International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-9, Issue-5; May, 2022
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.95.35

# Hydrological Risk Mitigation from Natural Hazards in Ojirami Dam Edo State Nigeria

Jonathan Abulime[1], Ikri Samuel Obokparo[2]

[1]Department of Civil Engineering, Benson Idahosa University, Benin City, Edo State, Nigeria.
jabulime@gmail.com
[2]Institution of Civil Engineers, London, United Kingdom.
sikri@biu.edu.ng

Received: 19 Apr 2022,

Received in revised form: 11 May 2022,

Accepted: 18 May 2022,

Available online: 31 May 2022



***Keywords*— Reservoir, Catchment area, Spillway, Dam, Return period, Precipitation**

***Abstract*— *The objective of this paper works is to analyze the rainfall and runoff discharge of the Ojirami dam area, and effective modeling and simulation of hydraulic parameters in water distribution network and design of hydraulic structure (Reservoir water tank). The engineering tools used in this research work are EPANET PROGRAM, AUTOCAD, GOOGLE EARTH and GIS for portable pipe born-water supply, regarding to the relief of the inhabitants towards mitigation of risk from natural hazard, by protecting lives and properties against diseases: such as cholera and dysentery. During investigation and modeling the water network, the following climatic elements are defined: monthly and annual rainfall, maximum wind velocity for prevailing direction, free water surface evaporation, air temperature, relative humidity and sediment transportation. The capacity of the reservoir of the Ojirami dam is equal to 5 Mcm (5 X $10^6$) the dam height of 7m and is located within Akuku community boundaries, Akoko-Edo Local Government Area, Edo-State. The area has a moderate slope around the dam too steep in higher parts of the dam. Due to proper researched on the internet and other information collected from Edo state water board and relevant statistics data from census of Nigeria. The dam was constructed across Onyami river the output capacity of the reservoir is about 473$m^3$ per/hr. The construction dam is used as a source to supply water to the water distribution network. Google earth was used to generate toposheet of Akoko-Edo Local Government boundary, while Geographic information system was used to create Nigeria local government map and boundaries, due to local government shapefile data of Nigeria. Epanet program was used to digitalized the water network, whichis based on census data and to estimate water demand. The Epanet tracks the flow of water in each pipe, the pressure at each node, the height of water in the tanks, and the concentration. The preliminary modeling of the (WDN) concluded that the water distribution network is sufficient to supplied water to communities. The water quality and the cost of modeling the water distribution network (pipe network) were estimated.***

## I. INTRODUCTION

The atmospheric part of the circle when the moisture of the atmosphere return to the ground as precipitation. Important engineering problems arise from the variability of precipitation in space and time. They include securing the water supply conveyance for humans, agriculture and industrialneeds, providing storm water supply from drainages due to floods ranging in magnitude from minor over bank flows to the largest floods and that in which nature can produce.

In study of hydrology of catchment does not limit to geological nature of specific importance in the determination of maximum rainfall which is critical for hydraulic structural design. Furthermore, the determination of the appropriate reservoir pattern of precipitation, seepage and evaporation. Thus, the acquisition essential for such forecast and design purpose. The basis of hydrological forecasting is the representation of basin processes and the movement of water both through and over the land surface which also represent the aquifer processes such as forecasting can lead to improved water management, including flood and drought prediction or water demand supply. The chorological graphical representation of stage or discharge is often used to portray the behavior of the river during normal weather conditions, flood or droughts.

It is an unfortunate trait of human nature that all professions like to hesitate to advert their failure. Notable successes are broadcast for the world to hear, but the failures are spoken of only in muffled tone. Professionals pride and ethics are the principal reason for this situation. It is nevertheless true that a full knowledge of the failures and their causes provides some of the most valuable informationthat can possibly serve to guide the engineer or other practitioner.

