ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

GENERATION OF RIVER DISCHARGE USING WATER BALANCE COMPUTER MODEL: APPLICATION TO RIVER OYUN, KWARA STATE, NIGERIA.

[1]MANTA I. H, I. E. AHANEKU[2] AND N. Y. PAMDAYA[3]
[1]National Centre for Agricultural Mechanization, Ilorin, Nigeria.
[2,3]Dept. of Agric. and Bio-resources Engineering, F.U.T. Minna, Nigeria.
[1]E-mail: 2manta@yahoo.com

ABSTRACT

The paper presents a study on river discharge generation using a water balance computer model. The results of the data generated shows that the computer program designed gave a good prediction of the recorded discharge within 95% confidence interval. The model is therefore recommended for other catchments with similar hydrological and soil characteristics.

Key words: River discharge, water balance, computer program, Oyun river.

1.0 INTRODUCTION

Discharge of a river or stream is said to have occurred when some vital climatic factors and soil characteristics would have concomitantly taken place (Jimoh and Ayodeji, 2003). The climatic factors (meteorological data) and soil characteristic that determine the occurrence of discharge include rainfall, temperature, evapo-transpiration, solar radiation, relative humidity and soil infiltration rate (WMO, 2005).

Discharge is one of the most important hydrological data needed as the key element for the construction of any hydraulic structure. Therefore, the quest for discharge of any river or stream, in any form whatsoever has become enormous in today's hydrology for the design and construction of hydraulic structures (Linsley and Frazini, 1992).

There are so many ways of generating discharge, this includes direct recording using flow-meter, mathematical extrapolation, and computer stimulation e.t.c. Computer simulation incorporates the development of a computer program that will generate discharge using a model. However, Peter and Robert (2009), highlighted that hydrological and meteorological data required to run a model are difficult to obtain and much of which are sensitive; and even if all these are in place, a large amount of these data is required in order to initialize the model. They further reiterated that the model should be as simple as possible and easily adaptable to the current technology and should give room for future improvement as science evolves.

The construction of hydraulic structures has today become very necessary for the provision of potable water, irrigation water, access roads, hydro-power, and embankment for the protection of our threatened environment among others.

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Therefore, generation of river discharge cannot be over emphasized as it is vital for the construction of all kind of hydraulic structures with its attendant beneficial effects to the populace.
River behaviour is said to be stable if it would have been under observation for a period of not less than thirty five (35) years (Chow et al., 1988). Therefore, for the design of a perfect hydraulic structure, a data of not less than thirty five (35) years is needed. However, data of such duration is generally lacking in most developing countries.

The change in our climatic conditions that has gone extreme to the notice of the general populace within the catchment was exemplified by the extreme floods of 2007 and 2008 due to heavy downpour (rainfall); especially the very one of 11th October, 2008 with rainfall record of 111.2 mm (NCAM Met Station, 2008). The second highest rainfall recorded in 2008 occurred on the 25th April, 2008 with a depth of 58.2 mm. This difference is simply too much. Meteorological records from stations around and peoples opinion living around the catchment attest to the fact that such down pour have not been experienced over the past thirty (30) years.

The National Centre for Agricultural Mechanization (NCAM) and the entire area situated at the lower basin of the river stand to benefit from the study, especially if any kind of hydraulic structure is to be designed and constructed in and around the catchment. Thus, it is important to design this program as it will contribute immensely in mitigating the current global climatic changes which effects are already being felt within the catchment area.

The objective of this research is to develop a water balance computer program that will be used to generate discharge of a river using available meteorological data and soil characteristics of the catchment.

2.0 MATERIALS AND METHODS

2.1 Study Area

River Oyun basin lies in the sub-humid climatic zone. This climate is influenced by the Inter-tropical Covergence Zone (TCZ), which results in wet and dry seasons. The rain usually starts in April and lasts till late October, with the peak rainfall occurring both in June and September and the dry season lasts between November and March. The mean annual rainfall of the area is 1700mm, while the mean monthly maximum and minimum temperatures in the basin are 31°C and 29°C, respectively, with the highest temperatures recorded in the months of February, March and April. The potential evapo-transpiration of the area is between 1500 - 1700mm per annum (Met. Report, 2009).

