# The Hydrogeology of Delta State, Nigeria.

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## ABSTRACT

This paper presents a review of the hydrogeology of Delta State, Nigeria. This research provides comprehensive findings from different published literature on the subject matter which will assist individuals and governments in the sustainable exploitation of groundwater resources in the study area. Delta state, falls approximately between Latitude $6^{0}40^{l} - 6^{0}15^{l}$N and Longitude $6^{0}40^{l}$E – $6^{0}45^{l}$E and is blessed with abundant surface water and groundwater resources with a high average annual precipitation of about 1900mm. The basin fill is made up from the oldest to the youngest; Akata, Agbada, and Benin Formations.

Groundwater in most parts of the State is found in two aquifers all within Benin formation and the poorly understood recent deposits of Ameki and Ogwashi-Asaba Formations which extend from Anambra State into Asaba in Delta State. The maximum thickness of the first aquifer is less than 50 meters and aquifer here is unconfined to semi-confined and prone to contamination. The second aquifer is found at greater depths and sandwiched between grey-dark clays, clay shale, and lignite bands and the aquifer here is confined.

(Keywords: aquifers, groundwater, well logs, Fence diagram, Delta State)

## INTRODUCTION

Groundwater is the most widely valuable natural resources in the world. It is known to occur within the Earth's sediments, rocks, or sand formations. The occurrence and distribution of this natural resource are restricted to some geological formations and structures called aquifers. An aquifer is explained as a subsurface formation which is capable of storing and transmitting water at a pace fast enough to provide sufficient quantity to wells (Fetter, 2007).

The presence of water in a formation does not in any way imply that the water quality is good enough for domestic consumption. However, groundwater that occurs in formations which are properly sealed by a non-porous formation is known to provide good quality water (Todd, 2004).

Sometimes a confining layer of less porous rock might occur above and below the aquifer layer. When this happens, the aquifer is referred to as a confined aquifer. In such a situation, the rocks surrounding the aquifer confine the pressure in the porous rock and its water. The pressure inside the aquifer might just be enough to move the water to the surface if a borehole is sank into the aquifer. When this occurs, the well is called an artesian (Todd, 2004).

The depth to the groundwater aquifer varies and sometimes could be as deep as 50m or greater. Therefore, exploring this resource requires proper planning and technique. Some of the techniques that have been used to source groundwater includes aerial, surface, subsurface and esoteric (Fetter, 2007). The most common procedures are the surface and subsurface methods (Anomohanran, 2014). The surface methods are made up of geophysical, geological, geomorphological, hydrogeological, geobotanical, and geochemical methods (Anomohanran, 2015).

The subsurface methods involved drilling and well logging. This stage is attained using available information from surface methods. This provides the most reliable information to properly classify aquifer systems.

In southern Nigeria, especially in areas like Delta State underlain by sedimentary Formations, groundwater is usually present in abundance. This is partly because of the prevalent equatorial climate that fosters abundant rainfall and hence

ensures adequate aquifer recharge, coupled with the availability of suitable aquifers and impervious sediments that favor the storage of the recharging water (Olabaniyi et al., 2007).

Groundwater resources are gaining increasing importance and they represent an increasing proportion of the water supplies used for different applications (Hernandez, 2003). Groundwater is an important water resource in both the urban and rural areas of Nigeria but in the cities, pipe-borne water is also available. Rural dwellers rely basically on hand-dug wells for potable water supply as the streams usually dry up in dry season. These resources are under threat from pollution either from human life style manifested by the low level of hygiene practiced in the developing nations (Punmia et al., 1998, Ikem et al., 2002; and Akujieze et al., 2003).

Since groundwater is held by geologic units (rocks, sediments, etc.) it could be found in usable form without immediate need for treatment. Surface waters, because of its exposure to point and non-point sources, is more likely to interact with contaminants/pollutants making it almost impossible to consume without proper treatment.

There is limited information on hydrogeology of the study area because of the fact that most boreholes are drilled by quakes and such information on well logs is scanty. Government agencies responsible for groundwater development hardly have up to date information on groundwater occurrences in Delta State. So this paper will try as much as possible to compile available information from different authors on hydrogeology and groundwater conditions of Delta State.

## LOCATION OF STUDY AREA (DELTA STATE).

Delta State, Figure 1, falls approximately between Latitude $6^{0}40^{I} - 6^{0}15^{I}$N and Longitude $6^{0}40^{I}$E – $6^{0}45^{I}$E, is bound on the east and north east by the River Niger and on the west by the rolling slopes of the Asaba plateau. The River Niger and the Asaba Plateau with its undulating slopes dominate the Asaba landscape. These slopes descend gently eastwards towards the River Niger such that Asaba City itself is located on the valley and west bank of the river.

