NIGERIAN TRANSBOUNDARY AQUIFERS: PHYSICAL AND MANAGEMENT ISSUES.

ADENLE Depo

Box 20077, UIPO, Ibadan, Nigeria

Abstract

The surface water resources of Nigeria is dominated by two main transboundary drainage basins – the Niger, with its main tributary the Benue that drains about 60% of the country, and the Lake Chad drainage basin which drains about 20% and into which a significant part of the rivers of the northeastern part of Nigeria drains.

Current water challenges in this part of West Africa are due to the rapidly increasing demand as a result of high population growth rate (>2.8%), increased urbanization, increase in irrigation farming and industrialization. These challenges have been exacerbated by persistent drought and have resulted in greater dependence on groundwater resources with its attendant adverse impacts. It has also awakened the riparians to manage the resource cooperatively on an integrated basis by entering into multilateral and bilateral agreements – the Niger Basin Authority, the Lake Chad Basin Commission and the Nigeria–Niger Joint Commission.

The framework document on "International Shared (Transboundary) Aquifer Management" noted that in transboundary aquifer, recharge may be received on one side while natural discharges are across the border. The Chad Formation and the Iullemeden main aquifers are examples of such. The Iullemeden aquifers consist of Mesozoic continental deposits outcropping along northern and eastern periphery of the basin. Recharge almost entirely occurs in the southeastern outcrops in Nigeria where rainfall exceeds 500mm per year. A significant part of the discharge is in Niger and in the River Niger itself. The Chad Formation consists of three zones – the upper, middle and lower zone aquifers. It has been widely reported that the phreatic aquifer in the Chad Basin receives most of its recharge in Nigeria along the Komadugu-Yobe drainage system and from the bottom of Lake Chad.

In 1995, the Japanese International Cooperation Agency observed that water crisis in northeastern Nigeria resulted in increased groundwater abstraction to such a level that it caused land subsidence around Maiduguri, a town in northeastern Nigeria. The little attention paid to the hydrologic inter-relatedness of the Komadugu-Yobe, Hadejia-Nguru Wetlands, the Lake Chad and the shared aquifer in this area has been a source of international concern. The concern centers on the gradual loss of the wetlands, the virtual disappearance of Lake Chad and the reduction in recharge to the phreactic aquifer on which the Republic of Niger and other down gradient users depend. It has also resulted in a reduction in recharge via the bottom of Lake Chad.

The impact of poor land use on the Nigerian side of the Iullemeden Basin as well as overexploitation of groundwater in this area could have untold impacts across the Nigerian border.

The paper proposes how a framework can be developed to avoid conflict in the management of these two transboundary aquifers that Nigeria shares with her neighbours. Specifically the paper explores the feasibility of evolving the kind of management structure and instruments in existence between Israel and Palestine.

1 INTRODUCTION

The Iullemeden Basin is located in the northwestern part of Nigeria. It is a large, elongate sedimentary and structural basin that trends in a northwest direction from Nigeria into the Republic of Niger. Only about 10 percent of the Iullemeden Basin lies in the northwestern part of Nigeria where it is known as the Sokoto Basin (Figure 1). It lies between longitudes 3º 30' E and 6º 58' E and latitudes 10º 20'N and 14º N and it covers an area of about 59,570 km². The land surface is drained mainly by the Sokoto River System. Oteze (1989) noted that though a lot of work has been done on ground water in this part of the country, there is still not enough data to confidently determine the magnitude of recharge.

The Chad Basin covers an area of about 190,000 km² of the northeaster corner of Nigeria. It lies between longitudes 7º 45' E and 14º 50' E and latitudes 9º 50' N and 13º 30' N. It is bordered by the Benue Basin to the south, Sokoto Basin to the West, Cameroon Republic to the East and Niger Republic to the North. The Chad Basin in Nigeria constitutes about 8% of the total land area of the hydrographic Chad Basin in West and Central Africa.

