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AN APPRAISAL OF GROUNDWATER MAPPING AND ITS IMPLICATIONS FOR SUSTAINABLE RURAL WATER SUPPLY IN NIGERIA

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ABSTRACT

Groundwater plays a vital role in rural water supply, but its development has undermined fundamental information on the hydrogeological conditions and groundwater potentials of the various regions of the country. Thus, this state of affairs has not only resulted to unsuccessful water supply, but in the wastage of funds in expensive water supply technologies whereas cheaper and more sustainable ones exist. This in turn has grossly affected government's efforts to increase rural water supply coverage. It is therefore in line with the foregoing observation that Nigeria, through the Federal Ministry of Agriculture and Water Resources (FMA&WR) has initiated a hydrogeological mapping of groundwater resources in order to significantly improve water supply coverage in the country using low – cost, simple water supply technologies. This exercise, if completed, will in no small measure facilitate regional overview of the groundwater resources and improving water budgeting and planning. More importantly, it will help in guiding feasible water supply technology options to consider in various areas and also provide possible indications of areas with low water supply coverage, which require deserving attention. It is also expected that the availability of groundwater maps will help in the reduction of well failures and cost of water supply systems resulting in increase in water supply coverage to the rural population of Nigeria.

KEYWORDS: Groundwater mapping, groundwater potential, groundwater development, sustainable groundwater management, rural water supply.

INTRODUCTION

Nigeria is located on the West African region of Africa. It lies between latitudes $4^0$1' and 13^0 9'N and longitudes 2^0 2' and 14^0 30'E and shares border with four countries: the Republic of Niger to the North, Republic of Chad and Camerron to the East, and Republic of Benin to the West. It is bounded on the south by the Atlantic Ocean with a coastline, which measures about 800km. The country has a total area of 923, 770sqkm, with land area of 910, 770 km^2 and water area of 13,000km^2 (Schoeneich, 2003).

Groundwater plays a vital role in domestic water supply in Nigeria, and has come under increasing focus since independence, but particularly during the last 20 years when the country participated in the global efforts and initiatives aimed at addressing the problem of low access to safe water.

Groundwater development plans at both the federal, states and local Government levels have however been made with very little information on the hydrogeological conditions and groundwater potentials of various areas. This has not only resulted in unsuccessful water supply but also in funds being spent on very expensive technologies when cheaper and more sustainable options are possible. Similarly, water wells have sometimes been constructed in areas with poor water quality leading to abandonment while others have constructed too deep making them very expensive to construct.

The current national rural water supply coverage is estimated at 50% (MICS, 1999) and is to be significantly improved to be at least 95% by 2015. The focus is on groundwater development using low – cost, simple water supply technologies. There is thus a dire need to assess and map groundwater resources of the country so as to guide planning of groundwater development activities thereby targeting poorly served areas. This paper therefore emphasizes that sustainable groundwater resources development and management can only be possible if hydrogeological mapping which provides reliable sand dependable data on the distribution and overview of groundwater resources and water supply situation in the various parts of the country is carried out.

Geology and Water Resources of Nigeria

Nigeria is endowed with about 267 billion cubic meters of surface water and about 52 billion cubic metres of groundwater annually (RADWQ, 2005). About 50% of the Country is underlain by crystalline rocks, 50% by unconsolidated sedimentary materials. Fig. 1 shows the geological map of Nigeria, highlighting areas covered by both the sedimentary regions and basement complex.