River Oyun flows from South East to South West, with a vegetation that is basically savannah (Southern Guinea Savannah Zone) characterized with interspersed grassland and remnants of tropical forest. The forests are typical of large trees and few shrubs found mostly along the watercourses.

River Oyun runs down the valleys of some extruding metamorphic rocks upstream, where it gains its source. This river came to being through the contribution of so many tributaries that run down these rocks. The river has been dammed for the purpose of water supply at the upper reaches of the study area.

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This research was carried out at the National Centre for Agricultural Mechanization (NCAM) premises, Idofian, about 20km outside Ilorin metropolis, Kwara State, Nigeria. The study area is 370m above sea level and lies on Longitudes 4°30' East and Latitude 8°26'N (Ahaneku, 1997). The spill of the river runs across the premises of the National Centre for Agricultural Mechanization (NCAM), which is the focal point of the research.

2.2 Data Collection

During this research, some of the available hydrological data (rainfall, relative humidity, temperature and solar radiation) enumerated above were collected from the NCAM Meteorological Station Report (2008), while some that were not readily available were collected from Ilorin International Airport Meteorological Station report (2009). The soil characteristics which include soil potential infiltration rate and the soil coefficient of the catchment area were predetermined by the Land and Water Engineering Department of NCAM. The summaries of 2008 meteorological data and soil characteristics are presented in tables 1,2,3,4 and 5, respectively.

Table 1: Average Monthly Rainfall

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	552.48	516.14	523.93	495.45	544.23	520.91	539.37	517.01	555.81	564.55	534.93	549.74
Mean	17.82	17.8	16.9	16.51	17.56	17.36	17.4	16.68	18.53	18.21	17.83	17.73
STD	4.15	4.61	4.59	4.01	3.99	3.94	4.38	4.32	4.8	4.46	4.35	4.64
Min.	10.32	10.46	11.06	10.16	11.61	10.15	10.42	10.43	10.14	10.12	10.53	10.5
Max.	24.94	24.65	24.99	23.03	24.56	24.32	24.48	24.36	24.73	24.82	24.88	23.56

Table 2: Average Monthly Relative Humidity

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	899.81	899.87	941.94	966.34	954.3	885.65	909.22	958.29	913.94	865.65	860.31	978.86
Mean	29.03	31.03	30.39	32.21	30.78	29.52	29.33	30.91	30.46	27.92	28.68	31.58
STD	5.78	5.02	6.02	5.66	5.31	5.9	6.22	6.01	5.81	5.15	5.22	5.87
Min.	20.19	22.01	20.21	21.17	22.17	20.91	20.25	20.58	20.48	20.01	20.47	20.51
Max.	39.31	38.69	39.73	39.67	39.96	38.6	39.81	39.91	39.96	38.93	39.16	39.76

Table 3: Average Monthly Temperature

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	718.49	634.95	730.56	654.7	741.27	731.4	753.07	715.56	732.83	708.53	684.55	692.59
Mean	23.18	21.89	23.57	21.82	23.91	24.38	24.29	23.08	24.43	22.86	22.82	22.34
STD	4.99	5.11	4.01	4.38	5.02	4.69	4.44	5.34	4.41	4.46	4.24	5.16
Min.	15.62	15.13	17.76	15.09	16.04	15.58	15,93	15.16	15.6	15.84	15.29	15.04
Max.	30.9	30.79	30.83	30.87	30.94	30.57	30.34	30.85	30.88	30.07	30.39	30.73

Table 4: Average Monthly Sunlight

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total	106.6	92.22	102.85	105.7	108.13	102.46	104.89	99.34	109.13	112.54	109.46	106.1
Mean	3.44	3.18	3.32	3.52	3.49	3.42	3.38	3.2	3.64	3.63	3.65	3.42
STD	0.82	0.9	0.94	0.84	1.05	0.9	0.73	0.89	0.89	1	0.86	0.89
Min.	2.05	2.06	2.03	2.04	2.02	2.09	2.06	2.04	2.14	2.06	2.29	2.15
Max.	4.93	4.97	4.97	4.97	4.99	5	4.83	4.96	4.92	4.99	4.95	4.96

