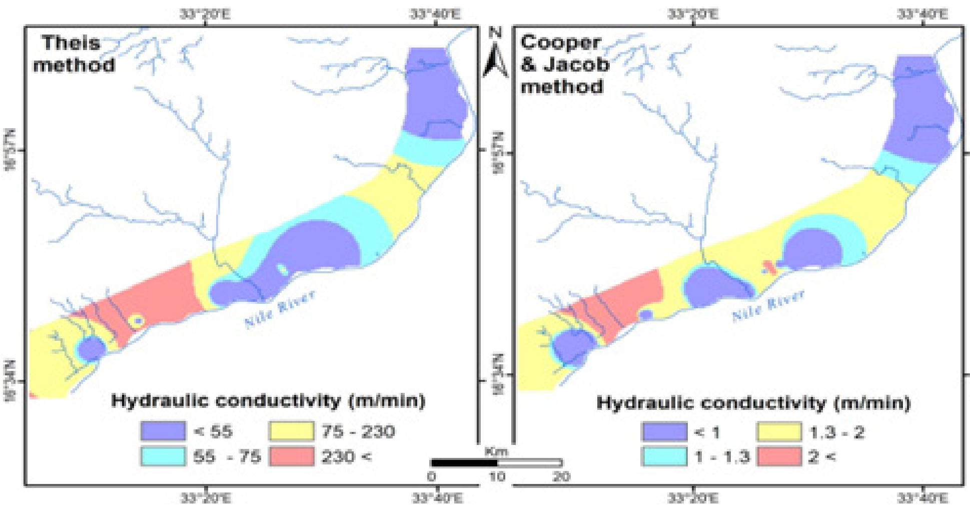


Figure 7: The Hydaurolic Conductivity Distribution in the Study Area

Transmissivity (T)

Transmissivity (T), is the rate of flow of water through a vertical strip of aquifer one unit Wide and extending the saturated thickness of the aquifer Transmissivity is equal to the product of hydraulic conductivity and formation saturated thickness. It's express by meter2 / min. Transmissivity values obtained by recovery test are more accurate compared to those obtained by draw down tests. At borehole in the study area the transmissivity (T) values range between 0.0106 to 390 m2 /min and average are 71.11 m2 /min using Jackob method Also the transmissivity (T) values range between 0.0313 to 3440 m2 /min and average is 822.54 m2 /min using Thies method (Figure 8), (Table 2).