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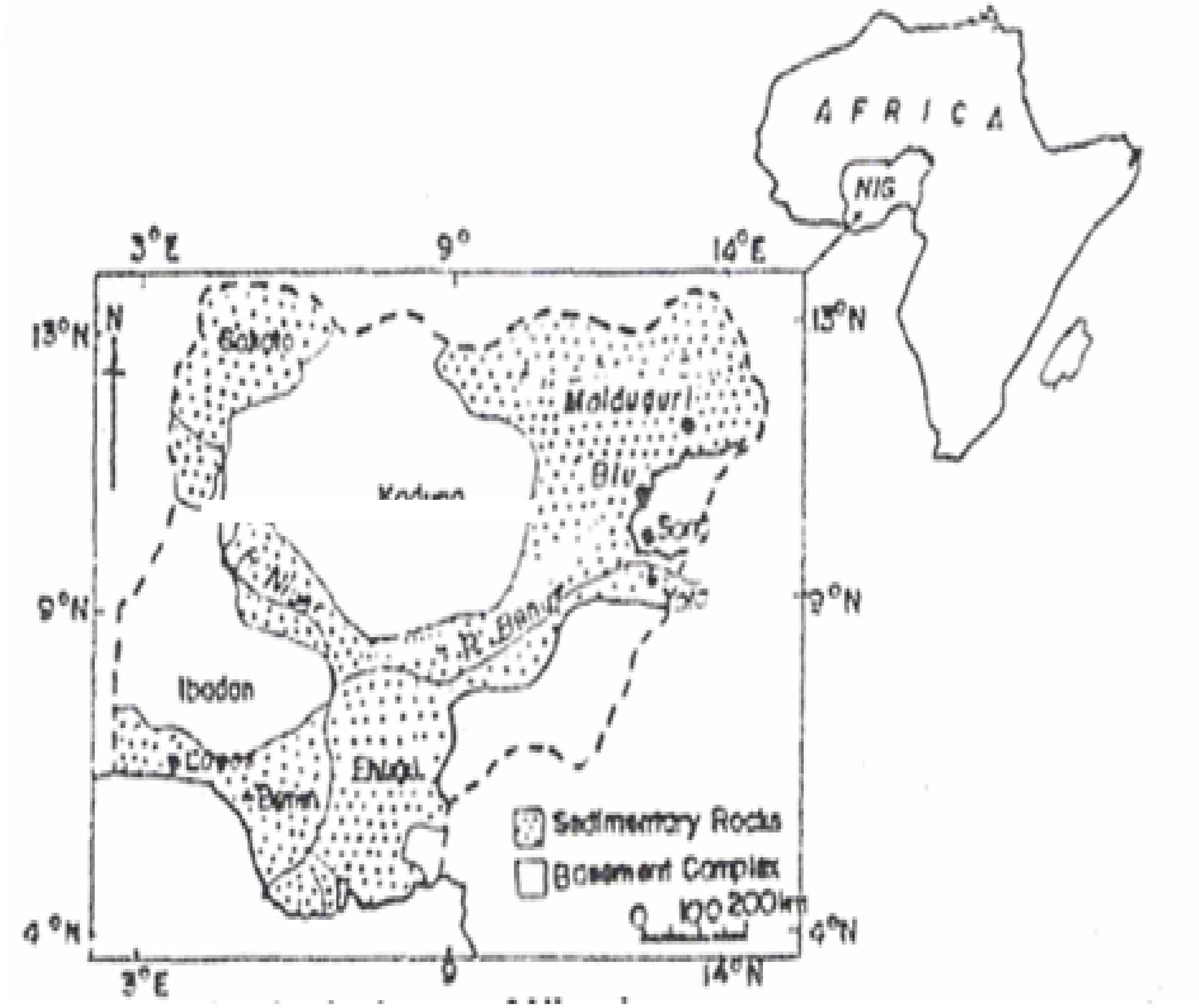

Fig.1: Geological Map of Nigeria (Source: Parker, *et al.,* 1964)

In the southern part of the country where rainfall is high, surface water and springs (groundwater brought to the surface) are often the most appropriate source of water, particularly where groundwater aquifers are deep. In the North where rainfall is scarce and aquifers are shallow, groundwater is usually the only practical source.

The occurrence of groundwater is greatly influenced by the local geological conditions which also control well yields. Recharge to aquifer influences the safe yields of wells i.e maintenance of a long-term balance between the amount of withdrawal and amount of recharge (Sophocleous, 2000). Thus, rainfall ultimately controls the amount of groundwater recovered from wells in any given locality (Offodile, 1979).