Most history of hydrology examples of hydrologic failure was as result of faculty understanding of the principle of hydrology failures which include the failure of dams resulting from inadequate spillway capacity, causing overtopping and erosion of embankment, the economic failure of water-power development, storage reservoirs, water supply system etc

A dam is a hydraulic structure of impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. These purposes may be irrigation, Hydro- power, water supply navigation. Dam may be built to meet the one of the above, purpose or they may be constructed for fulfilling more than one purpose and as such it can be classified as single or multipurposedam.

A spillway is structures constructed near the dam site to dispose of surplus water from the reservoir to the channel downstream. Spillway is provided for all dams as safety measures against overtopping and the consequent damages and failures. A spillway act as a safety value for the dam, because as soon as the water level in reservoir rises above a predetermined level, excess water is discharged safely to the downstream channel and the dam is not damaged. The spillway must have adequate discharge capacity to pass the maximum flood downstream without causing any damage to the dam or its appurtenant structures. At the same time the reservoir level should not rise above the maximum water level (M. W. L)

A spillway of inadequate capacity may lead to the overtopping of the dam which may cause serious damages and even the failure of the dam. On the other hand, a spillway of much larger capacity than therequired would be an uneconomical design. In addition to provide adequate discharge capacity, the spillway must be hydro dynamically and structurally safe. The spillway surface should be erosion resistance to withstand the high velocities created by the fall of water from the reservoir surface to the tail water. Moreover, the spillway should be located so that the spillway discharge will not undermine the downstream toe of the dam. Generally, some energy dissipating device such as hydraulic jump is providedat the toe for the dissipation of excess energy.

A spillway may be located either in the middle of the dam or at the end of the dam near the abutment.In some cases, the spillway is located away from the dam as an independent structure. If there is a suitablesaddle, such a spillway is called a saddle spillway. Generally, a saddle spillway is designed as an auxiliary or an emergency spillway, which is an addition to the main spillway at the dam site.A major portion of the storage volume in the reservoir on the upstream of a dam is below the spillway crest level. Dam outlets are provided in the body of dam or its abutment below the crest level of the spillway so that the water can be withdrawn from the reservoir. Sluiceways are special type of outlets provided in the body of a concrete (or masonry) dam.

Outlet are required for releasing the impounded water as at when needed for various purposes such as hydro-power, irrigation, municipal water supply and pollution control on the downstream. Outlets are also used for diverting water into canals or pipelines. Sometime outlet is design to pass a part of the design flood to the downstream, as a supplement to the spillway. The water released by an outlet may bealso used for a combination of multipurpose requirements. An outlets work may also act as a flood controlregulator for releasing water stored temporally in the space reserved for flood control or to evacuate storage space in anticipation of high floods. The outlets may also be used to empty the reservoir up to the crest level to permit inspection to make needed repairs or to maintain the upstream face of the dam or other structures. Outlets are usually provided with gates and valves for controlling the outflow. These gates and valves may be used for regulating the outflow or for completely closing the outflow depending upon their location and design.

An outlet is a closed conduit formed in the body of the dam, it may also be in the form of pipe or tunnel that passes through the hill side at one end of the dam. The function of an outlet is to discharge the stores water into the channel downstream, for a concrete (or a masonry) dam, the outlets pass through the body of the dam, and they are called sluiceways.

For the earth and rock fill dams, the outlet is generally placed outside the limits of the dam. However, the small earth dams sometimes the outlets conduits are permitted to pass through the body of the dam. Generally, there are more than one outlet in a dam. If the outlets discharge varies considerably, it is always better to provide several small outlets than one larger outlet

## II. EXPERIMENTAL WORK/METHODOLOGY

### 2.1 CATCHMENT AREA

The catchment area controlled by the dam is about 600km$^2$ the towns located in the dam area are Ojirami patesi, Ojirami Afekunu, Dagbala, Uneme – ose, Eturu, Akuku, Enwan, Igara, Okpe, Ikao, Ugboshi.