Table 5: SoilCharacteristics of the Catchment

Parameter	Value
Average Potential Infiltration Rate (mm/hr)	3.0
Soil Coefficient (K)	2.0
Groundwater recharge (m^2/m	1.25

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2.3 Computer Program and Model Design

A 2008 meteorological data which comprises of rainfall, relative humidity, temperature and solar radiation (recorded) and the soil characteristics of the likes of potential infiltration, Kc value and ground water recharge (determined) within the catchment were itemized and arranged to conform with the terms and language of the computer program. A water balance equation to determine discharge was written as equation1.

$$D = R - ET_p\ P_{inf} + G_w \qquad (1)$$

where,

D = Discharge (m^3/s)
R = Rainfall (mm)
ET_P = Evapo-transpiration (mm/day)
Pinf = Potential infiltration (mm)
Gw = Ground water (mm^3)

Evapo-transpiration, ETP in equation 1 is expressed as adjusted by Blaney-Criddle Model for the tropics (Fapohunda and Ude, 1992).

$$ET_p = \frac{(37.846-0.254R_h)K_cK_tS}{100} \qquad (2)$$

where,

R_h = Relative humidity
K_c = Soil coefficient of the area
K_t = (0.0173T 0.314) monthly temperature factor
T = mean monthly temperature in °F
S = monthly percent of daylight hour of the year

A water balance model computer program named "Dischargepro" using Visual Basic 6.0 programming language was developed. The program was used to generate discharge using available meteorological data and soil characteristic that were recorded and determined, respectively from the catchment.

Discharge is the flowing water in the river, stream or canal that occurs as a result of rainfall, which is a remnant of evaporation (due to solar intensity, change in temperature and humidity). This flowing water is said to have exceeded the infiltration capacity of the underlying soil.

The program computed the rainfall records against all other parameters (temperature, relative humidity, solar radiation, evapo-transpiration, soil potential infiltration and coefficient of infiltration) to generate discharge. A flow-chart of the program was developed as illustrated on Figure 1 taking into consideration the water balance equation and all the relevant hydrological data and soil characteristics as highlighted above.

The daily discharge for the year 2008 was generated by the program using equation 1 and the available parameters stated above. The generated discharge was graphically compared with the recorded discharge, while the factor of fitness was determined through statistical analysis using the t-test for equality of means.

