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EVALUATION OF THE EFFECTS OF WEATHER VARIATION, CLIMATE CHANGE AND TIME ON THE HYDROELECTRIC POWER POTENTIAL OF A RIVER

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ABSTRACT

Data on the rate of water discharge and head of a river is of critical importance to the determination of the hydroelectric potential of the river and these important quantities vary with climate change and time. When there is a long break in data collection of the flow rate of a river, researchers become skeptical about the authenticity of the old data for the determination of hydroelectric potential of the river. This paper evaluates the effects of climate change and time on the hydroelectric potential of Otammiri River over a period of 28 years (1984 to 2012). The evaluation is achieved by analyzing and comparing data for the river obtained from the hydrological department of Anambra Imo River Basin Development Authority (from 1984 to 1987) to the data taken from the river in 2012 by field experiments using the Valeports' model 106 direct/self-recording current meter. Matlab software is used for the analysis and the variation is observed to be less than 5%.

Keywords: Hydroelectric potential, Valeports' model, Otammiri River

INTRODUCTION

Climate change and weather variations present one of humanity's greatest challenges in recent times. To counteract global warming and guarantee economic growth and prosperity in the future, energy must be generated and utilized in an environmental and climate friendly way. Compared to fossil fuels, renewable energies have the advantage that they are practically in-exhaustible and abundant in nature [1]. The hydroelectric potential of a river depends on the amount of the flow parameters such as the discharge of the river in m^3/s and the water head in meters that can be harnessed from the river. The Otammiri River has a hydroelectric potential of hundreds of kilowatts which is expected to vary with climatic change and weather variation all through the year. The river is one of the main rivers in Imo state of Nigeria which flows through major towns and rural communities [2].

Effect of Weather Variation and Climatic Change on Otammiri River

The Otamiri River is one of the main rivers in Imo state, Nigeria located LAT: 05^o 26'N LONG: 07^o02'E. It has its source at Egbu community in Owerri North Local Government Area and passes through Owerri town and other sub-urban and rural communities of Nekede, Ihiagwa, Obinze, Mgbirichi, Eziobodo etc. The river flows from the Obinze station and passes through the Federal University of Technology Owerri (FUTO) community. The area drained by the river is located within the humid tropical region with two distinct climatic seasons, namely, wet and dry seasons. The wet or rainy season runs from April to September, and the dry season from October to March. The annual rainfall fluctuates between 1500mm to 1800mm with most rains falling during the wet season [3]. This phenomenon creates high discharges into the river during the rainy season. Also, temperature fluctuates between 28^0C

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to 40^0C all year round with high evaporation occurring mostly during the dry season [4]. The river has a mean slope of 38.5% draining about 18700 hectares of land. There are different projects on ground which is geared towards harnessing the Otammiri River as a potential site for erecting a hydroelectric power plant for supply of portable power supply to Federal university of technology Owerri, community. The feasibility survey and investigations have been carried out by a team from the department of hydrology, Anambra Imo River Basin Development Authority and the presenter of this paper in harnessing the power potential of the river from the given parameters, which are water head, and discharge rate, calculated from the water depth and speed and area of the river. The natural flow of the river is analyzed in other to obtain the given parameters [5].

HYDRO POWER GENERATION, SYSTEM DESIGN AND ANALYSIS

Power Output

The installed capacity and energy output is calculated using standard equations:

$$P = (Q \text{ x } \rho \text{ x } H \text{ x } g \text{ x } \eta)/1000$$

Where:

P = power or installed capacity in kilowatts.
Q =discharge rate in cubic meter per second.
ρ = density of water in kg per cubic meter.
H = effective head in meters.
g = acceleration due to gravity and is 9.81 m/s^2.
η = efficiency of hydro turbine generator in percent.

And

$$\text{Annual Output Energy (kWh)} = P \text{ x hr x CF}$$

Where:

P = power or installed capacity in kilowatts.
hr = Annual continuous generating duration (8760 hours in a year).
CF = Plant Capacity Factor (typically 95% for run-of-the-river type systems) [6].

Effective head (*HEF*)

In real hydro systems the water delivered to the turbine will lose some energy as a result of frictional drag and turbulence as it flows in channels and pipes. Thus, the effective head will be less than the available head

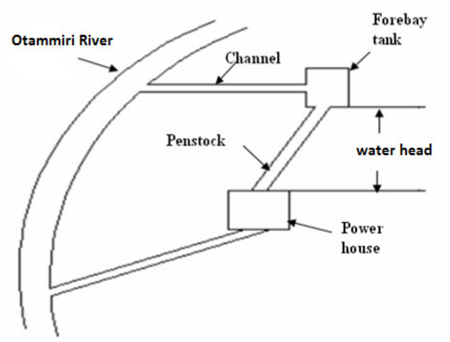
System Efficiency (η)

The efficiency of turbines varies according to the type of turbine and the flow rate into the turbine. The system efficiency considers both the combined efficiency of the generator, converting mechanical to electrical energy, and the turbine [7].

Typical Scheme Layout of Micro Hydro Power Generation for Otammiri River

Micro-hydro power generation capacity is dependent on the topography of the site. The flow of water in a river may be regulated by means of a small dam or weir. The weir also slightly raises the water level of the river and diverts sufficient water into the conveyance system. The water is channeled to a forebay tank where it is stored until required and it forms the connection between the channel and the penstock. The penstock carries the water under pressure from for ebay to the turbine. The penstock is a very important part of a hydro project as it can affect the overall cost and capacity of a scheme. The penstock connects to the hydraulic turbine, which is located within the powerhouse [8].

