ZIBELINE INTERNATIONAL PUBLISHING

Water Conservation & Management (WCM)
DOI: *http://doi.org/10.26480/wcm.01.2019.20.26*

ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

REVIEW ARTICLE

DAM STRUCTURES AND TYPES IN NIGERIA: SUSTAINABILITY AND EFFECTIVENESS

Youdeowei, P.O[1]; Nwankwoala, H.O[2*], Desai, D.D[3]

[1]Institute of Geosciences and Space Technology, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria
[2]Department of Geology, University of Port Harcourt, Nigeria
[3]Department of Civil Engineering, Faculty of Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria
**Corresponding Author Email: nwankwoala_ho@yahoo.com*

ARTICLE DETAILS

Article History:

Received 04 January 2019
Accepted 21 February 2019
Available Online 27 February 2019

ABSTRACT

This paper focused on the various dams in Nigeria, their effectiveness with respect to configuration and purpose, sizes, lifespan and sustainability. The study observed the causes of dam failures and also compared their lifespans to their configuration, location and objectives. The results obtained from this study shows that Nigeria has large, medium and small dams which are also single and multipurpose. The dam structures will live out their lifespan as estimated from the designs, work effectively and sustainably except for action of some factors such as change in the hydrology of the dam location, changes in the design criteria and natural disasters. The need to know the degree to which dam structures achieve its expected result or purpose, the lifespan of each dam before rehabilitation and the sustainability of the dams in Nigeria, bringing the attention of the government and private owners to the need of dam construction and maintenance is the basis of this paper.

KEYWORDS

Dams, effectiveness, lifespan, sustainability

1. INTRODUCTION

A dam is a barrier of concrete, earth or steel that is built across a river or stream to obstruct or control the flow of water, especially in order to create a reservoir. A dam is a barrier that is built across a river in order to stop the water from flowing [1]. According to a study, dams are defined as structures that regulate, store and divert water from rivers [2]. Thus, dams from the above definition are man-made artificial blockades constructed across the water. The Wikipedia defined dams as a barrier constructed to hold water and raises its level forming a reservoir used to generate electricity or as a water supply [3]. They are reservoirs or lakes primarily for storing water or to produce electricity.

Dams, therefore, are structures made up of various forms built across streams, springs or rivers. Dams serve as a center of tourist attraction, creating jobs for the unemployed, a rich source of fish and a fallback in times of drought, a dam also creates electricity from nothing other than the falling of water through its turbines. In Nigeria, like in many other parts of the world, dam projects are often seen as key to economic solution through hydroelectric power supply. The hydraulic structures that are normally constructed across rivers, streams, or springs are weirs, rockfill or concrete gravity structures in nature.

Almost each dam that has been constructed all over the world is unique. This is so because a particular type is chosen because of the considerations of many factors. In fact, dam engineering brings together a range of disciplines, like geo-technical engineering, environmental engineering, structural engineering, geology, hydraulics and hydrology etc. Nevertheless, the primary purpose of a dam is to provide for the retention and storage of water. Structurally, a dam must be stable against overturning and sliding, either or within the foundations. The rock or soil on which it stands must be competent to withstand the superimposed loads without crushing or undue yielding. The reservoir basin it created must be watertight and seepage through the foundation of the dam should be minimal.

Though each situation demands a unique proposal for the type of dam, a broad classification based on the construction material can be made in dividing the types of dams that have been commonly constructed in Nigeria as:

(a) Embarkment dams, which are constructed of earth fill and/or rock fill, and
(b) Concrete dams, which are constructed of mass concrete

Of course, there are some dams that were constructed using rubble masonry but mostly embarkment dams are more common for technical and economic reasons all over the world, and they account for nearly 80% of all the large dams that have been built in modern times.

Many dams have been built round the world, playing an important role in helping communities and economies harness water resources for numerous uses. Yet these services do not come without a potential cost to communities. The impact of dams on people's livelihood, health, social systems and culture are not easily quantified and hence often ignored when analyzing the costs and benefits of dams. According to the World Commission on Dams report published in 2000, 60% of the world's rivers have been affected by dams and diversions, with their construction leading to the displacements of some 40 – 80 million people worldwide [4]. In Nigeria, many communities lose their homes and farmlands annually to the flooding of hydroelectric dams. Many people were displaced by flood resulting from the failure of the Tiga and Challawa dams in Niger and Jigawa states in August, 2001 [5]. The need to know the degree to which dam structures achieve its expected result or purpose, the lifespan of each dam before rehabilitation and the sustainability of the dams in Nigeria, bringing the attention of the government and private owners to the need of dam construction and maintenance is the basis of

this paper.

