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Economic Sustainability of Integrated Hydropower Development of Ero-Omola Falls, Kwara State, Nigeria.

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Abstract:

Economic sustainability of integrated hydropower development of Ero-Omola Fall was investigated in compliance with Hydropower Sustainability Development Protocol (HSDP) developed by International Hydropower Association (IHA) in 2004. Field work was carried out to obtain primary data like streamflows, sediment characteristics, petrographic information, water quality, water quantity demand, hydropower load demand and land topography. Economic optimization of hydropower generating potential of Ero-Omola Fall, integrated with water supply, irrigation and drainage was carried out based on the data obtained from the field work. The potential hydropower of Ero-Omola Water Fall was estimated at 8.0MW, Water supply to communities is estimated at 18 Mm^3/day, irrigation water for Fadama farmers at 2.2 x $10^6 m^3$ and ecological water release of 0.0504 x $10^6 m^3$ were also derivable from the scheme. The modified internal rate of return for hydropower, water supply and irrigation yielded the highest returns of 13% on capital, while hydropower alone yielded 5%. The NPV of cumulative generated cash flows is positive, which indicates that the project would not operate at a loss. The findings also showed that, the sustainable conjunctive use of hydropower releases is the most sustainable mitigation measures against seasonal flooding downstream of the proposed hydropower plant. The study has established a rational basis for the assessment of a typical medium scale hydropower plant which could be adopted for similar locations in Nigeria.

Keywords: Integrated Hydropower, Sustainability, and Engineering Economics.

1. Introduction

There are several thermal power plants and hydropower plants in Nigeria with total installed capacity of 8664MW (FMP, 2013). The combined installed capacity of the three major hydropower stations in Nigeria. (Kainji, Jebba and Shiroro) is estimated at 1900 MW, The estimated demand is 10,000 MW while the available capacity was 5514MW in 2012 (FMP, 2013). The situation is compounded by the failure of the existing power stations to replace vital spare parts due to unsustainable cost recovery mechanism as well as downstream flooding and inundation of farmlands between September and October which has become an annual phenomenon in Nigeria. The inability of the hydropower stations to operate at installed capacity could be attributed to many reasons amongst which are (Jimoh, 2007);

(a) Hydrological factors, such as (i) seasonal variation in flow to the reservoirs (ii) inter-annual variation in flow to the reservoir (iii) conflict among competitive uses and (iv) sedimentation

(b) Non-hydrological factors, such as (i) maintenance and spare part problems (ii) inadequacy of funds (iii) human resources and (iv) engineering economics.

In order to solve these problems many authors (Sule; 1987,1988, 1992), (Jimoh, 2007) and (Salami and Ayanshola, 2006) have carried out reservoir optimization studies to model hydropower releases for optimum benefits. Even though the benefit of optimal hydropower reservoir policy is to reduce seasonal flooding of downstream plains, it does not however optimize the usage of continuous hydropower releases which could as well provide sustainable potable water supply, irrigation and flood control for the benefits of downstream communities. It is widely believed that reservoir operations policy alone may not guarantee security against seasonal flooding. The formulation of sustainable conjunctive use of hydropower releases is the best mitigation measures against seasonal flooding of farmland. Conjunctive use of hydropower releases involves provision of fish passes, water supply facility, irrigation and drainages as well as ecological water balance for downstream eco-systems (IHA, 2007). It has also proved to be the most effective and most sustainable ways of controlling flood since almost 90% of releases would be diverted for useful purposes. The conjunctive use of hydropower releases also ensures that economic activities of benefitting communities are not disconnected by developmental projects. A sustainable water resource system is one designed and managed to fully contribute to the aspiration and desires of the benefiting communities, now and in the future, while maintaining their ecological, environmental and hydrological integrity (IHA, 2007). Economic efficiency and fiscal sustainability demand that the capital costs of hydropower, water supply and irrigation infrastructure should be recovered from the users in order to permit longer –term replication of investments.

For an investment to be worthwhile, the expected return on capital must be greater than the cost of capital. The cost of capital is the rate of return that capital could be expected to earn in an alternative investment of equivalent risk.

Sustainability development protocol of a hydropower project requires that the following activities are carried out accurately and evaluated before development is contemplated:

(a) An accurate prediction of inflow to hydropower plant is critical to sustainable overall prediction of energy derivable from such sites.

(b) Raw water quality must be established to determine its impact on mechanical components of the project and to protect it from corrosion activity as well as to develop an effective treatment plant.

(c) Sediment characteristics of potential site must be carefully determined, so as to ensure that turbines runner is protected to last longer.

(d) Drainage facilities must be provided to divert unwanted flood water from hydropower facilities.

(e) Appropriate pricing mechanisms must be developed based on affordability and willingness to pay.

It is becoming increasingly recognized that poor performance of hydropower project is not only a consequence of poor management problem alone, but that many of the problems stem from inadequate economic justification abinitio. This situation could be attributed to a number of reasons as identified by Labaide (1993, 2004) include:

1. Inordinate focus on project design and construction
2. Inadequate consideration of routine operation and maintenance issues once the project is completed;
3. New unplanned issues which may arise, but were not originally considered;
4. Conflict and competition among competing uses during drought period; and
5 Complex legal agreements, regional issues and pressure from various special interests;

Thus, attention must focus on improving the economic sustainability, use of effective price mechanism and efficiency of reservoir operation to maximise the benefits of such projects and to minimise adverse effect on the environment.

The Federal Government of Nigeria initiated an electricity reform process from 2001-2005. The new reform among other things unbundled the Power Holding Company of Nigeria (PHCN) and brought about the establishment of Nigeria Electricity Regulatory Commission (NERC) in 2005. The new reform allows for provision of electricity by private investors. The purpose is to inject both private and foreign investment into the power sector and allow for appropriate pricing. It is hoped that **a**ppropriate pricing will guaranty:

(a) Recovery of an appropriate return on capital invested, depreciation and replacement of capital and recovery of operation and maintenance including overhead cost.

(b) Appropriate electricity tariff as the key to cost recovery and underpins the long term viability of power projects. Currently prices charged do not reflect the true cost of providing electricity services in Nigeria.