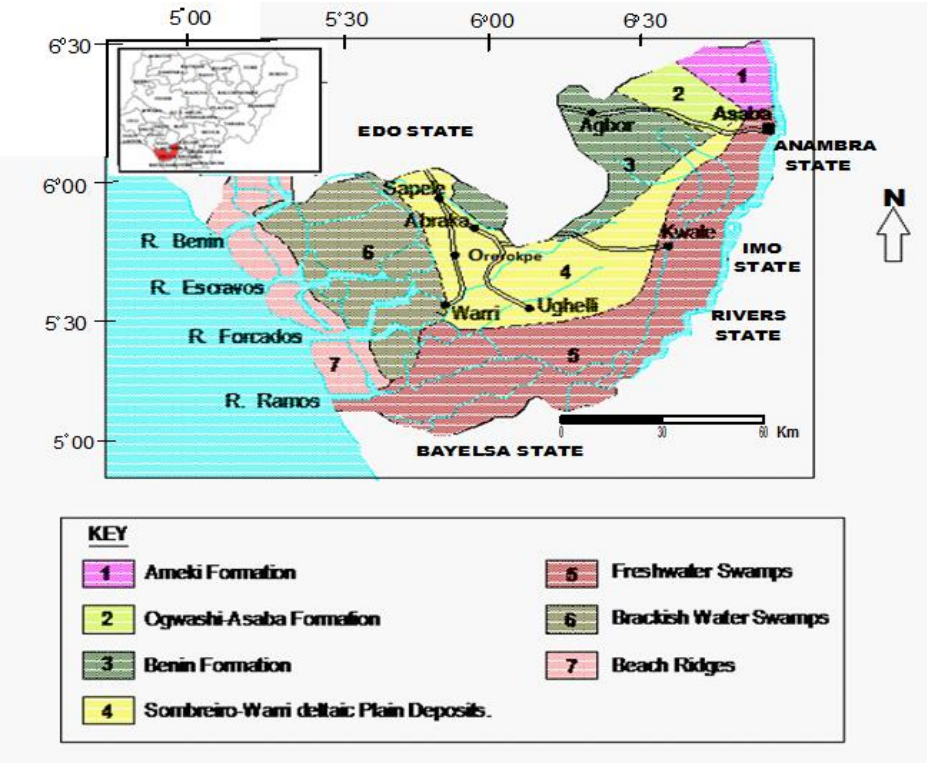


**Figure 1:** Geological Map of Delta State (modified from Akpoborie, 2011).

Okpanam and Ibusa are located on the scarp of the Asaba plateau. The plateau itself disappears completely just south of Asaba. Several streams that originate as springs at higher elevation dissect the plateau slopes but only one, the relatively broad Amilimocha River joins the River Niger at Asaba Town. Mean annual temperatures range from about $22^0$C to $34^0$C, while rainfall is between 1,501mm and 1850mm; mean evapotranspiration is 1117mm (Akpoborie et al., 2011; NIMET, 2003).

## GEOMORPHOLOGY OF STUDY AREA

The geomorphology of the Niger Delta may be divided into three main environments namely the continental, transitional and marine environments. Five major geomorphological units have been recognized in the Niger Delta (Allen, 1965; Short and Stauble, 1967; Ugbe 2011). These include:

- Active and abandoned coastal beaches
- Salt water mangrove swamps
- Freshwater swamps, back-swamps deltaic plan, alluvium and meander belt
- Dry deltaic plan with abundant swamp zones, Sombreiro Warri plain
- Dry flat land and plain

## GEOLOGICAL SETTING

The subsurface geology of Delta State which is part of the Niger Delta Basin is depicted in Figure 1. Information on the Geological setting of the Niger Delta has been well published (Nwajide, 2006; Short and Stauble, 1967; Frank, Cordry and Murat, 1970; Asseez, 1989). The basin fill is made up of three formations, namely from the oldest to the youngest, Akata, Agbada, and Benin Formations.

The Akata Formation is composed of continuous shale and about 10% sandstone. The shale is believed to be over pressured and under-compacted. It ranges from Eocene to Recent and was deposited under marine conditions.

The Agbada Formation conformably overlies the Akata Formation in the subsurface. It is a parallic sequence of alternating shale and sandstone with a variable age ranging from Eocene in the north to Pliocene/Pleistocene in the south, and Recent in the delta surface. Its lateral equivalents at the surface are the Ogwashi-Asaba Formation and Ameki Formation of Eocene- Oligocene age. The Ogwashi-Asaba Formation constitutes the main rock outcrops in the Asaba Capital Territory.

The continental Miocene-Recent Benin Formation conformably overlies the Agbada Formation. It is composed of more than 90% sands and about 10% shale/clays. The sands range in size from gravelly, coarse to fine grained. They are also poorly-sorted, sub-angular to well-rounded, and bear lignite streaks and wood fragments. The Benin Formation occurs just west and northwest of Asaba town (Akpoborie 2011) and this extends into Agbor town. However, west and just south of Abraka as well as Sapele, Warri and Ughelli the Benin Formation is masked by the younger Holocene deposits of the Sombreiro-Warri Deltaic Plain, the Mangrove Swamp and Freshwater Swamp wetlands. These deposits which have not been assigned formal geological names because they are universally considered to be recent expressions of and a continuation of the Benin Formation are only identified by the physiographic terrains in which they occur. The aerial distribution of these delta top deposits coincides somewhat with the associated physiographic subdivisions shown in Figure 1.

## METHODOLOGY

Borehole logs were used to determine lithology and aquifer thicknesses in different parts of study area. Published literature on resistivity surveys in study area was also valuable in determining varying aquifer thicknesses in Delta State. A Fence diagram revealing a 3-dimensional geometry of aquifer in Abraka and environs was drawn in order to project the changes in aquifer thicknesses in the area.

## RESULTS AND DISCUSSIONS

A review of the hydrogeology of Delta State shows that there is sufficient occurrences of both surface water and groundwater in most parts of the study area, the major concern would rather be aquifer vulnerability and quality of both water sources.

Rainfall as mentioned previously is high at 1900mm annual average. Much of the rain is lost as run off which drains by gravity to the River Niger. Some of it also gathers in pools and

puddles all over the state from where it is either evaporated or infiltrates into the ground as direct recharge.

Ground water occurs in all the geological formations described in the foregoing: the older terrace deposits, the Ogwashi-Asaba Formation and the deeper Ameki Formation. The Ameki Formation is relatively too deep in this area to be considered an economically viable aquifer, as a result of which no boreholes are drilled into it. Thus two important and economically viable aquifers exist in Asaba. The first aquifer consists of the terrace deposits and the underlying upper horizons of the Ogwashi-Asaba Formation. The second and deeper aquifer consists of the sand horizons of the Ogwashi Asaba Formation.

Available records indicate that a great majority of boreholes in Asaba obtain water from the shallower old terrace alluvium. The maximum thickness of this deposit may not be more than 50 meters around the city center. It decreases in thickness westwards on the slopes of the plateau towards Ibusa and northwards at Okpanam where it merges with the upper horizons of the Ogwashi-Asaba Formation (Akpoborie, 2011).

