AN ASSESSMENT OF HYDROMETEOROLOGIC ASPECTS IN RESERVOIR MANAGEMENT OF THE KAINJI HYDRO POWER BUSINESS UNIT.

ADEAGBO,ADEWUMIMOHAMMED
M.TECH,SSSE/918/2003/2004
DEPT. OF GEOGRAPHY.

A THESIS

SUBMITTED
TO

THE POSTGRADUATE SCHOOL, FEDERAL
UNIVERSITY OF TECHNOLOGY, MINNA.
N PARTIAL FULFILMENT OF THE REQUIREMENTS
rOR THE DEGREE OF MASTERS OF TECHNOLOGY
(M.TECH) IN METEOROLGY

DEPARTMENT OF GEOGRAPHY, SCHOOL OF
SCIENCE AND SCIENCE EDUCATION, FEDERAL
UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA.

NOVEMBER, 2005.

CERTIFICATION

This thesis titled: An Assessment of Hydrometeoriogic in Reservoir Management of the Kanji Hydropower Business Unit Aspect by Adeagbo, Adewumi Mohammed (M.Tech/SSSE/2003/200/918) meets the regulations governing the award of the degree of Master of Technology (M.Tech) of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

Dr. A. S. Abubakar

Major Supervisor

Signature & Date

Dr. P. S. Akinyeye .... ~ -1.....9..~.{.l.9.(Ob

Head of Department

Signature & Date

{prOf.G. D. Momoh

Dean, SSSE

Signature & Date

Prof. J. A. Abalaka ....~!i~l.m

Dean, Post Graduate School

Signature & Date

DEDICATION

This project is dedicated first to Almighty Allah, for preserving my life from the beginning of this program till this time, to my Family; Mulikat Adeoti Adeagbo (Wife), Mariam Adetayo Adeagbo, Mohammed Adedayo Adeagbo (Jr.), Mulikat Adetola Adeagbo (Jr.) and my late father Pa Sadiku Alabi Adeagbo who rested in the Lord at the peak (11/03/05) of this research.

ACKNOWLEDGEMENT

A project of this nature could not have been completed without the contribution and supportive roles of some people. I therefore wish to acknowledge the role of my employer, (NEPA) now Power Holding Company of Nigeria (PHCN) and its top management team for approving my participation in the course of study. They are Engr. 1.C. Okoli, C.O.O Generation (Kainji), Engr. O.K Ozoemena (Former Executive Director Generation), Engr. M.O. Ofomata (Head Production) and Engr. S.T. Sanni (Head Plant)

I am greatly indebted to Dr. M.T. Usman (Head, Department of Geography) for playing a mojor role throughout the course of study.

I wish to express my special thanks to my supervisor Dr. Abubakar, Ahmed Sadauki-Deputy, Dean Student Affairs for finding time to scrutinize this work and making useful comments and suggestions. My sincere thanks also go to Dr. Sola Akinyeye for his supportive role.

I am also grateful to Dr Halidu, Dr. Apollo, Dr. Yomi (Maths Dept), Mr Seun Fadare, Mr. Tayo (Science Education Dept.) and the Nmanu family for their stimulating discussion, advice and encouragement in various ways.

I am extremely indebted to my wife, Mulikat A. Adeagbo and children for bearing my absence from home with patience.

Finally and above all, to the glory of Almighty ALLAH, who made me what I am. To Him I say AL-HAMDULILAH1.

ABSTRACT

Efficient reservoir management, sound operational decisions and monitoring depend solely on continuous statistical analysis of instrumental records taken from hydrometric monitoring stations. Thus, collection, collation, interpretation and analysis of daily hydro meteorological quantities from within the entire Niger Basin network from the basis of reservoir operation as well as determine the success or failure of hydro-plant operation.

The hydro meteorological factors of constraints in the performance of hydroelectric power stations have been determined using the correlation and linear regression analysis. This has been done to determine the strength of the relationship between climatic factors and how they could affect the performance of hydro electric power station. The independent variables considered were the climatic factors which were rainfall and reservoir evaporations. The dependent variables on the other hand were reservoir elevation, average turbine discharge and power output.

The climatic variables (independent variables) were observed to have an effect on the dependent variables. From the analysis carried out, some of the relationships were found to be strong and some weak. This has shown that climatic factors could limit the performance of hydro electric power stations. Thus, the hydro meteorological aspect of power generation has been found to form an integral part of hydropower generation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

INTRODUCTION

1.0 HISTORICAL BACKGROUND

The history of dams and ~eservoir management and operation for large hydro-electric power generation dates back to 1951 when a noticeable growth of industries and rapid urbanization in Nigeria made demand for electricity grow faster than supply. Prior to this small or mini hydro plants had been developed for mining on the Jos/Bauchi Plateau. (NESCO, 1930).

Consequently, the Electricity Corporation of Nigeria (ECN 1968) then, realized that a large and cheap source of power must be found to satisfy this growing demand. Between 1953 and 1957 the Federal Government commissioned different consultants to investigate the hydro-electric power potentials of the Niger, Benue and Kaduna rivers.

The report of the consultants was submitted in 1958 with recommendations and consequent approval that an integrated system of hydro-electric power development project be constructed on the river Niger at Kainji, Jebba and the Shiroro Gorge on the Kaduna River. The Niger Dams Authority (N.D.A.) was established in 1962 by an act of parliament.

Under the Niger Dams Authority, plan of action at Kainji, a 760 megawatts station was planned, the next being a 540 megawatts station at Jebba, to be followed by a 600 megawatts station at Shiroro. Today, their proposals had become realities. At present PHCN operates seven (9No.) hydro-thermal stations with a diverse energy mix with a total installed capacity of 6,000 megawatts.

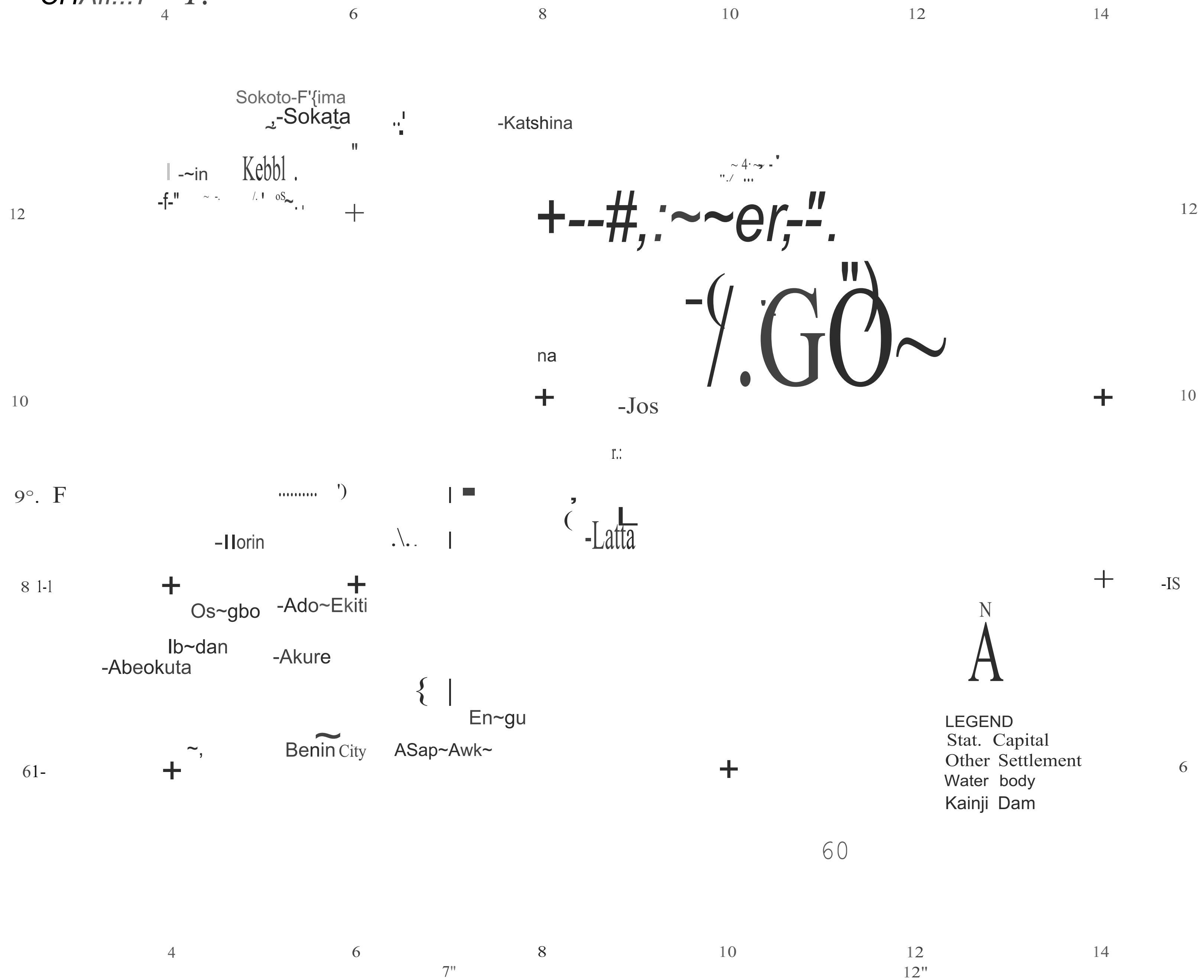
The Kainji dam is built across River Niger on Kainji catchment basin and the impounded water is used to generate electricity. It has the main dam and the saddle dam or rim dyke. The reservoir is an extensive body of water surrounded by arable land. The dam is rock filled, with concrete face and 65.5 meters high above the original riverbed elevation. The saddle dam is rock filled and it has a safety drive to ease the main dam in the event of flooding. The dam has the intakes; each intake has a steel opening of 8.55 meters diameters. This is called the penstock. It is a design where water from the lake passes through to rotate the turbine blades and convert mechanical energy to electrical energy. In compliance with the international law on dams across international rivers. Kainji dam has two navigational locks; the upper and lower locks. These locks are opened for the navigation of barges or work boats from the upstream to downstream of the dam. See Chart 1.