The exact amount of groundwater storage is not yet known, but available records indicate that major aquifers in Nigeria are located in the sedimentary deposit basins which cover about 50% of the nations land area. The remaining 50% is underlain by crystalline rocks of the basement complex. Table 1 shows the static water resources of Nigeria while Table 2 shows the summary of the total static water resources in Nigeria.

Table 1: Static Water Resources of Nigeria, Groundwater, fresh Meteoric water only

Province	Structural unit	Area SQKM	TWRS M1 Million (M^3)
CRYSTALLINE HYDROGEOLOGICAL PROVINCE	N. Nigeria Shield	234516	94979
	W. Nigeria Shield	115529	46789
	Mandara Hills	18460	2492
	Biu Plateau	4418	123.54
	Adamawa Mountains	60152	8121
	Oban Hills	4276	577
	Total Cryst.	**437351**	**166212**
	Sokoto Basin	66424	3188352
	Katsina Basin	3564	28512
SEDIMENTARY HYDROGEOLOGICAL PROVINCE	Nupe Basin	36704	1468160
	Coastal Monocl.	12365	296760
	Keri-Keri Basin	22593	101669
	Abakaliki + Mamfe	24945	374175
	Benue Synclinr	96216	1443225
	Niger Delta	104234	2084660
	Borno Basin	119377	2148786
	Total Sedim..W.	486422	11134299
	Total Fresh GWtr	923773	11134299
	Total Water Nig.	923773	36201836

N/B: TWRS = Total Static Water Resources (Source: Schoeneich, 2003).

Table 2: Summary of the Total Static Water Resources in Nigeria

TWRS			Percent	Cubic Metres
Rain	Fresh water	Atmospheric water	3.08	$1,117 \times 10^9$
Surface		Fresh Surface Water	0.03	12×10^9
Ground Water		Fresh Groundwater	31.23	$11,301 \times 10^9$
	Salty Groundwater		65.66	$23,772 \times 10^9$
Total Water Nigeria			100.00	36.202×10^9

(Source: Schoeneich, 2003)

Aquifers within the basement are limited, their thickness range from 16-180m, but depth of hand dug wells and boreholes are therefore seldom more than 60m with a variable average of static water level between 1-45m below the surface. This shallow depth coupled with the poor hydraulic conductivity no doubt account for the general low yield of $1.0m^3/hr$ (Nwaogozie, 1995).

Rural water supply in Nigeria: Efforts so far

About half of the population of Nigeria, that is 70 Million, live in rural communities, half live in small communities of less than 1, 500 persons where hand pumps are likely to be the most suitable technology, making it possible for women and children to trek not more than 500m walking distance, to get potable water, while the other half live in larger communities between 1, 500 and 5000 persons where small pipes systems are Likely to be appropriate (RADWQ, 2005).

About 71% of those living in the rural communities in Nigeria do not have access to safe water supply. However, the National Policy on water supply for rural areas guarantees minimum level of service of 30 litres per capita per day within 250 metres of the community of 150 to 5000 people, serving about 250 to 500 persons per water point (FMWR, 2000b).

Rural water supply is funded by the Federal, State and local Governments, international Agencies such as United Nations children's Fund (UNICEF), United Nations Development Programme (UNDP), and a number of other bilateral, and external support agencies and oil companies assistance to their host communities.

In spite of these efforts by the Government, one observes that many industrial establishments needing large volumes of water on a regular basis are forced to develop their private supplies to insulate themselves from the supply. Also observed are the countless number of private boreholes in both rural and urban areas. All of these are indication of imbalance in demand and supple of potable water in recent times. The national policy on water supply published in the year 2000 by the then Federal Ministry of Water Resources (FMWR, 2000b) guarantees 90 and 110 liters per capita per day for semi – urban and urban dwellers, respectively. According to this policy, it is expected that the national target of improving service coverage from 40% to 60% could be achieved by the year 2003. Also, the extension of service coverage to 80 and 100% of the population would be realized by the year 2007 and 2011, respectively (FMWR, 2000b).