Lithologs of Water boreholes in Asaba (Figure 2) show an upper horizon of the Ogwashi-Asaba Formation which is made up of medium-coarse Sand layers occurring in most boreholes between 30-80m, distinct and separated from a deeper aquifer by a hard feruginized sandstone bands.

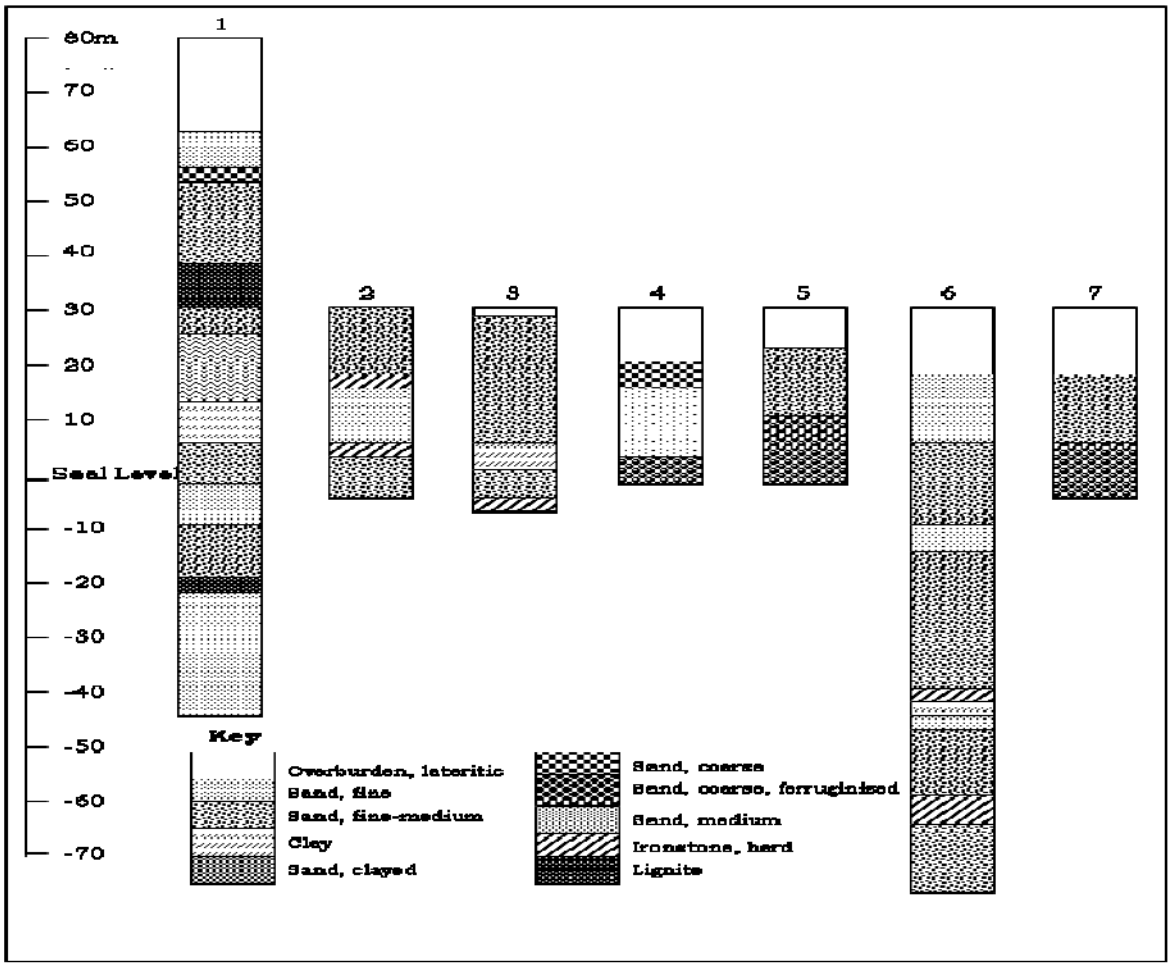


**Figure 2:** Lithologs of Shallow Boreholes from Asaba:1 Ibusa, 2. Jarret St. 3. Township. 4. opp. DDPA. 5. Old Secretariat. 6. St. Patrick's College. 7. Oko-Amakom (Log for borehole No.1 obtained from the archives of Delta State, State Ministry of Water Resources Development).

**Table 1:** Depth to Water Level Measurements in Abraka and Environs
(Adapted from Akpoborie et al., 2014)

| Eastings | Northings | Location | Well type | DWL | Head |
|---|---|---|---|---|---|
| 6.1369 | 5.731333 | Aragba | Dug well | 5.1 | 9.01 |
| 6.125633 | 5.746067 | Abraka Inl | Dug Well | 3.9 | 13.22 |
| 6.137133 | 5.782383 | Ugono | Dug Well | 4.5 | 5.7 |
| 6.097833 | 5.792 | Geology Lab. | Borehole | 3.69 | 16.3 |
| 6.103472 | 5.778833 | Winners Rd | Borehole | 14.63 | 4.27 |
| 6.117789 | 5.789828 | Delsu, Site 3 Pool | Borehole | 16.82 | 12.77 |
| 6.063889 | 5.75825 | Oria | Borehole | 15.03 | 3.87 |
| 6.148333 | 5.783875 | General Hospital | Borehole | 13.41 | 10.36 |
| 6.159883 | 5.752183 | Umuebu | Dug well | 4.2 | 11.42 |
| 6.148333 | 5.846183 | Morka Primary School, Obiaruku | Borehole | 31.2 | 3.10 |

An improbable layer of highly resistive "hard granite or rock" from the subsurface at Ibusa have been reported by Okoli (2010). The hard rock may well be the same hard, ferruginized sandstone layer that marks the uppermost limit of the Ogwashi-Asaba Formation in the valley at Asaba.