(c) Achievement of an economical, sustainable and efficient allocation of resources in a free market economy where producers and consumers would be paid and pay, respectively, for costs associated with services so produced.

The reform also provides a special hydropower intervention fund at the Bank of Industry (BOI), United Nation Development Programme (UNDP) and Central Bank of Nigeria at 5% interest rate, so as to boost electricity through Public-Private-Partnership (PPP), Nigeria Independent Power Producers and the National Integrated Power projects (NIPP) arrangement.

This study seeks to analyze capital investment and operating costs of an integrated hydropower scheme at the Ero-Omola Falls over the useful life of the project with a life-cycle assessment of alternatives forming an integral component of evaluation processes. The Ero-Omola Fall is located along Osi- Isolo-Ajuba Road off Osi-Idofin road in Oke-Ero LGA, Kwara State, Nigeria. It is about 116 km from Ilorin, the capital of Kwara State. The height of the fall is about 59.01m. The catchment area of Ero-Omola-Falls is about 145km^2 with contribution from two rivers namely, Ero-river from Iddo- Faboro near Ifaki in Ekiti State and Odo-Otun river from Ajuba. Ero-Omola Falls lies between latitude 08^0 09’ 34.6”N and 08^0 09’ 30.8”N and between longitude 05^0 14’ 07.4”E and 05^0 14’ 06.7”E. Figure 1, shows map of Kwara state and the location of the falls near Ajuba village.

Figure 1: Project Location Map

2. Study Approach and Methodology

2.1. Stream Gauging, Discharge Measurement and Rating Curve

Various site visits were undertaken to facilitate gauge installation and hydraulic head survey. Gauge readers were effectively engaged by June 2009 and have since continued to monitor the gauge till date. A staff gauge is the simplest device for measuring river stage or water surface elevation. The staff gauge is a graduated self-illuminated strip of metal marked in metres and fractions thereof. Water levels were read daily, recorded and collated on monthly basis. Limited numbers of discharge measurements (10Nos.) were undertaken each month for a range of stage to define a relationship between stage and discharge at the two gauging stations. Discharge measurements taken at various times were used to generate the discharge rating curves and to establish the minimum and maximum water levels.

The stage-discharge relation, which is the rating curve, is then combined with continuous periodic stage measurements to record discharge as well as stage simultaneously. The rating curve was converted to discharge. In general for a gauge height H (m); the discharge Q (m^3/s) is related to height H (m) as (Punmia and Pande, 2008):

$$Q = K(H +/- H_o)^n \qquad \textbf{(1)}$$

(when $H_o=0$,

The rating equations is given as (Sharma, 1979)

$$Q = KH^n \qquad \textbf{(2)}$$

Where

Q = Discharge (m^3/s)

H = Gauge Height (m)

H_o = Gauge Height when the flow is zero (m)

n and k are constants

This is a parabolic equation which plots as a straight line on double logarithmic graph sheet. K & n are determined using the least square methods

Taking logarithms of both sides of equation (2) we obtain the relation:

$$\log Q = \log K + n \log H \qquad (3)$$

which is of the form $y = a_0 + a_1x$, where $y = \log Q$, $a_0 = \log K$, $a_1 = n$; $x = \log H$. Then k and n can be calculated from the formulae $a_0 = \log K$ and $n = a_1$.

Taken summation on both sides and assuming N pairs of observation gives, then

$$\sum \text{Log } Q = N \text{ Log } K + n \sum \text{Log } H \quad (4)$$

Multiplying both sides by log H gives;

$$\sum \text{Log } Q \text{ Log } H = \text{Log } K \sum \text{Log } H + n \sum (\text{Log } H)^2 \quad (5)$$

These two equations were solved simultaneously to determine constants k and n and hence rating equation of each month.

2.2 Streamflow Extension

Inadequate hydrological data may lead to over or under design of the power plant. Stochastic theory is applied in order to minimize the risk of such uncertainties. The stochastic theory provides opportunity to forecast and extend short duration data in a planning process (Matalas, 1967). If hydro-power projects are planned and designed on the basis of rather short time series of observed hydrological data the danger of inaccurate solutions is high. When only short term data are available at project site, the short term data is normally extended with the help of long term data of other sites on the same stream or in the adjoining catchments (Warren, et al, 1972). The Thomas Fierring method (McMahon and Mien, 1978) was employed to extend the 12 months data obtained at Ero-Omola Falls.

2.3 Demographic Data

Population is a major driver of energy demand. Other important determinants of energy demand include the level of economic activity and its structure, measured by the Gross Domestic Product (GDP). From the demographic data, the projected population was used in the estimation of energy demand of the benefitting communities. The project catchment areas comprises of three local government areas namely: Ekiti, Oke-ero and Isin, LGAs with a combined population of 172,207 (NPC, 2006). This is projected to 2036 using the average national population growth rate of 2.83%.

2.4 Meteorological Data

Meteorological data such as temperature, wind speed, sunshine hour, relative humidity and rainfall were collected at Omuaran, Kwara state for the purpose of estimating the evaporation losses. Meteorological variables were also collected from ECWA Primary School at Osi, Kwara state for the estimation of the crop water requirement for vegetables, maize and sugarcane which are the crops planted downstream by Fadama farmers. The crop coefficients were obtained from International Institute for Tropical Agriculture in Ibadan, Nigeria.

2.5. Determination of Sediment Characteristics and Mineral Composition.

Scientific evaluation of sediment inflow, its distribution in sizes and gradation are essential for sustainable management of hydropower project, both in the long and short term. The gradation of sediment is paramount in the selection of suitable turbine blades and vanes. The sediment samples from Ero-river were analyzed at the University of Ilorin Civil Engineering Department to determine the sediment load. Sediment can cause damage and sometimes very serious damage to under water components of the generating equipment such as runners, guide vanes, etc. resulting in loss of power generation and costly repair and maintenance of equipment. It has been observed that high concentration of even fine angular quartz particles can cause maximum erosion in most hydropower plants. A variety of sediment exclusion and extraction measures must be provided to reduce size and concentration of sediment particles in the flow reaching the generating equipment in order to reduce damage to a power plant. The planning and design of these measures depend on the sediment characteristics. Hence the sediment characteristics like, size, shape, hardness and concentration which are site specific must be assessed with as much accuracy as possible for planning and design of cost effective sediment exclusion and extraction measures at intake (U.S. Army Corps of Engineers, 1995).