Indeed these targets for 2003 were never actualized, given the state of water demand presently. What is obvious is the identification of the factors militating against the low water supply production. These according to Akujieze, *et al.,* (2003); Nwankwoala & Mmom (2006); Nwankwoala (2009) include:

(i) Lack of state wide groundwater maps and inventory
(ii) Poor planning and management
(iii) Inadequate funding
(iv) Insufficient relevant manpower
(v) Haphazard implementation and perhaps, the lack of national policy for water supply prior to the year 2000.

Therefore, the remedy to the above listed problems is through groundwater mapping programme, improved planning, monitoring efforts and the creation of enduring and accessible data bank for the entire country.

Hydrogeological Mapping of Nigeria Project

Mapping is a highly technical and complex exercise that involves the collection of numerous data and their transformation into maps (Adelemo, 1982; Adelemoa & Balogun, 1989; Adeniyi, 1989; Amori, 2000; Areola, 1986; Balogun, 1985; 1998 & 2003). Groundwater resources mapping therefore can be defined as the set of activities aimed at transforming an array of information on available groundwater resources into maps and other related products. It involves basically the publication, in map form, of all available groundwater resources data for adequate characterization of the various parts of the country according to hydrology in relation to their geology. Nigeria has initiated a hydrogeological Mapping Project. The project involves basically the publication, in map form, of all available water resources data viz: hydrogeological, meteorological, isotopic, and water quality, etc data to enable the characterization of the various parts of the country to hydrology in relation to their geology.

The aim of the project is to access and map groundwater resources at the district, regional and national level in order to guide efficient and cost effective water resources planning and development. The project is intended to achieve the above objective on varying scales most especially 1:250,000. This is aimed at facilitating regional overview of groundwater resources in terms of quantity and quality, and improved budgeting of the same with surface water to meet various needs thereby ensuring good health, food security and poverty alleviation and sustainable development of groundwater resources.

So far it is reported that, eleven (11) sheets covering part of the Chad Basin to the north east had been mapped, leaving a balance of eighty-nine (89) sheets unmapped out of the one hundred (100) of such sheets covering the entire country on scale 1:250,000. The mapping which could not continue due to insufficient budgetary provisions embraced publications of only existing data collected from repositories and those down loaded from satellite imageries with non from the exploratory drilling source which therefore is not good enough.

Usefulness of Groundwater Maps in the Improvement of Water supply Coverage

Though a lot of funds and efforts have been put so far in the hydrogeological mapping project, it is important to note that, when work resumes, efforts should be made to enlarge the exercise, to enable the production of specific groundwater maps as discussed below:

(i) **Hydrogeological Characteristic Map:**

The hydrogeological characteristics of an aquifer in an area are usually illustrated by means of parameters measured during the drilling process. These measured parameters are then presented as separate inset maps. The hydrogeoogical parameter maps are also used in preparation of the water supply technology map. Use of the above maps will result in groundwater development being carried out in a cost effective manner leading to construction of more water sources using the same resources thereby increasing access to safe drinking water to the population of Nigeria.

(ii) **Groundwater Potential Map**

Groundwater potential is a very broad term and may be influenced by many factors but the definition of groundwater potential implied in this context is the simplest possible and may be stated according to Tindimugaya (2004) as “the ability of a particular area to supply an adequate quantity of groundwater of potable quality to satisfy the demand of that area”

In order to categorize ‘groundwater potential’ it is necessary to categorize the principal factors that influence it i.e well yield and water quality.