The selected site for the micro hydro project is Otammiri River located LAT: 05° 26'N, LONG: 07° 02'E



A hydrological data was collected from Anambra Imo River Basin for 1984 to 1987 hydrological year consisting of water discharge and head plots of the maximum and minimum discharge against the different months in each hydrological year are given in columns, while curves are plotted showing mean discharge per month in each hydrological year, MATLAB was used to do a forecast up to 2012, also indicating the columns and curves for the year 2012, the summary is given as follows [9]:

Name of River / Stream: OTAMIRI, Catchment Area: 100 SQ KM

Location: LAT: 05° 26'N, LONG: 07° 02'E

Hydrological year: 1984/85

Table 1. Water Stage and Water Discharge of Otamiri 1984/85

Month	*Water Head (m)*		*Water Discharge (m^3/s)*		*Mean Discharge*
	Minimum	*Maximum*	*Minimum*	*Maximum*	
April	0.75	0.79	5.90	6.38	5.90
May	0.76	0.82	6.02	6.74	6.35
June	0.79	0.85	6.38	7.10	6.81
July	0.84	0.95	6.98	8.40	7.33
Aug	0.86	1.02	7.22	9.38	7.82
Sept	0.84	0.92	8.53	7.98	7.55
Oct	0.89	1.02	7.55	9.38	8.07
Nov	0.93	0.98	7.44	8.82	8.53
Dec	0.73	0.97	7.43	8.68	8.44
Jan	0.87	0.94	7.34	8.26	7.82
Feb	0.80	1.01	6.50	9.24	7.19
Mar	0.87	1.01	7.34	9.24	7.82
Average	0.83	0.94	7.33	8.30	7.47

Maximum water head is 1.02, Minimum water head is 0.75
Maximum water discharge is 9.38, Minimum water discharge is 5.90

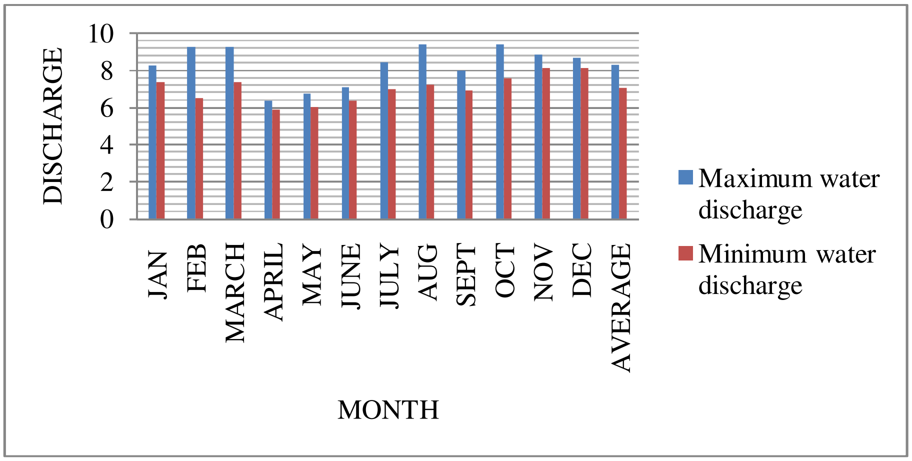


Figure 1. Maximum and Minimum Water Discharge of Otamiri 1984/85

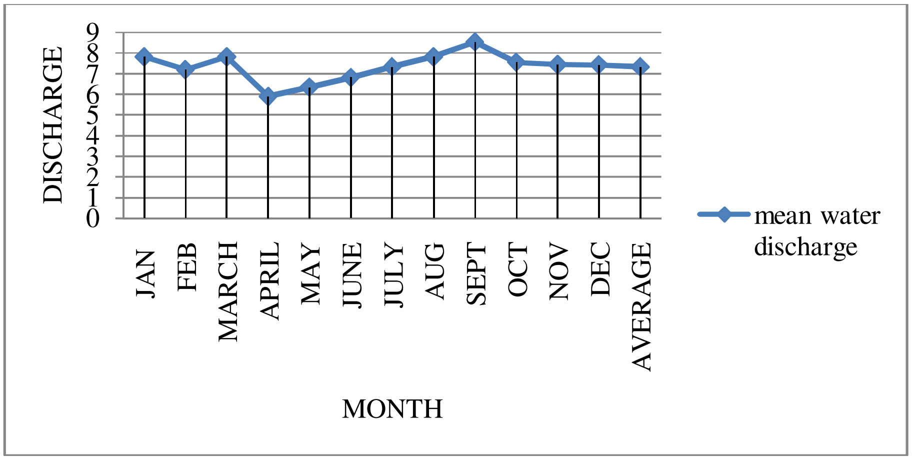


Figure 2. Monthly mean water discharge hydro graphs 1984/1985

The table and graphs were also prepared for 1985 to 1988 hydrological year from which the forecasts were obtained for 2012/2013 hydrological year. The forecast carried out using the MATLAB software gave the following results for 2012. The Valeports' model 106 current meter used for the experiment is shown in Fig.3.