The Chad Basin just like the Sokoto (Iullemeden) Basin is locate in the driest part of Nigeria (Sahelian climatic belt) with annual rainfall ranging from 1,400 mm in Jos Plateau area of Nigeria to less than 300mm in the northeastern end around Yau. A similar situation occurs in the Sokoto Basin. With very few perennial streams in the two basins reliance on groundwater for urban and rural supply and for small-scale irrigation is heavier here compared to other parts of Nigeria where rainfall is relatively more appreciable.

2 GEOLOGY

2.1 Sokoto/Illumeden Basin

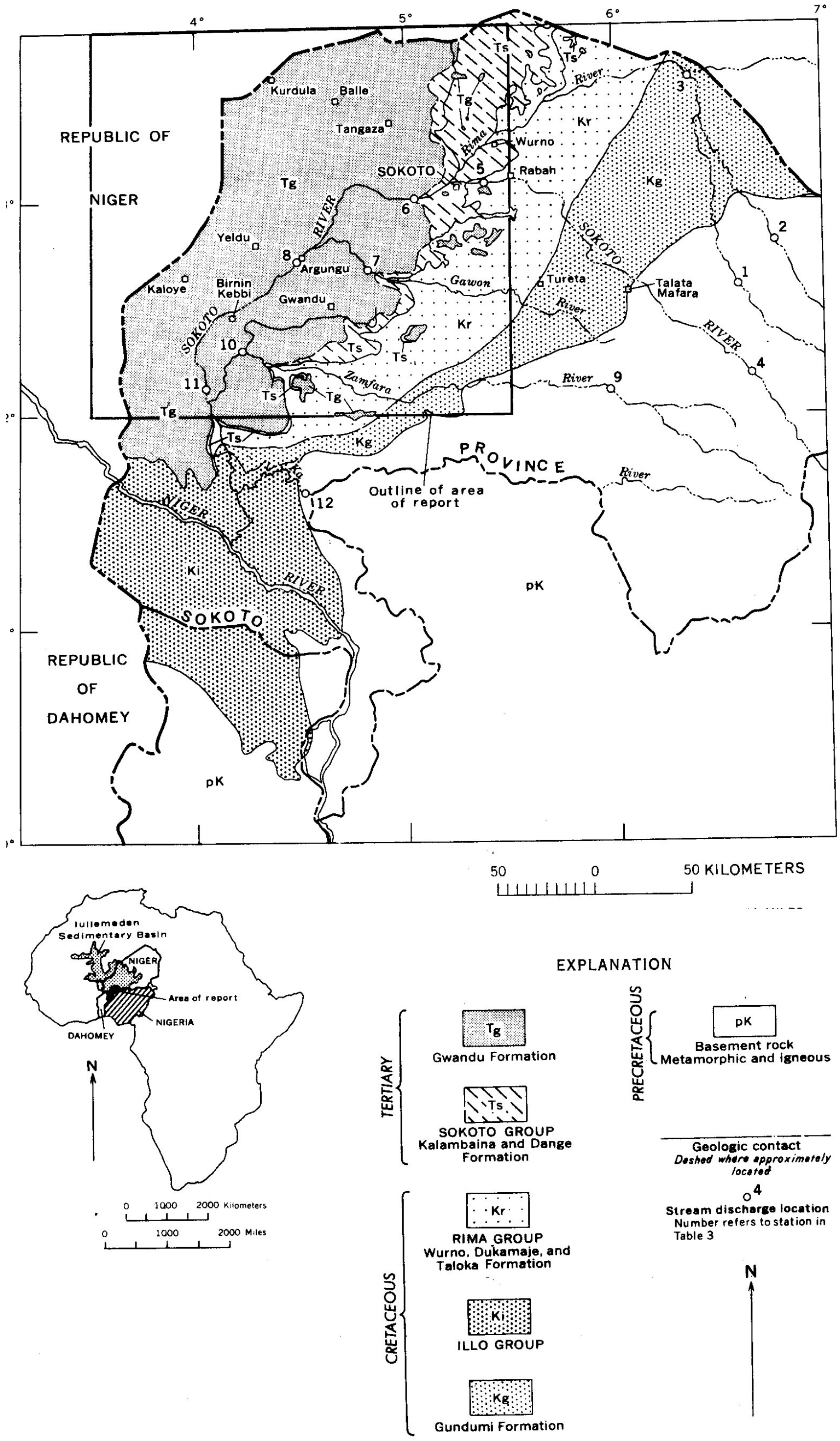
Griegert (1961) noted that the Sokoto Basin lies in the southeastern part of the Iullemeden Basin, a large synclinal structure whose long dimension trends northwest-southeast. In this basin, the sedimentary rocks of cretaceous to recent age rest on a pre-Crtaceous basement complex of crystalline rocks which form the borders of the basin to the east and south in Nigeria. Exploratory work in this basin has not penetrated formations older than the Eocene (lower Gwandu). The sedimentary formations of the Sokoto Basin, which dip gently and thicken gradually toward the northwest are largely unconsolidated sediments that attain maximum thickness of more than 1067m near the Niger frontier.