Well yield is measured with the aim of assessing the ability of the source to sustain a handpump whose maximum capacity is $1m^3$/hr and satisfy the minimum yield is requirements of 0.5m3/hr for a rural water source. For map preparation purposes, Well yield is thus classified into four categories, mainly: >$1m^3$/hr, 0.7 1m3/hr, 0.5 – $0.7m^3$/hr and < 0.5m3/hr (Tindimugaya, 2004).

The groundwater potential map is used when planning future water supply activities in an area to indicate the zones of lower potential in which more investigation effort will be required in order to develop a successful water source of where groundwater development should be avoided altogether. Use of the map will not only reduce the number of unsuccessful boreholes, but will also ensure that areas with unacceptable water quality are not targeted for groundwater development.

(iii) **Water Supply Technology Option Map**

This map demonstrates the suitability of different areas for different possible technical options for groundwater development. This map is the most important map with respect to groundwater development planning as it servers to indicate the type of technology that may be appropriate in different areas. The map is prepared by considering the distribution of the first and the main water strikes, the estimate well yields during drilling and whether they occur in the overburden or in the bedrock. If water strikes occur shallower than 15m below ground level in the overburden and minimum yield of $0.5m^3$/hhr was estimated, such an area would be suitable occur between 15 and 30m in the overburden, then the area would be suitable for shallow drilled wells while if they occur deeper than 30m whether in the overburden or bedrock, then the area would be suitable for deep boreholes.

In financial planning terms, the choice of technological option will also clearly have a very significant influence on the overall cost of water source provision in an area and hence water supply coverage.

Governments' effort so far with respect to the Rapid Assessment of Drinking Water Quality is commendable. States were selected based on available technology options, location of the state in the hydrological area, activities, upstream, downstream oil sector, intensive/extensive agricultural activities, salt water intrusion, mining activities). The broad areas, the selected state and technology options are shown in Table 3. Table 4 shows the distribution of percentage access to water by states and technology types.

Table 3: Selected States and Technology Options

Broad area	**States**	**Technology options considered**
HA1	Kebbi	BT, PDW, UP
HA2	Kaduna	PDW, UP
HA3	Adamawa	PDW
HA4	Benue + Plateau	BT, PDW, UP
HA5	Rivers	BT, UP
HA6	Lagos + Oyo	BT, PDW, UP, VT
HA7	Enugu	UP
HA8	Kano (Borno and Yobe)	BT, PDW, UP

BT Borehole Technology; PDW – Protected Dug Well; UP – Utility Piped Water; VT – Vehicle Tanker
(Source: RADWQ, 2005)