### 2.2 GEOLOGY OF THE AREA

The service area lies on the basement complex, the broken edge of a widely extending high rocky plateau that dominate the region. The local crystalline rocky of the basement complex consist of granites, gneisses and schist's comprising derivatives such as grandiose, variably magmatised biotite, quartz biotite, hornblende granites and granite ferrous biotitic genesis. The rock is practically impermeable, and aquifer are defined as cleaved jointed and fractured, the decomposed crystalline loose angular sands, clay and lateral horizon on the surface. This loose mantle normally contains some shallow groundwater mainly along intermittent river course where some local hand dug well has been located.


*Fig.1: Physically illustrates the natural geographic features of Akoko-Edo terrain, such as themountain and valley*

### 2.3 DAM Description

The dam is an earth fill structure of about 200m long 7m high at its highest section. The earth embankment has a crest elevation of 78 and the upstream face has a slope of about 2.5 to 2.8. the upstream was design to be mostly grassed. The dam is provided with services spillway which are supported with abutment on both sides.

The spillway is made of concrete with a gate made of metal (iron) two set of outlet pipes were installed below for the release of water from the reservoir to the head works, weir and intakes. These outlets are open during period of flow when insufficient water is discharged over the spillway. All pipes are made of PVC of 400mm diameter and thickness of 4mm.

*Fig.2: Image of the Ojirami dam*

*source of water distribution to the network*

**2.4 RESERVOIR CAPACITY:**

The capacity of the reservoir impounded in the dam is approximately, but during my research I found out the present capacity is now 5Mcm.

**2.5 USE OF RUNOFF COEFFICIENT**

Most analytical procedures of estimating runoff involve the use of a coefficient of runoff, which takes cognizance of the drainage area. The volume of runoff could be estimated using an equationof the form.

Q = KP

Where

Q = runoff or discharge

P = rainfall

K = coefficient whose value depends on the surface of the drainage of the area

**2.6 RATIONAL METHOD**

This method is used in evaluating peak runoff rate, a vital parameter in the design of hydraulic structures. If rain fall on an impervious surface at a constant rate, the intensity of the resulting runoff would eventually be equal to the rate of rainfall. At the beginning only a portion of the rainwater gets to the outlet but after a period water will start arriving at the outlet from the entire area, when the runoff rate becomes equal to the rate of rainfall. The time required to attain this equilibrium state is referred to as time of concentration (TC). For small impervious area we may assume that if rainfalls continuously at a uniform rate for a period at least to the time of concentration, the peak runoff will be equal to the rate of rainfall. This forms the basin of the rational formula and which may be expressed as;

$Q_{max} = c \cdot I(tc) \cdot A$

Where:

Q = Max is the peak flow C = Is a runoff coefficient A = Is the catchment area

I(tc) = Is the intensity of rainfall of duration equal to the tc (as in the IDF curve)

**2.7 TIME OF CONCENTRATION (TC)**

It is defined as the time needed for water to flow from the most remote point in a watershed to thewatershed outlet. It is also the time necessary for watershed to entirely contribute to the surface flow. The time of concentration depends on topography, land use and geomorphology.

**2.8 RECURRENCE INTERVAL OR RETURN PERIODS**

Return period (or recurrence interval), Tr is the average time that elapse between two event that equal or exceed a specified level. In other word an "N" year flood is that flood which can be expected to be equaled or exceed on the average once every "N" year. An estimate of its recurrence interval overturns.

Period Tr is given by the Hazen's formula Tr = 2n/2m1

But the most widely used is the Gumbel formula

P = m/n + 1 or Tr = n + 1/m

## III. DATA ANALYSIS AND DISCUSSION OF RESULTS

### 3.1 SEDIMENT TRANSPORT IN ONYAMI RIVER AT OJIRAMI RESERVIOR

The Ojirami reservoir basin has small capacity (5 MCM) and the Onyami river having large inflow (174 MCM), the capacity inflow ratio is low corresponding trap efficiency is also small, Morgan (1986). Most of the inflow is quickly discharged to downstream and the suspended sediment are not able to settle fully.