2. CLASSIFICATION OF DAMS IN NIGERIA

They are generally classified as small or large dams depending on whether or not the height (H) of the crest level above the waterbed level is lower or greater than fifteen metres, that is for small dams, H≤15 m while for large dams H>15 m [6]. Benefits provided by dams include water supplies for drinking, irrigation and industrial uses, flood control, hydroelectric power, recreation and navigation.

Dams are built for single purpose or for multipurpose. The dams constructed for single purpose include hydroelectric power generation at the Shiroro Dam in Niger State as well as Tura Dam in Kankara Local Government Area of Katsina State built along River Tura in 1983 to supply domestic water to Malumfashi and Kankara Towns and their neighbouring villages [7,8]. Multipurpose dams are put to diverse uses such as water supply for municipal and industrial use, livestock and fish production, flood control, electricity generation, irrigation and tourism among others. There are about 300 dams in Nigeria [9]. In 1973, Nigeria was divided into 11 River Basin (RB) areas each under the Federal Ministry of Water Resources. The functions of these RBs include among others, the provision of potable water to many communities. Bakolori dam for example falls under the Sokoto-Rima Basin Development Authority in Northern Nigeria. The Tiga Dam, Challawa Gorge Dam and the Kafin Zaki Dam are located in the Hadejia – Jama' are River Basin in Northern Nigeria while the Kainji, Jebba and Shiroro are found in the Niger Basin [5,6,10,12]. Others that fall under Ogun-Osun River Basin in the South west include Asejire, Eleyele, Erinle, Oyan, Ikere-Gorge, Egbe, Ero, Erelu and Ejigbo [13]. Success stories of dams in Nigeria include the generation of electricity mainly Kainji, Jebba and Shiroro. Kainji was designed to have a power generating capacity of 960 Megawatts. The dam generates electricity for all the large cities in Nigeria. It is 135 km long and about 30 km at its widest point and support a local fish industry [6].

Another success story of dams in Nigeria is the increase in food production and hence poverty alleviation through irrigated agriculture and fisheries. The Bakolori dam has a design capacity to irrigate 35,000 ha of farmland, Kafin-zaki dam 125,000 challawa 40,000 and Tiga 20,000 ha. Dams have equally done so much ecological and human damages in Nigeria in the last decade. Several lives have been lost, thousands of people displaced, and several villages destroyed due to dam failures.

3. TOPOLOGY OF DAMS

Dams can be grouped according to the type of material which they are constructed [14]:

Concrete gravity dams rely on weight of the concrete of which they are built to resist the forces (gravity etc to which they are subjected.

Concrete arch dams and buttress dams can be built using a smaller amount of concrete that is required for a gravity dam and as a result it cheaper to build.

Fill or embanement dams: Earth dams are built of homogenous impermeable earth materials so that the impermeable membrane is the whole dam wall.

Earth or rock fill dams have a relatively narrow, impermeable earth or clay core inside the dam, but most of the dams are constructed of permeable rock which by, itself would be capable of retaining water.

Concrete faced rock fill dams are constructed of permeable rock fill, the impermeable membrane being a concrete slab on the upstream face of the dam wall.

In the literature on dams in Nigeria, the concrete arch dams buttress dams, earth or rock fill dams and concrete faced rock fill dams are the types that have been constructed by the federal government of Nigeria. They are in different states of the federation.

4. THE NIGERIAN DAM TYPES

The dams in Nigeria are classified into their various categories and types according to construction material, sizes and purpose for which they were constructed. Classification based on construction material brings the Nigerian dam types into earthfill, rockfill, earth + rockfill and concrete dams. This classification still comes under the conventional classification which are embarkment dams (rockfill and earthfill), and concrete dams. Further classification is based on height (large, medium and small dams), and the purpose of construction, ranging from single purpose to multipurpose. Dams in Nigeria are built for the supply of potable water to communities (e.g. Eleyele or Asejire dams in southwest Nigeria) or for the generation of hydroelectric power (e.g. Kainji, Jebba and Shiroro dams in Niger State) or for irrigated agriculture (e.g. Bakolori dam in Sokoto State and Oyam dam in Ogun State). Other uses of dams include silt retention, fisheries, transportation, and tourism and flood control. Examples of multipurpose dams in Nigeria are Kainji, Shiroro, Kafin-Zaki, Dadinkowa, Kiri, Tiga, Zobe and Oyan.