Table 4: Distribution of % access to water by state and technology types

		Assumed safe technologies (A)					**Assumed unsafe technologies (B)**			
States of the Federation	Total No of House Holds	Piped Water	Bore Hole Tube Wells	Protected Dug wells	Vehicles/ Animals/ Tankers/ vendors	Sub Total A	Ponds/Streams /Rain water	Unprotected Dug wells	Sub Total of B	
Abia	625550	23	7.7	1.8	12.8	45.8	54.7	0	54.7	100
Adamawa	551, 850	9.9	11.2	18.7	3	42.8	43.6	13.6	57.2	100
Akwa Ibom	610, 200	8.9	16.2	0	0	25.1	75	0	75	100
Anambra	716, 250	6.8	4.4	3.3	19.7	34.2	64.2	1.6	65.8	100
Bauchi	595, 188	9.6	29.2	2.4	0	41.2	7.9	51	58.9	100
Bayelsa	339, 892	24.1	4.9	0	0	29	60	11	71	100
Benue	714, 560	6.9	6.1	29.7	2.6	54.3	47.6	7.2	54.8	100
Borno	670, 956	31.6	12.5	13.5	11.5	69.1	3	27.8	30.8	100
Cross River	644, 904	1.1	21.6	0.2	0	22.9	76.5	0.6	7.1	100
Delta	869, 400	1	31.3	24.7	0.8	57.8	38	4.2	42.2	100
Ebonyi	324, 058	0.9	22	0.9	0.3	24.1	73.4	2.6	76	100
Edo	716, 844	20	17	3.7	7.8	48.5	49.8	1.6	51.4	100
Ekiti	647, 820	5.4	3	26.1	0.2	34.7	63.1	2.2	65.3	100
Enugu	643, 542	27	1.5	1.9	9.9	40.3	55.1	4.6	59.7	100
Gombe	326, 700	17.6	8.7	7.3	0.2	33.8	22.2	44	59.7	100
Imo	805, 350	13	7.3	1.5	16.8	38.6	59.8	1.5	61.3	100
Jigawa	533, 400	13.2	25.6	4.3	0	43.1	3.5	1.5	61.3	100
Kaduna	856, 090	32.2	4.1	8.8	0	45.1	6.6	48.3	54.8	100
Kano	1, 293, 102	25.8	21.3	11.4	18.0	77.4	6.5	16.1	22.6	100
Kastina	850, 780	8	8.1	28.5	0	44.6	2.2	53.2	55.4	100
Kebbi	622, 340	14.8	31.5	41.2	0	87.5	1.7	10.7	12.4	100
Kogi	552, 240	12.9	10.2	7.3	19.3	49.7	41.7	8.6	50.3	100
Kwara	528, 064	59.5	11	7.8	0	78.3	21.1	0.7	21.8	100
Lagos	1, 906, 700	51.1	39.3	1.2	5.6	97.2	2.8	0	2.8	100
Nassarawa	269, 512	12.6	2	10.5	1.9	27	63.4	9.6	73	100
Niger	653, 268	22.4	7.8	11.7	0.2	42.1	50.7	7.1	57.8	100
Ogun	1, 094, 450	29	10.8	22.9	0	62.7	31.9	5.4	37.3	100
Ondo	933, 330	9.6	8	26.9	1.4	45.9	49.6	4.6	54.2	100
Osun	719, 453	22.4	12	28.2	0	62.6	37.4	0	37.2	100
Oyo	1, 186, 634	24.2	9	32.9	0	66.1	29.8	4.2	34	100

Plateau	427, 679	17.9	4.8	10.7	0.4	33.8	55.7	10.7	66.4	100
Rivers	819, 808	15.5	29.9	3.7	0	48.8	34	17.1	51.1	100
Sokoto	939, 600	11.7	6	18.3	0	36	17.7	46.3	64	100
Taraba	384, 000	0.8	3.7	4.1	4.1	12.7	79.9	7.4	87.3	100
Yobe	367, 517	27.4	15.8	5.8	0.2	49.2	5.6	45.2	50.8	100
Zamfara	535, 920	12.1	7.8	1.9	0	21.8	21.2	57.1	78.3	100
Fct	118, 030	19.6	0.3	3.8	9.7	33.4	42.8	23.8	66.6	100
Total	25404981	649.2	473.6	427.6	147.3	1697.7	1399.7	602.9	2002.6	
% of HH		19.58	14.7	12.86	4.36	51.5 No VT4			48.5	100
Modified after FOS (2003) Report on National Modular Child Labor Survey-Nigeria 2000/2001 p 168										

CONCLUSIONS

Groundwater mapping is very important in supporting water development programmes by providing information on the distribution of groundwater resources and the feasible water supply technology options. This not only results in sustainable groundwater plans but also leads to cost effectiveness and hence rapid increase in water supply coverage to rural population of Nigeria.

Groundwater maps will guide LGAs, states and federal governments as well as political and technical officials on the feasible water supply technology options to consider in various areas. It will also help with indications of areas with low water supply coverage which require more attention.

Although an evaluation of the usefulness of the groundwater maps has not yet been carried out, there is no doubt that the maps will provide an overview of the groundwater resources and water supply situation in the various parts of the country for use in planning of future water supply projects. It is expected that with the availability of groundwater maps, there will be reduction in failure of wells and cost of water supply systems. It worth emphasizing that the availability of good quality groundwater data which is currently not readily available, will require a big effort to collect.

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