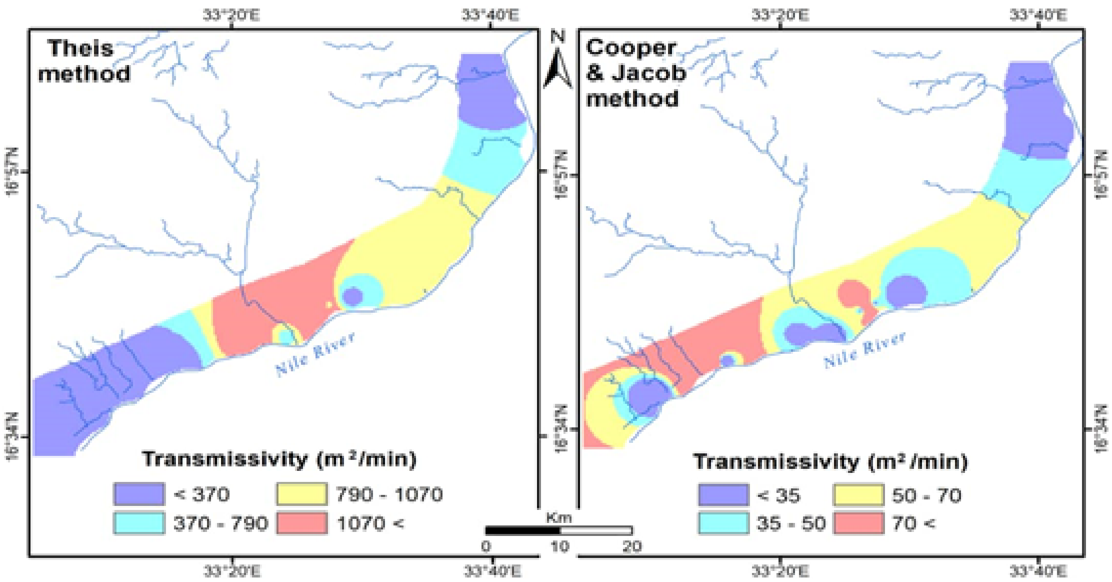


Figure 8: The Transmissivity Distribution in the Study Area

Storativity (S)

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. At borehole in the study area the storativity (S) values range between 0.00011 to 1.7 and average is 0.46 using Jackob method. Also the storativity (S) values range between 0.00265 to 0.5 and average is 0.30 using Thies method (Figure 9), (Table 2).

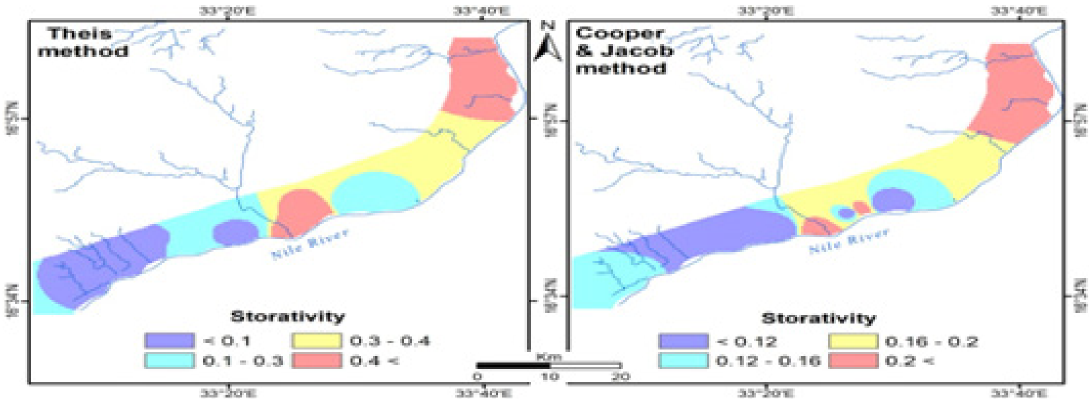


Figure 9: The Storativity Distribution in the Study Area

Table 2: Hydraulic Properties of the Aquifers in the Study Area

Thies Method			Jackob Method			Method
S	K	T	S	K	T	Location
	(m/min)	(m2/min)		(m/min)	(m2/min)	
0.125	0.000895	0.0313	0.163	0.000305	0.0106	1
0.00324	0.232	30.8	1.706	11.1	390	2
0.241	1720	0.602	0.0734	0.011	0.386	3
0.173	0.00123	0.0433	0.00023	0.00422	0.147	4
0.00265	0.189	1730	0.00011	0.0414	27.8	5
0.5	26	650	0.5	0.743	18.6	6
0.5	31.7	1270	0.117	0.733	29.3	7
0.5	86	3440	1.06	4.97	199	8
0.5	17.7	884	0.5	0.551	27.8	9
0.5	5.67	220	0.5	0.456	18.1	10