1.2 PROBLEM STATEMENT

There have been a number of cases of power failure in the country either during the dry or wet season. This problem of power failure which is inadequate (insufficient energy output) has not been given much attention focusing on the hydrometric resource inputs (climatic factors) but rather attention has been so much focused on other technical areas such as mechanical, electrical or structural failure with neglect of relevant climatic factors.

The hydrological inputs into reservoir include the discharge (inflow) flood from the principal river (Niger) and its major tributaries (Rivers, Sokoto-Rima, Malando, DanZaki, Ganwo and Kende). During the dry season - (November to May) most major tributary rivers dry up due to lack of rains (seasonal rivers). This is the period of drawing down the lake to its minimum pool elevation of 132.58 meters with the corresponding storage

CHAfl...7 1. NIGERIA SHa,wING LOCATION OF KAINJI DAM ON THE RIV~ NIGER



- $2.8528 \times 10^9 m^3$. The onset of the rain starts from March/April but the effect of the flood will only be appreciable around July of every hydrological season, which herald the arrival of white flood, which occurs between July and October annually. Between these periods there is active monsoon, which generates a lot of inflow of water into the lake for power generation. All the available machines/turbines are always programmed and put into operation. There is generally an increase in power output to the national grid especially from the hydro-stations during this period. If the season is excessively wet, the volume of water again continues to increase in the reservoir which can be read through calibrated staff gauge or automatic water level recorder.

When the maximum pool elevation (14l.73 meters) is achieved, in order to avoid overtopping, the spillway gates are opened to allow for the passage of excess water for the safety of the dam structures.
The effect of black flood is noticed towards end of November to February. In terms of magnitude and duration, the white flood is higher. The black flood on the other hand varies in magnitude from year to year depending on the pattern of weather (water) outside the country, which is the major source of flow. The black floods arrive into the Kainji reservoir during the dry season period when evaporation rate is usually high.

The fact that the source of the River Niger is from the Futa Jallon highlands in Guinea makes it vulnerable to be dammed at the upper course which from technical study could affect / reduce the amount of incoming flood into the Niger Basin.
For example Niger -Republic carried out feasibility study on the construction of a dam called Khandaji dam project (refer to attached West African map) which is yet to be executed. The effect of the dam will be

disastrous to the Kainji as it will drastically reduce the inflow of water into the dam.

1.3 AIM AND OBJECTIVES

The principal aim of this research project is to assess some hydro meteorological resource inputs (water as source of fuel), climatic factors such as evaporation and rainfall that can affect (positively or negatively) or limit the performance or otherwise of a hydro electric power station.

Other objectives of the study include:

- Assessment of the energy production constraints due to low water level, as influenced by evaporation and rainfall.
- Assessment of the impact of the two floods along the Niger on electricity production.
- To examine the flood flow variability at Kainji Dam.

1.4 . JUSTIFICATION

Hydroelectric power schemes are energy that is also renewable and environment friendly vis-a-vis air pollution or any other form of pollution. These schemes are generally known to be highly capital intensive but a very low running and maintenance costs. In the long term therefore they tend to be much cheaper than competing alternatives such as gas, steam and oil fired thermal plants, solar, wind wave etc. Nuclear power, however, though cheap in long term can be an environment nuisance as experienced at three-mile island USA. Chernobyl *(C.1S)* and the Russian Mishaps (1991). The Kainji Dam for example commissioned at the beginning of 1969 cost 79 million pound (136 million dollars). Running and maintenance cost of Kainji have generally been around 3% of initial investments in the first 20 years of operation in line with international standards. In time, with normal international practice, the estimated amount of energy generated amounted to approximately (19.6 billion

KWH) yielding revenue of about (392.5 million dollars) at an exchange rate (12 dollar per naira) at the time.

This study intends to provide an overview of the hydrometerological factors that can affect the management of the Kainj i hydroelectric power station. The reason being that hydro meteorological factors play an important role in the management of hydroelectric power stations. Too much or too little rainfall brings about increase in the water storage level and if this is not regulated, an overtopping of the dam is envisaged, which could cause serious structural and electrical damage to the dam or major disaster if the dam fails. High rate of evaporation or too little rainfall can affect the storage level of the reservoir.

Strong wind can damage structures especially (earth dams) not rock fill dams, constructed to specification and cause high tension cables to break off when they make contact which is long overdue for a change instead of underground wiring system to reduce the problem of power failure when a line squall is approaching.

Atmospheric lighting also causes damage to transformers. This is why "lighting arresters" are mounted on transformers to prevent short - circuiting. These are essentially some of the climatic factors of constraint that affect the performance of hydroelectric power plants. The hydroelectric plant though little in number is the most popular and reliable electric power supply in Nigeria.

The study therefore is intended to examine the techniques developed to estimate the hydrological inputs especially flood discharge, its impact, the rate of output when the operating head is high vis-a-vis the optimum efficiency on the plants. When the lake is at maximum pool elevation, the efficiency is high compared to when the lake is at minimum pool elevation. The efficiency drop as the operating head drops. It will also highlight the degree of sustainability of the black flood as a complementary factor to the prolonged water availability for continuous and optimum power generation especially at the cessation period of the local rains.

1.5 SCOPE AND LIMITATION

This study is limited in scope to some extent. This is because the weather observatory centre at the Kainji hydrometric power station is not fully equipped with all the weather observing instruments. The wide catchments basin from the power intake to the end of *back-water effect* area after Yelwa is supposed to have more than five standard meteorological weather observation and monitoring stations instead of one as it is at present. This has made comparison of weather data a bit difficult.

1.6 STUDY AREA DESCRIPTION.

The formation of the lake at the completion of the dam caused the resettlement of about 44,000 people of Borgu and Yauri Emirates respectively. They were resettled at New Bussa and Yelwa.

The Niger river on which kainji dam is built is located between latitude 4° and 7° North, longitude 12°W and lSoE. The perimeter length is about 4,200km. The Niger flows for about 1,700km in Nigeria towards the Gulf of Guinea before it finally discharges its water into the Atlantic Ocean.

The lake has two flood seasons: the white flood and the black flood. The white flood is the accumulation of rainfall through its principal and lateral rivers within its catchments basin that flows into the lake. The black flood is the precipitation from Guinea, Mali and Niger, which directly feed the lake. The white flood along with its lateral flows arrive the lake in July, this is when appreciable inflow starts to manifest. The black flood arrives around December as it has to travel longer distance from these countries already mentioned before it gets to Kainji lake basin.

1.6.1 THE LAKE

The length of the lake is about 136 kilometers long. The width is about 24 kilometers at its widest point with maximum pool elevation at 141.73 meters. The minimum pool elevation below which the plant is not safe to operate is *132.58* meters above the sea level. The total storage capacity is 15 billion cubic meters. Out of this volume, 3 billion constitute the dead storage, that is, water below the penstock. The remaining 12 billion constitutes the life or usable storage.