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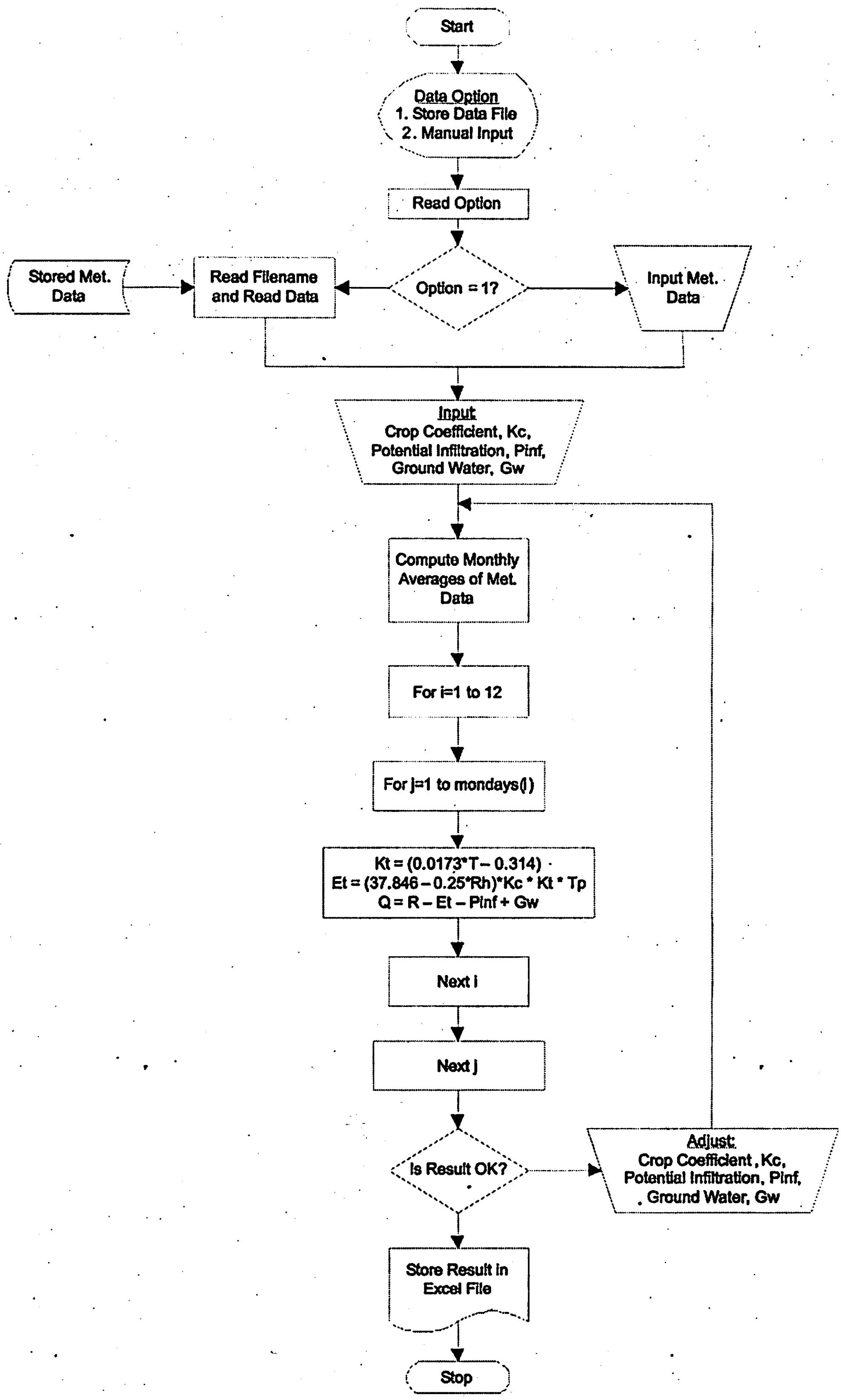

Fig. 1: The Flow Chat of Dischargepro.

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3.0 RESULTS

The daily recorded discharge were produced and tabulated as shown in Table 6, while the generated discharge were calculated and Tabulated on Table 7.

Table 6: Daily recorded discharge (m3/s) of River Oyun for 2008.