The Formations in the Sokoto Basin are Basement Rock, Gundumi, Taloka, Dukamaje, Wurno, Dange, Klambaina and Gwandu. The Gundumi Formation is the oldest sedimentary sequence in the Sokoto Basin and it rests on pre-Cretaceous crystalline rocks of the basement complex. It consists principally of lacustrine and fluvatile deposits of continental origin. The formation appears to thicken southwestwards and may attain a thickness of 305m or more at depth.

The Rima Group overlies the Gudunmi and it includes the Taloka, Dukamaje, and Wurno Formations. The Dukamaje Formation in the north, which is shally and which contains thin limestone bands, separates the two latter formations. To the south, the Dukamaje thins out until the Taloka and Wurno are undistinguishable because of their similarities.

The Sokoto Group, which overlies the Rima Group comformably, includes the Dange and the Kalambiana Formations. These formations form an outcrop of about 16 km wide near the Niger Republic border, but gradually narrow to little or nothing near Jega. The Dange Formation consists of indurated shale and it is interbedded with thin layers of limestone. The Kalambiana Formation consists of white marine clayey limestone and marl, calcareous mudstone and slightly indurated shale.

The Gwandu Formation outcrops most extensively in the Republic of Niger and in the northwestern Nigeria, it lies at or near the land surface over a continuous expanse of about 22, 000 km^2. It overlies the older marine Sokoto Group uncomformably. In the south, it has contacts with the Rima Group and the Continental Illo Formation. The outcrop areas of the Gwandu Formation consist of gently undulating plains with laterite-capped hills usually not more than 45m above surrounding lowlands.