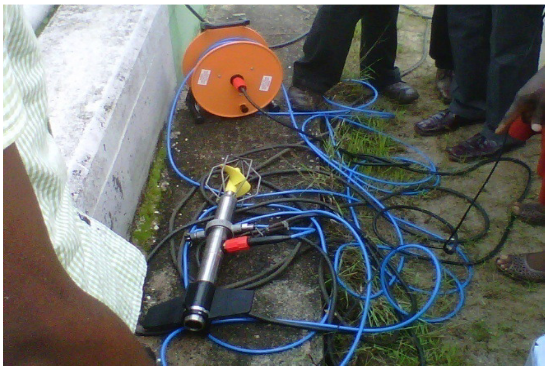
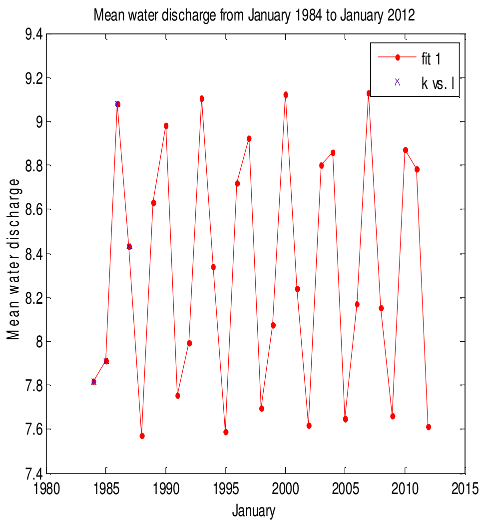
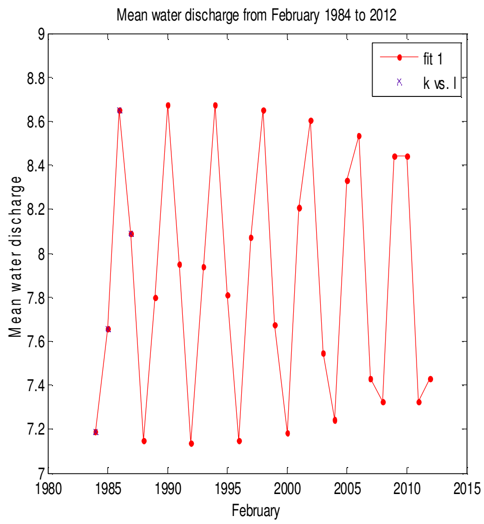
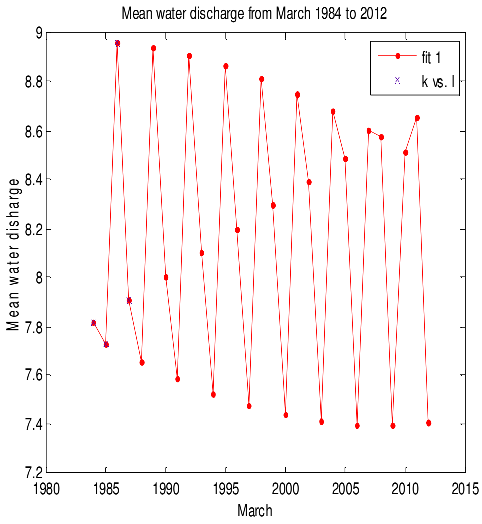
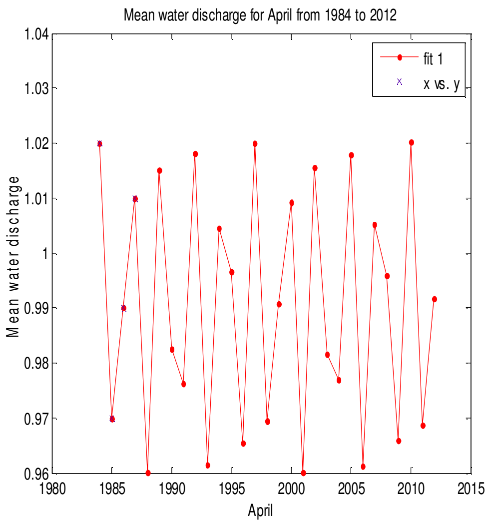


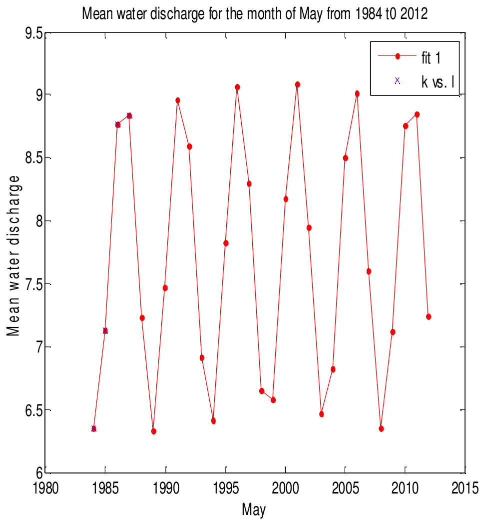
Figure 3. The Valeports' model 106 current meter