Petrographic analysis is the determination of mineral composition of the sediment. Samples taken from sites were analyzed in the Geology Laboratory at the University of Ilorin. As the plant components coming into contact with the water such as slide valves, pressure pipes, turbines, rotors and casings are destroyed by the suspended matter, it is necessary to determine its composition and concentrations. One of the essential requirements for the design of a hydropower plant is that the water drawn in should be free of sediment as far as possible. The presence of sediment, especially sharp-edged sand particles, may cause wear of the turbine runner vanes and other steel parts besides causing damage to the tunnel lining. Abrasion effects become more pronounced with increase in head.

2.6 Raw Water Quality

In order to effectively control aggressive corrosion, the chemical analysis of water is important to have knowledge of presence of salts and the nature of water (acidic or alkaline) which could affects metals, equipment and concrete structure. The raw water was also tested for physical and chemical characteristics to determine the type of treatment required for suitable water supply. The physical, chemical and microbiological parameters tested in the laboratory were compared to the permissible limits set by Nigeria Water Quality Standard (FMWR, 2007).

2.7 Survey Works

Preliminary survey work was carried out to develop topographical maps, hydraulic head, choice of dam axis, pipeline route for the transmission of raw water and total length of required penstock. The gross head is the vertical distance that the water falls through in giving up its potential energy (i.e. between the upper and lower water surface levels). Having established the gross head available, it would be possible to estimate losses, from trash racks, pipe friction, bends and valves. The hydraulic head profile along the Ero-Omola river course with the gross head were estimated from the topographic survey mapping of the sites. The gross head minus the sum of all the losses equals the net head which is available to drive the turbine.

2.8 Electrical Load Demand Survey and Load Projection

Five households each from the three LGAs within the project catchment areas and four other adjoining LGAs were surveyed for 30 days. A template or checklist for determination of historical load profile within the LGAs was developed and was distributed and monitored for 30 days. The survey was undertaken with the assistance of Zonal office of PHCN at Omu-aran, Kwara State. The peak daily demand load and future typical load forecast were attained with the model equation developed by International Atomic Energy Agency (IAEA) known as the Model for Analysis of Energy Demand (MAED).

The demand projection method of MAED is expressed by the following equation (Aluko, 2004)

$$Ei = e_i * VDi = e_o * Fi * VDi \tag{6}$$

Where Ei = energy demand in year i for (i=2010-2036)

e_o = base year energy intensity,

e_i = the value in year i.

VD_i = value of the determinant of energy demand in year i.

F_i = modifier of e_o for year i; it depends on such factors as penetration of technology, energy use efficiency, economy, life style, demography, and other social-economic and technological factors that affect energy demand, in year i relative to the base year;

2.9 Assessment of Hydropower Potential

The following are the basic steps used to compute average annual power based on the guidelines of the US Army Corps of Engineers (1995):

i) **Determination of the flow losses:** Flow losses such as consumptive losses include reservoir surface evaporation losses and diversion such as for irrigation and water supply. Non-consumptive losses include ecological requirement, leakage through/around dams and embankment structures and leakage around spillway or regulating outlet gates.

ii) **Development of head data** – A head versus discharge curve to reflect the variation at tail water elevation with discharge.

iii) **Selection of plant site:** First the plant hydraulic maximum discharge that can be met through the turbine is selected. For preliminary studies the initial plant size was based on the average annual flow or a point between 15% and 30% excedence on the flow duration curve. Next the net head corresponding to the assumed hydraulic capacity was identified.

iv) **Definition of usable flow range and derivation of head–duration curve:** The flow duration is reduced to include only the usable flow range, because the turbine characteristics limit the stream flow that can be used for power generation using the flow – duration data and time versus discharge data,

v) **Derivation of Power Duration Curve:** the energy available at 100% exceedence is derived from power versus flow time.

2.10 Engineering Economics and Financial Analysis

Financial feasibility is the evaluation of the ability of the project to provide debt service from the capital required to construct and operate the project. Economic feasibility is the evaluation of project costs and benefits with the project deemed feasible when benefits exceed costs. In this study, cash flow represents all quantified costs and benefits, so that the financial analysis provides the cost (disbursement) and benefits (receipts) for the economic analysis. The economic criterion used is the Financial Internal Rate of Return (FIRR). The economic evaluation of hydropower development plans combines basic methods of engineering economics with benefit estimation procedures. Analyses of economic costs and benefits provide important information for use, along with various other forms of information, in making a myriad of decisions in planning, design, operations, and other water resources engineering activities (Gittinger, 1984).

3. Design of the Integrated System

3.1 Layout of the Scheme

Figures 2 and 3 show the hydraulic head profile along the Ero-Omola river course with the gross head estimated at 59.01m. The gross head minus the sum of all the losses equals the net head, which is available to drive the turbine. The longitudinal profile of the proposed dam axis is shown in Figure 4, while figure 5 shows the layout of the integrated system. The design of each component was carried out using all the data and information described in section 2 above.