The terrace deposits and the upper horizon of the Ogwashi- Asaba Formation which are in hydraulic continuity may thus be classified as the first aquifer in the Asaba area. Ground water occurs in this first aquifer under unconfined and semi-confined. Depth to water (Table 1) ranges from about 3 meters at the Amilimocha flood plain just east of the Delta State University, Anwai Campus to about 25 meters at Cable Point in the old city center. In addition to about ten municipal boreholes, hundreds of privately owned boreholes tap this shallow aquifer. More are being constructed on a daily basis as the city expands (Akpoborie et al 2011).

The second Aquifer, of the Ogwashi-Asaba Formation has its saturated zone occurring at greater depth in Asaba. Outside of Asaba where the formation is exploited for water supply, it consists of coarse grained sands and sandstones which are sandwiched between the grey-dark clays, clay shale and lignite bands that characterize the formation (Akpoborie et al., 2011).

The regional ground water flow system in the Ogwashi-Asaba Formation is established and the static water level in this aquifer ranges between 110m and about 180m. Ground water flow direction is from north to south as opposed to the west to east flow direction for the first aquifer. Loss of circulation of drilling fluids into the formation also characterizes drilling operations in this horizon both east and west of the River Niger (Osiatuma, 2005; Nfor, 2006; Akpoborie et al., 2011; Tahal, 1965).

Elsewhere in Delta state (Abraka, Ughelli, Warri and Sapele), water table conditions prevail in the area. Depth to water varies from about 4 m at Abraka Inland to 26 m at Oria. Water table head above mean sea level determined at each location is shown in Table 1 (Akpoborie et al., 2014).

In Ndokwa land section of Delta State, groundwater clearly occurs at water table conditions and seasonal water level fluctuation in 2009 was an average of 0.83m with a range of 1.61m at Ogume to 0.11m at Okpai. The lithologic logs for boreholes located at Ndemili, Etua-Etiti, Ossisa, Kwale, Aboh, Abbi and Ellu are shown in Figure 3.

The sediments are predominantly fine –medium grained, medium to coarse grained and coarse grained sands deposited in a fining upwards cycle. A thin clay layer (<2m) appears to consistently occur in this succession at different depths in the depositional cycle. Boreholes are screened at the lowermost coarse grained layer.

At Aboh and Ossissa on the Freshwater Swamps, the topsoil contains dead vegetation while the grey gravelly sands contain fresh feldspars and angular quartz. The deposits at Abbi and Etua–Etiti exhibit a predominantly whitish coloration with depth.

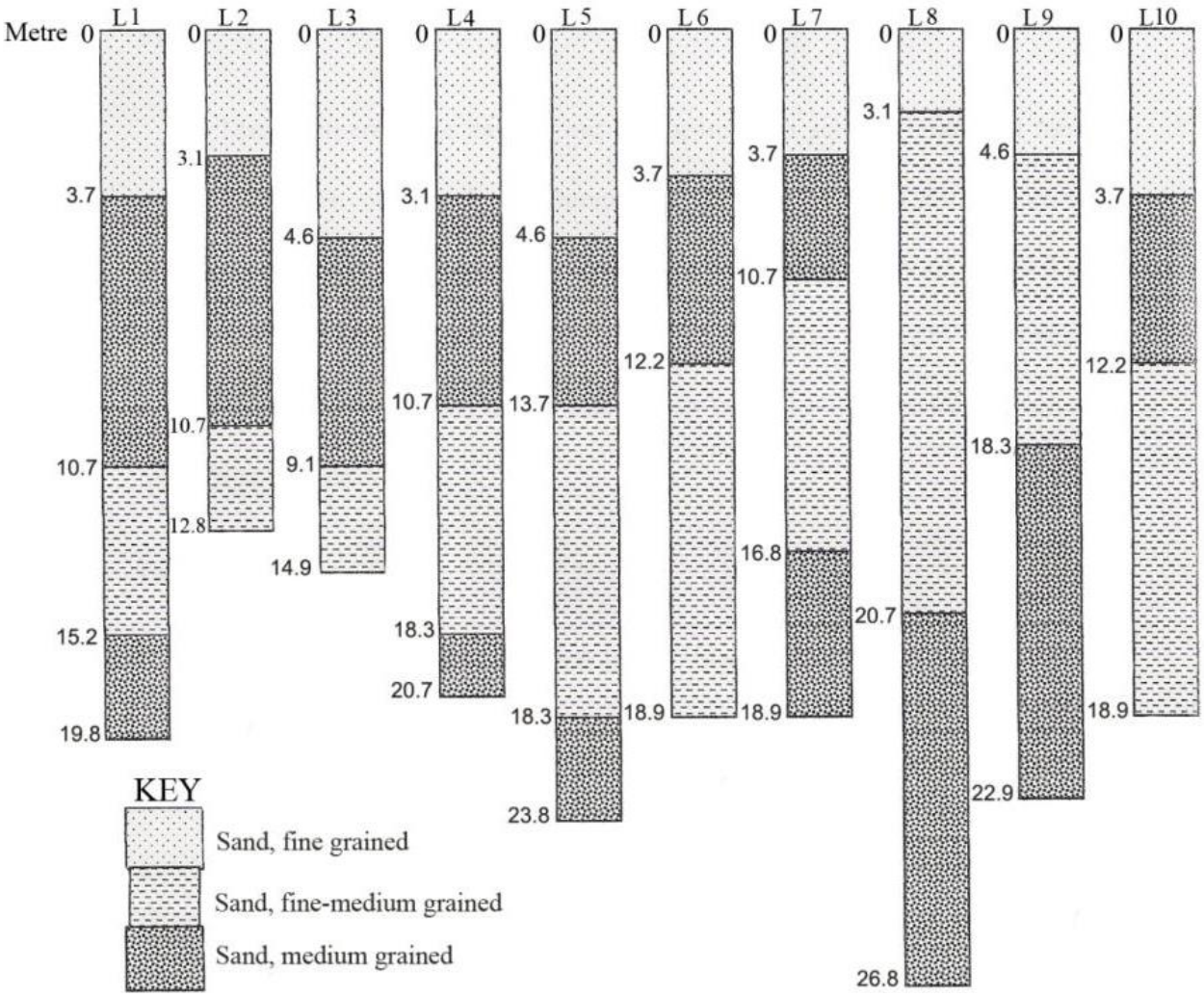


**Figure 3**: Lithologs from Water Supply Wells in Abraka. L1, Geology Lab; L2, Abraka Hall; L3, Omono Street; L4, Campus 3 New Administrative Block; L5, Oria; L6, Winner's Road; L7, Erho; L8, Urhuoka; L9, General Hospital; L10, Nasarrawa Road. (Adapted from Akpoborie et al., 2014).