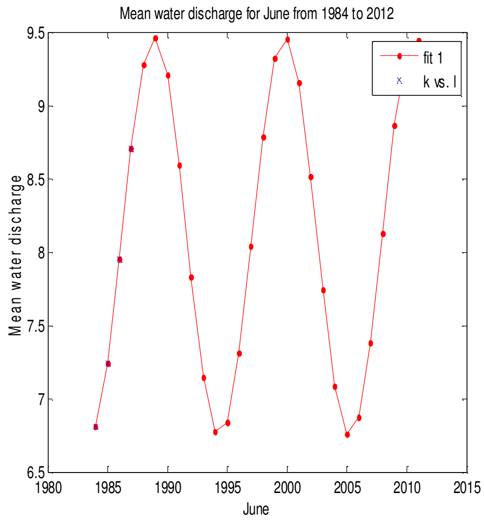

Mean water discharge from January 1984 to January 2012

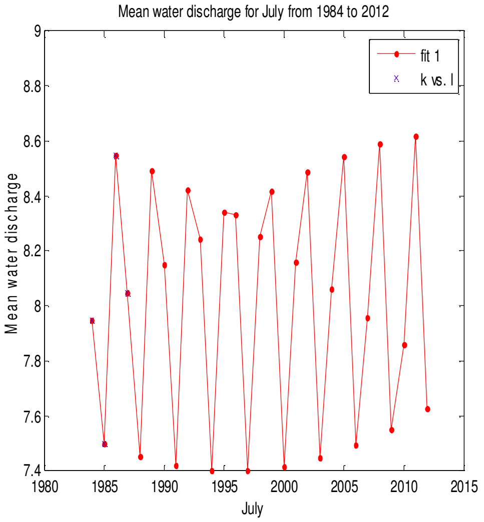

Mean water discharge from February 1984 to 2012

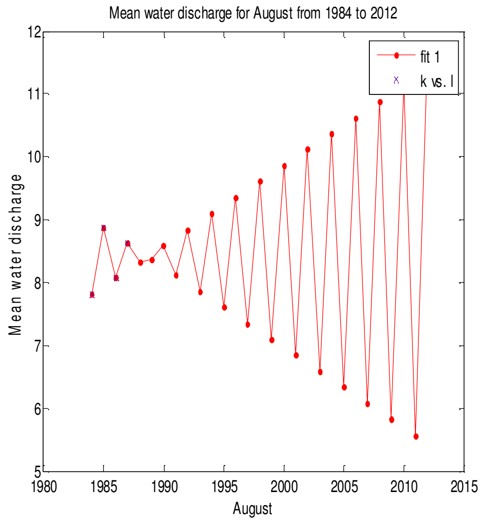

Mean water discharge from March 1984 to 2012

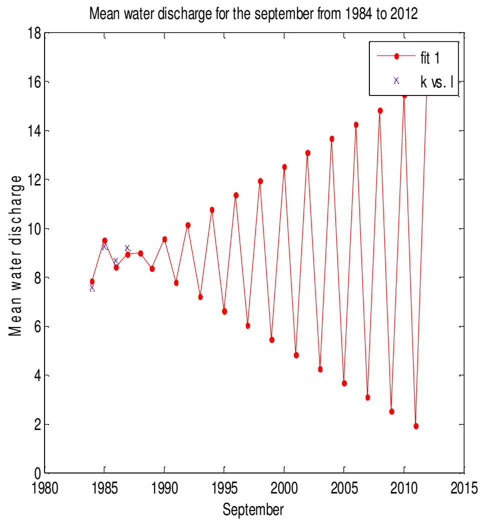

Mean water discharge for April from 1984 to 2012

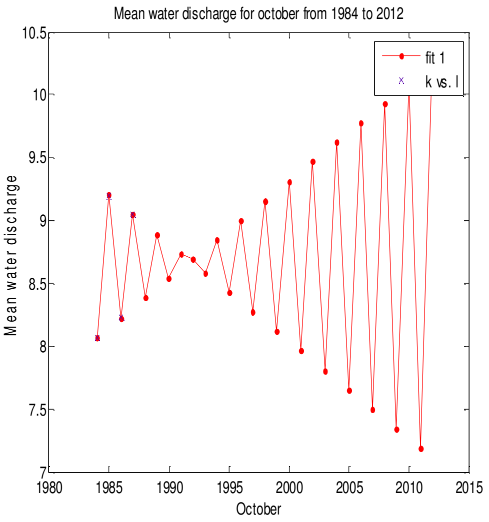

Mean water discharge for the month of May from 1984 t0 2012

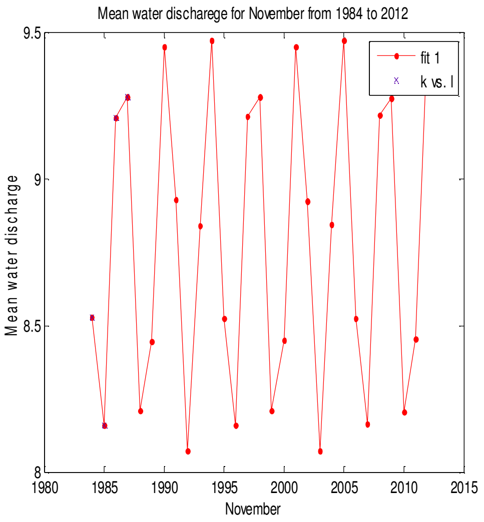

Mean water discharge for June from 1984 to 2012

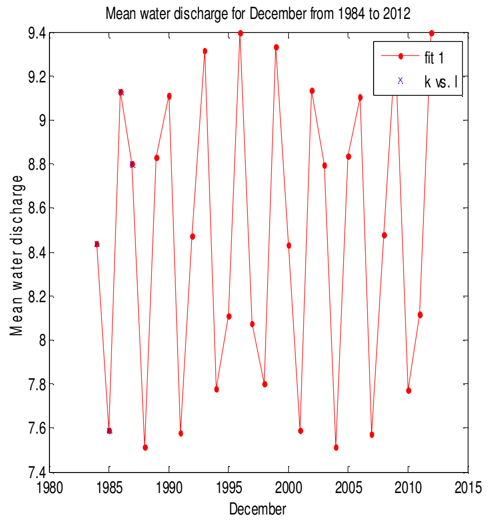

Mean water discharge for July from 1984 to 2012