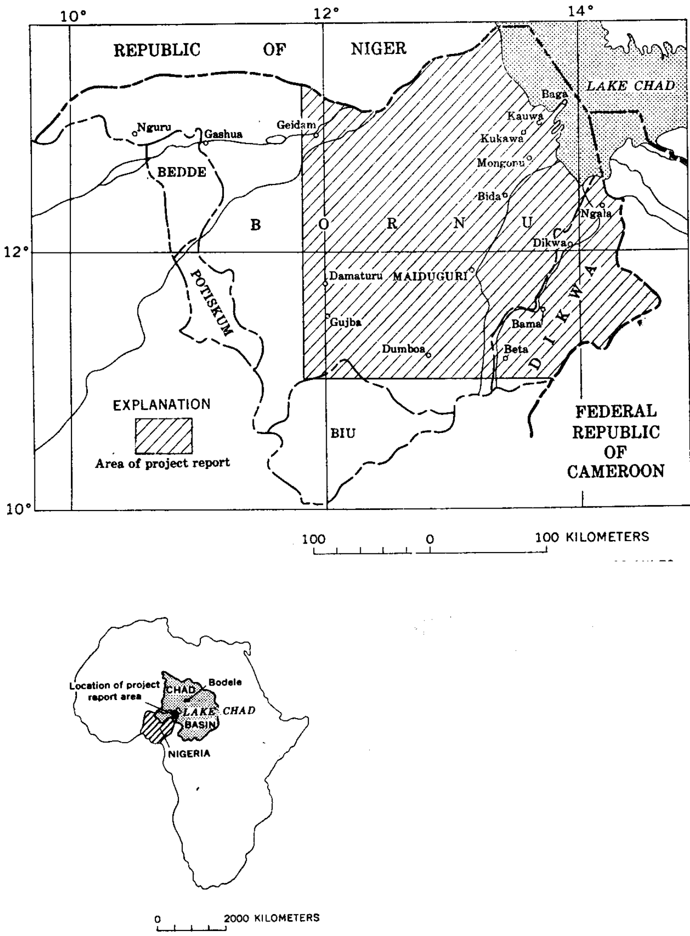


Fig. 1: Sokoto and Chad

On the basis of previous studies by several authors' generalized stratigraphic section, for example, Oglibee and Anderson (1965) and Oteze (1976), it can be concluded that the Gwandu Formation constitutes the youngest definite lithostrastrtigraphic unit in the Nigerian flank of the Iullemeden Basin. The formation consists of a series of continental clay/mudstone and sandy strata alternating with one another. Oteze 1971 and 1976) identified four sand zones separated by clay horizons in this formation. These he designated, from top to bottom, as Upper Zone I, Upper Zone II, Middle Zone and Lower Zone respectively.

2.2 Chad Basin

Miller, et al. (1968) noted that the Chad Basin has apparently been a structural depression since early Tertiary time and, therefore, has been a locus of subsidence and sedimentation rather than erosion. The youngest of the sediments known as the Chad Formation is a fresh-water, sedimentary sequence of Pleistocene (? Pliocene age). It consists of a succession of clays and silts in which beds and lenses of sand and gravel occur at various levels. It was deposited in or near an ancestral Lake Chad on an uneven surface, and it is underlain by the Tertiary Kerri-Kerri Formation, Cretaceous sedimentary rocks, and the basement crystalline complex. Based on data from boreholes that were drilled into the Chad Formation to depths of as much as 560m (Barber and Jones, 1960) divided the Chad Formation into three water-bearing zones – upper, middle and lower.

The Upper Zone consists of a widespread series of interbedded sand, clay, silt, and sandy clay which extend from the surface to an average depth of about 60m but locally to little over 180m. The Middle Zone consists of interbedded sand and clay, which underlie at least 52 km^2 of northeastern Nigeria. A clay layer of about 60m to 300m thick confines the water in this zone. The Lower Zone consists of about 76m of interbedded clay, sandy clay, and sand.

Hanidu, et al. (1989) contends that the Kerri-Kerri Formation has been correlated with the Continental Terminal in the Francophone area of West and Central Africa. They further contend that the Continental Terminal also refers to the "so called" Lower Zone of the Chad Formation and that this Lower Zone is a lateral equivalent of the Kerri-Kerri Formation. This controversy is not the focus of this paper and thus the acceptability of Hanidu, et al.'s (1989) claim will not be discussed.

3 CHALLENGES FACING GROUNDWATER RESOURCES MANAGEMENT IN SOKOTO AND CHAD BASINS

The following are the challenges of groundwater resources management in both the Sokoto/Illumeden and Chad Basins: rapid population growth rate, increased urbanization, increased industrialization, increased irrigation farming, competing water uses, poor land use practice, water scarcity as a result of climate change, paucity of data for planning and management, regulation (Decree 101 of 1993) that lacks clarity and that cannot be enforced because of the inadequacy of responsible institution. Some of these challenges are at the core of not just the physical issues of transboundary water management but also the management issues, and will thus be further elaborated in the discussion of these issues.

At the current rate of population growth rate of about 2.8 percent a year, the country's population will double within the next 25 years. The implication of such population growth rate on the growth of demand for water is mind-boggling. Increased urbanization is a consequence of rapid population growth as well as a host of other factors including increased industrialization. Most industries in developing countries are clustered around urban centers, and these lead to rise in rural-urban migration.

4 DUBLIN PRINCIPLES AND THEIR RELEVANCE TO THE MANAGEMENT OF NIGERIA TRANSBOUNDARY AQUIFERS

The management issues of the transboundary aquifers in both the Sokoto and Chad Basins are tied to some of the key elements of the four Dublin Principles that are at the core of sustainable management of water resources through an integrated approach. These are:

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. (This paper focuses on the groundwater component of fresh water resources. Groundwater protection is one of the key management activities that are necessary to ensure the sustainability of the resource. Allowing the artesian waters of the two basins to run to waste does not demonstrate that the water users in these two basins appreciate the vulnerability of the resource.)

- Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels. (The importance of participatory approach in managing Nigerian transboundary aquifers will be discussed in the later part of this paper.)

- Women play a central part in the provision, management and safeguarding of water.

- Water has an economic value in all its competing uses and should be recognized as an economic good.

Sustainable management of the groundwater resources in the two basins (Sokoto and Chad) will have to focus on both the physical and management issues discussed below.

5 MANAGEMENT ISSUES

The following can be considered as core management issues with respect to the sustainable management of Nigeria's transboundary waters: inadequate data for planning and management, inadequate and/or unreliable monitoring system, uncoordinated use of both groundwater and surface water resources especially where there is ample evidence of groundwater/surface water interactions and where there is little attention paid to such phenomenon, frequent changing institutions (especially with respect to how the creation of new political units affects the exploitation of interstate water resources), poor land use practices, the lack of awareness about conservation as regards allowing artesian to flow to waste in the two basins, and the implication of lack of full cooperation by coriaprians in these basins, especially when part of the recharge to these transboundary aquifers are externally derived. The implications of some of these to managing groundwater sustainably are obvious and will not be further discussed. For example, the issue of inadequacy of data or data collection system.

Goes and Offie (1999) identified six water management problems, some of which are related to the management issues of transboundary aquifers in the Chad Basin such as uncoordinated water management throughout the basin; uncoordinated operation of dams; absence of an overall water management strategy and absence of a well coordinated hydrological monitoring network.

The operational area of Hadejia-Jama'are River Basin Development Authority (HJRBDA), and the Chad Basin Development Authority (CBDA) are respectively the upper parts of the Yobe River Basin in Kano and Jigawa States, and the lower parts of the basin in Borno and Yobe States. The boundaries are political rather than hydrological. Thus the inward-looking nature of the two authorities their development-oriented mandates which have no accompanying responsibilities of environmental protection, and absence of coordination between them constitute a major obstacle for the sustainable utilization of the water resources of the basin.

The need for coordination and consultation was one of the recommendations of the 1993 Kuru Workshop for sustainable management of the water resources in the Komadugu-Yobe Basin (Thompson, 1995). The Workshop also recommended the establishment of a coordinating body for the management of this Nigerian part of the Chad Basin.

LCBC (1998) Strategic Action Plan document concluded that the integrated management of the Komadugu-Yobe basin raises a thorny issue of relations between water use upstream and its consequences downstream. There is need to reach an agreement not only between Nigeria and Niger but also between the various States within Nigeria itself, namely Kano, Jigawa, Bauchi, Yobe and Borno. The downstream States, in particular Borno and Bauchi, as well as the Republic of Niger, complain that construction of many dams upstream, with no regard to any integrated water management policy, has deprived the Komadugu-Yobe of regular water supplies and this in addition to the droughts, have led to the situation in which this river is dry for half of the year, whereas before it flowed for 9 months. Furthermore, the decrease in flow has resulted in the duration of flooding and the floodable area. Flooding could reach about 2,000 km^2 in the Hadejia-Nguru plain prior to the construction of the Tiga and Challawa dams. Now it covers no more than 1,000 km^2. As reported by Thompson (1995) there is significant amount of recharge in the floodplain wetlands of the Hadejia-Jama'are Basin. The recharge role of the annual floods, for shallow alluvial aquifers around the wetlands and the Chad Formation upstream of the wetlands is the wetland's most important function because the vast majority of the populace in this area is dependent on groundwater for both domestic use and agricultural activities. Furthermore, the value of the groundwater recharge, which is yet to be valued in monetary terms can be visualized in terms of the hardships that will be visited on the more than two million people of this area who depend on groundwater for their socio-economic activities.