In general, the greater the capacity inflow ratio, the greater is the trap efficiency. In other words, the sedimentationrate is higher in relatively larger reservoirs. (Abubakar and Sagar, 2013) and (Creaco Enrico,2019)

### 3.2 STUDY AREA DESCRIPTION

The Akoko-Edo Local Government Area lies between latitudes $7^{0}5'59''$ and $7^{0}35'24''$N and longitudes $5^{0}55'12''$E and $6^{0}25'47''$E. It headquarters is at Igarra, approximately 160km from the stste capital. The population as captured by the 2006 population census is 261,567. The total land area is about 1371 km$^2$ with a population density of three people per square kilometer. The area is made of (fourth) 40 villages which is accessible by major and minor roads, main paths and footpaths which link the villages and towns together.

The area has undulating landscape with highland consisting of granite outcrops east of the area. The study area is characterized by the wet-dry tropical climate (Koppen climate type Am), with two districts season the rainy season (April-October**)** and the dry season (November-March). The average annual rainfall is between 1000 and 1500 mm with temperature as high as $37.7^{0}$ being recorded in the region. The vegetation belt that is most prominent in the study area is the Guinea Savannah which is made up of sparsely distributed tress, herbs, shrubs and grasses,

The major agricultural products in the aera are yams, cassava, plantain, maize, cocoyam, livestock and cash crops such as cocoa, cashew, kolanut, oil palm and coffee. Akoko Edo is very rich in mineral resources. Some of the mineral resources available in Akoko- Edo include Marble in Ikpeshi, Gold in Atte, Dagbala and Ososo, previous stones in Ibillo, Granite in Ikpeshi and Gravel in Igarra

(Ogbeide et al. 2003)