The technology of dam construction in Nigeria is still experimental. There are so many unknown factors in dam design, construction and operation which affect dam safety, performance and lifespan. For concrete gravity dams built since the 20th century, there are no standards for the normal working period (lifespan) in Nigeria or other countries. According to literatures, the earliest dams in Nigeria were built in the year 1942/1946 and most of these dams have failed and their lifespan was short. The main reason is that the level of design, construction and reinforcement was very low, for example, flood control standard was low, or there were obvious shortcomings in dam structures and construction quality, or the technology of operation and maintenance were limited. Since the 20th century, the design and construction of concrete gravity dams have been standardized and technologies in reinforcement are getting more and more advanced, which have led to longer lifespan of concrete dams and embarkment dams.

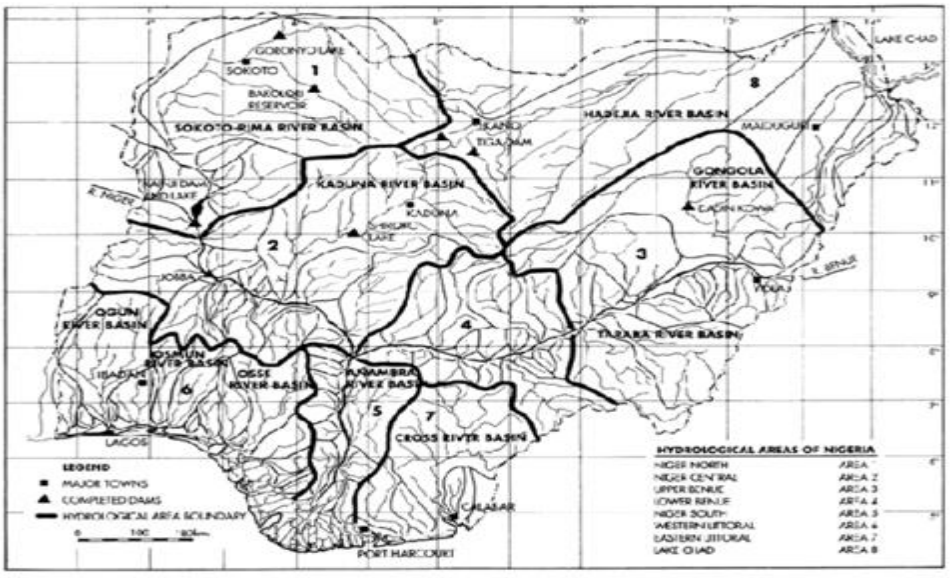

Figure 1: Hydrological map of Nigeria showing the large dams and their locations in their respective river basins [15,16].

Lifespan of a dam not only depends on the quality of dam but on the environment and the needs of the society. At the same time, it also has close relationship with the reinforcement. It has been recognized that there is a direct relationship between dam safety and its lifespan, i.e if a dam is unsafe, its lifespan has expired. The lifespan of any dam is as long as it is technically safe and operable. Dams age at different rates and in a different way, depending on a variety of circumstances. Some dams may remain safe for a thousand years, others may start to crack and leak after less than a decade [17,18].

Various factors come into play in determining how long a dam will remain usable, including its design and construction materials, the composition of the foundation rock, how well the dam is maintained, local temperature and humidity levels, the risk of earthquakes and other natural hazards, and the sediment levels of feeder rivers. The main factors, which have an impact on the service life, and which may call for upgrading of a dam include changes in the design criteria based on new information obtained since the initial design of the dam, results of risk assessments, and ageing of construction and foundation materials and components. Dense frost-resistance concrete should have a very long service life. Concrete dams, which do not have any steel reinforcement, have a much longer life than reinforced concrete structures exposed to weather. The service life of a well-designed, well-constructed and well-maintained and monitored embarkment and concrete dams can easily reach 100 years. Neglecting civil maintenance will unequivocally lead to a shortened lifespan, which signifies an economic loss, and in a loss of confidence in the safety of dams by the affected people.