1.6.2 CLIMATE

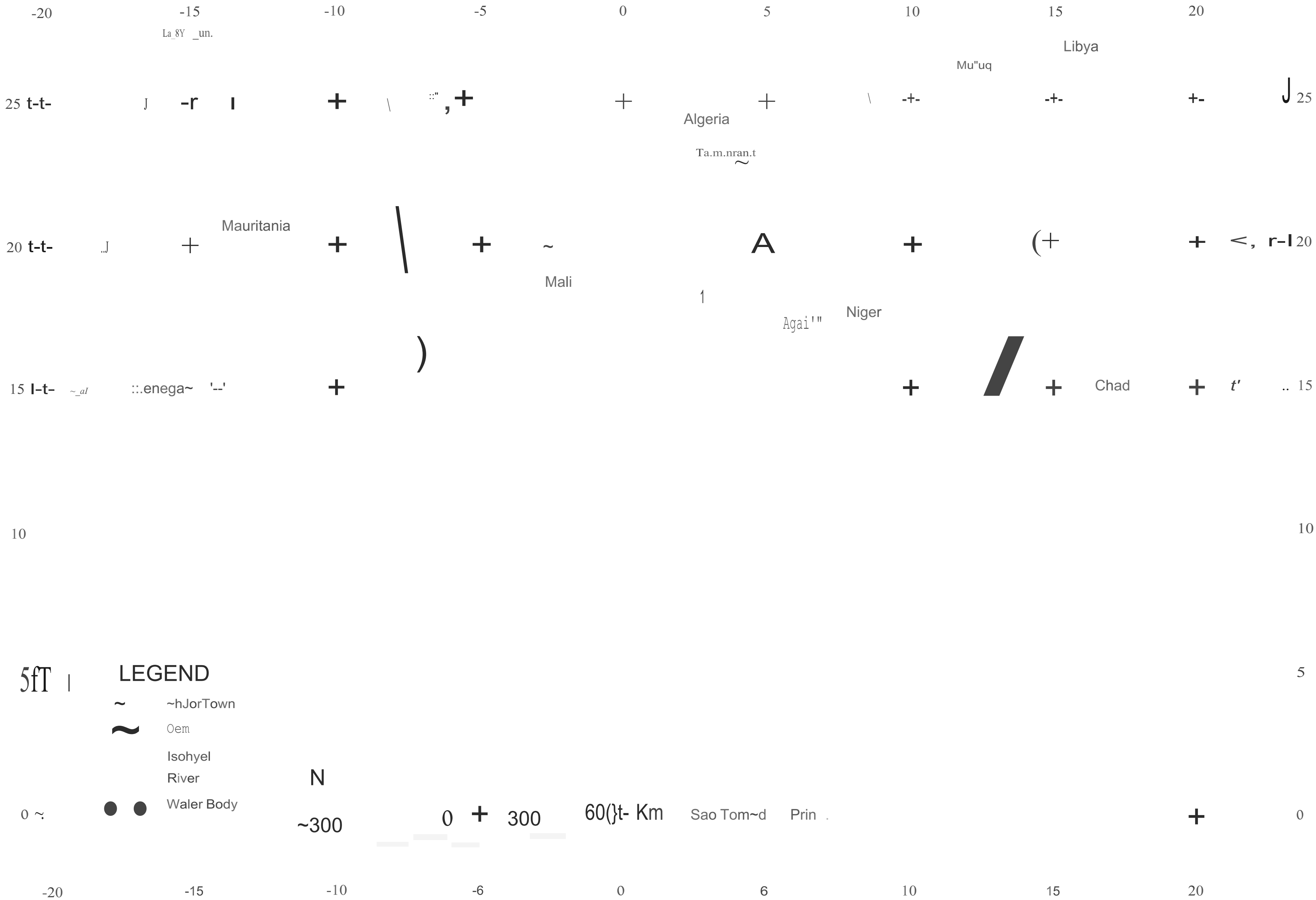
The hydrological behaviour of the Niger River Basin is influenced by a climate that is dependent on an annual cycle of two air masses, i.e. the Northeast trade winds from the Sahara Region and the southwest monsoon from the Atlantic Ocean. Generally, the climate is characterized by a marked hot raining season and cool dry season in conformity with the prevailing winds. The amount and duration of the rain also decreases from the south of the basin northwards except where there are reliefs or local microclimate modifications.

The upper portion of the Niger i.e. the headwater of the watershed in Guinea constitutes the wettest areas within the upper basin. Here, mean annual rainfall usually varies between 2S00mm in the south west to about 700mm in the Northeast. In the middle Niger, rainfall increases in the downstream direction and ranges from 200mm at Tossaye to 900mm at

Malanville. The lower Niger especially the coastal delta in Nigeria constitutes the wettest portion of the entire basin as rainfall in this reach increases in the downstream direction from 900mm to nearly 4000mm in the Gulf. See Chart 2.

C-HAP-.I

VVEST AFRICA SHOWING RIVER NIGER, SOME EXI STING AND PROPOSED DAM ON IT



CHAPTER TWO

2.0 Literature Review

2.1 Introduction

Kazman (1965), defined flood as a "relatively high stream flow as measured by either gauge height or discharge rate". Whenever the stream channel in a reach is over taxed, causing water to cover lands outside the usual channel boundaries, the stream is said to have reached flood stage. The benefit to be derived from the prevention of flooding and the consequent reduction in property damage is the principal justification of flood-control projects. Thus, an important sub-category of statistical analysis deals with floods:- the recurrence interval, the "design" flood, maximum probable discharges and stages, and so forth.

Flood flow results from intense precipitation, its intensity vary from place to place. Damaging floods sometimes result from an accident, such as dam failure when a reservoir is full or the sudden opening of reservoir floodgates after heavy rains, to draw down the storage so that runoff from a possible subsequent rain will not be passed without detention through a full flood-control reservoir.

Over the last four decades, a number of studies have been undertaken on the hydrology of the river Niger and later Kainji Dam - reservoir located on it. One of the earliest of these studies is that of NEDECO (1961) who conducted a full pre-impoundment hydrological investigation of the flow regime of the Niger. Their report provided the basis upon which Kainji dam was designed and built.

During the first 5 years of its operation after the commissioning of Kainji dam in 1968, the well-documented Sahelian drought of 1972173 struck with its negative impact on the flow regime of the Niger into Kainji Dam reservoir. This made Abiodun (1973) to reassess the project performance vis-a-vis hydrological prediction and concluded that the Sahelian drought has made Kainji Dam - reservoir a failure due to inadequate water to run the installed power generating turbines.

The same study made predictions about the effect of scarcity of water in the Niger River on the future performance of Kainji hydroelectric power station.

Abiodun's work was closely followed by the related study of Sagua (1977) who discusses the regulation of the River Niger's floods at Kainji with particular reference to 1973174 Sahelia drought. Sagua and Fregene, (1979) study also sheds light on the understanding of the Niger's flow to sustain 8 generating sets at Kainji.

In their study in India, Dhar and Rakhecha (1975) attempt to provide an up-to-date information on the importance of hydrometeorological studies of rainfall in the development of water resources. According to them, rainfall is the most important source of water on land, and therefore, the principal hydrometeorological parameter in the development and sustenance of water resources of a region. Earlier, Freeman (1974) notes that fully equipped meteorological stations for data collection are not numerous but opines that rainfall data are not only readily available but has a vast and greater effects on channel's water flow.

The work of Oguntoyinbo and Ayoade (1989) further buttress Dhar and Rakhecha and Freeman's observation when they note that the amount and variation of water in a lake or reservoir whether seasonal or annual are primarily determined by meteorological conditions which control the rates of water inflow into the lake. Oguntoyinbo and Ayoade go further to state that the amount of river inflow to a lake is highly dependent on the precipitation conditions in the catchments of the rivers that feed the lake. According to them, even in the case of lakes not fed by rivers, direct precipitation on the lake surface is the only means of water replenishment for the lake. They therefore conclude that precipitation is the single most important control of the amount of water in storage in a lake. As part of their studies on weather extreme, in West African sub-region, Aluko, Abiodun and Fasheun (1995) distinguish between flood and simple runoff in the sense that river flood results whenever a channel capacity is exceeded by the runoff. Citing Hayward and Oguntoyinbo (1987), the three workers maintain that the predisposition of a climate to storm producing excess precipitation is the fundamental basis of the flood hazard.

These flood-producing storms could occur regularly or follow a seasonal pattern. Generally, two types of storms have been identified for initiating flooding - the violent thunder shower, which produces a flash flood and the prolonged, wide-spread rain which produces plenty of water leading to extensive flooding over the entire watersheds.

In addition, scientist including Omotoso (1986, cited in Aluko, Abiodun and Fasheun (1995) are of the view that in West Africa, the storm producing system varies and may be of convective, frontal or orographic in origin but are commonly characterized by high rainfall intensity and amount.

The same study also notes that the weather systems associated with these flood-producing systems are Inter-Tropical Discontinuity, the squall lines and the easterly waves.

Further scientific discussion on hydrometeorological elements and stream flow includes that of Dhar et al. (1975) who works in an Indian environment. Part of Dhar's study concerns variability of hydrometorological elements. According to him, even if rainfall of a country is less variable from year to year, but it is highly variable from month to month. Besides, he opines that this seasonal variability is responsible for causing flood in a river channel. The report of Subbaramayya and Rao (1989) is similar to Dhar's. Their quantitative and qualitative evaluation and explorative data analysis of twenty stations in the Godavari river rare flood of the century in India show that the resultant storm runoff and flood was rainfall - induced. Reservoir operation is an essential aspect of reservoir management. Oke, Fregene and other (1992) citing Peterson (1984) and Acres (1985) define reservoir operation as involving the routing of stream flows through the reservoir and making reservoir releases in accordance with schedules for various specified purposes and for flood control. Peterson (1984) and Acres (1985) definition as cited in Oke, Fregene and others (1992) has been extended by Wurbs (1993) who adds that optimizing reservoir operations involves allocating resources, developing stream flow regulation strategies and operating rules and making real-time release decisions within the guidelines of the operating rules. Wurbs extends his above statement when he adds that a reservoir-system regulation plan, operating procedure or release policy is a set of rules for determining the quantities of water to be stored and to be released or withdrawn from a reservoir or system of several reservoirs under various conditions. Seen in the context of these definitions, reservoir operations are a vital part of reservoir management as the control the supply of water to various users and uses over time. In addition, it is thus imperative that the planning of operational releases over short and long term periods are made so as to maximize benefit on a continuous basis. But no reservoir is operated on trial and error basis. Reservoir Operations Planning (ROP) may be mere water resources engineering gamble if there are no rules to guide water releases programmes. This is because too much or too little releases over a specified time period have implications on the dam-reservoir itself and water users downstream. This leads to reservoir operating rules and rule curves which are commonly adopted in river basin and reservoir management practices (Louckks and Sigvaldason, 1982; cited in Oke, Fregene and others (1992).

During the last two decades, scientists have made advances on flood flows into a reservoir and implication for dam safety. Contributing to dam-reservoir operation and water releases, Tarafdar (1992) stresses the importance of safe operation particularly during floods.