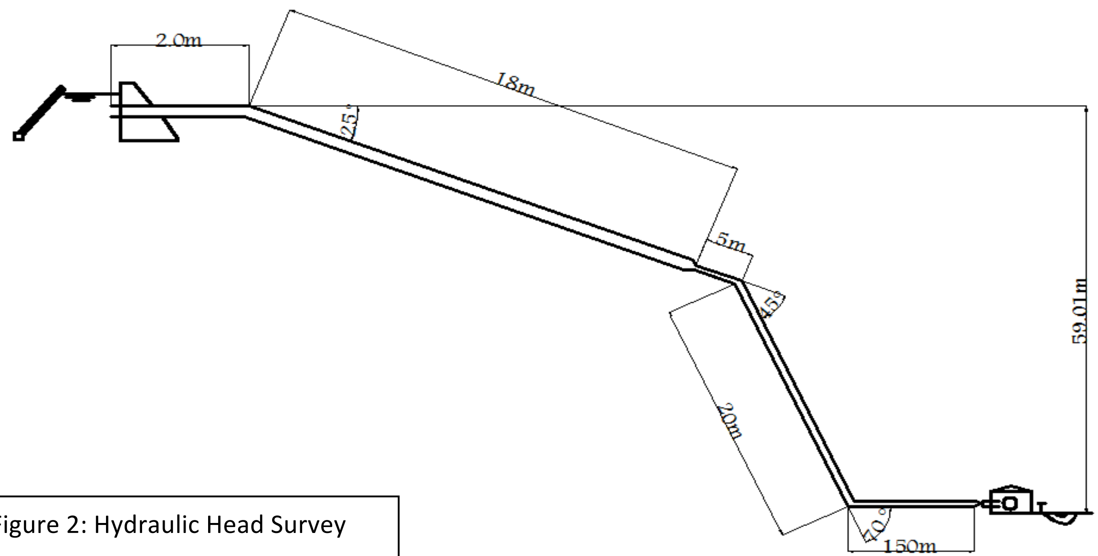

Figure 2: Hydraulic Head Survey

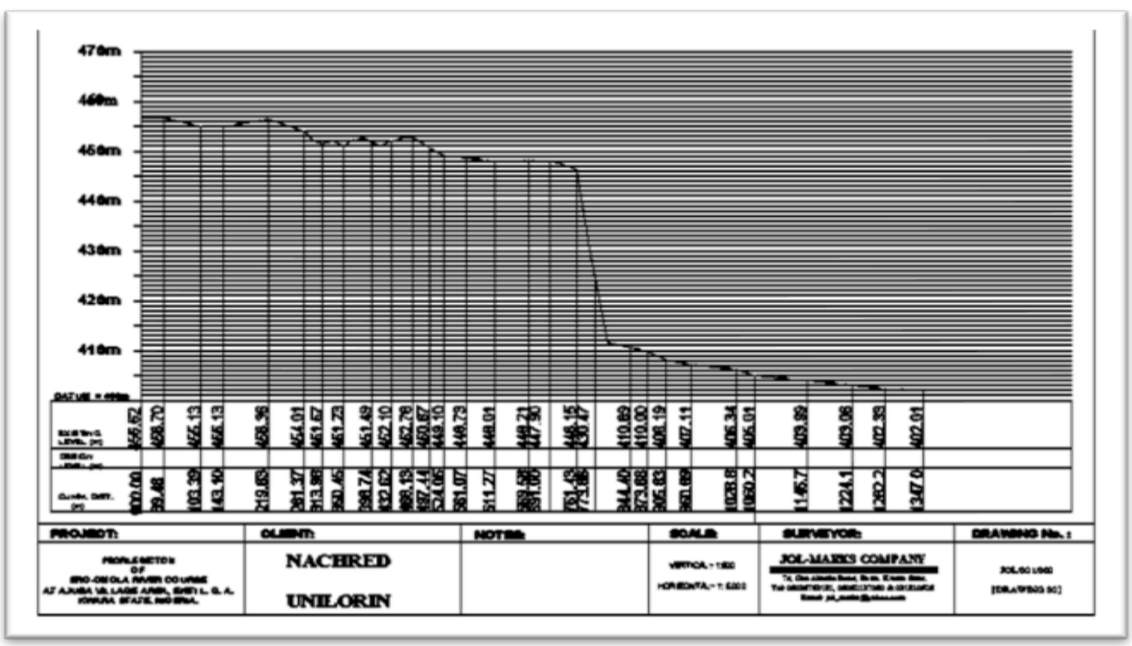

Figure 3: Hydraulic Head Profile

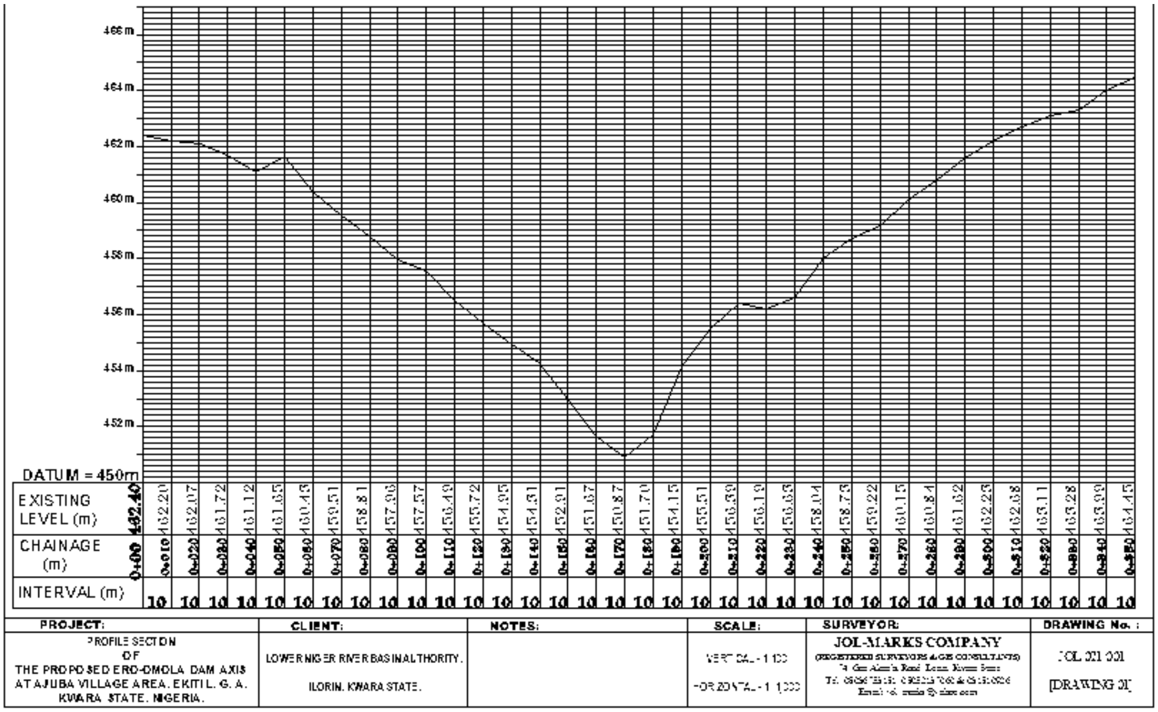

Figure 4: Longitudinal Profile of Dam Axis

3.2 Hydropower System Components

The component of hydropower system consists of intake channel, trashrack, sediment tank, forebay tank, overflow conduit, penstocks, draft tube, tailrace channel, power house, turbine and generator. The designs of these components were carried out to allow for costing of the project. The summary of the main features of the components are;

i) Intake Channels:

The width of the river at intake site is 24 m. It is proposed to construct a simple stone masonry channels to divert water into the sediment tank. The length of intake channel from intake to sediment tank is about 600 m. The parameters of the channel are given below:

Type	= Trapezoidal
Discharge, Q	= 24.01 m^3/s
Bed slope, S	= 1/600
Rugosity Coefficient,	n = 0.016
Water depth	= 3.5 m
Bed width	= 24 m
Free board	= 1.50 m

ii) Trash Rack

At the intake of channel, a trash rack and steel gate is provided to check the floating material and to control the flow. Trash rack is to be fabricated with Mild Steel flats with 25 mm clear spacing centre to centre. The parameters of the Trashrack are given below;

Mild steel mesh	=25mm c/c
Velocity	=3m/s

iii) Design Head & Discharge

The following levels were measured between the power house (ground floor) and permanent bench mark position.

Water level at intake	= +462.40 m
Water level at forebay	= +461.02 m
Water level at tailrace	= +402.01m
Gross head	= 461.02-402.01 = 59.01 m

Head loss =462.40-461.02 =1.38m

Gross Flood =24.01m^3/s

Design flood =21.00m^3/s (80yrs return period)

iv) Petrographic Information

Grain Size Distribution = 0.02-0.2mm

Quartz Sand = 0.05mm

v) Sediment Tank Cpacity

Length =40m

Width =24m

Heigth =24m

Freeboard =1.5m

Slope angle =26.6^0

Bed slope =1:600

vi) Forebay Tank

The forebay tank is located on a relatively flat area followed by the penstock provided along moderately slopping side leading to power house on a flat terrace. A 250 mm dia pipe is also provided in the forebay for flushing of silt. The length of flushing pipe is about 180 m.

Design discharge = 7.00 m^3/s

Storage required = 180 minutes

Water depth = 24.0 m

Width = 24.0 m

Length = 40.0 m

Free board = 1.50 m

vii) Overflow Conduit

Type: = HPDE

Discharging Capacity =7m^3/s

Length: =180 m

Width =4.5m

Depth =3.5m

Material: =Stone masonry

Slope =1:60

Velocity =3m^3/s

viii) Penstock

The design features of penstock are given below.

Penstock material = mild steel

Design discharge = 7.00 m^3/s

Length = 48 m

Diameter =1200mm

Velocity (say) = 3.0 m/s

Area of pipe required =7.00/3.0 = 2.3 m^2

Provide, diameter of pipe = 1200mm

Thickness of Pipe: =16 mm

Bends: = 4 No.

Expansion Joints: = 4 No.

ix) Head loss

System Friction loss =2.5m

Anchor Blocks =150m c/c

Surge Tank =@28.6m along penstock

Area of inlet of surge tank =180.83mm^2

x) Draft Tubes

Material =mild steel

Diameter =1200mm

Length =15m

xi) Tail Race Channel

Tail race channel is designed as trapezoidal section to handle design discharge of 21.00 m^3/s. The length of tail race channel is about 240m. .

Design Discharge = 21 m^3/s

Length = 240m

Bed Slope, S = 1/500

Roughness Coefficient, n = 0.016

Water depth, d = 6.0 m

Bed width, B = 25 m

Free board = 2.5 m

xii) Power House Building

The layout of the power house has been worked out on the basis of use of standard Cross flow turbine The dimensions of the power house are 15.0 m (L) x 15.0 m. (B) x 5.5 m (H) other details are;

Type: =Surface Power House

Installed Capacity: =3 unit of 2500 kW

xiii) Turbine

Type: =Francis Cross Flow Reversible pump

Number =3 units

Rating =2500 kW

xiv) Type of Generator

Type: =Synchronous

Nos.: =3 units

Capacity: = 65KVA with 25% continuous over load capacity, 0.415kV, 3 Phase, 0.9 pf, 50HZ, 3%, 2500 rpm, Class "F" Insulation

3.3) Water Supply

Water demand estimates based on population of the three LGAs, as presented in Table 1:

Table 1: Water Demand Estimates

	Category	Population	Litres/day	m^3/day
I)	Population 3 LGAs Domestic Demand	172,207 (C)	©150	25831.05
ii)	Residents 80% of 172,207	137765.6		20664.84
iii)	Non-Resident (i-ii)	34441.40		5166.21

iv)	Visitors and services 5% of C	8610.35	1291.55
v)	Industrial Demand 30% of C	51662.1	7749.31
vi)	Institutional Demand 20% of C	34441.4	5166.21
vii)	Fire fighting 10% of C		2583.10
viii)	Leakages, Houses waste unaccounted		
ix)	water 15% of C		3874.65
	Grand Total.		**46,495.89**

The daily water requirement for the 3 LGAs is estimated at 46495.89m^3 or approximately 46,500m3/day.