5. DAM SUSTAINABILITY

The positive and negative effects of the various dam types in Nigeria covering technical, financial, social, environmental and economic performance defines their degree of sustainability [19]. Kainji, Jebba and Shiroro dams (built in 1968, 1985 and 1990, respectively) are some of the Nigeria's major dam projects. The three largest dams in Nigeria (Jebba, Kainji on River Niger and Shiroro on River Kaduna) has prime purposes of hydropower generation and irrigation. Some other dams in Nigeria are the Ede-Erinle reservoir (Osun State), Bakolori and Goronyo dam in Sokoto, Tiga dam and Challawa Gorge in Kano state, Oyan river dam and Asejire dam in Oyo State. Katsina States Jibiya dam supplies 142 million m^3 of water for municipal use and irrigation. The water from the dams is essential to increase agricultural productivity and industrial food processing, its availability enhances better production practices. In addition, Dadin Kowa dam with 2,800 million m^3 capacity is located in Gombe State, while Kiri dam (Adamawa State) covered 11,500 hectares and has 615 million m^3 capacity. In addition to Jibiya dam, Katsina State has Zobe Dam (177 million m^3) for water supply, fishing and agricultural purpose [20].

These dams have contributed immensely to socio-economic growth and development of Nigeria. For instance, hydropower dams situated in Niger, Kebbi, Kwarra and Plateau States generate not less than 50% of electric power consumed in Nigeria. Beyond this, large dams are developmental spectacles – much like airports, soccer stadia, steel plants and skyscrapers. Beyond the developmental impacts of these dams, they also have negative consequences on the people and their environment, which are often skimped over at policy levels. Although not much different from the rest of dam communities in around the world, physical displacement, the disintegration of the social fabrics of the communities caused by such displacement, landlessness, impoverishment, denial of community right to natural resources and so on, are some of the negative consequences of large dams to host communities in Nigeria. For instance, the construction of Kainji Dam in the 1960s displaced more than 50, 000 people leading to massive relocation. Furthermore, studies have shown that dam communities of Nigeria have also suffered a great deal of ecological problems and socio-economic losses due to dams built in their areas. For instance, the Kainji, Tiga, Challawa and Shiroro Dams have consistently modified the terrestrial ecosystem and the natural flow of rivers with negative impacts on the quality of water [21]. Besides, the annual recorded breakdowns of these dams have also subjected local communities to miserable and pathetic conditions. Given the foregoing, it is believed that environmental challenges in dam communities are not only deplorable but are specific to people living around such projects.

Table 1: Large and notable dams in Nigeria [6,15,22-24].

S/N	H.A	Dam	Active Capacity (mem)	Height (m)	Objective	Completed Year
1	1	Zibiya	121	21.5	Irri/W.S	1990
2	1	Zobe	170	18.9	Irri/W.S	1983
3	1	Bakolori	403	48.0	Irri/H.P	1982
4	1	Goronyo	833	20.0	Irri/W.S	
5	1	Kainji	11,500	65.5	H.P	1968
6	1	Kubli	62	23.0	Irri	1992
7	2	Kontagora	200	32.0	Irri	?
8	2	Asa	344	27.0	W.S	?
9	2	Kagara	39	31.0	W.S	?
10	2	Jebba	1,000	40.0	H.P	1983
11	2	Omi	220	43.0	Irri	?
12	2	Zaria	29.8	15.0	W.S	1974
13	2	Kangimi	59.3	19.2	Irri/W.S	1975
14	2	Shiroro	6,050	105.0	H.P	1989
15	2	Suleja	48.5	27.8	W.S	?
16	2	Usuma	100	45.0	W.S	1984
17	3	Balanga	63	41.0	Irri	1987
18	3	Dandi	1,770	42.0	Irri/H.P	1988
19	3	Kiri	325	37.0	Irri	1982

20	**4**	**Doma**	**28.5**	**15.7**	**Irri**	**1982**
21	**6**	**Ikere**	**565**	**47.5**	**Irri/W.S/H.P**	**?**
22	**6**	**Oyan**	**254**	**30.4**	**Irri/W.S/H.P**	**1983**
23	**8**	**Erinle**	**92.5**	**27.0**	**W.S**	**1989**
24	**8**	**Gari**	**203**	**22.0**	**Irri**	**1980**
25	**8**	**Challawa**	**900**	**38.0**	**Irri/W.S**	**1992**
26	**8**	**Watari**	**92.7**	**19.8**	**Irri**	**1980**
27	**8**	**Tiga**	**1,845**	**47.2**	**Irri/W.S**	**1975**
28	**8**	**Kafin Zaki**	**2,500**	**40.0**	**Irri**	**?**
29	**8**	**Tomas**	**56.6**	**13.7**	**Irri**	**1976**
30	**8**	**Jakar**	**54.4**	**14.3**	**Irri.**	**1976**