Days	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.007	0.005	0.008	0.008	0.028	0.015	0.153	0.742	0.631	0.137	0.098	0.057
2	0.007	0.006	0.007	0.006	0.012	0.018	0.102	0.725	0.591	0.134	0.090	0.048
3	0.060	0.006	0.012	0.006	0.013	0.015	0.093	0.719	0.481	0.124	0.078	0.040
4	0.045	0.036	0.059	0.057	0.138	0.139	0.316	0.985	0.824	0.332	0.139	0.053
5	0.057	0.046	0.076	0.073	0.174	0.180	0.370	1.066	0.888	0.397	0.152	0.052
6	0.074	0.059	0.099	0.095	0.228	0.234	0.460	1.179	0.987	0.484	0.173	0.053
7	0.079	0.077	0.128	0.125	0.300	0.308	0.582	1.332	1.155	0.604	0.205	0.058
8	0.090	0.091	0.151	0.148	0.354	0.364	0.671	1.448	1.266	0.695	0.227	0.060
9	0.101	0.106	0.176	0.173	0.414	0.425	0.771	1.576	1.392	0.794	0.251	0.062
10	0.110	0.121	0.202	0.198	0.476	0.488	0.875	1.708	1.527	0.898	0.278	0.065
11	0.120	0.136	0.226	0.223	0.535	0.549	0.972	1.834	1.651	0.996	0.302	0.067
12	0.130	0.151	0.251	0.248	0.595	0.610	1.072	1.962	1.779	1.096	0.327	0.070
13	0.140	0.166	0.276	0.273	0.655	0.672	1.173	2.091	1.909	1.196	0.352	0.072
14	0.150	0.181	0.301	0.298	0.715	0.733	1.273	2.218	2.036	1.296	0.377	0.075
15	0.160	0.196	0.326	0.323	0.775	0.795	1.373	2.346	2.164	1.396	0.402	0.077
16	0.170	0.211	0.351	0.348	0.835	0.857	1.473	2.474	2.292	1.496	0.427	0.080
17	0.180	0.226	0.376	0.373	0.895	0.918	1.573	2.602	2.420	1.596	0.452	0.082
18	0.190	0.241	0.401	0.398	0.955	0.980	1.673	2.730	2.548	1.696	0.477	0.085
19	0.200	0.256	0.426	0.423	1.015	1.041	1.773	2.858	2.676	1.796	0.502	0.087
20	0.210	0.271	0.451	0.448	1.075	1.102	1.873	2.986	2.804	1.896	0.527	0.090
21	0.220	0.286	0.476	0.473	1.135	1.164	1.973	3.114	2.932	1.996	0.552	0.092
22	0.230	0.301	0.501	0.498	1.195	1.226	2.073	3.242	3.060	2.096	0.577	0.095
23	0.240	0.316	0.526	0.523	1.255	1.287	2.173	3.370	3.188	2.196	0.602	0.097
24	0.250	0.331	0.551	0.548	1.315	1.349	2.273	3.498	3.316	2.296	0.627	0.100
25	0.260	0.346	0.576	0.573	1.375	1.410	2.373	3.626	3.444	2.396	0.652	0.102
26	0.270	0.361	0.601	0.598	1.435	1.471	2.473	3.754	3.572	2.496	0.677	0.105
27	0.280	0.376	0.626	0.623	1.495	1.533	2.573	3.882	3.700	2.596	0.702	0.107
28	0.290	0.391	0.651	0.648	1.555	1.595	2.673	4.010	3.828	2.696	0.727	0.110
29	0.300	0.000	0.676	0.673	1.615	1.656	2.773	4.138	3.956	2.796	0.752	0.112
30	0.310	0.000	0.701	0.698	1.675	1.718	2.873	4.266	4.084	2.896	0.777	0.115
31	0.320	0.000	0.726	0.723	1.735	0.000	2.973	4.394	0.000	2.996	0.000	0.117
Total	5.250	5.296	10.914	10.822	25.972	24.852	45.824	76.875	67.101	46.515	12.481	2.485
Mean	0.169	0.189	0.352	0.349	0.838	0.828	1.478	2.480	2.237	1.500	0.416	0.080
STD	0.092	0.114	0.226	0.226	0.541	0.537	0.901	1.154	1.113	0.902	0.227	0.022
Min.	0.007	0.005	0.007	0.006	0.012	0.015	0.093	0.719	0.481	0.124	0.000	0.040
Max.	0.320	0.391	0.726	0.723	1.735	1.718	2.973	4.394	4.084	2.996	0.777	0.117

ISSN: 0189-9546
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Table 7: Daily generated discharge (m3/s) of River Oyun for 2008.