Water Quality Design Principle is based on the Nigeria Standard for Drinking Water Quality (NIS 554:2007). Hence the treatment system comprises of coagulation, flocculation, sedimentation, filtration and chlorination. Others are:

a) Daily Water Demand =46500m^3/day
   Static Head=506.857-450.939 = 55.918m
b) Pump capacity =32m^3/s High lift
c) Treatment plant capacity =18 Mm^3/day,
d) Elevated (Clear Water Tank) =22,500litre (22.5m^3) or 5000 Gallons

3.4) Irrigation Water Requirements

The computed results for the Fadama irrigation scheme are peak water requirement and total gross water requirement. Irrigation crop water requirements were estimated at 2.2 x $10^6 m^3$ using the FAO CROPWAT 8.0 software, irrigation and drainage parameters are presented below;

Number of Fadama farmers =56

Climatic data =35 years

Peak Irrigation Water Requirement =0.43 l/s/ha

Gross Irrigation Water Requirement =7.568 x $10^6 m^3$

Drains type: Reinforce Concrete Rectangular

Length of main drain: 3,627m

Capacity: 2m x 1m x 1m

Length of feeder drain: 1,373m

Capacity: 1mx1mx1m

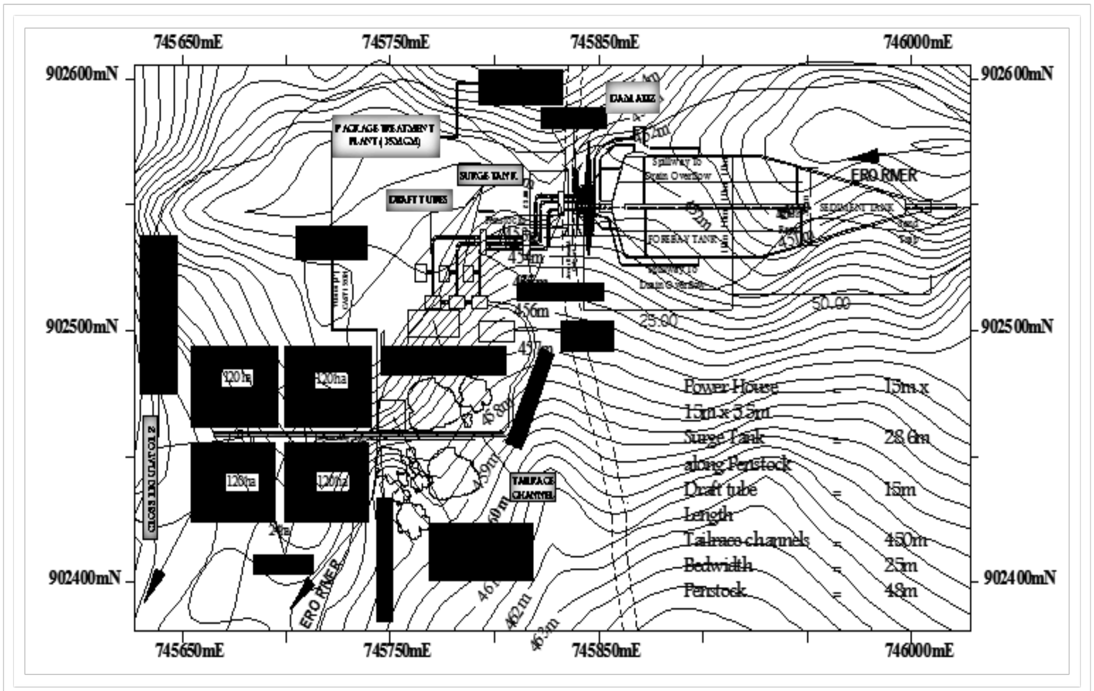

Figure 5: General Layout of Integrated Hydropower Scheme

4 Financial and Economic Analysis

4.1 Capital Cost Element of Hydropower

The financial and economic evaluation of the project has been prepared according to the Hydropower Sustainability Development Guidelines based on a project life of 30 years. The capital costs for each component were estimated as shown in Table 2. The cost elements for hydropower were based on IHA (2007). The breakdown is shown in Table 3.

Table –2: Project Cost Summary

S.No	Description	Cost Millions(N)
1.	Hydropower	750
2.	Water Supply	245
3.	Irrigation and Drainage	108
Total		**1,103**

Table 3: Capital Cost Element of Hydropower

Capital Cost Element of Hydropower	% of Total Cost
Planning and Design/Supervision	3-10
Civil works	15-45
Mechanical/Electrical	25-55
Electricity Distribution	8-12
Interest during Construction	5-10
Contingency	5-10
Total Capital Cost	25-30
Running Cost	30-35
Fixed cost	5-10
Variable Cost(O&M)	2-5
Contingency	2-5

Source: IHA, 2007

The total financial cost of development of Ero –Omola Fall is estimated at N1,103, 000,000,00 which include the headworks, civil, electrical and the mechanical components .

4.2 Amortization Analysis

The discount factor computed at 5% interest rate is: (IHA, 2007).

$A = F\left(\frac{i}{(1+i)^{N}-1}\right)$=$A = F\left(\frac{0.05}{(1+0.05)^{30}-1}\right)$=0.01505

Amortization of various components of the project costs outlined above in Table 2, was computed at an interest rate of 5%. The total sum of N16,538,300.00 annually over the assets life of the project (30 years) is expected to be deducted installmentally in order to pay back interest and the capital. The projected cash flow is presented.in Table 4. The cash flow indicates that Ero-Omola project is expected to grow by 5% profit beginning from year 2015. The total Kilo Watt Hour unit available annually at 90% dependability is 15137.28 MWh.

4.2.1 Costs and Financing -General Data and Assumptions

(a) Exchange Rate

All costs given are in ₦ and, where necessary converted from US Dollars to Naira at an exchange rate of US$ 1.00 = N161.00.

(b) Reference Date and Investigation Period

The reference date for all FNPV and FIRR calculations is 01.01.2011. It is assumed that the commercial operation date is 01.01.2013. Thus the first year of operation is a full calendar year with 365 days of operation. The analysis period comprises the years 2013 to 2043. The planning, tendering and construction period have been assumed to commence by 01.01.2011 and end on 31.12.2012, (i.e. a construction period of 2 years.) The operation period has been assumed to commence on 01.01.2013 and end on 01.01.2043, covering 30 years. A **50**% capacity utilization is assumed in the first year of operation.

(c) Installed Capacity: 8000kw

i) Annual electricity delivered to national grid (2013): 8000kw x 24hours x 365days x 0.2(flow reduction factor) =14016000kwh = 14016 MWh or 7008MWh at 50% capacity utilization in the first year of operation.

(iii) Electricity tariff= N14.00/kwh

(iv) Electricity sales =Cash flow= 14016 x 10^3 kwh x N14.00/kwh = 196.224 Million (2014) or 7008 x10^3 kwh N14/kwh = N98.112 Million (2013) at 50% capacity utilization.