Conclusion

- The study area is located in north central Sudan at the western bank of the river Nile between latitudes 16° 32´ 17 N and 17° 07´ 17 N and longitudes 33° 04´ 44E and 33° 40´49E.
- The main geological units in the study area are Precambrian Basement complex almost totally covered by Mesozoic to recent sedimentary sequence; The Basement complex includes metamorphosed sedimentary, plutonic rocks. The Nubian sand stone series consisting of a flat laying sequence unconsolidated gravels; sand, sandy clay and clays are common. The superficial and clay plains deposits consist of laminated, compacted clay, silt, sandy clay and clayey.
- From the geological studies the groundwater storage is controlled by the rock types and their major structures.
- 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. While the deep groundwater aquifers are recharge from the regional groundwater regime and from the river Nile.
- In this study provide that fixed sand dunce were used to criteria of groundwater aquifers occurrences.
- At borehole in the study area the hydraulic conductivity (K) values range between 0.000305 to 11.1 m /min and average is 1.86 m /min using Jackob method. Also the hydraulic conductivity (K) values range between 0.000895 to 1720 m /min and average is 188.75 m /min using Thies method.
- At borehole in the study area the transmissivity (T) values range between 0.0106 to 390 m2 /min and average are 71.11 m2 /min using Jackob method. Also the transmissivity (T) values range between 0.0313 to 3440 m2 /min and average is 822.54 m2 /min using Thies method.
- At borehole in the study area the storativity (S) values range between 0.00011 to 1.7 and average is 0.46 using Jackob method. Also the storativity (S) values range between 0.00265 to 0.5 and average is 0.30 using Thies method.

15

Acknowledgement
Authors were indebted to Non-Nile water corporation, Atbara Branch for providing most of hydrogeochemical data and direct support during field work in the study area.