Isiorho, et al.(1996) noted that the phreactic aquifer of the Chad Basin is recharged by waters of the Lake Chad. Similar observations have been made by Goes and Offie (1999) Concerning the Komadugu-Yobe River system. What happens in the Cameroon Republic affects the volume of discharge into Lake Chad vis-a-vis the volume of water available to recharge the phreactic aquifer from the Lake Chad bottom. It is believed that the Chari/Logone River system contributes about 90 percent (LCBC, 1998) of the annual discharge into the Lake Chad. In essence how much water is available for the recharge of the phreactic aquifer depends on the goodwill of the Chad and Cameroon Republics, the international agreement (the Lake Chad Basin Commission - LCBC) between Nigeria and these two other coriparians in the Lake Chad Basin notwithstanding.

In the case of the Sokoto Basin most of the recharge is from within Nigeria. Thus the recharge into the aquifers of this basin is mainly affected by human and natural causes that are from within the country. The magnitudes of recharge which have been calculated by Oteze (1989) will not be realizable if steps are not taken to minimize the poor land use such as deforestation as a result of slash and burn farming, cutting of fuel wood, lopping of tree branches for feeding livestock and uncontrolled grazing. Kebbi State Environmental Protection Agency (KESEPA)(2000) noted that the area occupied by Sudan and Guinea Savannah has decreased by about 50% between 1976/78 and 1993/95 in Kebbi State of northwestern Nigeria. Deforestation leads to increase in surface runoff vis-à-vis decrease in recharge and desert encroachment. Thus estimated recharge by Oteze (1989) in the recharge areas listed under the section on physical issues will be unrealizable.

Frequent changing institutions in the water sector contribute to uncoordinated management of water resources in Nigeria. Several states have been created in the past two decades and the galloping water demand created as a result of rapid urban growth at the newly created state capitals have resulted in developing new schemes without consultation with existing state water agencies. Furthermore, capacity to plan or manage the resource is limited in newly created states, and with the creation of new states, the existing monitoring systems break down.

Respect for the various clauses of the international agreements - Lake Chad Basin Commission (LCBC), Niger Basin Authority (NBA) and Nigeria-Niger Joint Commission (NNJC) - are important to the sustainable management of the groundwater resources of these two basins. A framework that enables the realization of the objectives of these international agreements needs to be established. It should be possible to adapt the framework employed by Israel and Palestine in the management of their transboundary aquifer.

6 PHYSICAL ISSUES

The discussion of the physical issues focuses on the natural factors that are important in the sustainable development and management of transboundary aquifers. These are – the spatial distribution of the aquifers; recharge areas of the aquifers and their extent as well as characteristics; the magnitude and relative significance of recharge from outside the country; groundwater–surface water interactions (magnitude of groundwater contributions to surface water resources and vice-versa. Human or water resources management activities affect these interactions. For example, groundwater–surface water interactions both in the Sokoto and Chad Basins are modified by coordinated or on uncoordinated use of water resources. In the case of the Komadugu-Yobe drainage Basin, which has been discussed under the management issues section, the challenge of groundwater resources management centres on lack of coordination and consultation among stakeholders.

The Chad Formation underlies approximately 155,000 km^2 of the northeastern corner of Nigeria, which is the Lake Chad Basin part of the country. The Chad Drainage Basin drains about 20 percent of the country. Miller, et al. (1968) claimed that the areal extent of both the upper zone and lower zone aquifers of the Chad Formation have not been reliably determined because of inadequacy of available data. The only known area of occurrence of Lower zone is near Maiduguri. Hanidu, et al. (1989), however, noted that the Continental Terminal aquifer's (Miller, et al's Lower Zone) occurrence is not limited to Maiduguri as originally suggested by Miller, et al.. They claim that there are evidences from boreholes drilled in the Seventies and Eighties have confirmed, that this zone is extensive and could be found in Cameroon and Chad Republics as well as in other parts of Borno State. However, the areal extent of the middle zone has been estimated to be at least 52,000 km^2 in the northeastern part of Nigeria by Miller, et al. (1968).