The logs confirm the difficulty in distinguishing the Benin Formation proper from the overlying deposits in the subsurface. The clay bands encountered at Etua-Etiti, Ndemili, and Aboh apart from being too thin at less than a meter each, are characteristically discontinuous and as such do not constitute any form of confinement to the underlying sands. The deposits with the Benin Formation thus form one continuous but layered aquifer (Akpoborie, 2011).

## AQUIFERS SYSTEMS IN DELTA STATE

Two distinct aquifers of varying thicknesses occur in most parts of Delta State. Aquifers in study area are unconfined with few occurrences (areas like: Etua, Ndemili and Aboh) where clays of less than 1meter provides semi-confined conditions.
In Abraka and environs (Sombreiro-warri deltaic plain deposits), the first aquifer (fine-medium sand) can be penetrated at less than 4meters while the second occurs at less than 14 meters to the surface.

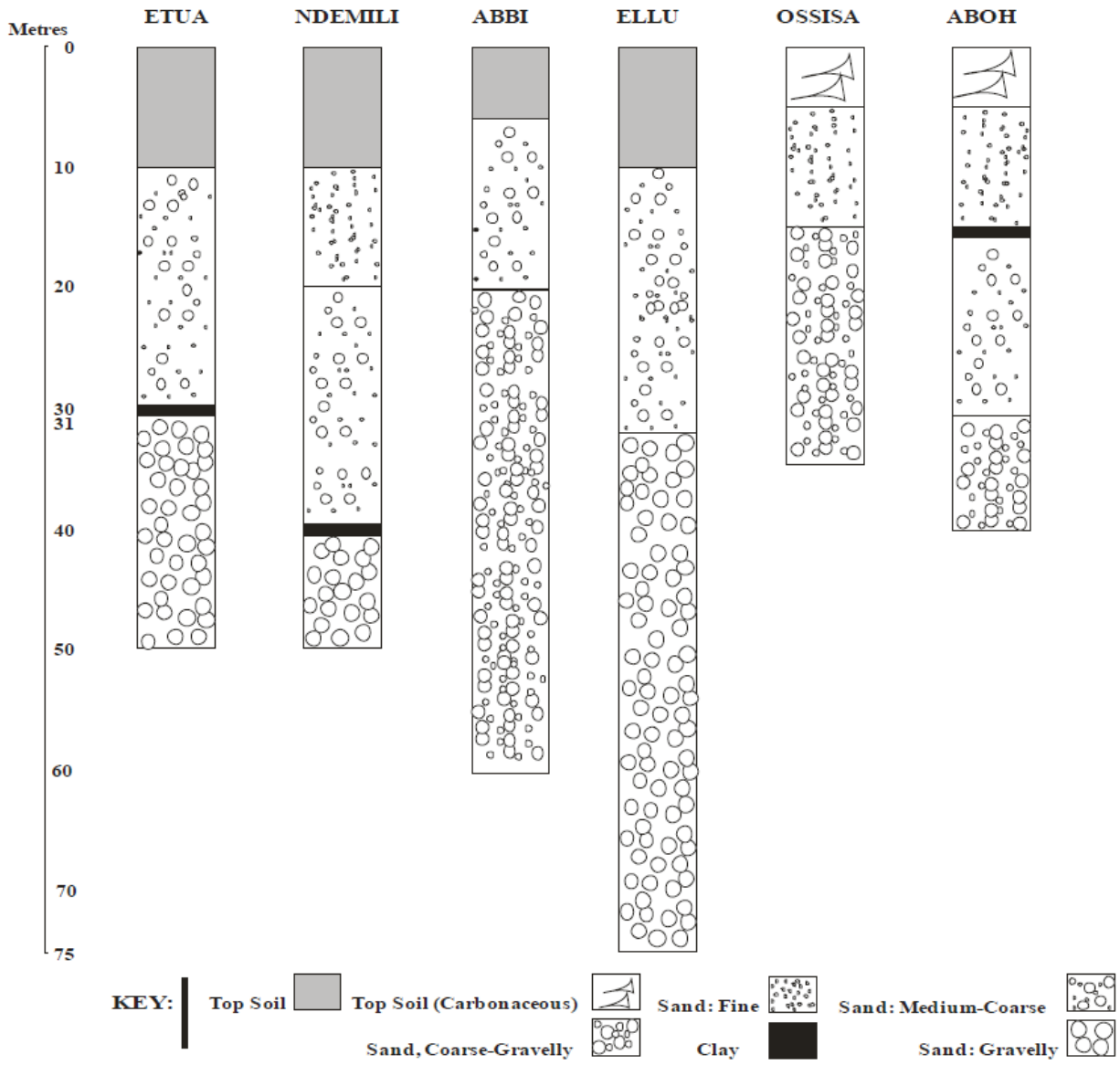


**Figure 4:** Lithologs from Ndokwa land, Delta State. (Akpoborie, 2011).

A fence diagram drawn with lithologs and borehole co-ordinates in Abraka and environs revealed that the second aquifer occurs at shallow depth in the northern part of the area (Oria and Abraka) and laterally thins out completely towards Obiaruku and in the Northesatern part. In the Southern portion of the area (Aragba and Umuebu), the second aquifer (medium sand) occurs deeper to the ground surface (greater than 20meters). Three cross-sections drawn with Borehole and Dug Well logs from Abraka and Environs further reveals lateral changes in thickness of aquifers in parts of Study Area.