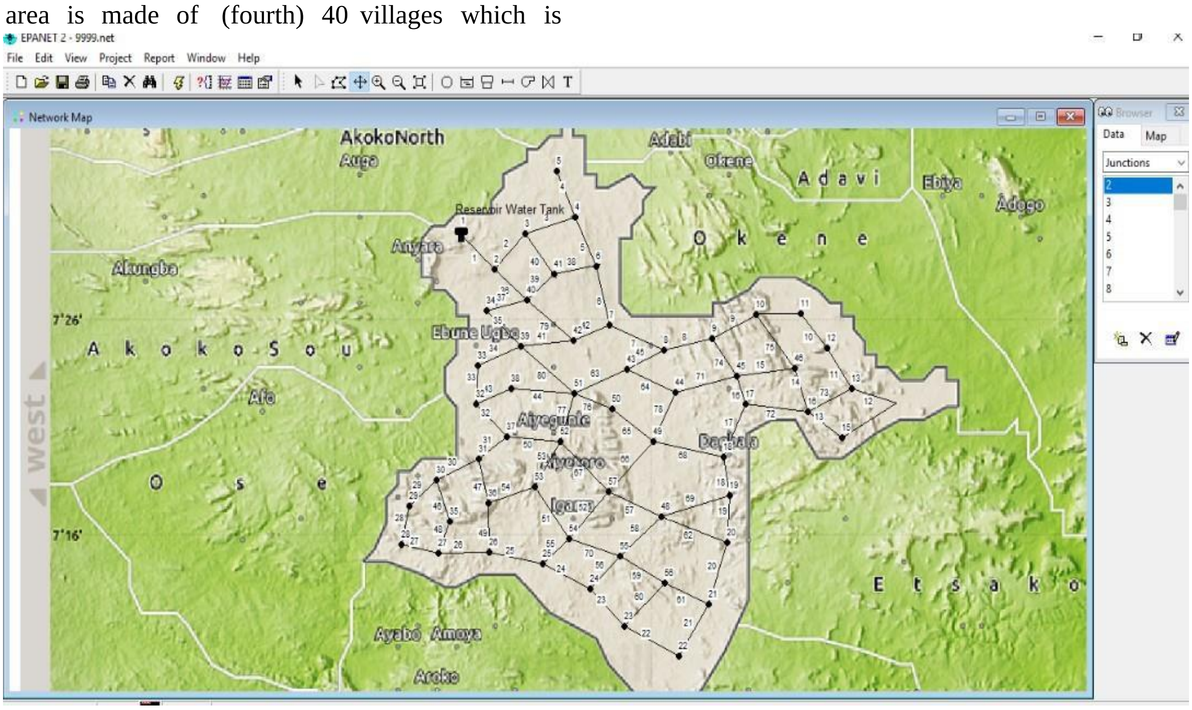


*Fig.3: The digitization of the network with Epanet program*

### 3.3 The Schematization of Akoko Edo Distribution Network System (WDN)

The layout of the schematization of the water distribution network due to rule of thumb, in satellite map shown the land surface as it really looked. Based on image taking from the earth orbit.

After the schematization of the network with epanet platform, the next step was to assign network parameters. The parameters include the pipe length, diameter and roughness, coefficient, node and links ID **(Hazen Williams Equation by the Epanet).** These are basic network parameter on which future.

### 3.3 Water Quality Analysis

The transport of decayed of chlorine was specified in the network due to the manual guide. The bulk coefficient was specified with **-1.0**, the bulk coefficient is what happened in the center of the pipesnear the wall. And the wall coefficient was also specified with **1.0** due to water reaction with the impurities of pipes parameter.

simulation will be based depending on the flow to being simulated. The pipe network is made of asbestoscement pipes varies of different length from (600m, 500m and 400m)

In accordance with the best practice in pipeline analysis, the Hazen Williams friction factor from asbestos cement pipe is 130 (**http://www.primepump.com.au/index**)

### 3.4 Reaction Report of Water Distribution Network

Since only specified the decayed of the bulk flow, that is where most of the decay is coming fromwhereby 0.06% is coming from the tank, shown in figure 3