Note: Irri = Irrigation; W.S = Water Supply; H.P = Hydroelectric Power; Mem = Capacity millions of m^3; H.A = Surface Area Hectares

6. SUSTAINABILITY OF DEVELOPMENT DUE TO DAMS

The subject of sustainability of development has been extensively debated over the last two decades. In Nigeria, the creation of dams and establishment of River Basin Development Authorities to manage the nation's large reservoirs has proved to be effective in the conservation of freshwater environments [16]. Dams have solved many problems of communities served and have provided basis for economic development that has sustained itself. Employment opportunities have been generated, incidence of poverty has been reduced, rural population including nomads has been stabilized locally and migration of rural unemployed population to urban centres has been reversed. Food security to ever growing population, protection from floods and droughts to chronically vulnerable areas and generation of the cleanest form of energy, namely hydropower, are some other benefits of water resources development. Many urban and industrial centres have been provided with water supply for consumption and transport of waste for treatment.

Gated reservoirs provide for less submergence in totality of long-term sustainability of the irrigation service by avoiding excessive silting above the crest of the spillway. A substantial part of that storage quantity stands almost perpetually guaranteed. Navigation, fishery, irrigated forestry, recreation and leisure are some other obvious benefits. The overall development due to dams is there for everybody to see and the benefits, costs and risks undoubtedly increase with size of a dam. Efforts should be made by dam planners to maximise benefits, minimize costs and build in defensive measures in dam components to take care of risks by deploying appropriate technology and design features. Incidents involving dam failures are decreasing from decade to decade and the safety record is likely to be better than in many other sectors of infrastructural development.

Sustainability has become the touch-stone for development effort since Agenda 21 was adopted at the Rio Conference in 1992. Although its definition has had different connotations for various development sectors, it means that fruits of development ought to be sustained nature to meet needs of future generations as well and should not be of transient nature to address only present day concerns. The International Commission on Irrigation and Drainage (ICID) fully underlines the recommendations of the Rio Conference and actively promotes their implementation. Recently, the Global Water Partnership has come up with the following definition of Integrated Water Resources Management, 'a process which aims to ensure the co-ordinated development and management of water, land and related resources to maximise social and economic welfare without compromising the sustainability of vital ecosystems. For instance, in case of dams, the present decisions ought to result into outputs for a long enough time. It is possible only through Integrated Water Resources Management (IWRM) which is enshrined in Agenda 21. While achieving it, quality and quantity i.e. sustainability of natural resources themselves must not be affected. Dams have a finite life like any other man-made structure. The right combination of large and small dams in a river basin, which provides such sustained fruition throughout the structures' life, has to be ascertained by scientifically oriented specific studies. The IWRM has to address the needs of the ultimate stable size of global population expected to be reached. Such needs can be met with from basin-wise availability, through the desired combination of dams to provide a model for sustainable development. Within a basin itself, conflict of interests often manifests due to perceived shortages regarding size of dams. Appropriate policies and guidelines are needed to resolve such conflicts. Appropriate policies and guidelines also on sustainability aspects of dams need to be fully developed, and where developed, they need to be uniformly applied. Basically, dams store flood runoff of the rivers and make the storage available for withdrawal to meet with beneficial needs. In this context, the range of variability of availability, appropriate withdrawals are designed to import sustained supplies and hence sustained productivity. The waters of a basin thus get redistributed at minimum economic cost and hence ensure sustenance of the source as well as fruits for development. Dams have major roles to play in sustainability. Sustainability means that the present generation must not rub the coming generations. Rather, we must leave an ecological footprint of judicious use of environmental resources in such a way that they become "renewable". This could otherwise be regarded as socio-cultural and economic sustainability. From the environmental point of view, sustainable development means the use of environmental resources in such a way that the action is not hazardous or deleterious to the environment and the components therein [25]. Many of the Sustainable Development Goals (SDGs) can be achieved by proper and functional water systems at all levels. Nonetheless, improper construction and poor attitude to maintenance from the general public and the policymakers could debar the attainment of these goals by 2030. There has been lack of timely and formal maintenance policy which institutionalizes maintenance with financial backing. The following recommendations are made:

(i) environmental impact assessment (EIA), soil and a material test should be made compulsory for all residential, industrial, institutional, and commercial water structures including dams and reservoirs so that their huge roles in the actualization of the Sustainable Development Goals (SDGs) are intact. Good water facilitates is pivotal to economic and also essential for development (Goal 8);

(ii) all professionals in engineering should play key roles to actualize their respective obligations during construction and maintenance of water structures so as to maximize its ability to provide food, water and energy. Sustainable water infrastructure would go a long way to enhance water use efficiency (Goal 6);

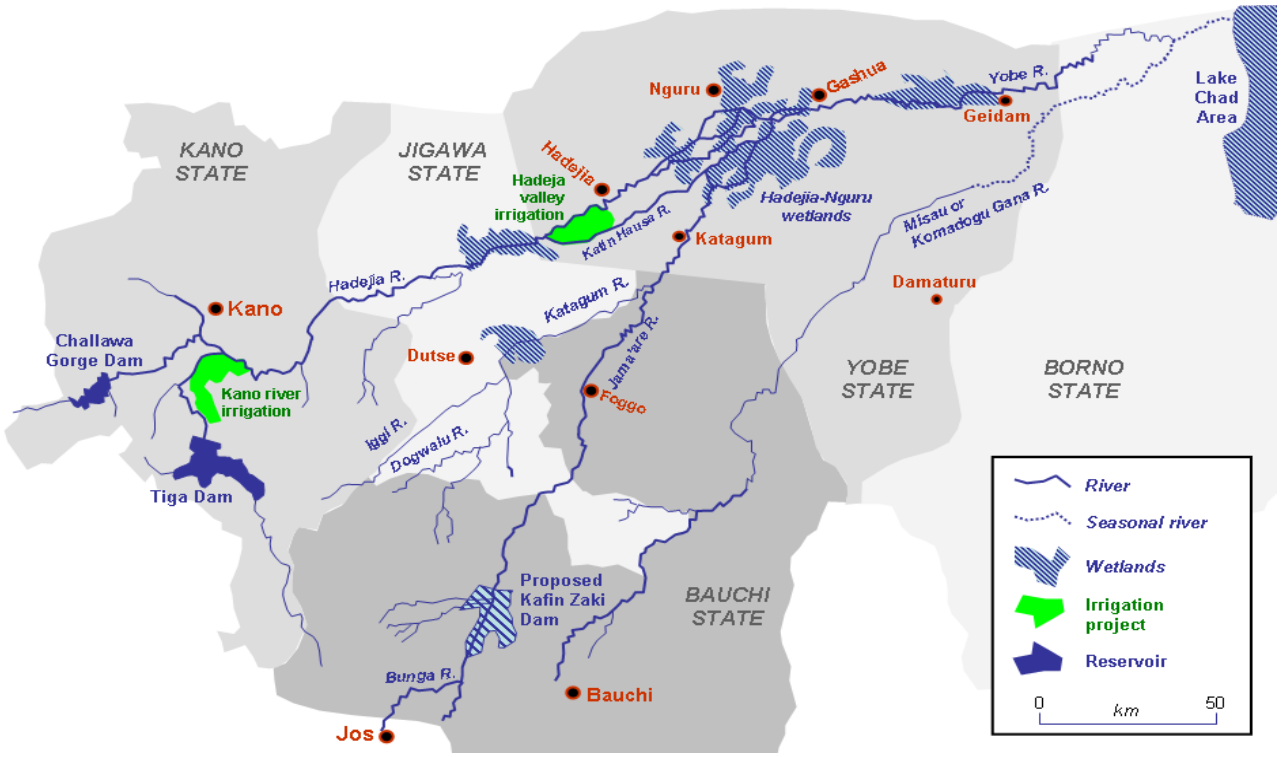

Figure 2: Catchment area of the Yobe River – Tiga dam to the west, south of Kano

Figure 3: Typical Dam primarily for water supply, erosion and flood control as well as the provision of irrigation facilities to boost large-scale farming.