**Table 2:** Water Table Data.

| Locations | Latitude/ longitude | Surface elevation | Actual depth to water table for dry season | Actual depth to water table for wet season | Rise in water level within the period | Hydraulic Head for Dry Season |
|---|---|---|---|---|---|---|
| Ogume (Hand dug well) | N 05° 45' 00.4" E 06° 19' 21.3" | 10 | 4.58 | 2.97 | 1.61 | 5.42 |
| | N 05° 45' 18.6" E 06° 19' 25.3" | 13 | 3.76 | 2.07 | 1.69 | *9.24 |
| Umukwata (Hand dug well) | N 05° 48' 17.9" E 06° 14' 58.5' | 22 | 2.94 | 2.20 | 0.74 | 19.06 |
| | N 05° 48' 17.4" E 06° 14' 39.1" | 11 | 3.42 | 3.06 | 0.36 | *7.58 |
| Ebedei (Hand dug well) | N 05° 49' 32.0" E 06° 14' 39.3" | 40 | 1.89 | 1.69 | 0.20 | 38.11 |
| | N 05° 49' 34.9" E 06° 14' 39.0" | 22 | 4.70 | 4.55 | 0.15 | *17.30 |
| Okpai (Borehole) | N05° 43' 33.0" E06° 36' 02.4" | 18 | 5.36 | 5.29 | 0.11 | *12.64 |
| Aboh (Hand dug well) | N05° 33' 14.7" E06° 31' 49.1" | 14 | 1.39 | 0.30 | 1.09 | *12.61 |
| Ashaka (Hand dug well) | N05° 39' 10.2" E06° 24' 25.7" | 16 | 5.39 | 4.76 | 0.63 | *10.61 |
| | N05° 38' 50.2" E06° 24' 14.7" | 23 | 8.35 | 7.74 | 0.61 | 14.65 |
| | N05° 38' 44.9" E06° 24' 07.0" | 12 | 7.33 | 7.00 | 0.33 | 4.67 |
| Utagbe-Ogbe (Hand dug well) | N05° 41' 21.3" E06° 25' 43.3" | 15 | 8.33 | 8.01 | 0.32 | *6.67 |
| | N05° 41' 25.6" E06° 25' 46.6" | 17 | 8.04 | 7.68 | 0.36 | 8.96 |
| | N05° 42' 07.3" E06° 25' 58.7" | 16 | 8.01 | 7.70 | 0.34 | 7.99 |
| Utagbe-Uno (Hand dug well) | N05° 52' 57.8" E06° 23' 12.2" | 32 | 3.66 | 2.63 | 1.03 | 28.34 |
| | N05° 52' 48.2" E06° 22' 44.6" | 26 | 3.04 | 1.94 | 1.10 | *22.96 |
| | N05° 53' 05.7" E06° 23' 21.4" | 23 | 2.95 | 2.12 | 0.83 | 20.05 |
| | N05° 53' 05.0" E06° 23' 24.3" | 20 | 2.88 | 2.05 | 0.80 | 17.12 |
| Ndemilli (Borehole) | N06° 01' 33.0" E06° 17' 05.3" | 79 | 23.01 | - | - | *55.99 |
| Umuaja (Borehole) | N05° 56' 07.6" E06° 14' 01.9" | 34 | 15.02 | 14.05 | 0.97 | *18.98 |
| Umutu Borehole | N05° 55' 01.1" E06° 13' 36.1" | 34 | 16.74 | 16.58 | 0.16 | 17.26 |
| Obiaruku (Borehole) | N05° 50' 58.4" E06° 09' 19.8" | 57 | 14.14 | - | - | *42.86 |