References

1. Hggaz Y (1990) Ground water in north and West Africa (natural resources/water series no.18.
2. M Mukhtar (1999) Evaluation of ground water in Atbara basin by resistivity methods. Sudan. Bull Geol Surv Sudan 18-76.
3. Kheir Alla MK (1966) Astudy of Nubian sandstone formation of the Nile valley between 14 N and 17 – 42 N with refrence to the groundwater geology. M.Sc. U of k. 234.
4. Almond DC (1980) Precambrian events at Sabaloka, near Khartoum and their significance in the chronology of the basement complex of northern Africa – Precambrian Research. 13: 43-62.
5. Omer MK(1983) The Geology of The Nubian Sand Stone Formation In Sudan, Stratigraphy, Sedimentary Dynamics, Diagenesis – Geological and Mineral Resources Department, The Ministry of Energy and Mining, Sudan. 224.
6. Butler JJ, W Leu (1993) Pumping tests in ununiform aquifers: The radially symmetry case. Water resour Res. 29: 250-269.
7. Adil Elkrail, Sadam Hassan, Randa Gumaa (2014) Hydrochemical Characteristics of Groundwater at Northeast Atbara Town, Nile River State, Sudan. International Journal of Innovation in Science and Mathematics. 2: 2347-9051.
8. Arain MB, Kazi TG, Jamali MK, Jalbani N, Afridi HI, et al. (2008) Total dissolved and bio available elements in water and sediment samples and their accumulation in or eochromismossambicus of polluted Manchar Lake.Chemosphere. 70: 1845-1856.
9. Anderson MP, WW Woessner (1992) Applied ground watermodeling, Simulation of Flow and Advective Transport. 1-27
10. Babiker S, Mohamed MAA, Hiyama T (2007) Assessing groundwater quality using GIS. Water resource Manage. Springer science + Business Media BV. 21: 699-715.
11. Belkhiri L, Boudoukha A, Mouni L (2010) Groundwater quality and its suitability for drinking and agricultural use in AinAzel plain, Algeria. Journal of Geography and Regional Planning. 3: 151-157.
12. Boulton NS (1963) Analysis of data from nonequilibrium pumping tests allowing for delayed yield from storage. Proceedings of the Institute of Civil Engineers. 26: 469-482.
13. Bouwer H, RC Rice (1976) A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resources Research. 12: 423-428.
14. Bras RL (1990) Hydrology: An Introduction to Hydrologic Science, Addison-Wesley Publishing, Reading, Mass.
15. Cooper HH, Jacob CE (1946) A generalized graphical method for evaluating formation constants and summarizing well field history, Am Geophys. Union trans. 27: 526-534.
16. Cooper HH, JD Bredehoeft, IS Papadopulos (1967) Response of a finite diameter well to an instantaneous charge of water. Water Resources Research. 3: 263-269.
17. Butler JJ (1988) Pumping tests in ununiform aquifers: The radially symmetry case. J. Hydrol. 101: 15-30.
18. Butler JJ, CD McElwee (1990) Variable – rate pumping test for radially symmetric nonuniform aquifers,water resour. 26: 291-306.
19. Domenico P, Schwartz F (1998) Physical and Chemical Hydrology (second Ed.). John Wiley& Sons Inc, New York, USA. 234-247.
20. Durov SA (1948) Natural waters and graphical representation of their composition. Dokl Akad Nauk. USSR 59: 87-90.
21. Fetter CW (1990) Applied hydrogeology.merrill publisher company, bell and howell information company-USA.
22. Geological Research authority of sudan (2003) Report about Geological Formation in Matammah Locality. Unpublish Report.
23. Gorrell HA (1958) Classification of ground waters based on Sodium chloride content: Am. Assoc. Petroleum Geologists Bull. 42: 2513.
24. JI Drever, (1997) The Geochemistry of natural waters: surface and groundwater environments. 3ed Edition, Printice Hall, Englewood Cliffs.
25. Libian foreign investment company (2001) Hydrogeological final report, phase three: Agriculture studies and system of irrigation. Wade EL Nuga agriculture scheme. Unpublished Report.
26. Lloyd JA, Heathcote JA (1985) Natural inorganic hydrochemistry in relation to groundwater: An introduction. Oxford Uni. Press, New York. 296.
27. Mahmmud A (1986) Groundwater between theoretical and application. First edition. Traplus. 242.
28. Piper AM (1944) “A graphic procedure in the geochemical interpretation of water analysis”, American Geophysical Union Transactions. 25: 914-923.
29. RA Freeze, JA Cherry (1979) Groundwater, Prentice- Hall 604.
30. Sadam HMA Eltayib, Adil BM Elkrail (2018) Regional Groundwater Flow Modeling of Aldamer Area, River Nile State – Sudan, International Journal of Applied Science and Mathematics. 5: 2394-2894.
31. Sadam HMA Eltayib (2019) Hydrochemical Characteristic and Ground Water Quality of the Aquifers in area around Aldamer Town-River Nile Sate – Central Sudan, International Journal of Geology, Agriculture and Environmental Sciences. 7: 2348-0254.
32. Sajil Kumar PJ (2013) Interpretation of groundwater chemistry using Piper and Chadha´s diagrams: a comparative study from Perambalur taluk. Elixir Geoscience. 54: 12208-12211.
33. Saxena V, Ahmed Shakeel (2003) Inferring the chemical parameters for the dissolution of fluoride in groundwater. Environmental Geology. 43: 731-736.
34. Schandelmeier, Pudlo (1990) The central Africa fault zone (CAFZ)in sudan a possible continental transform fault. Berliner Geowiss Abh. 120: 31-44.

35. Scholler H (2003) Geochemistry of ground water, In ground water studies–An international guide for research and practice, UNESCO, Pris. 1-18.
36. Shyamala R, Shanthi M, Lalitha P (2008) Physiochemical analysis of bore well water samples of Telungupalayam area in Coimbatore District, Tamilnadu, India. E-Journal of Chemistry. 5: 924-929.
37. Stiff HA (1951) The interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology. 3: 15-17.
38. Kheiralla (1981) has carried out comprehensive study of ground water resources of the northern Sudan.
39. Vail JR (1971) Geological reconnaissance in part of Berber District, Northern Province, Sudan-Bull. Geol Surv Sudan. 18: 76.
40. Whiteman AJ (1971) The geology of the Sudan Republic Oxford (Clarendon press). 290.