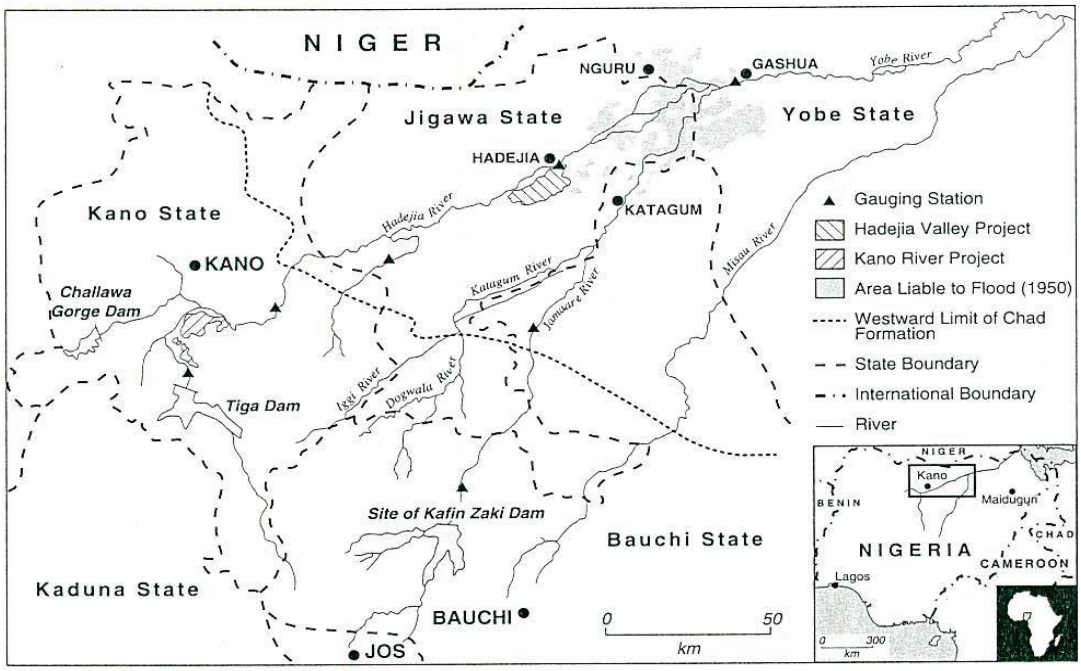

Figure 4: Location of Some Nigerian Dams

7. EFFECTIVENESS OF DAMS FOR DEVELOPMENT

Whether large or small dams, if built without adequate preparatory work, it can fail to deliver expected results. Any dam could prove less effective than planned hence it is therefore necessary to select cases of success or failure of both large and small dams. Lessons are to be drawn from failures to guide future action. The owners of such dams have to be approached first for their assessments. If a new dam is identified, a bench-mark status if not available at the time of construction, might have to be ascertained to realistically assess its effectiveness. Where much depends on how the delivery system is operated, the dam is hardly the reason for any loss of efficiency. Greater attention is necessary in the irrigation sector to bring about and maintain perfection in the delivery systems. Storages of various magnitudes are a requirement for practically whole of the developing world and dams of various sizes fulfill that necessity. It is therefore, imperative that such a development process is supported by effective procedures to minimize negative effects, if any, and enhance benefits. Large dams contribute significantly to the productive efficiency of irrigation, in addition to giving ancillary and intangible benefits. The large dams built in the past have provided water supplies to needy areas for growing food, for drinking water, for reducing flooding, and for generation of hydropower at lowest of costs from amongst various options. The smaller a dam, the more is the cost per unit of water stored, but every size has its role in development of basin resources. They are complementary to each other. They cannot replace each other.

8. CONCLUSION

Dams in Nigeria vary in reservoir capacities, which is as a result of the different objectives for construction and their individual design criteria. The effect and sustainability of these dams depends on some factors which can be controlled and some others that cannot be contained. Factors such as the aging of concrete which leads to cracks on the body of the dams, and possible failures as well as natural disaster on the environment, leading to changes in the design criteria of the dams, cannot be stopped but can be controlled by maintenance of the structural components. Also, changes in the hydrologic conditions at locations of the dams some years after construction, is a factor that leads to the poor performance of the dams.

There is an urgent need for a visual dam inspection of all existing dams in Nigeria to determine their rated capacities. In some cases, as a result of neglect, trees have grown on the embankment of these dams thereby creating avenues for seepage which may eventually lead to dam failure. Apart from technical and environmental resources, dams require an unusual extensive social and economic data. More so, since dam safety depends on continual vigilance which in turn depends on regular and scrupulous monitoring, it is hereby suggested that the Federal Government should set up a dam safety inspection committee for regular inspection of dams, an exercise which may also involve some simple tests such as percolation test to detect seepages.

REFERENCES

[1] Hornby, A.S. 2000. Oxford Advanced Learner‟s Dictionary of Current English. Edited by sally Wehmeir and Michael Ashby. New york, Oxford University Press.