Recharge to the upper zone occurs in a significant but yet unmeasured quantity (Miller, et al. 1968) and it is believed that such recharge occurs chiefly in the vicinity of the major streams. Miller, et al. (968) were able to relate the use in the groundwater level at Dalori in June 1965 to infiltration from runoff due to local rains and to infiltration from surface flow of Ngada River. As earlier indicated above Thompson (1995) acknowledged the contribution of surface flow to upper zone aquifer recharge in the Komadugu-Yobe drainage system. Goes and Offie (1999) noted that groundwater recharge along the Yobe River between Geshua and Lake Chad in 1984 was 17 x $10^6 m^3$. Using data and maps of maximum flood extend contained for the area around Maikintari along the Marma channel they estimated that mean wet-season shallow groundwater recharge through the flood plains of between Hadejia and Nguru is 165 x $10^6 m^3$. Isiorho, et al. (1998) acknowledge that groundwater recharge (seepage) from Lake Chad was earlier suggested by earlier workers. Isiorho, et al. (1996) reckoned that the recharge from the Lake Chad (or $10^{10} m^3$ yr) represents an enormous amount of water available as groundwater resource in this part of the African Sahel.

It is important to note that the recharge from the lake bed is made possible through the annual discharge of the Komadugu-Yobe river system which is said to be responsible for only about 10 percent of total discharge into Lake Chad and from the Chari drainage system which contributes about 90 per cent of discharge into the lake. The Chari which flows through Chad Republic takes its source from the Central African Republic. The Logone originates from the Central African Republic and southern Cameroon. In essence the sustainability of the lake has a significant bearing on the magnitude of recharge to, and availability of the groundwater resources in the upper zone aquifer.

Recharge to the middle zone of the Chad Formation in Nigeria is probably small (Miller, et al., 1968). The only area of potential recharge to the middle zone lies between the rocky area fringe of the Chad Basin in Nigeria and trending roughly NW-SE Direction (the outer limit of recharge) and the line marking the intersection of the zones of the water table and piezometric surface (inner limit of recharge).

It is not known if there is recharge to the middle zone from the El Beid (Ebeji) River and the Chari River systems, because areas where recharge could occur are in the Cameroon and Chad Republics (Miller, et al.,1968). They concluded that if there is recharge to the middle zone from these river systems, movement of the water would be exceedingly slow, as the gradient of the piezometric surface is nearly flat. Furthermore, on the basis of hydrogeochemisty, du Preez, et al. (1965) felt that water enters the middle zone from three district areas of intake. The most well-defined area lies to the south of Maiduguri, the second intake is probably in the Niger Republic, and the third area of intake is in the Cameroon Republic. On the other hand Hanidu, et al. (1989) felt that recharge into the Lower Pliocene (middle one) aquifer is uncertain and that there is evidence that the Continental Terminal (the lower zone of Miller, et al.) is being recharged from southern Cameroon and Chad where it outcrops extensively, and that it is unlikely that it is being recharged anywhere in Nigeria. Furthermore, the Lower Pliocene (the middle one of Miller, et al.) does not outcrop anywhere in Nigeria or anywhere else. Recharge to this zone is thus doubtful.

The significance of these physical issues becomes more apparent when the impact of human activities on them is considered. For example, deforestation in Sokoto Basin increases surface runoff and reduces recharge, while construction of dams in the upper reaches of streams (Komadugu-Yobe) in the Chad Basin contribute to reduction in extent of flooding and groundwater recharge into the phreatic aquifer in their lower reaches.

Recharge into the aquifers of the Sokoto Basin are primarily from precipitation, and Adelana, et al (2002?) reported that high recharge coincides with periods of relatively higher rainfall while low recharge follows low rainfall. By extension, the persistent drought in the Sahelian parts of northern Nigeria signifies low recharge. The extent of the recharge areas and the estimates of recharge into the major aquifers of the Sokoto Basin as given by Oteze (1976) are summarized in the Table 1 below.