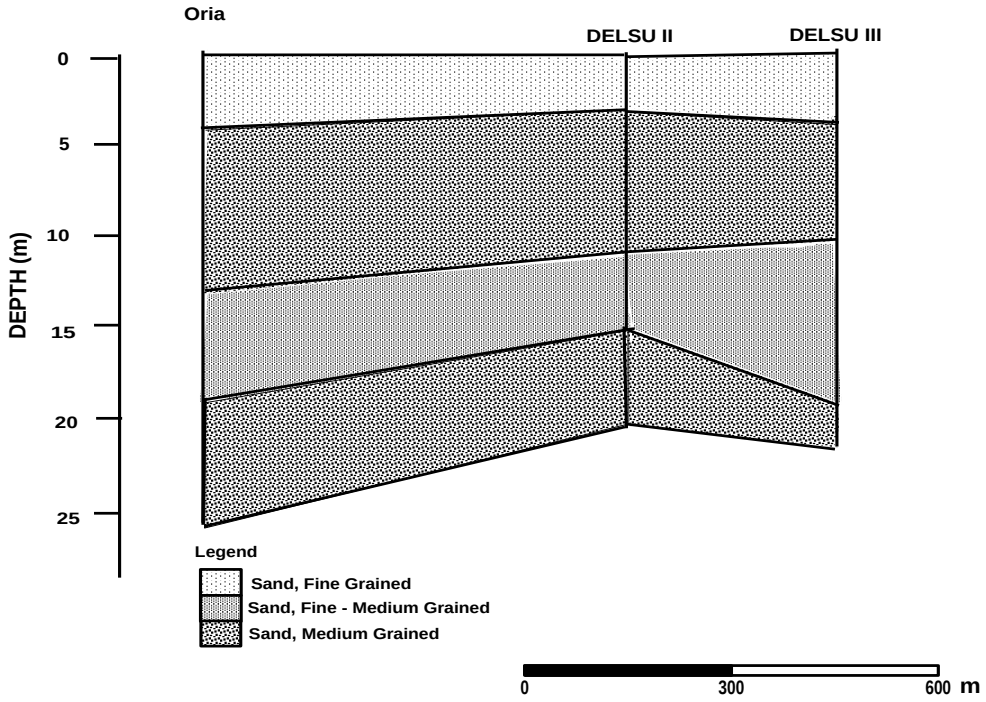


**Figure 5(a):** Aquifer Cross Section: Oria- DelsuII- Delsu III.

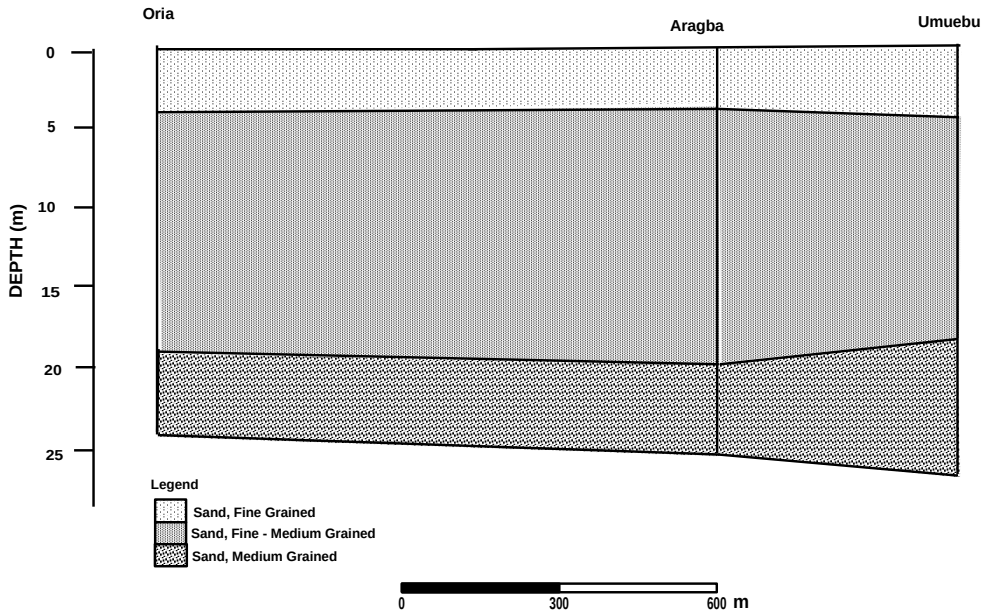


**Figure 5(b):** Aquifer Cross Section: Oria – Aragba – Umuebu.

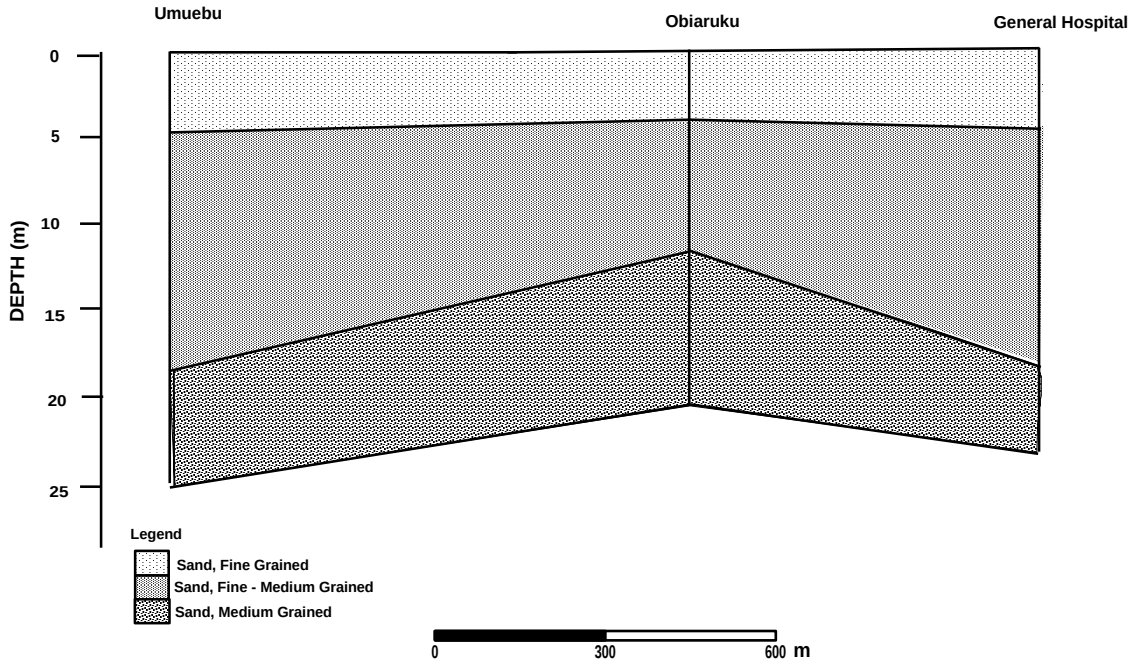


**Figure 5(c):** Aquifer Cross Section: Umuebu – Obiaruku - General Hospital.

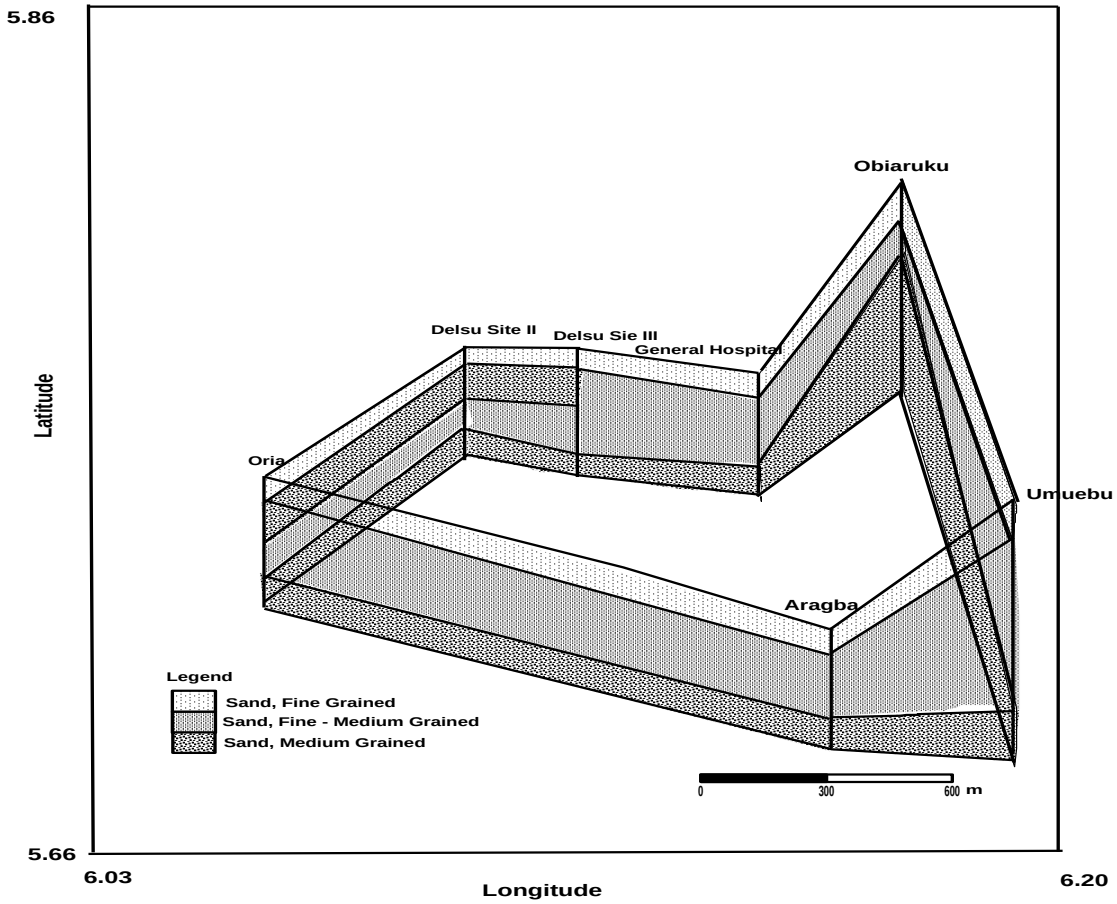


**Figure 6:** Fence Diagram Showing a 3-Dimensional Geometry of Lithology and Aquifers in Abraka and Environs.

Logs from Ndokwa land (Etua, Ndemili, Abbi, Ossisa, and Aboh) and parts of Isoko areas (Ellu), reveals two aquifers too. The first consists of medium-coarse sand while the second consists of coarse- gravelly sand. The first aquifer here can be penetrated at less than 10meters to the ground surface at Abbi and becomes more shallow at Aboh with both aquifers in this case having an overlying thin clay layer providing a semi-confined conditions.

Although two aquifers occur in most parts of Delta State, it is safer to harness water from the second Aquifer to avoid contamination/pollution of drinking water from surface infiltrations of pollutants and to ensure sustainable management of groundwater resources.

## Aquifer Parameters and Vulnerability in Delta State

The first aquifer (Benin formation which is less than 50m in thickness is overlain in the North and Northeastern part of Delta state by Ameki and Ogwashi-Asaba formation) is extremely vulnerable to pollution from surface sources especially due to the fact that water could be encountered in this formation even at depth of 4m or less. Consisting essentially of loose to poorly consolidated sandy materials, this aquifer is capped by lateritic soils. Results of aquifer parameters estimated in parts of Delta State revealed that the values of transmissivity and hydraulic conductivity are $418m^2$/day-$1637.3m^2$/day and 10.50m/day-45.71m/day, respectively. The results further show that aquifers in 75% of the study area displayed high aquifer potentials (Aweto et al., 2015).

Akudo et al., (2010) assessed groundwater quality in residential areas close to dumpsites in Warri and environs. The findings showed that the first aquifer in Warri from which most Wells and Boreholes are tapping water from, had high mean acidity (pH) values of 5.4 which renders water unfit for drinking in the area except if it is treated.