[2] Wong, E. 2013. Damning the Dams. A Study of Cost Benefit Analysis in Large Dams Through the Lens Of India's Sandarsarovar Project." Scripps senior theses paper 169 from http://scholarship/claremont/edu/scripretrieved 17th August 2015.

[3] Wikipedia - The Free Encyclopaedia. 2019. List of dams and reservoirs in Nigeria from http://en.wikipedia.org/wiki/listofdamsandandreservioursinnigeria, retrieved on 07/01.

[4] WCD. 2000. Dams and Development: A New Framework for Decision-Making. The Report of the World Commission on Dams. London, Earthscan http://www.damsreport. org/wcd_overview.htm.

[5] Niger River Basin Development Authority. 1979. The Shiroro Hydroelectric Project, Main report, 55.

[6] Awomeso, J.A., Ufoegbune, G., Gbadebo, A.M., Balogun, G.O., Eruola, A.O. 2009. Towards Effective Planning, Design and Monitoring of Dams in Nigeria. Journal of Agricultural Science and Environment, 9 (2), 45-63.

[7] SRBDA. 1983. Sokoto – Rima Basin Development Authority, (SRBDA) Sokoto. The Zobe Dam Irrigation Project, Main Report, 74pp.

[8] The Hadejia - Nguru wetlands (HNW). 1983. Environment, economy and sustainable use of a sahelian floodplain wetland, LUCN wetlands programme, Gland, Switzerland.

[9] Ogbeighe, H.E. 2002. Society for water and Public Health Protection Campaign against dams in Nigeria. www.fresh wateraction.net

[10] Upper Benue River Basin Development Authority, (UBRBDA) Yola. 1981. Gubi Dam and Irrigation Project, The Dam and Reservoir, final Report, 2, 150.

[11] Upper Benue River Basin Development Authority, (UBRBDA) Yola. 1986. Dadin Kowa Dam and Irrigation Project, Phases 1&2, 62pp.

[12] Adams, W.M. 1985. The downstream impacts of dam construction: a case study from Nigeria. Transactions of the Institute of British Geographers N.S.I.O, 292-302.

[13] Ogun-Osun River Basin Development Authority, Abeokuta. 1999.

Final Engineering Design of Igbojaiye Earth Dam, Main Report, 1, 75.

[14] Okosun, V.A., Amadasu, A.B. 2016. The Influence of Dams on the Growth and Development of Nigerian Economy. International Journal of Management and Applied Science, 2 (1).

[15] Ita, E.O., Sado, E.K., Balogun, J.K., Pandogari, A., Ibitoye, B. 1985. A preliminary checklist of inland water bodies in Nigeria with special reference to lakes and reservoirs. Kainji Lake Research Institute Technical Report Series, 14, 51.

[16] Akindele, E.O., Indabawa, I.I. 2015. A review of the effects of dams on the hydrology, water quality and invertebrate fauna of some Nigerian freshwaters. The Zoologist, 13, 28-35.

[17] Thomas, H.H. 1976. The Engineering of Large Dams, Part I, William Glowes and Sons Ltd, London, 326pp.

[18] United States Department of Interior. 1970. Design of Small Dams. Oxford and IBH Publishing Co, Calcutta, 611pp.

[19] Kimmage, K. 1991. Small scale irrigation initiatives in Nigeria: the problems of equity and sustainability. Applied Geography, 11, 5- 20.

[20] Oyekanmi, M.O., Mbossoh, E.R. 2018. Dams and Sustainable Development Goals: A Vital Interplay for Sustainability. Journal of Environment and Earth Science, 8 (4), 1 – 11.

[21] Michael, A.M. 1978. Irrigation Theory and Practice, New Delhi, 110002, 801pp

[22] Barbier, B.E. 2002. Upstream Dams and Downstream Water Allocation, the case of the Hadejia 'Jama 'are Floodplain, Northern Nigeria.

[23] Barbier, B.E., Thompson, J.R. 1998. The Value of Water: Floodplain versus Large-scale Federal Ministry of Water Resources, Abuja. Detailed Visual Dam Safety Inspection of Large Dams on the West of River Niger, 65pp.

[24] Kate, O. 2013. News Agency of Nigeria (NAN) Daily sun.

[25] Adeniji, O.A. 2012. The Sustainability of Dam Construction through Environmental Management. IOSR Journal of Environmental Science, Toxicology and Food Technology, 1 (1), 01-05.