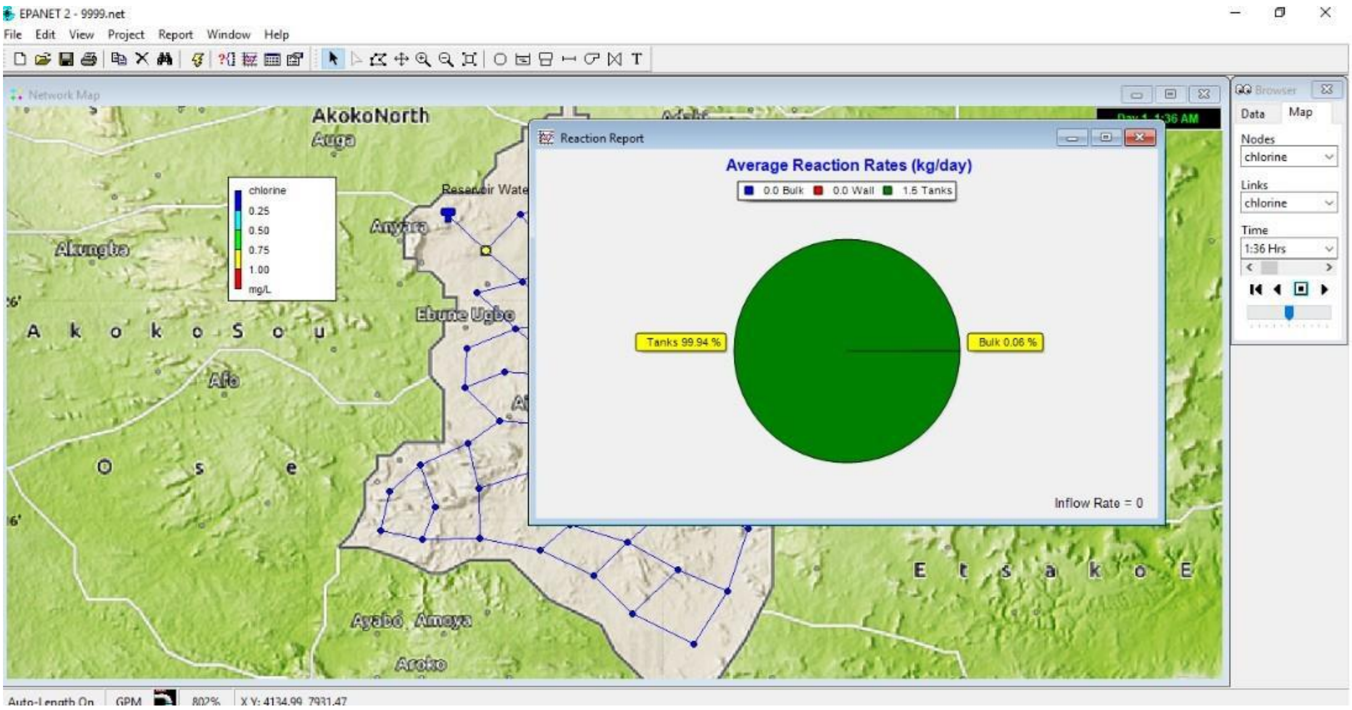


*Fig.4: The reaction of bulk flow in water distribution network*

### 3.6 EPANET Analysis of The Network with The Operation Of Water Proposed Tank

The total height of the water tank is 23m, Epanet was used to evaluate the scenario in which the height is elevated and the advantage, is that it increases the pressure head demand at each node. In real world how the installation of elevated water tank and laying of water pipe network is carry out on site is represented in pictures at the end of the result report analysis. (Creaco Enrico, 2019)

### 3.7 Nodal Head Result under Current Demand

After a proper investigation both on the internet and hydrology and hydraulic textbooks regarding to pressure (psi) in fluid pipes. if the water must move a couple of meters per second, which determine thepressure needed. the longer the pipe the more the energy lost and the greater the pressure drop.

In respect of the akoko-edo schematization water distribution network (wdn), which is designed for both industrial and residential purpose. which include 400,000 inhabitants with 4 stories building and 12meters in height and density area of about 237.8/km$^2$ with topography area of different elevation and with a pipe length of (600, 500, 400) meters which is little bit longer. since the network has a large density area and different surface elevation and longer pipes installation, thorough investigation shown that the (wdn) need a pressure (psi) of about 60 – 300 for both industrial and residential purposes.

With this pressure of flow in the pipe will enable the network to supply sufficient water to the public and supply water to the upper flood of the building. epanet program was used to digitize the akoko- edo water distribution network with a pressure (psi) ranging from

67 – 236 with shown that the (wdn) is generally good having the capacity to supply water to the public.

The main reason to control the pressure in fluid pipe, if the pressure is too high may damage the pipes and appliances. and if is too low (wdn) cannot supply sufficient water to the public. for the network to be on the safer side it was decided to installed the pressure regulatory device which helps to regulate the pressure (psi) in the fluid pipe. the result of the pressure (psi) is shown below in a tabular form with theepanet program.