Days	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.006	0.003	0.009	0.006	0.020	0.020	0.124	0.542	0.571	0.132	0.086	0.045
2	0.005	0.003	0.009	0.002	0.000	0.021	0.074	0.525	0.531	0.129	0.078	0.036
3	0.058	0.002	0.014	0.001	0.003	0.015	0.066	0.519	0.421	0.119	0.066	0.028
4	0.042	0.031	0.062	0.051	0.118	0.136	0.289	0.785	0.764	0.326	0.127	0.042
5	0.054	0.040	0.079	0.066	0.151	0.174	0.345	0.866	0.828	0.391	0.140	0.040
6	0.070	0.053	0.103	0.087	0.201	0.226	0.435	0.979	0.927	0.479	0.161	0.042
7	0.074	0.070	0.132	0.116	0.269	0.296	0.558	1.132	1.096	0.599	0.193	0.046
8	0.085	0.082	0.156	0.137	0.319	0.349	0.648	1.248	1.206	0.690	0.215	0.048
9	0.095	0.096	0.181	0.161	0.375	0.408	0.749	1.376	1.332	0.789	0.240	0.050
10	0.104	0.111	0.208	0.186	0.433	0.468	0.854	1.508	1.467	0.892	0.266	0.053
11	0.114	0.125	0.233	0.209	0.488	0.526	0.952	1.634	1.591	0.990	0.290	0.055
12	0.123	0.139	0.258	0.233	0.544	0.585	1.054	1.762	1.720	1.091	0.315	0.058
13	0.133	0.153	0.284	0.257	0.600	0.743	1.155	1.891	1.849	1.191	0.340	0.060
14	0.142	0.167	0.309	0.280	0.656	0.691	1.255	2.018	1.976	1.291	0.365	0.063
15	0.152	0.181	0.335	0.304	0.712	0.750	1.357	2.146	2.104	1.391	0.390	0.065
16	0.161	0.195	0.361	0.328	0.769	0.809	1.458	2.274	2.232	1.491	0.415	0.068
17	0.170	0.209	0.386	0.352	0.825	0.867	1.558	2.402	2.360	1.591	0.440	0.070
18	0.180	0.223	0.412	0.376	0.881	0.926	1.659	2.530	2.488	1.691	0.465	0.073
19	0.189	0.238	0.437	0.400	0.937	0.985	1.760	2.658	2.616	1.791	0.490	0.075
20	0.199	0.252	0.463	0.423	0.993	1.043	1.861	2.786	2.744	1.891	0.515	0.078
21	0.208	0.266	0.488	0.447	1.049	1.102	1.962	2.914	2.872	1.991	0.540	0.080
22	0.218	0.280	0.514	0.471	1.105	1.161	2.063	3.042	3.000	2.091	0.565	0.083
23	0.227	0.294	0.539	0.495	1.161	1.219	2.164	3.170	3.128	2.191	0.590	0.085
24	0.237	0.308	0.565	0.519	1.217	1.278	2.265	3.298	3.256	2.291	0.615	0.088
25	0.246	0.322	0.590	0.543	1.273	1.337	2.366	3.426	3.384	2.391	0.640	0.090
26	0.256	0.336	0.616	0.566	1.329	1.395	2.467	3.554	3.512	2.491	0.665	0.093
27	0.265	0.350	0.641	0.590	1.385	1.454	2.568	3.682	3.640	2.591	0.690	0.095
28	0.275	0.364	0.667	0.614	1.441	1.513	2.669	3.810	3.768	2.691	0.715	0.098
29	0.284	0.000	0.693	0.638	1.498	1.571	2.770	3.938	3.896	2.791	0.740	0.100
30	0.293	0.000	0.718	0.662	1.554	1.630	2.871	4.066	4.024	2.891	0.765	0.103
31	0.303	0.000	0.744	0.686	1.610	0.000	2.972	4.194	0.000	2.991	0.000	0.105
Total	4.968	4.893	11.206	10.206	23.916	23.698	45.348	70.675	65.303	46.356	12.122	2.115
Mean	0.160	0.175	0.361	0.329	0.771	0.790	1.463	2.280	2.177	1.495	0.404	0.068
STD	0.088	0.107	0.231	0.215	0.505	0.507	0.909	1.154	1.113	0.902	0.226	0.022
Min.	0.005	0.002	0.009	0.001	0.000	0.000	0.066	0.519	0.000	0.119	0.000	0.028
Max.	0.303	0.364	0.744	0.686	1.610	1.630	2.972	4.194	4.024	2.991	0.765	0.105

The monthly mean of both generated and recorded discharge are graphically illustrated as shown in Fig. 2, where the two discharges are plotted against time (twelve months of the year 2008).

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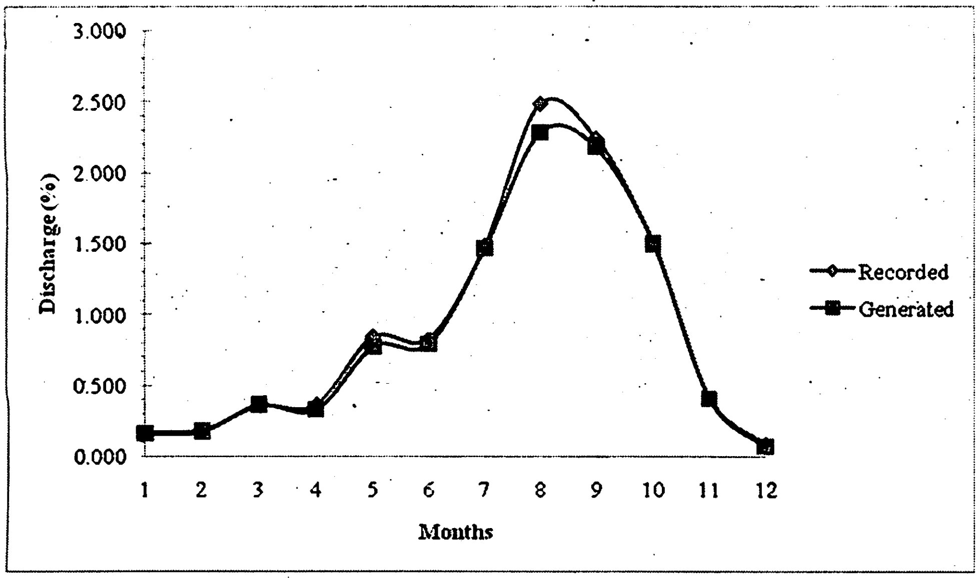