Also of note is the work of the Flood Working Party of the British Institution of Civil Engineers (1975). Their discussion paper defines a flood peak and volume through a reservoir. The document is considered as a reference on dam-reservoir operation and management in relation to dam safety.

As in the contemporary era, water has been and still a life sustaining natural resources. It is central to almost all human activities and civilizations which have survived or perished due to the amounts of water available. Fresh water is almost the life blood of all activities at hydro power stations. It is however, a finite resources as nature unfortunately does not usually provide the resources on a schedule compatible with human needs. Storage therefore provides a means of resolving some of the problem.

The subject of reservoir operation and management in hydro-energy production especially in a changing climate such as ours is as multifaceted as it is complex. The setting is even further compounded by the dependence of several upstream riparian countries and communities on the same river system upon which projects in the down stream reaches are based. Analysis of the water balance of storage reservoir under various hydrological sequences is therefore necessary and could generate a set of operational rules which would in tum yield the optimal water supply in various hydrological situations. Hydrological and related meteorological data thus provide the necessary information for managing our water resources systems and are pivots for consideration of hydrological assets and deficits and hence operational decision-making.

An assessment of the quantity of the water available is always an essential prerequisite for reservoir management and optimum power production.

The hydrology of any River basin is never static but continues to change in response to the environment and, to a large extent various human activities and control on the basin. Besides, changes at one location on a large complex system like the Niger River basin have an influence throughout the basin. A qualitative evaluation of the salient features of stream flow and the behavior of the River system upon which some of our power plants are based would always be relevant and to a very large extent, enhance power generation, remove engineering gamble and minimize wastes. This study constitutes the only scientific basis for operational decisions which can lead to optimum plant utilization.

CHAPTER THREE.

3.0 RESEARCH METHODOLOGY

The emphasis of this chapter is to highlight the method of data collection and computational method that were used or employed in the process of conducting and reporting the research and results.

3.1 DESCRIPTION OF DATA SET

The data and other relevant parameters collected for this project is from the Kainji hydro-electric power station. The data collected include:

3.1.1 Rainfall (1994 - 2003)

The rainfall data is an indication of the amount of rainfall that has fallen. The more the amount of rainfall that has fallen, the more the amount of water that will be available for storage in the reservoir and for power generation.

3.1.2 Reservoir elevation (1994 - 2003)

The reservoir elevation data is an indication of the water level measured in meters and this is dependent on incoming flood/inflow into the reservoir, evaporation and the intensity/amount of rainfall that has fallen within the basin. The higher the water level the more the storage level and the more the megawatt output to be generated through the turbine.

3.1.3 Average Turbine Discharge (1994 - 2003)

The average turbine discharge data is an indication of the amount of water that has been used to spin the turbines for megawatt output. This is also referred to as the discharge from the turbines. The discharge per unit of electricity is small when the lake is at maximum pool elevation than when it is at minimum pool elevation.

3.1.4 Lake Evaporation (1994 - 2003)

The lake evaporation data gives the amount of water that is lost in the form of vapor. The higher the lake evaporation the higher the amounts of water to be lost from the lake, which will consequently reduce the water storage, level in the reservoir.

3.1.5 Total Energy Generation (MWH) (1994 - 2003)

The data for the total consumption of energy generated gives the amount of megawatt output into the national grid. This power output is dependent on the rainfall availability and other limiting factors e.g. evaporation.

3.1.6 Peak and off - Peak Generation.

Peak generation is the maximum (MWH) demand especially in the evenings. Off - peak is the minimum demand (MWH) especially late morning and afternoon.

3.2 COMPUTATIONAL METHOD

There are different methods of analysis that can be used.

But the most relevant methods in this project include:

Spearman's rank correlation coefficient statistical technique. And linear regression analysis.

3.2.1 Correlation Analysis

Correlation is a measure of the strength of the relationship between two variable quantities. It seeks to determine how well a linear equation explains the relationship between two variables. The strength of this relationship is measured by the correlation coefficient (r). It is the geometric mean of the two regression coefficients of which formula is represented as follows:

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

The correlation coefficient always has between -1 and +1, The closer the value of the coefficient of correlation is to ±1 the stronger is the relationship between the variables. If $r = 1$, there is a perfect positive relationship, i.e. the two variable quantities are linearly related, one increasing at a proportional rate to the other. If $r = -1$, there is a perfect negative relationship, i.e. the rate of decrease of the one is proportional to the rate of increase of the other. If the value of the correlation coefficient is 0, there is no linear relationship between the two variables. If the value is + or -1, then there is perfect relationship.

3.2.2 Linear Regression Analysis

In a linear system the input is directly proportional to the output. Linear regression is an approach to estimating the numerical relationship between two variables. It could also mean the science of estimating in functional form, the dependence of one variable upon another.

From the linear equation:

$y = a + b x$,

Where a is the y intercept when $x = 0$

And b is the slope

The coefficients a and b of the linear regression function

y = a+ b x, are determined by

b = nL:xy - L:xL:y

nL:x2_ *(L:xi*

And a = y_ bx. The values of a and b will be computed.

The set of data to be used for this computation are the ones that have correlation coefficients.

The values of the root mean square errors will be estimated.

The equation is represented

Thus: R.M.S. = \]r--L:-(-y-_-y-)2-

The expected out come of this analysis is such that when the values of the root mean square errors have been computed manually. The average turbine discharge at high head, that is when the lake is full, has the greatest influence on reservoir elevation at maximum pool elevation and at lowest elevation, which consequently varies with the energy output.

In summary therefore, the average turbine discharge and reservoir elevation data are to be analyzed with a view to know the effect of drop as the reservoir recedes. Also to examine the complementary nature of the white and black flood.

CHAPTER FOUR

4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSIONS.

From the preceeding chapter, hydroelectric generation requires hydraulic pressure derived from consistent water from storage supply in the lake through the penstock to effect turbine turning. This hydrologic pressure in other words termed turbine discharge varies with the volume of water supply in the (Reservoir) and the elevation. The ideal reservoir elevation is one that produces high turbine discharge.

The reservoir elevation is also controlled by processes of precipitation and inflow, which add or supply water to produce megawatts. Evaporation and spill-way discharge on the other hand tend to subtract water from the reservoir storage. Since turbine discharge IS primarily depended on available water in the (reservoir), a correlation will be made between power out-put and turbine discharge to ascertain their interdependency. A correlation will also be made between turbine discharge and reservoir elevation to determine how reservoir elevation affects turbine discharge and in turn power output.

Based on the above findings, a correlation will be made between reservoir elevation and the processes that regulates the reservoir elevation (i.e. evaporation, precipitation and inflow) to ascertain how each of these factor vary with reservoir elevation. Consequent on the above findings, deductions can be drawn on how each of the three factors would affect turbine discharge and power output as they affect reservoir elevation upon which turbine discharge depends. However for verification, a correlation will be made between the factors of rainfall, precipitation and evaporation with turbine discharge and power output to verify the deductive approach.

Based on the data collected, spearman's rank correlation coefficient statistical technique will be employed. It is chosen as appropriate because it provides an easy way of making correlating analysis from large data set values. It makes use of ranked values in lieu of the actual figures which would otherwise be very cumbersome in the course of calculations.

Thus, the spearman's ranked correlation coefficient IS given as

1'=

In addition, a composite line graph of the mean monthly annual turbine discharge power out-put, reservoir elevation, precipitation, inflow and evaporation will be used to demonstrate their annual variability.

Table 1: Correlation Coefficients between Turbine Discharge/Power Outputs And Reservoir ElevationlTurbine Discharge.

	J	F	M	A	M	J	J	A	S	O	N	D
RAINFALL	0	4	5	6	8	9	10	11	12	7	3	0
Evap	9	11	12	10	6	4	2	1	3	5	7	8
Inflow	10	7	5	4	2	3	6	9	12	11	8	9
Res. Elev	11	9	7	5	4	2	1	3	6	8	10	12
Turb. Disc	12	10	7	11	9	2	1	3	8	4	5	6
Power out-put	12	8	10	11	5	2	1	2	5	3	7	9

Chart 3: Compound Line Graph of Power Output, Turbine Discharge, Reservoir 8evation, Precipitation, Evaporation and Inflow