Mean water discharge for August from 1984 to 2012


Mean water discharge for the september from 1984 to 2012


Mean water discharge for october from 1984 to 2012


Mean water discharege for November from 1984 to 2012


Mean water discharge for December from 1984 to 2012

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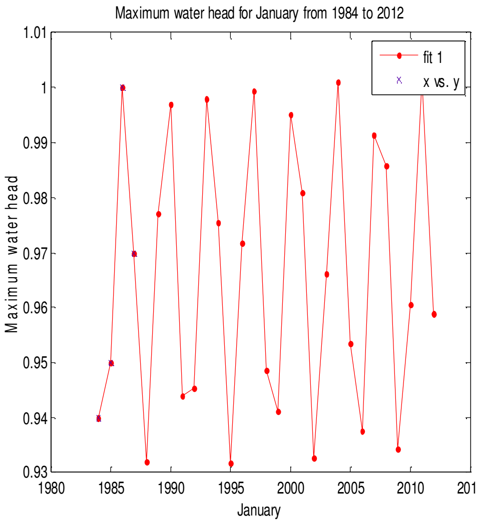
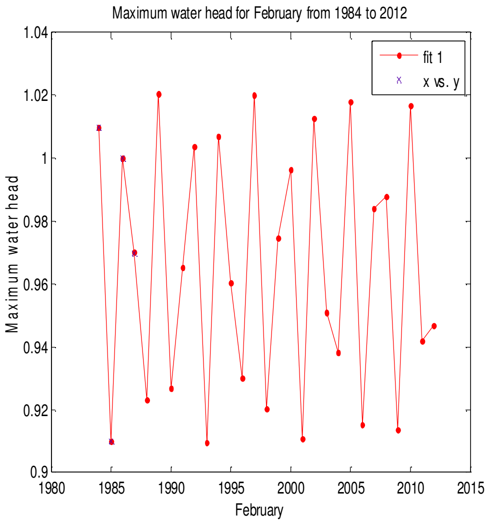
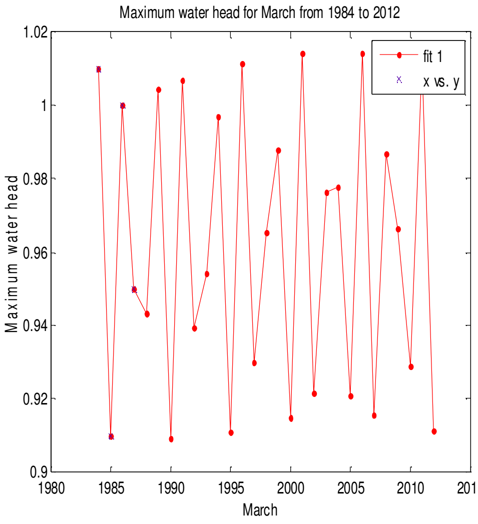
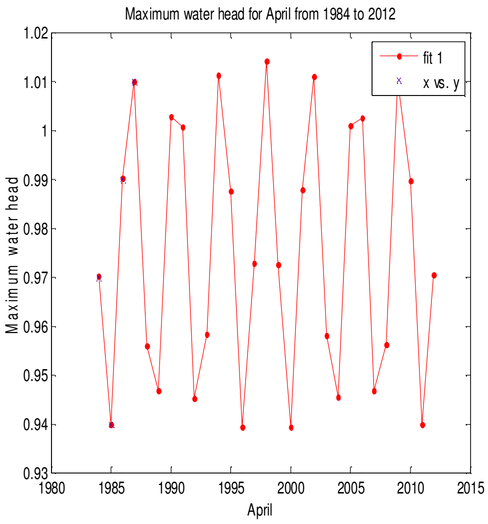
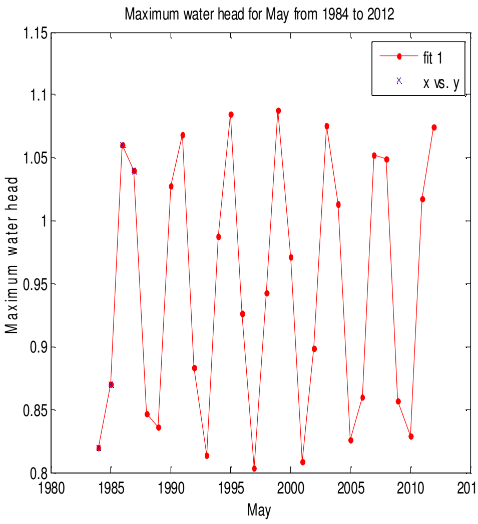
The forecasted results obtained for maximum water head using MATLAB are given as follows:

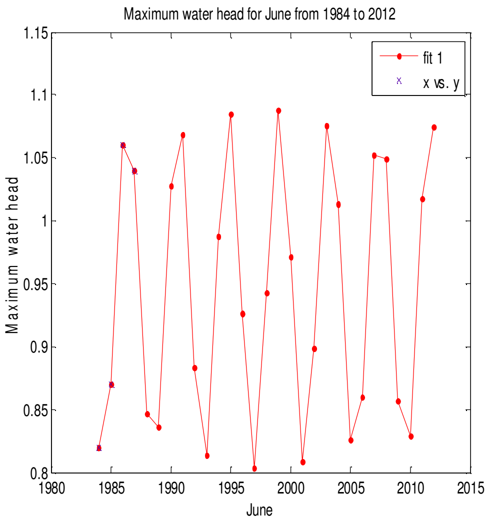












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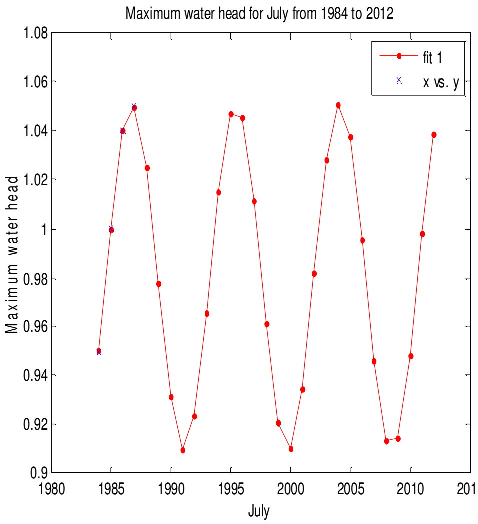
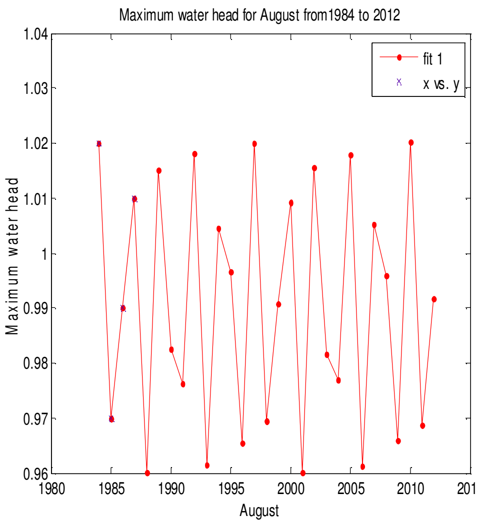
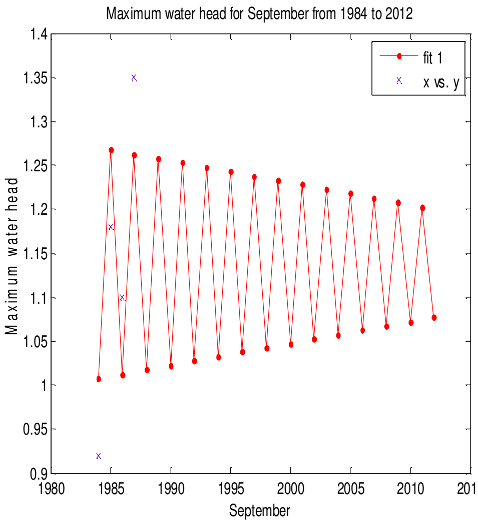


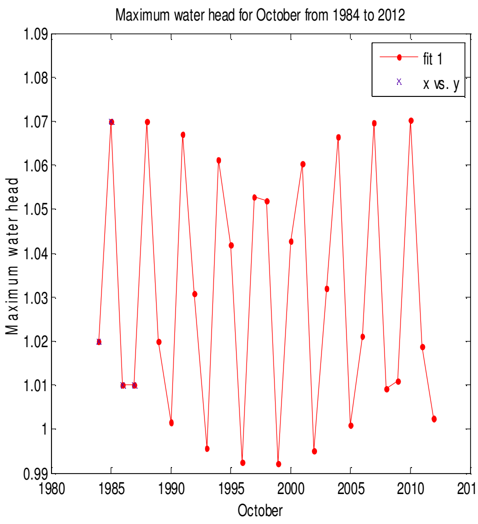
Maximum water head for July from 1984 to 2012



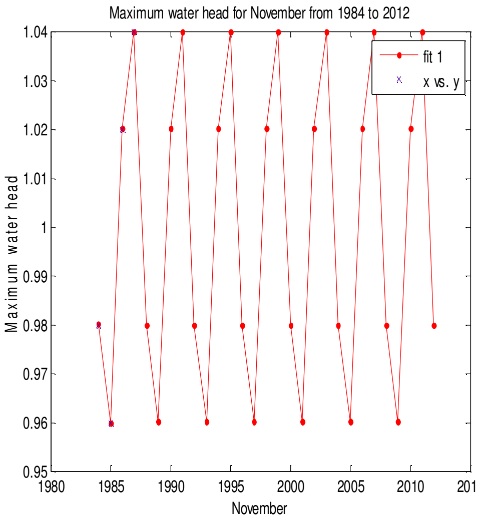
Maximum water head for August from1984 to 2012



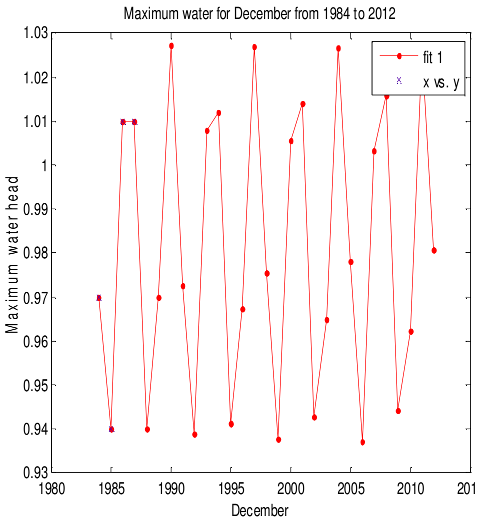
Maximum water head for September from 1984 to 2012



Maximum water head for October from 1984 to 2012



Maximum water head for November from 1984 to 2012



Maximum water for December from 1984 to 2012

From the graphs above, the curves are increasing and decreasing progressively at the same time as they vary from the different months of the hydrological years from 1984 to 2012. The

MATLAB curve fitting tool box was used to obtain a suitable fit for this forecast. Most of the curves were fitted using the first degree fourier fit. Other fits used were Exponential fit, and rational fit linear polynomial-linear polynomial.