Pollution of second aquifer system by surface sources can only be possible through vertical leakages if the overlying is an aquitard. Poor completion of Boreholes may also lead to contamination of the second aquifer by the first if the well does not exclude the first aquifer from contributing to the yield of the second.

## SUMMARY OF DISCUSSIONS AND RECOMMENDATIONS

A review of hydrogeology of Delta State has revealed that two aquifer systems occurs in most parts of Delta State with majorly unconfined conditions.

The Ogwashi-Asaba Formation is generally masked by its weathered products as well as by older terrace alluvium in the valley occupied by the city of Asaba. The terrace alluvium is an elongate strip that borders the River Niger's west bank in this vicinity and is a continuation of the deposits of the Sombreiro-Warri Deltaic Plain that are more prominent in the south and central part of Delta State. It is in hydraulic continuity with the River Niger and its channel deposits, as well as with the upper horizon of the underlying Ogwashi-Asaba Formation. Combined with this upper horizon of the Ogwashi-Asaba Formation, it is classified as the first aquifer underlying Asaba that is exploited extensively for water supply purposes. Southwards, and because the Asaba Plateau has also disappeared, it merges with and is indistinguishable from the widened River Niger flood plain deposits (Akpoborie et al., 2011).

Average precipitation is high (1900mm) which makes groundwater to be abundant in Delta state as rain fall almost all round the year. Care must be taken in abstraction of groundwater from areas like Ughelli, Warri, Abraka, etc., because of salt water intrusion into the first shallow unconfined aquifer which most boreholes and wells abstract water from. Groundwater monitoring wells should be installed in major towns like Warri, Ughelli, Abraka, Kwale, and Asaba where population expansion is high in order to understand the regional groundwater model for proper management of groundwater resources in Delta State.

It is recommended that government agencies (Delta State urban water board, etc.) responsible for groundwater development provide and preserve up-to date information in the form of well logs from drilled wells and pumping test data and analysis to enhance easy study and definition of the hydrogeology of Delta State.

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