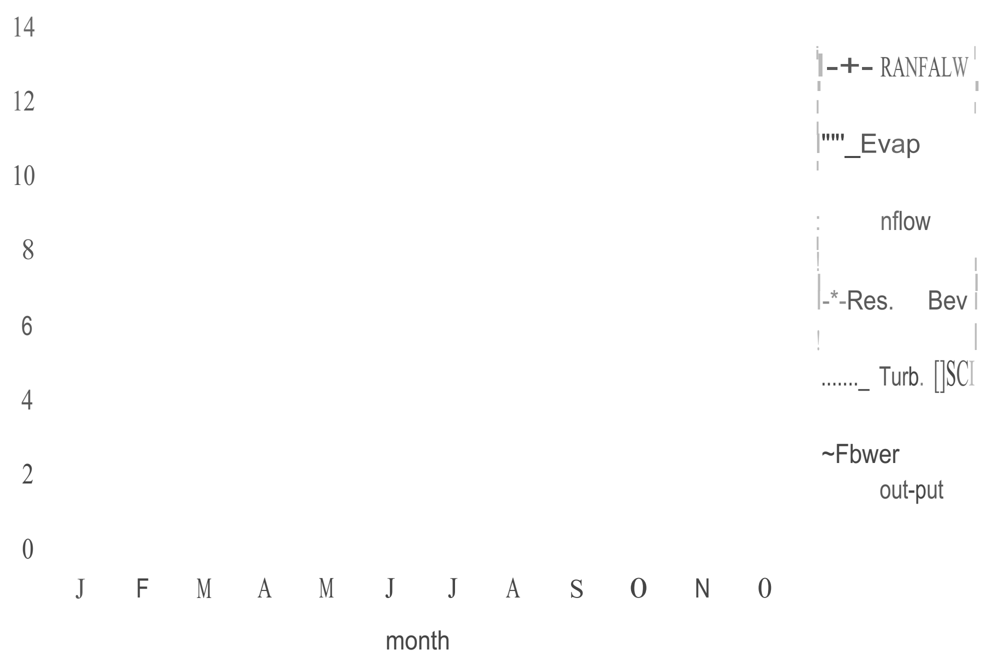


Table 2: Table Showing the Rank Correlation Coefficient of Turbine

YEAR	TURBINE DISCHARGE AND POWER OUTPUT	RESERVOIR ELEVATION & TURBINE DISCHARGE
1994	0.8461	0.7675
1995	0.9667	0.6346
1996	0.9790	0.7376
1997	0.9790	0.4965
1998	0.7203	0.4965
1999	0.4283	0.0890
2000	0.9196	0.3042
2001	0.9300	0.0769
2002	0.9300	0.5314
2003	0.8678	0.8252
MEAN	0.9515	0.3813
10 Yrs total average ranked corr. Coeff		0.2424

SOURCE: Kainji Hydro Power Business Unit (KHPBU) yearly technical report.

Observation from the correlation coefficient between turbine discharge and power output show positive coefficients. On the average, a positive coefficient 0.8678 (86.78%) is obtained. This implies that power out-put is a statistical function of turbine discharge. As turbine discharge increases, there is a corresponding increase in power out-put to about 86.75%. On a ten year average, it gives even a higher value of 0.9515 (95%). This indicates that if turbine discharge has increased over a prolonged period, power generation will also be maintained high.

The correlation coefficient between reservoir elevation and turbine discharge also shows high correlation in most of the years especially

2003, 1994, 1996 and 2002. Also very low correlation values are obtained in 1999, 2000, and 200l. (0.0890, 03042 and 0.0769) respectively. But on the average a fairly positive correlation coefficient of9.3813 (38.13%) is obtained. This shows a weak positive interference of turbine discharge on reservoir elevation. This implies that, if the reservoir elevation increases, there will also be a fair increase in turbine discharge and vice versa. This weaker coefficient is an indication that there are other factors apart from the variation of turbine discharge; these factors are basically operational and mechanical systems.

The negative values obtained in 1998 and 2001 (0.4965 and 0.0769) contrarily from the general tendency of the correlation is an indication of an anomaly probably due to operation hiccough. Again on a cumulative basis, the relationship also shows a weaker but positive correlation. This implies that if reservoir elevations continue to rise over a long period of time, there will be a corresponding fair increase in turbine discharge. It can therefore be deduced that reservoir elevation will have a fair positive correlation coefficient with power out-put. As the reservoir elevation increases, power out-put will also increase but fairly for short period and on cumulative basis.

TABLE 3: CORRELATIO COEFFICIENTS BETWEEN RESERVOIR ELEVATION & INFLOW, PRECIPITATION AND EVAPORATION. AS WELL AS TURBINE DISCHARGE AND INFLOW, PRECIPITATION AND EVAPORATION.

YEAR	r' RESV. ELI I FLOW	r' RESV.ELV & PPT	r' RESV. LEV. IEVAP	r' TURB. DISCH. & INFLOW	r' TURB. DISH. & PPT.	r' TURB. DIS & EVAP.
1994	0.6521	-0.4738	0.5297	0.7343	-0.3217	-0.5944
1995	0.6084	-0.9405	0.8863	0.0052	-0.5857	0.6818
1996	0.5944	-0.4580	0.4632	0.3546	-0.6923	0.7325
1997	0.6853	-0.7867	0.6783	0.1748	-0.6958	0.8111
1998	0.4545	-0.8182	0.2605	0.0769	-0.1660	-0.4840
1999	0.6224	-0.5559	0.4231	0.1206	-0.1556	0.1486
2000	0.6084	-0.7412	0.6783	0.0350	-0.0734	0.4196
2001	0.5315	-0.7412	0.4196	0.0350	-0.1678	0.1398
2002	0.5909	-0.7832	0.5000	0.2517	-0.0978	0.7517
2003	0.5151	-0.3671	0.4615	0.3420	-0.5979	0.7063
Average	0.5861	-0.7407	0.5300	0.1587	-0.3554	0.3313
10 Yrs Average	0.9300	-0.3939	0.69669	0.6242	-0.2727	-0.1151

SOURCE: Kainji Hydro Power Business Unit (KHPBU) yearly technical report. 1980.

As observed from the table above, the correlation coefficients between reservoir elevation and inflow yield high positive values with 0.5861 (58.61%) on the average. This is an indication that there is a cumulative basis, it gives higher value of 0.9300 (93%) this implies that if the inflow increases, there will be a resultant increases in reservoir elevation to about 58.61% on the average. Prolong period, the increase in reservoir elevation will be even higher by about 93%.

It can therefore be deduced that, inflow will have fair impact on turbine discharge in a positive way. Implying that as inflow into the reservoir increases, there will be fair increase in turbine discharge and thus power out-put since the inflow positively affects reservoir elevation, which in tum positively affect turbine discharge which enhance megawatts production. On a cumulative basis the correlation coefficient will be even higher for turbine discharge. This deductive inference is backed up by the correlation coefficients obtained between inflow and turbine discharge on annual and on cumulative basis which gives 0.1587 for annual and 0.6242 on a cumulative basis.

On the correlation coefficient between reservoir elevation and precipitation a high negative values are obtained with -0.7407 (74.07%) on the average. Contrarily, on a cumulative basis a weaker positive coefficient 0.3939 (39.39%) is obtained. these indicate that on an annual basis reservoir elevation has a strong relationship with precipitations. The negative sign implies that as precipitation increase, the reservoir elevation decreases and vice versa depending on the total discharge from the turbine. This is also graphically depicted on the compound line graphs of reservoir elevation and precipitation. There is an alternating wave pattern between the two line graphs. See chart 3.

It is however bewildered to accept the nature of that interdependence because ordinarily, an increase in precipitation should result to an increase in elevation. This could be explained from the fact that high turbine discharge can keep reservoir elevation low. Or spillways can be operated as a precaution against flood and collapse of the dam. However on a cumulative basis, it shows a weaker positive correlation indicating that if rainfall continue to increase for a long spell of time, there will be a fair rise in reservoir elevation while prolong drought will bring about a decrease in reservoir elevation.

To make a deductive evaluation of precipitation and turbine discharge, it should be expected that higher precipitation will yield a low power out-put on annual basis, based on the nature of its variability's with reservoir elevation. This deductive analysis is again supported by the actual correlation of rainfall and turbine discharge, which yield a value of -0.3554 (35.54%) on the average. On a prolonged basis it yields a lesser value of -0.2727 (27.27%).

Observation from the correlation coefficient between evaporation and reservoir elevation high positive values are obtained with 0.5300 (53%) on the average. This shows that reservoir elevation has a strong association with evaporation. As reservoir elevation increases, the evaporation also increases due to area coverage. On a cumulative basis, it also gives even a higher positive correlation coefficient of 0.6969 (6969%). This implies that as reservoir elevation continues to increase for a long period, there is a corresponding increase in evaporation depending on whether it is dry or rainy season, SInce the rate of evaporation is higher during the dry season.

Ordinarily, it will be expected that evaporation will result to a decrease in reservoir elevation. However, this contrast is attributed to the overshadowing effect of inflow on evaporation. As demonstrated on the line graph, the peak of evaporation is in the late autumn and winter (i.e. August to April). This corresponds with the peak of the inflow - the white flood which is generated from the catchments basin. The complementary flood - "The black flood" arrives the reservoir from the upper course of river Niger in Guinea high lands during its transit in the winter period. It takes some months for the black flood that brings in large volume of water but lower in quantity than the white flood. Reference to the actual correlation coefficient between evaporation and turbine discharge and power out-put a mean value of 0.3313 (33.13%) is obtained for turbine discharge and 0.5645 (56.45%) for power output.

However, on a cumulative basis a negative correlation coefficient of -0.1151 for turbine discharge and -0.0909 for power output imply that if evaporation persist on a prolong duration, turbine discharge and power out-put will reasonably drop depending on the size of the reservoir and the amount of storage.

4.1 THE NIGER FLOOD FLOW VARIABILITY AND THE KAINJIDAM

Water is the main source of fuel for power generation at Kainji power station. The fact that hydrology is highly data dependent, continuous monitoring of the available water is essential to the water that can be depended on certain conditions. Dependable water utilization in hydro-power generation at Kainji dam is very much tied to adequate data from across the river Niger's catchments at the upper, middle and lower courses.

4.1.1 SEASONAL VARIABILITY OF DISCHARGE

The mean monthly discharge over 33 years was computed to obtain the seasonal variability of the flow pattern on the Niger's regime in to Kainji reservoir Table 4. Indicates that the highest average discharge occurs in September and minimum average discharge occurs in the month of May.