Name of River / Stream: OTAMIRI, Catchment Area: 100 SQ KM

Location: LAT: 05° 26’N, LONG: 07° 02’E

Hydrological year: 2012/2013

Table 2. Water Stage and Water Discharge of Otamiri 2012/2013

Month	*Water Head (m)*		*Water Discharge (m^3/s)*		*Mean Discharge*
	Minimum	*Maximum*	*Minimum*	*Maximum*	
April	0.94	1.05	10.28	10.02	10.07
May	0.93	1.07	9.77	9.13	7.24
June	0.92	1.04	10.1	8.95	9.09
July	0.91	1.04	9.63	8.28	8.39
Aug	0.92	1.84	11.6	11.07	10.02
Sept	0.91	1.07	16.00	9.86	11.39
Oct	0.99	1.00	10.28	10.2	10.79
Nov	0.98	0.99	8.82	8.44	9.45
Dec	0.95	0.98	8.83	8.77	9.03
Jan	0.96	0.98	8.52	8.21	7.61
Feb	0.96	0.99	8.35	6.96	7.43
March	0.89	1.02	8.93	7.34	7.41
Average	0.94	1.09	8.94	10.09	8.99

Maximum water head 1.68, minimum water head 0.89

Maximum water discharge 16.00, minimum water discharge 7.24

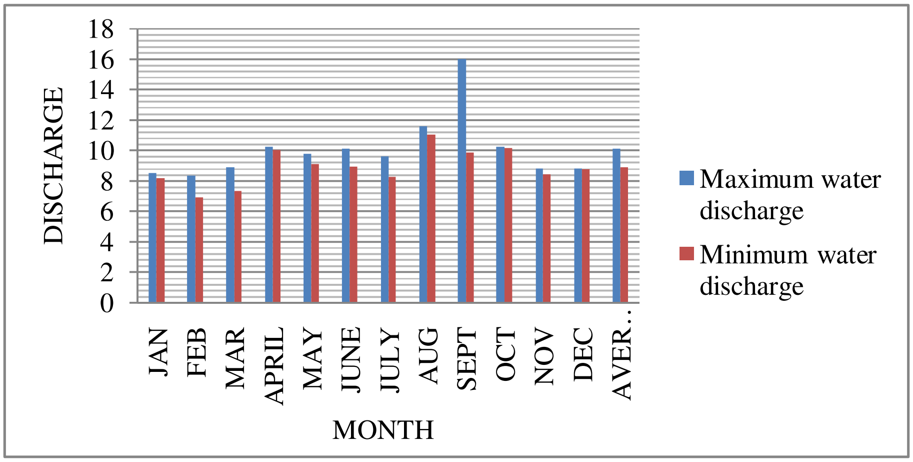


Figure 4. Maximum and Minimum Water Discharge of Otamiri 2012/2013

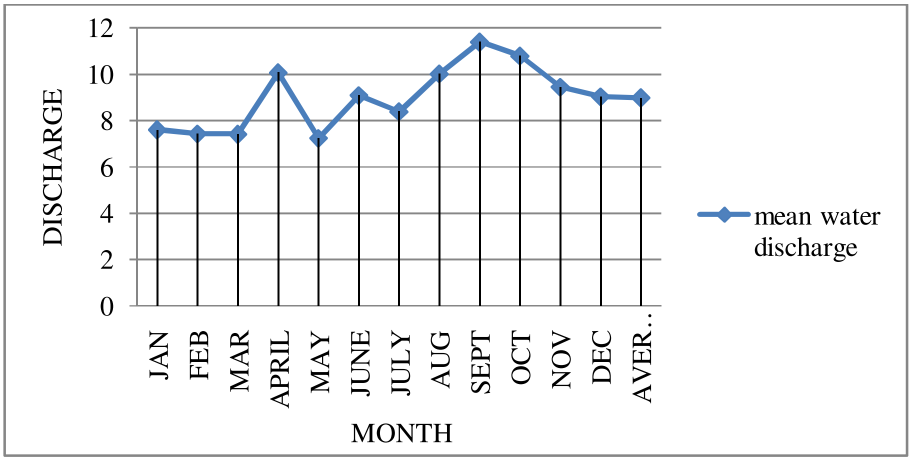


Figure 5. Monthly mean water discharge hydro graphs 2012/2013

From the data and plot above, it is seen that the 2012 hydrological year which starts with the rains in April has the following data:

Maximum water head for the year (August) = 1.84m

Minimum water head for the year (March) = 0.89m

Average minimum water head for the year = 0.94

Average maximum water head for the year = 1.09m

Maximum water discharge for the year (Sept) = 16.00m^3/s

Minimum water discharge (natural) for the year (May) = 7.24m^3/s

Mean water discharge for the year = 8.99m^3/s

Hydro Energy Available:

$P = 9.8 \times Q \times H$

Average Maximum water head of Otamiri H for 2012 hydrological year= 1.09m

Mean water discharge of Otamiri for the year 2012 Q = 8.99m^3/s

Taking the efficiency of the Kaplan turbine as 0.8[10], acceleration due to gravity as 9.81m^2/s, the dnsity of the river as 1000kg/m^3 (1g/cm^3), the average maximum water head as 1.09m and the mean water discharge as 8.99m^3/s, the power output is calculated thus

Conditions 1: when the natural head H_1 is used;

$P = 0.8 \times 9.81 \times 1000 \times 8.99 \times 1.09 / 1000$

P = 76.90kW app. 77kW.

Conditions 2: when the river is dammed H_2 is used

It is possible to generate a head of about 7 meters by damming the river; this value of head is in the low head range. This gives a power output that is not in the micro hydro range as a result of the dam, it gives an output in the mini hydro range. The cost of construction of a dam, and all equipment costs and installation should be put into consideration. The power output is then calculated thus:

$H_g = H_2$ (dammed head) [11]

Maximum water head of the dammed river $H_g = 7m$

Mean water discharge of Otamiri Q for 2012 hydrological year = $8.99m^3/s$

$P = 0.8 \times 9.81 \times 1000 \times 7 \times 8.99 / 1000$

$P = 493.87kW$

The maximum water discharge of the river obtained from the forecast for 2012/2013 hydrological year occurs in the month of September and is approximately $16.00m^3/s$.