(v) Power delivered to National grid: (2014):14016 MWh (100% capacity utilization)

d) Municipal Water Supply

(i) Installed capacity:18 mcm

(ii) Water Delivered to communities=46,500m^3/day (2014) or 23,250 m^3/day @ 50% capacity utilization in the year 2013.

(iii) Water Tariff= N15/m^3

(iv) Water supply revenue/annum=23,250m^3/day x N15/m^3 x 365days = N12,7293,750.00 or N127.29 Million/Annum (2013) or N255 Million/Annum (2014)

e) Irrigation Water Requirement

(i) Installed capacity= 2.2 mcm

(ii) Irrigation water delivered to farm = 43.07m^3/day =peal water requirement

(iii) Irrigation Tariff= N21/m^3/day

(iv) No of days per season = 6 months (November-April) =183 days

(v) Irrigation Revenue/Season (2014) = 43.07m^3/day x N21/m^3/day x 183 =N165,518.00 or 21.535 N21/m3/day x 183 = N82,625.00 at 50% capacity utilization in the year 2013

4.3 Cash flows

Total cash outflows are the total revenue accrued from the sales of electricity, municipal water supply and irrigation water supply. i.e 2013 = (N98,112 + N127 +N0.082625) x 10^6 Naira=225Millions Naira

Total cash outflows is the total initial construction costs of hydropower, municipal water supply and irrigation water supply provided in the Bill of Engineering Measurement and Evaluation (BEME) i.e (N750 +N245 + N108) x 10^6 =N1103 x 10^6 Naira (2012). 50% is assumed to have been utilized in the first year of construction period i.e N551.6 Million Naira.

Net Cashflow = Total Cashinflow --- Total Cash outflow {hydropower operation and maintenance + O/M Treatment Plant + Vat 5% + Company income tax (after 5 years of Tax holiday i.e 2018)}, while only the initial working capital is involved in the first year of 2013. Table 4 shows the cash flow analysis.

Table.4: Projected Cash Flow Analysis

HYDROPOWER,WATER SUPPLY AND IRRIGATION	CONSTRUCTION PERIOD					
	2011	2012	2013	2014	2015	2016
Hydropower Development						
Installed Capacity(kw)	8000	8000	8000	8000	8000	8000
Annual Electricity Delivered to Grid						
(10^3kwh)	0	0	7008	14016	14016	14016
Tariff(N14.00/kwh)	0	0	14	14	14	14
Cash Inflows	0	0	98.112	196.224	196.224	196.224
Annual Electricity Sales($10^{6)}$ Naira	0	0	98.112	196.224	196.224	196.224
Municipal Water Supply						
Installed Capacity (MCM)	18	18	18	18	18	18
Water Delivered to Communities (m^3/day))	0	0	23,250	46,500	46,500	46,500
Water Tariff(~~N15/m~~^{3} /day)	0	0	15	15	15	15
Water Supply Revenue/Annum(10^6) Naira	0	0	127	255	255	255
Irrigation Water Supply						
Installed Capacity (mcm)	2	2	2	2	2	2
water Delivered to farmers(m^3/day)	0	0	22	43	43	43
Irrigation Tariff(N21/m^3/day)	0	0	21	21	21	21
Irrigation Revenue/Season (Naira)	0	0	82,625	165,518	165,518	165,518
TotalCcash Inflow (10^6) Naira			225	451	451	451
Total Cash outflows(10^6)Naira	551.5	1103	184.535419	38.1708509	38.1708509	38.1708509
Fixed Assets Investment	551.5	1103				
Working Capital(15%)	0	0	165.45			
Operation/maintenance Cost(0.75%)millions	0	0	4.136	8.272	8.272	8.272
O&M Treatment Plant(3%)Millions	0	0	3.675	7.35	7.35	7.35
Vat (5%) Millions	0	0	11.2744188	22.5488509	22.5488509	22.5488509
Company Income Tax(30%)	0	0	0	0	0	0
Inflation Rate 12.6%	0	0	27.058605	54.11724216	54.1172422	54.1172422
Depreciation Charge(20%)	0	0	1103	2.206	2.206	2.206
Net Cash flow	-551.6	-1103	41	413	413	413

			OPERATION PERIOD										
2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016
14	14	14	14	14	14	14	14	14	14	14	14	14	14
196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224
196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224
18	18	18	18	18	18	18	18	18	18	18	18	18	18
46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500
15	15	15	15	15	15	15	15	15	15	15	15	15	15
255	255	255	255	255	255	255	255	255	255	255	255	255	255
2	2	2	2	2	2	2	2	2	2	2	2	2	2
43	43	43	43	43	43	43	43	43	43	43	43	43	43
21	21	21	21	21	21	21	21	21	21	21	21	21	21
165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518
451	451	451	451	451	451	451	451	451	451	451	451	451	451
38.1708509	51.7001614	51.7001614	51.7001614	51.7001614	51.7001614	51.70016144	51.7001614	51.7001614	51.7001614	51.7001614	51.7001614	51.700161	51.70016144
8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272
7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35
22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.548851	22.5488509
0	13.5293105	13.5293105	13.5293105	13.5293105	13.5293105	13.52931054	13.5293105	13.5293105	13.5293105	13.5293105	13.5293105	13.529311	13.52931054
54.1172422	54.1172422	54.1172422	54.1172422	54.1172422	54.1172422	54.11724216	54.1172422	54.1172422	54.1172422	54.1172422	54.1172422	54.117242	54.11724216
2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206
413	399	399	399	399	399	399	399	399	399	399	399	399	399

2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016	14016
14	14	14	14	14	14	14	14	14	14	14	14	14
196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224
196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224	196.224
18	18	18	18	18	18	18	18	18	18	18	18	18
46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500	46,500
15	15	15	15	15	15	15	15	15	15	15	15	15
255	255	255	255	255	255	255	255	255	255	255	255	255
2	2	2	2	2	2	2	2	2	2	2	2	2
43	43	43	43	43	43	43	43	43	43	43	43	43
21	21	21	21	21	21	21	21	21	21	21	21	21
165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518	165,518
451	451	451	451	451	451	451	451	451	451	451	451	451
51.7001614	51.70016144	51.7001614	51.7001614	51.7001614	51.7001614	51.7001614	51.70016144	51.7001614	51.7001614	51.7001614	51.7001614	51.7001614
8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272	8.272
7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35	7.35
22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509	22.5488509
13.5293105	13.52931054	13.5293105	13.5293105	13.5293105	13.5293105	13.5293105	13.52931054	13.5293105	13.5293105	13.5293105	13.5293105	13.5293105
54.1172422	54.11724216	54.1172422	54.1172422	54.1172422	54.1172422	54.1172422	54.11724216	54.1172422	54.1172422	54.1172422	54.1172422	54.1172422
2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206	2.206
399	399	399	399	399	399	399	399	399	399	399	399	399