The daily values have been used to develop the hydrographs shown in Chart 4. There is a striking similarity to the seasonal rainfall induced white and black floods with two distinct peaks. The highest peak, which range between 1467m^3/sec to 5141m^3/sec corresponds to the white flood generated during the wet season experienced between July and October at the lower Niger in Nigeria. The Shorter peak corresponds to the Black flood period, which occurs between November and April, the following year. This second flood is as a result of the rainfall occurrence at the headwaters of the Niger in the Fouta Djallon Highlands in Guinea and the Guinea-Malian border: These findings agree with earlier studies of NEDECO (1961) and Sagua and Fregene (1977).

(J-IAIZT 4-

HYDROGRAPH OF RIVER NIGER AT JIDDERE BODE.

4500
4000
3500
3000
2500
2000
1500
1000
500
0

-1988/89
-1994/95
1998/99
-2000/01
-2001/02
-2002103
-2003/04
-2004/05
2005/06

MONTHS

4.1.2 ANNUAL VARIABILITY OF DISCHARGE

The pattern of discharge variation from the river Niger into Kainji reservoir for alternate years over a period of 33 years is summarized in Table 4. The Table shows that there are both wet dry years occurring over different periods. It also shows that a sequence of wet years is followed by a sequence of dry years.

The first wet phase in the post impoundment operation history of Kainji dam reservoir lasted for years (1970-1971). Hardly had the dam been commissioned when the well-documented sahelian drought struck in 1972 and a dry phase was begun and lingered for several years and up to the early 1990s. Annual discharge within these dry phase was generally below 30 Billion nr'. Within this dry phase, there are however isolated wet years such.as 1979, 1981 and 1988 when inflows are significant.

The second wet phase that started in 1994 and was in progress up to 1999, which is characterized by high inflows of between 3931 to 5141m^3/sec recorded in 1994 1998 and 1999 with annual runoff of 35.6, 43.2 and 45.00x109 m^3/sec respectively.

Table 4: Monthly Average Inflow into Kainji Reservoir in m^3/sec

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL ($X10^9M^3$)
1969	2095	2133	1574	626	225	145	471	1341	2430	2236	1564	1963	49.2953
1971	1770	1764	975	330	84	46	395	918	2448	1758	1578	1751	34.9411
1973	1612	1069	436	102	2	127	278	974	1467	1443	1454	1556	25.3255
1976	1913	1929	1181	416	182	221	224	851	1412	1600	40	1617	36.0069
1978	1363	849	309	149	146	213	286	1045	2331	1689	1566	1624	24.2427
1980	1920	1681	733	198	52	128	697	11337	1571	1453	1438	1543	27.9966
1982	1694	1511	447	145	79	143	306	1278	1646	1411	1399	1410	25.8067
1984	901	432	172	44	32	112	145	538	1088	1348	1167	1079	17.2376
1986	1230	591	252	60	55	102	505	927	1563	1400	1342	1327	24.5085
1988	962	467	185	80	92	170	505	1490	2898	2157	1544	1555	32.8208
1990	993	462	190	73	52	56	262	1046	1594	1283	1315	1301	24.3351
1992	1208	624	271	98	69	84	378	1177	2234	1419	1341	1347	25.8235
1994	1073	573	209	61	32	183	456	2104	3369	2664	1706	1678	46.0158
1996	1685	1541	674	282	188	273	344	1182	2167	1761	1486	1531	32.4663
1998	1475	938	329	146	150	444	1018	2568	3095	2762	1668	1694	45.3126
1999	1753	1445	631	258	150	183	659	2207	3748	2644	1734	1720	47.6838
2000	1799	1773	1090	368	151	219	506	1703	1851	1644	1508	1581	38.2784
2001	1674	1408	601	203	89	175	729	1897	2825	2057	1556	1622	38.9598
2002	1659	1319	578	290	192	334	447	1059	1987	2025	1487	1447	33.6857
2003	1302	633	262	148	96	362	1034	2160	3278	2698	1716	1772	40.8846
2004	1819	1635	731	263	176	153	804	1794	2092	1538	1324	1414	36.1986

Source: KHPBU HYDROLOGICAL RECORDS

Table 5: Summary of Historical Inflows into Kainji Reservoir For 31 Years (1970-2000)

MONTH	MEAN MONTHLY FLOWS M^3/Sec	AVERAGE HISTORICAL MAX FLOWS M^3/Sec	AVERAGE HISTORICAL MI FLOWS M^3/Scc	AVERAGE HISTORICAL RUNOFF X $10^9 M^3$
JAN	1445.78	1654	1283	3.8744
FEB	1106.87	1373	845	2.7081
MAR	572.06	893	372	1.5321
APRIL	473	387	129	0.6003
MAY	105.76	248	61	0.3093
JUN	171.13	414	87	0.4523
JUL	419.67	958	176	1.1243
AUG	220.06	2080	604	3.2603
SEP	2052.04	2509	1657	5.3115
OCT	1728.13	2084	1502	4.6276
NOV	1480.43	1567	1437	4.8431
DEC	1535.29	1577	1419	4.0959

SOURCE: KHPBU HYDROLOGICAL RECORDS, 1980

4.1.3 THE WHITE FLOOD

Chart 4 shows the hydro-graphs of the inflow into Kainji reservoir from the river Niger for some years selected. Table 6 presents variations in the onset cessation duration and maximum discharge of the white flood into Kainji reservoir from 1970-2003. It should be noted at onset that the river Niger flow rate as measured at Jiddere-Bode is usually lower than total inflow into Kainji reservoir, which includes contributions from lateral feeder channels such as Rivers Sokoto-Rima and Malando.

Chart 4. Show that the white flood is usually initiated in the month of June but the hydrographic response of the flow becomes prominent in July. The duration of the white flood from the onset to cessation varies from minimum of 110 days in *1989190* to maximum of 194 days in 1991192, with a mean duration of flood flow of 150 days for over 33 years. Table 6 also shows the variation in the magnitude of the peak discharge rates of the white flood. The highest peak occurred in *1998/99* with a flow rate of *3719m3/sec* while the lowest peak of *1211m3/sec* occurred in *1983/84* hydrological season. Interpreted together, the White flood is of higher magnitude than the Black flood but of shorter duration.

4.1.4 THE BLACK FLOOD

The pattern of yearly variation in the initiation, peak discharge rate and duration of the black flood are also discernible from an examination of both Chart 4 and Table 7. From Table 7, it will be seen that the highest peak discharge value of *2375m3/sec* was obtained in 1969 and ever since, peak flow has been below *2000m3/sec.* Infact , it has been on a downward trend generally below *1600m3/sec* between 1982 and 1993 until 1994 when significant improvement starts again. The lowest peak discharge value of *1190m3/sec* is that of 1983. Interestingly enough, the lowest peak flow rate of both the White and Black floods occurred in 1983. As Table 7 indicates, the start of the Black flood is usually in November each year to peak in January. There are however isolated cases when the Black flood starts in October (1978 & 1982) or in December (1975, 1976 & 1994).

On duration of flow and in contrast to the White flood, Black flood is of longer flow duration which caries from a maximum of 239 days (1992) to minimum of 178 days (1979) and a mean duration of 208 days, for 33 years of recorded flow. It is pertinent to state here that over years, the complementary role and, indeed, the contributory benefit of the Upper Niger flood flow (Black flood) to the success of Kanj i reservoir operation has never been in doubt. For instance under normal operating condition, the runoff from the local white flood gives Kainji reservoir a build up to storage of about 8 billion cubic meter of water. It is the Black flood which originates from the Upper Niger that usually raise Kainji reservoir to its full supply storage of 15 billion cubic meter of water. In summary, Kainji reservoir is being fed by the waters of both White and Black floods.

Table 6: Variations in the Onset Duration and Peak Discharge of the White Flood Inflow into Kainji Reservoir As Measured At Jiddere-Bode

HYDROLOGICAL YEAR	START OF FLOOD	ENDOF FLOOD	DURATION OF DAYS	PEAK DISCHARGE (mJ/sec)	PEAK DATE
1969170	10/6/69	16/11169		1570	1/1069
1970171	717170	7/11170	123	2604	2119170
1971172	28/6171	14/11171	137	2446	11/9171
1972173	21/6172	12/11172	135	1878	18/9172
1973174	417173	1/11173	120	1570	27/9174
1974175	217174	20/11174	141	2780	25/9174
1975176	20/6175	1112175	164	2314	4/10175
1976177	3/6176	4112176	183	1451	3/10176
1977178	217177	11111177	132	1682	15/977
1978179	217178	2411 0178	114	1818	5/10178
1979/80	3/6179	22/11179	145	2278	5/10179
1980/81	19/6/80	4/11/80	162	1589	15/9/90
1981182	19/6/81	31/10/81	134	1752	23/9/81
1982/83	20/6/82	30110/82	132	1760	2/9/82
1983/84	16/6/83	2/11184	139	1211	1/9/83
1984/85	15/5/84	19/11/84	188	1268	17/9/84

Continued,

HYDROLOGICAL YEAR	START OF FLOOD	ENDOF FLOOD	DURATION OF DAYS	PEAK DISCHARGE (m3/sec)	PEAK DATE
1985/86	22/6/85	31110/85	131	1886	26/9/85
1986/87	16/586	22111186	190	1573	28/9/86
1987/88	29/5/87	1311/87	168	1354	5110/87
1988/89	116/88	18111188	170	2878	12/9/88
1989/90	16/6/89	4110/98	110	1768	4110/89
1990/91	19/6/90	1111190	135	1635	15/10/90
1991/92	12/5/91	22/11191	194	1966	9/9/91
1992/93	29/6/92	24/10/92	117	2198	15/9/92
1993/94	6/6/93	2/11/93	149	1535	1119/93
1994/95	7/7/94	15112/94	191	3047	25/9/94
1995/96	27/6/95	31110/95	126	1627	3110/95
1996/97	116/96	5/11196	157	2246	17/9/96
1997/98	28/5/97	29/10/97	154	1744	20/9/97
1998/99	18/5/98	22111198	188	3719	28/9/98
1999/2000	116/99	29/1199	180	3271	14/9/99
2000/2001	28/5/2000	2111112000	176	2038	24/8/2000
200112002	31/5/2001	21/11/2001	173	2718	22/9/2001
2002/2003	1/6/2002	22/11/2002	173	2054	21/9/2002
2003/2004	29/5/2003	24111/2003	178	3480	1/10/2003
2004/2005	18/6/2004	411112004	138	2038	16/9/2004

SOURCE: KHPBU HYDROLOGICAL RECORDS

Table 7: Variations in the Start Duration and Peak Discharge of the Black Flood Inflow into Kainji Reservoir As Measured At Jiddere-Bode.