REPORT AND ANALYSIS OF THE WORK CARRIED OUT USING THE MODEL 106 SELF RECORDING/ DIRECT RECORDING CURRENT METER

This practical was carried out by our research group and a team from the hydrological department of the Anambra Imo River Basin.

Aim

I. To compute the water speed and hence the water discharge of Otammiri river in FUTO community.
II. To ensure a reasonable power output through the water discharge realized

Apparatus

The apparatus used in the experiment include the model 106 self-recording/ direct recording current meter, fish weight, measuring tape, laptop, laser jet printer and an AC generator.

Theory

The current meter has many models used in the recording of parameters such as water speed, pressure and temperature directly from the equipment to the PC or inside the equipment itself. This particular model is used to record the water speed. It is inserted into the river and a stop watch is used to calculate the period the instrument is in water. The water speed is calculated with the aid of the data log use software installed in the laptop PC. In other to obtain the discharge, the area of the river was computed, and then multiplied by the water speed.

PROCEDURE

a. The current meter was primed i.e. the propeller cap was filled with water from Otammiri River.
b. The different components were attached to it such as the cable, the battery, the connector to the computer etc.
c. The width of the river was measured (to be able to calculate the area).
d. The fish weight and a measuring tape were inserted into the river to record the depth from the surface to the bottom of the river.
e. The current meter was inserted into the river with the connector to its telemetry connected to the laptop.
f. The water speed was then measured at different selected depths throughout the width of the river.

RESULTS OF EXPERIMENT

The width of the river was divided into 8 parts and the depth was measured at seven different positions, a fish weight was used to calculate the depth of the river at different positions, the following results were obtained:

Width of the river = 16m

Height of the river from the bridge to the surface =9.6m

From the height of the bridge to the bottom of the river, the following measurements were obtained:

The depth of the river at the 14th position = 11.2m

The depth of the river at the 12th position= 11.4m

The depth of the river at the 10th position= 12.4m

The depth of the river at the 8th position= 12.5m

The depth of the river at the 6th position= 12.5m

The depth of the river at the 4th position= 12.4m

The depth of the river at the 3rd position= 11.7m

Error in measurement of the depth was provided for as 0.3m

Therefore, the actual depth at these positions including the error difference is calculated thus:

Actual depth of the river at the 14th position= 11.2- (9.6+0.3) = 1.3m

Actual depth of the river at the 12th position= 11.4- (9.6+0.3) = 1.5m

Actual depth of the river at the 10th position= 12.4-(9.6+0.3) = 2.5m

Actual depth of the river at the 8th position = 12.5-(9.6+0.3) = 2.6m

Actual depth of the river at the 6th position = 12.5-(9.6+0.3) = 2.6m

Actual depth of the river at the 4th position = 12.4-(9.6+0.3) = 2.5m

Actual depth of the river at the 3rd position = 11.7- (9.6+0.3) = 1.8m

The water speed was measured at two different depths on the same position at 0.2m and o.8m from the bridge. The two different depths at the different positions were obtained thus;

Taking the error in depth measurement into account as 0.03m.The area of the river is calculated thus:

Area of the triangle from the left = ½ x b x h = ½ x2 x 1.3 = 1.3m^2

Area of the 1st trapezium = ½ (a+b) x h = ½ x (1.3+ 1.5) x 2 = 2.8m^2

Area of 2nd trapezium = ½ (a+b) x h = ½ x (1.5 + 2.5) x 2 = 4.0m^2

Area of 3rd trapezium = ½ (a+b) x h = ½ x (2.5 +2.6) x 2= 5.1m^2.

Area of rectangle = L x W = 2 x 2.6 = 5.2m^2. Area of 4th trapezium = ½ (a+b) x h = ½ x (2.6+2.5) x 2 = 5.1 m^2

Area of triangle at the right = ½ x b x h = ½ x 4 x 2.5 = 5.0m^2

The following results were obtained for water speed from the current meter using the datalogue software:

The following results were obtained from the water discharge from the water speed of Otammiri River for the month of September:

Table 3. Results of one of the experiments

Section No.	*Distance (m)*	*Width (m)*	*Depth (m)*	*Velocity at point (m/s)*		*Mean Velocity (m/s)*	*Sub sectional Area (m^2)*	*Discharge (m^3/s)*
A	14	2	1.3	0.044	0.216	0.220	1.3	0.286
				0.229	0.184			
				0.463	0.183			
B	12	2	1.5	0.677	0.931	0.823	2.8	2.304
				0.709	0.963			
				0.748	0.912			
C	10	2	2.5	0.905	0.850	0.852	5.5	4.686
				0.857	0.847			
				0.819	0.833			
D	8	2	2.6	0.722	0.691	0.715	5.1	3.649
				0.795	0.653			
				0.747	0.680			
E	6	2	2.6	0.666	0.648	0.646	5.2	3.359
				0.697	0.576			
				0.572	0.716			
F	4	2	2.5	0.628	0.524	0.560	5.1	2.856
				0.582	0.481			
				0.713	0.429			
G	3	4	1.8	0.014	0.000 0.100	0.038	5.0	0.190
Total								17.328

Total Discharge= 17.328m^3/s

This correlates with our MATLAB forecasts, which gives16.00 m^3/s as the maximum water discharge for the same month of September in which this experiment was carried out.

CONCLUSION

From the results observed so far, it is obvious that despite the length of time and the likely change in climate conditions over the period under review, there have been no significant change in the important parameters that make for the hydroelectric power potentials of the river used in this case study. It is therefore reasonable for anybody performing experiments that require data from flow measurements for any river within the geographical region (tropical region) concerned in this research to accept as correct such a data even for an extended period of 28 years. However, it must be noted that this may not apply to all geographical regions of the world as this parameters vary from one geographical region to another.

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