Table 1: Aspects of Recharge in the Sokoto Basin
(Compiled from Oteze, 1976 & 1989)

Aquifer	Outcrop Area (Km²)	Recharge Area (km²)	Area extent (Km²)	Direction of Flow	Recharge Estimate
Gundumi	10,890	Eastern part of the outcrop area. (642 km² of the outcrop area recharges Taloka)	} 59,600	Water flows from NE recharge area westwards. Some flow into Republics of Niger and Benin	Insufficient data
Illo	6,810	---- ditto---	}	---ditto--	---ditto--
Taloka	8,700	5,177 (includes the 642 recharge area of Gundumi)	41,500	Westerly and northwesterly.	--ditto--
Wurno	330	330	9,000	Generally northwesterly	-- ditto--
Kalambaina	3,200			East towards northwest	
Gwandu	No information	Recharge area on the eastern outcrop areas.	22,075	No Information	
Gwandu (Middle Zone)			20,900		
Lower Zone			14,100		

7 CONCLUSION

Groundwater is not intensively used in the Sokoto Basin at present but as population increases at greater than 2.8%, urbanization increases, industrialization increases and large-scale irrigation farming increases the groundwater of this basin will be more in demand. If its management is not coordinated in this Sahelian part of Nigeria, where rainfall is highly variable and where there is persistent drought, it will be difficult to guarantee future generations the kind of access that current inhabitants of this basin enjoys.

On the other hand there are already signs of intensive use of the groundwater in the Chad Basin especially around Maiduguri where water level decline of as much as 6m per year has been recorded and where fears of exhausting the Lower Pliocene and the Continental aquifers are already being entertained by major water users such as the Borno State Water Board (Hanidu, et al., 1989). An integrated approach that promotes the coordinated development and management of water, land and related resources, is the surest way to the sustainable management of the groundwater of these two basins. This integrated approach should benefit from the recommendations of the Kuru Workshop of 1993 and the experiences elsewhere, for example, the Israeli/Palestinian approach.

REFERENCES

Adelana, S.M.A., Olaseinde, P.I and Vrbka, P., 2002, A Quantitative Estimate of Groundwater Recharge in Parts of Sokoto Basin, Nigeria, International Groundwater Conference…Abstract.

Barber, W., and Jones, D. K., 1960, The Geology and Hydrology of Maiduguri, Bornu Province: Nigeria Geol. Survey Recs. 1958.

Du Preez, J. W. and Barber, W. 1965, The Distribution and Chemical Quality of Groundwater in Northern Nigeria, Geological Survey of Nigeria Bulletin No. 36.

Goes, B.J.M. and Offie, M.O., 1999, Surface Water Resources in the Hadejia-Jama'are-Yobe River Basin, *in* Water Management Options for the Hadejia - Jama'are – Yobe River Basin, Northern Nigeria. IUCN – The World Conservation Union, Hadejia –Nguru Wetlands Conservation Project.

Greigert, J., 1961, Carte Geolgique de Reconnaissance du Basin de Iullemeden, Echelle 1/1,000,000: Direction Federale de Mines, Republique du Niger.

Hanidu, J.A., Oteze, G.E. and Maduabuchi, C.M., 1989, Geohydrology of Drought-Prone Areas In Africa: The Chad Basin in Nigeria: Preliminary Report Submitted to the Commonwealth Science Council, London.

Kebbi State Environmental Protection Agency, 2000, Environmental Problems in Kebbi State.

Lake Chad Basin Commission, 1998, Integrated and Sustainable Management of the International Waters of the Lake Chad Basin: Strategic Action Plan.

Miller, R.E., Johnson, R.H., Olowu, J.A.I. and Uzoma, J.U., 1968, Groundwater Hydrogeology of the Chad Basin …U.S.G.S. Geological Survey Water-Supply Paper 1757-I.

Oteze, G.E., 1976, The Hydrogeology of the North-Western Nigeria Basin. Geology of Nigeria, ed. By C.Kogbe, pp. 373 – 390.

Oteze, G.E., 1989, Recharge Characteristics of the Rima Aquifers, Sokoto Basin, Water Resources, Vol. 1, No. 2.Oglibee, W and Anderson, H.R., 1965, Exploratory Drilling for Groundwater in Western Sokoto Province, Nigeria, with Special Reference to Artesian Aquifers in the Gwandu Formation. U.S.G.S Open File Report July 1965.

Thompson, J.R., 1995, Hydrology, Water Management and Wetlands of the Hadeji-Jama'are Basin, Nigeria, University of London Ph.D. thesis.