4.4 Sensitivity Analysis

Financial analyses were performed with loan periods of 30 years and interest rates of 5%. 10% and 21%. Project cashflow were estimated based on a 30-year project life span. Using these variables, and the energy generation assumptions, The financial performance indicators for the Ero-Omola hydro power plant and configurations were analyzed based on three different scenarios as follows:

(i) First Scenario:

Loan for the project would be obtained from either Central Bank of Nigeria or the United Nation Development Bank intervention fund with Nigeria Bank of Industry at an interest rate of 5%. The project life is assumed to be 30 years. The performance indicators obtained are:

FNPV = Financial Net Present Value = N4, 286.27
FIRR = Financial international Rate of Return =13%
MIRR= Modified internal rate of return =8%
WACC= Weighted Average Cost of capital = 7.50%

(ii) Second Scenario:

Loan for the project would be obtained from Nigeria Bank of Industry direct fund at an interest rate of 10%. The project life is assumed to be 30 years. The performance indicators obtained are:

NPV = Financial Net Present Value = N314.79
FIRR = Financial international Rate of Return =13%
MIRR= Modified internal rate of return =11%
WACC= Weighted Average Cost of capital = 7.50%

(iii) Third Scenario:

Loan for the project would be obtained from open market or Commercial Bank at an interest rate of 21%. The project life is assumed to be 30 years. The performance indicators obtained are:

FNPV = Financial Net Present Value = N294.7
FIRR = Financial internal Rate of Return =13%
MIRR= Modified internal rate of return =19%

WACC= Weighted Average Cost of capital = 7.50%

While the internal rate of return (IRR) assumes the cash flow from a project are reinvested at the (IRR), the modified internal rate of return assumes that positive cash flows only are re-invested at the cost of capital. Therefore MIRR accurately reflect the true cost of viability and profitability of a project than the IRR. The intervention fund with the Bank of Industry in Scenarios 1, appears to be the best option for this project. This fund allows the project to grow at a sustainable level of 7.5% under the influence of prevailing inflation rate of 12.6%.

5. Conclusion

Limited research works are available on the economic sustainability of integrated hydropower development in Nigeria. In order to boost energy supply situation in the country, Ero-Omola Fall located in Oke-Ero LGAs of Kwara State has been studied for sustainable integrated hydropower development. The study shows that, several factors like appropriate design techniques, accurate hydrological assessment, sedimentation study, petrographic information's, water quality assessment, as well as engineering economics of integrated hydropower development contribute significantly to economic sustainability of hydropower projects. Economic efficiency and fiscal sustainability demand that the capital costs of hydropower, water supply and irrigation infrastructure should be recovered from the users in order to permit longer–term replication of investments. For a hydropower investment to be worthwhile, the expected return on capital must be greater than the cost of capital or the internal rate of return. The Internal rate of return however, is that discount rate that makes the net present value of a net benefit or cash flow derivable from electricity sales, equal zero or is the maximum interest rate that a project could pay on invested capital, if the project is to recover its investments and operating costs and still break even. It could also be defined as the rate of return on capital outstanding per period while it is invested in the project. The study demonstrate that the formulation of conjunctive use of hydropower releases is the most sustainable mitigation measures against seasonal flooding downstream of hydropower plant. The potential hydropower estimated from this study if developed would reduce electricity generation deficit in the country. The following conclusions are also drawn from the outcome of this study.

a) The potential hydropower generating capacity of Ero-Omola fall at 100% dependable flow of 80 years return period is estimated at 8.011MW. The annual average energy is estimated at 14035.272MWh and plant efficiency of 0.70. (by the flow duration method)

b) The potential hydropower generating capacity of Ero-Omola fall at 100% dependable flow of 80 years return period is estimated at 10,091.502MW. The annual average energy is estimated at 18,401.56501MWh and plant efficiency of 0.70. (by Simulation).

c) Water treatment plant capacity is estimated at 22,500 litres or 22.5m^3/s or 5000 gallons/day at N50/m^3 water tariff. Monthly revenue is estimated at N33, 750.00/month or N405, 000.00. .

d) The raw water quality test indicated that the river is safe for purpose for which it is intended.

e) Irrigation water requirement is estimated at 2.2 x $10^6 m^3$ with peak irrigation water demand of 43.07m^3/day at N21.00/m^3 irrigation water tariff. Monthly revenue is estimated at N27,134.1.00/month or N325, 609.00/annum.

f) The engineering economics of integrated hydropower development with water supply, irrigation and drainage facilities yields highest return of 13% on capital invested at 5% interest rate.

g) The cumulative generated cash flow is positive for each scenario which indicates that the project will not operate at a loss. The investment is considered worthwhile since the MIRR is higher than the cost of capital. It can therefore be said that the project is economically viable and financially sustainable.

h) Sensitivity analysis under different interest rate regime of 5%, 10% and 21% indicated that intervention fund with Nigeria Bank of Industry offers the best returns on equity.

i) The results show that hydropower project is economically sustainable when it is integrated with water supply and irrigation. It is regenerative when 90% of the flow is returned to the stream and the ecological water releases is allow to recharge downstream aquifers. It can therefore be inferred that the project is economically viable and financially sustainable based on the findings outlined above.

j) It is not economically sustainable to develop hydropower plant to stand alone any longer, except where it is practically impossible to integrate other component of the projects. Comprehensive assessment of integrated hydropower potential should be encouraged nationwide.

k) Finally the study shows that the formulation of conjunctive use of hydropower releases is the most sustainable mitigation measure against seasonal flooding downstream of hydropower plant

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