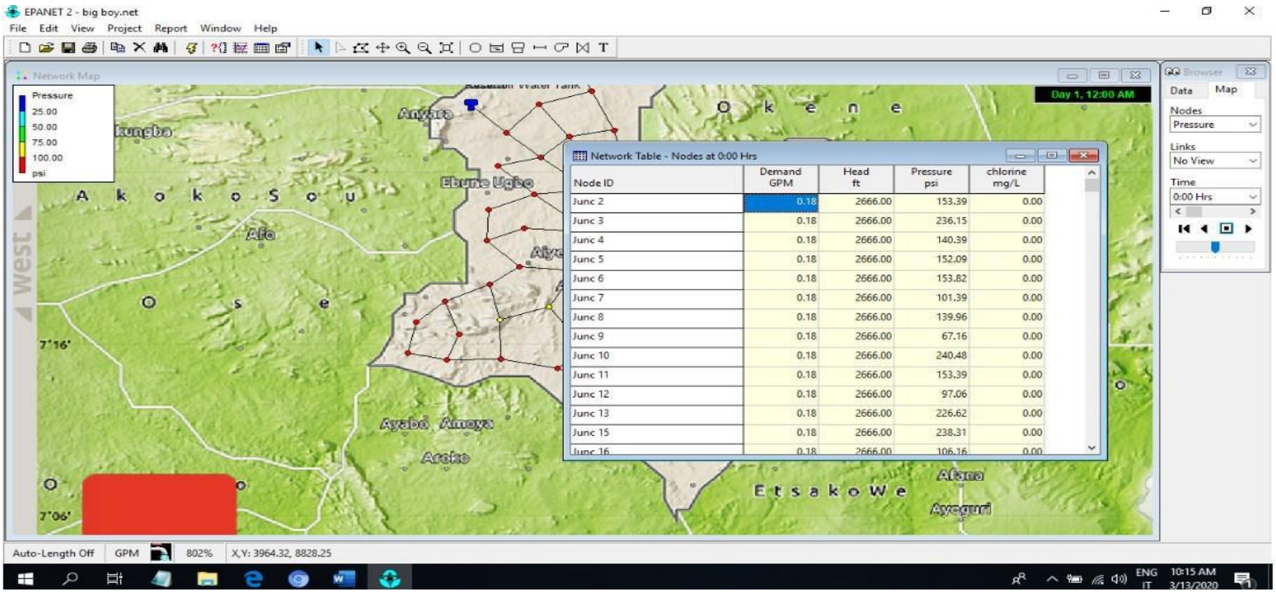


*Fig.5: Epanet Result*

## IV. CONCLUSION

a) In this study, the empirical analysis of the Akoko-Edo Local Government, Edo-State, Nigeria. Water distribution network has been put using epanet computer-based simulation software for water distribution network. Prelude to the analysis a review of literature was carried out whereby the inhabitants leaving in Akoko-Edo Local Government are lacking potable water for drinking.

b) The result of all analysis was supported by charts, screen print and pictures, the current analysis revealed sufficient water supply to the communities attached to the network.

c) The result of the analysis shows that the network has very good pressure heads at reach nodes, and the velocity in the pipes has adequate flow rate.

## V. RECOMMENDATION

The objective of a dam operation been able to manage at any moment resources accumulated in the storage capacity and the expected ones to face the need and to avoid loss of water or lack of storage. So, hydrological studies of dam during the design step as well as in the operation period are essential. As a result, hydrological studies of dam and reservoir can provide better guaranteed on waterallowance for various-uses.

## REFRENCES

[1] Abubakar, A.S and Sagar, N.l. (2013): Design of NDA water distribution network using epanet, international journal of emerging and engineering (IJESE) ISSN: 2319-6378, volume 1, issue 9.

[2] Akintola J.O. “Rainfall distribution in Nigeria (1892-1983) impact publisher Nigeria Ltd, Ibadan. (1986)

[3] Arora K.R “Irrigation, waterpower and water resources engineering” standard publisher distribution (2004)

[4] Creaco Enrico, lecture slide for Hydraulic infrastructures, university of pavia, Italy.

[5] Mario Martina, lecture slide for Hydrological risk, IUSS, Pavia, Italy

[6] Paolo Ghilardi, fluvial hydraulic, for sediment transport, university of pavia, Italy.

[7] Paolo Ghilardi and Patricia Gabriella, lecture slide for flood propagation and structural measures for flood risk mitigation. University of pavia, Italy

[8] LInsley R.K “Water resources engineering” McGraw-Hill book company Inc. New York, N.Y (1986)

[9] Ogbeide H.E. Uyigue E, Oshodin O. (2003) “The impact of dams on the environment and people of Nigeria-Okhore and Ojirami dam in Edo-State as a case study, submitted to society for water and public health protection (SWAPHEP) supported by the global green grant/tide’s foundation.

[10] Taylor D.M. Leslie M.K and Johnson R.C “Ground water modelling key to isolating contamination” wastewater international USA (1989).