HYDROLOGICAL YEAR	START OF FLOOD	ENDOF FLOOD	DURATION OF DAYS	PEAK DISCHARGE (mJ/scc)	PEAK DATE
1969/70	17/11169	6/7/70		2375	20/3/70
1970/71	8/11/70	27/6/71	217	1869	2411/71
1971/72	15/11/71	20/6/72	217	1906	2311/72
1972/73	13/11/72	3/7/73	228	1690	7/1/73
1973/74	2/11/73	1/7/74	215	1571	22/12/73
1974/75	21111/74	19/6/75	222	1876	2111/75
1975/76	2/12/75	2/6/76	182	1990	3111/76
1976/77	5/12/76	1/7/77	208	1882	12/2/77
1977/78	12/11/77	1/7/78	231	1497	6/1/78
1978/79	25/10/78	2/6/79	220	1795	2411/79
1979/80	23/11/79	20/5/90	178	1935	16/1180
1980/81	5/11/80	18/6/81	225	1566	23/12/80
1981182	1111181	19/6/82	230	1721	1411/82
1982/83	31110/82	15/6/83	227	1369	19/1183
1983/84	3/11/83	14/5/84	192	1190	1112/83
1984/85	20/11/84	2116/85	213	1558	22/12/84
195/86	1111/85	15/5/86	195	l355	9112/85
1986/87	23/11185	28/5/87	186	1297	15112/85
1987/88	14/11187	31/5/88	198	1596	12/12/97

Continued,

HYDROLOGICAL YEAR	START OF FLOOD	ENDOF FLOOD	DURATION OF DAYS	PEAK DISCHARGE (m3/sec)	PEAK DATE
1988/89	19111188	15/6/89	208	1362	1/11/88
1989/90	16/11/98	18/6/90	214	1340	11112112/89
1990/91	2/11/90	11/5/91	190	1362	26-27111190
1991192	23/11191	2/7/92	221	1428	18112/91
1992/92	2/11/92	29/6/93	239	1362	14/12/92
1993/94	3/11193	7/6/94	216	1363	10/12/93
1994/95	16/12/94	26/6/95	192	1846	29t11 Jan ,_2nd Feb, 1195
1995/96	4111/95	3115/96	208	1768	26-27/1/96
1996/97	5/11196	27/5/97	202	1596	17/1197
1997/98	30/10/97	17/5/98	199	1581	31112/97
1998/99	23/11198	3115/99	189	1776	2211/99
1999/2000	29/11/99	27/5/2005	178	1830	4/2/2000
2000/2001	22111/2000	30/5/2001	188	1697	1911/2001
200112002	22/1112001	30/5/2002	188	1713	11/112002
2002/2003	23111/2002	28/5/2003	185	1466	21/12/2002
2003/2004	25/1112003	17/6/2004	172	1853	15/112004
2004/2005	5111/2004	3/6/2005	178	1443	24112/2004

SOURCE: KHBU HYDROLOGICAL RECORDS

4.2 FLOODS MANAGEMENT AT KAINJI DAM

Spillways and or other reservoir outlet facilities are designed to handle a pre-determined problem maximum flood (PMF). Flood problem at a dam site and the environment can be very severe, if the predetermined PMF exceeded or there are inadequate flood routing facilities. The dam may be overtopped or the flood may escape through another route. Either of the two events can lead to damages to the dam structures, power house facilities, loss of lives, properties and general ecological damages.

4.2.1 FLOOD CONTROL STRATEGIES

Kainji reservoir operation under the flood control zone as shown in Chart 5. Three major forms of flood control strategies are usually adopted at Kainji depending on the magnitude of the anticipated flood and how much the situation threatens the safety of the dam. They are:

a Flood control that requires storage

b Flood control that requires a draw-down

c Flood control that requires step-release

For flood control strategy that requires storage, it must be borne in mind that the large storage space of 15 billion m' of Kainji reservoir is for flood control. The flood is retained in the reservoir and flood releases can be made later.

In the second approach, the filling operation of the reservoir is delayed to allow as much flood water to be routed out. The strategy is to lower the water level in the reservoir in anticipation of flood as predicted by hydrological forecast. Error in flood forecast may however result in wastage. This method as chart 5 indicates was very effective in 2000

DISCHARGE IN M3/ SC
EVAPORATION TAKEN INII ACCOUNT

YEAR OF OPERAnON

NIGE~ DAMS AUTHORITY
KAINJI O~VEIO"MEN'
FLOOOCONTROL· FIWHG . AND
EMPTYING CURVES

When Kainji reservoir was draw-down to elevation 131.6m in July-the lowest in the history ofKainji operation.

The third strategy whIch is the step-release schedule is usually adopted when the reservoir level is still very much below the design pool level of elevation 141.73m.

In summary, spillway releases are considered uneconomical at Kainji Power Station as water constitutes the main fuel for power generation. But available operation data have shown that spillway releases are embarked upon to:

a Prevent overfilling and or overtopping which could affect the structure of the dam.

b Boost Jebba reservoir which is located downstream.

4.2.2 FACILITIES FOR FLOOD MANAGEMENT

Four gated spillways have been incorporated into the design and has built of Kainji dam to increase the flexibilities of operation of the reservoir for flood control. The spillways are located on the left bank of the power house. Each spillway gate when fully raised up, its maximum operating height of 7.2 meters is capable of discharging a flood magnitude of 1195 m3/sec and a total discharge of 7900m3/sec when all the four spillway gates are opened simultaneously at full supply level. The gates are however designed to route the PMF of the River Niger estimated at 10,OOOm3/sec (NEDECO & Balfour Beatty, 1961). Because the design flood was based on limited data, a navigation canal was incorporated in the construction of Kainji hydro facility. As designed and built, this gated canalization has the dual function of allowing the passage of vessels up stream or downstream of the dam as well as discharge flood volumes remaining from the flood routed by the gated spillways especially when flood flows exceed the spillway capacity, at times of emergency to prevent over toping of the dam structure by extra-ordinary flood which could be very disastrous. Other flood defensive measure provided is a freeboard of about four meters, a high value intended to increase the storage capacity. Finally, the design of the Cofferdam is such that temporary heightening can be made to increase the flood control capacity of Kainji dam-reservoir.

4.3 MAJOR FLOOD EVENTS DURING POST DAM PERIOD

In the design of major water resources engineering scheme such as dams, the Probable Maximum Flood (PMF) is often considered because it represents the maximum flood potential. Thus, flood, a hydrological extreme event of significant is very important to dam-reservoir operation. The PMF estimated for the design and construction of Kainji dam reservoir is put at 1O,000m^3/sec (NEDECO, 1961).

Between 1969 and 2004, which is during the 35 years of Kainji dam, a series of significant floods have been recorded on the Niger River but they have been successfully routed through the dam's large storage reservoir and the spillways.

Plate 1 shows the flood routing from the four spillways at Kainji dam and administrative building.

PLATE 1

FLOOD ROUTING FROM THE FOUR SPILLWAYS AND ADMINISTRATIVE BUILDING {1980}

TABLE 8: MAJOR FLOOD EVENTS (POST DAM PERIOD)

Year	Peak flood (m3/sec) in descending order	Date of occurrence	Total inflow (billion m")	Total spillage (Billion m')
1974	3384	5 Sept.	3l.1	*14.5*
1988	3492	10 Sept.	3l.9	60
1994	4074	22 Sept.	*35.6*	*5.8*
1998	3931	28 Sept.	43.2	*2.5*
1999	*5141*	17t11 Sept.	*45.0*	17.1
2000	2038	24 Aug.	37.2	6.7

SOURCE: KHPBU HYDROLOGICAL RECORDS

Table 8 shows that all significant flood event except those of 1984 and 2000, occurred in September and the three highest flood peaks in the series occurred in the 1990 with 1999 value of *S141m3/sec* being the highest flood peak since Kainji dam was constructed in 1969.

Although the estimated PMF of 1*0,000m3/sec* has never occurred, it however appears in Table 8 has indicated conditions of increasing magnitude and or severity over varying timescale particularly from 1991 to 1999. The 1984 flood peak *1467m3/sec* is the lowest on records with the least annual runoff of $18.7331 \times 10^9 m^3$. However, this 1984 low flood peak value increased to *3492m3/sec* in 1988, *4074m3/sec* in 1994, and *S141m3/sec* in 1999. It however drops to another low value *of2038m3/sec* in the year 2000 flood flow.

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

From analysis in chapter four, it is observed that turbine discharge has a very strong positive inter-correlation with power out-put with a correlation coefficient of 86.78% on the average. A much stronger correlation of 0.9515 on a cumulative basis. This implies that when the turbine discharge increase, average power out-put is also increased on annual and cumulative basis and vice - versa.

The correlation coefficient between turbine discharge and reservoir elevation also yield a positive value but comparatively less than that obtained between turbine discharge and power out-put. A mean value of 0.3813 (38.13%) and on a cumulative basis, a lesser positive value of 0.2242 (22.42%) was obtained. This again implies that when the reservoir elevation increases, the turbine discharge will slightly be stepped up. The increase in turbine discharge and power out-put due to increase in reservoir elevation is much lower on a cumulative basis than on annual basis. The relatively weak correlation coefficient is an indication that other factors such as operational, technical or mechanical factors interplay to determining turbine discharge.

It is also seen that inflow has a very strong correlation coefficient with reservoir elevation to a mean value of 0.5861 (58.61%) and on a cumulative basis a higher one 0.9300 (93%). This shows a high positive interdependence. It implies that as inflow increases, reservoir elevation also increases proportionately. It was deductively viewed that inflow also impact positively on turbine discharge and in turn power out-put though at a lesser extent yielding 0.1557 for turbine discharge and 0.2031 for power out-put. It implies that when inflow increases, turbine discharge and power out put slightly on the Increase depending on the level of the reservoir.

Correlation between rainfall and elevation, yield high positive values with mean correlation value of 0.7409 (74.09%), While on a cumulative basis, it yield a positive weaker value of 0.3939 (39.39%). This reveals that on annual basis when rainfall increases, the reservoir elevation will increase and vice versa. Deductively it was observed that rainfall has a fair negative implication on turbine discharge and power out-put. It yields a mean value of -03554 and on a cumulative basis -0.2727. Thus as rainfall increases, turbine discharge and power out-put fairly reduce, at times to allow lake build-up. It is anticipated that the inverse interdependence of reservoir elevation on rainfall is due to the high consumption rate of turbine discharge and spillway release to avert flood and collapse of the dam during heavy rains.

The correlation between evaporation and reservoir elevation yield moderate positive value with values of 0.5300 (53%). On a cumulative basis, it yields a much higher positive value of 0.6969 (69.69%). It indicates a good interrelation between evaporation and reservoir elevation. This means when reservoir elevation increase, there is a corresponding increase in evaporation both on annual and prolonged basis. The nature of this interdependence is contrary to the natural law but it is attributed to be overwhelming effect of inflow (black flood) that arrive the reservoir in the dry months when evaporation is high.

Deductively it is observed that evaporation has a fair positive correlation with turbine discharge and power out-put. A mean value 0.3313 (33.13%) for turbine discharge and 0.5654 (56.54%) for power out-put were derived. This indicates that as the rate of evaporation increases the turbine discharge and power out-put has tendency to increase. But on a cumulative context a negative slight value of -0.1151 (11.51 %) for turbine discharge and -0.0909 (9.09%) for power out-put were derived. This implies that if evaporation increase over prolong years, the turbine discharge and power out-put will slightly reduce.

Total energy generation basically depend on turbine discharge. The extent of turbine discharge is determined by reservoir elevation and storage among other factors such as operational and mechanical systems. Reservoir elevation from which turbine discharge is derived is much more been recharged by the inflow basically the white & black floods which arrives the reservoir in summer and winter respectively. The recharge (inflow) on a prolonged duration affects reservoir elevation and power out-put positively. That is increase in precipitation over a long period will produce an increase in reservoir elevation and corresponding power out-put.

Thus the inflow is considered the most significant process that ensure a consistent high power out-put which is determined by the magnitude of precipitation in the lower & upper Niger course which has its source from the Guinea high lands.

The hydrology of the river Niger has been discussed with particular reference to its flood and flood management for sustainable hydro electric power generation at Kainji dam. A large and long river such as the Niger which traverses climatic and political boundaries of Mali, Niger Republic and Nigeria is an important asset to the countries it traverses in West African sub region, constituting a source of wealth and social development.

An essential element in the rational use of the potential of the river Niger and adaptation of the river's regime to human need is the construction of dam projects whose primary purpose is power generation but with additional benefits in the areas of flood control, improved river Navigation, draw down and irrigated agriculture, fisheries, recreation and tourism among others.

From Hydrometeorological point of view, the Niger river is not different from any other river in a tropical environment with distinct Wet and Dry seasons. Rainfall is therefore not uniform over the entire catchment area varying from an average annual value of l090mm at the upper Niger, about 568mm at the middle Niger and 958mm as measured at the lower Niger.

Following the rainfall regime, the Niger's water level starts to rise when the wet season stabilizes in June/July with the onset of the White flood which reaches its peak in September/October. The Niger's level then recedes sharply then flattening down in the dry season between November and December to be intercepted by the in-coming Black flood water from the Upper Niger. The water of the Black flood which is clearer sustains the Niger's flow during the dry season from November to the following year to reach its lowest level in June/July.

The advantage of the river Niger over most rivers in West Africa is its dual and complementary White and Black flood regime. The flow rate of the White flood which is of higher flow magnitude but shorter duration varies from annual peak value of historical maximum and minimum of 3748 and 145m^3/sec respectively.

Analysis of about 35years of recorded flow data has shown water deficits sparring over two decades. This has been compounded by the Sahel ian drought which lingered till early 1990s. There were however isolated cases when copious inflow with peaks of between 3,000 and 5,OOOm3/sec entered Kainji reservoir making Kainji Dam to be operated outside the scheduled (proposed) filling and emptying (draw - down) operation curves. Such years include 1969, 1994, 1998 and 1999 during which flood flows particularly the 1998 and 1999 events were unprecedented and were accompanied by spillway releases as forms of flood control.

In concluding this study, I wish to state that hydrological investigation and discussions on river Niger and its basin are on-going. The ever growing trend through information technology is expected to strengthen scientific investigation so as to discover new concepts that will facilitate improved reservoir operation and management of the millennium hydro plants.

SUGGESTIONS FOR FUTURE/FURTHER RESEARCH.

These research projects assess the Hydro meteorological aspects in Reservoir management of the lake basin; the constraints are mostly in the area of having adequate and this provides potential for deficiencies in studies carried out in this domain.

Since this study provides hydro-meteorological information necessary for the management of the Kaniji Hydro Power Business Units. Suggestions are for future researches, attention should be focused on development of networking of continuous observation and monitoring geared towards impact studies on Hydro meteorological variables of the study area.

REFERENCES

Abiodun, A.A (1973). Waters oflake kainji-hydrological predictions and performance. In: Hydrological Science Bulletin 18(39) pp321-327.

Abiodun, A.A (1975): Analysis of Seepage into ground water sytem.

Acres, B.D., Rains, A.B., King, R.B., Lawton, R.M., Mitchell, A.J.B. and Rackman, L.J. (1985): African Dambos: their distribution, characteristics and use.

Aluko M.O., Abiodun, B.J. and Fasheun, T.A. (1995). Numerical prediction of weather extremes in the West African sub-region. In: the proceedings of the Regional Training workshop on impact of Human Activities on the west Africa Savanna,Akure, Nigeria.

Dhar O.N, Rakhecha P.R, Sangam R.B, 1975: Study of major rainstorms over and near Mahi basin up to Kadana dam site for evaluation of probable maximum design storm.

Freeman W.H (1974): "Water a primer". San Francisco.

Hayward, D.F, Oguntoyinbo J.S, (1987): The Climatology of WestAfrica. Huchinson, London

Tropical Hydrology and Water Resources by J. O. Ayoade (1988)

NEDECO and Balfour Beatty (1961). Niger Dam project. 2 (2) Hydrology and Reservoir Operation, The Hague.

Some research priorities. In: The proceedings of the National conference on two Decades of Research on Lake Kainji, New Bussa.

Oke, V.O, S.P. Fregene and Adeagbo, M.A. (1992). Status of NEPA reservoir operation and management. Paper presented at Nigeria's Water Forum at NWRl, Kaduna

Oguntoyinbo, J.S and Ayoade, T.O. (1989). Meteorology and the Hydrological behavior of natural and man-made lakes in Nigeria:

Peterson J.A, (1984): Stratigraphy and sedimentary facies of the Madison Limestone and associated rocks in parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming: U.S.Geological Survey Professional Paper 1273-A, 34 p

Subbaramayya, I and Rao, G.N. (1989), Hydrometeorological aspects of the 1986 floods in Godavari River: Indian Journal of Power and River Valley Development.

Sagua and Fregene (1979): Kainji Dam and the hydrology of the River Niger. In: The proceedings of the international conference on Kainji Lake and River Basins Development in Africa, Ibadan; pp223-233.

Sagua, V.O. (1977). The effect of Kainji Dam Nigeria upon fish production in the river Niger below the dam at Faku.

Tarafdar M.R. (1992). Measures taken for operation of Dam before, during and after flood: case study: paper presented at a NEPA Organized Training workshop on Dam Operation, Maintenance and Safety, Lagos; pp5.

Guide to Hydrometeorological practices, (1970), by
WMO-No 168.TP 82.

Wurbs R.A, (1993): Reservoir system simulation and optimization model.