Fig. 2: Graph of the Recorded and Generated discharge of River Oyun in 2008.

The result of the statistical analysis carried out to determine the factor of fitness using difference of two means or t-test equality of means was to determine the difference between the recorded and the generated discharge. The two discharge records were subjected to mean difference analysis, where it was observed that the group mean of the recorded discharge was slightly higher than the generated discharge as shown in Table 8.

Table 8: Grouping analysis of the recorded and generated data.

	Categories	N	Mean	Std. Deviation	Std. Error Mean
readings	Recorded	12	0.9108	0.8271	0.2388
	Generated	12	0.8728	0.7894	0.2279

However, the mean difference between the recorded and the generated data was carried out to determine the significant difference between the recorded and the generated discharge. This was found to be not greater than or less than 0.038, (+0.038 and - 0.038); which had less than 5% likely error. Therefore, this analysis has shown that the research had negligible error, with an efficiency of 95% as highlighted in table 9 (95% Confidence Interval of the Difference).

Table 9: T-test equality of means for the reded and generated data.

	t-test for Equality of Means						
						95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
readings	0.1150	22	0.9090	0.0380	0.3300	-0.6465	0.7225

The discharge for 2009 and 2010 was generated using the same computer program and this was graphically illustrated in Figure. 3 and 4

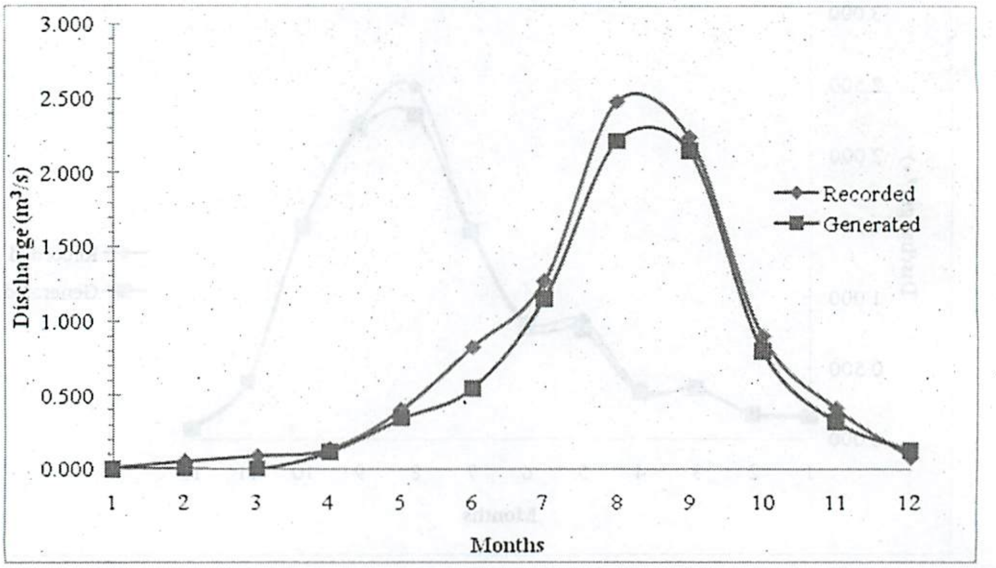

Fig. 3: Graph of the Recorded and Generated discharge of River Oyun in 2009.

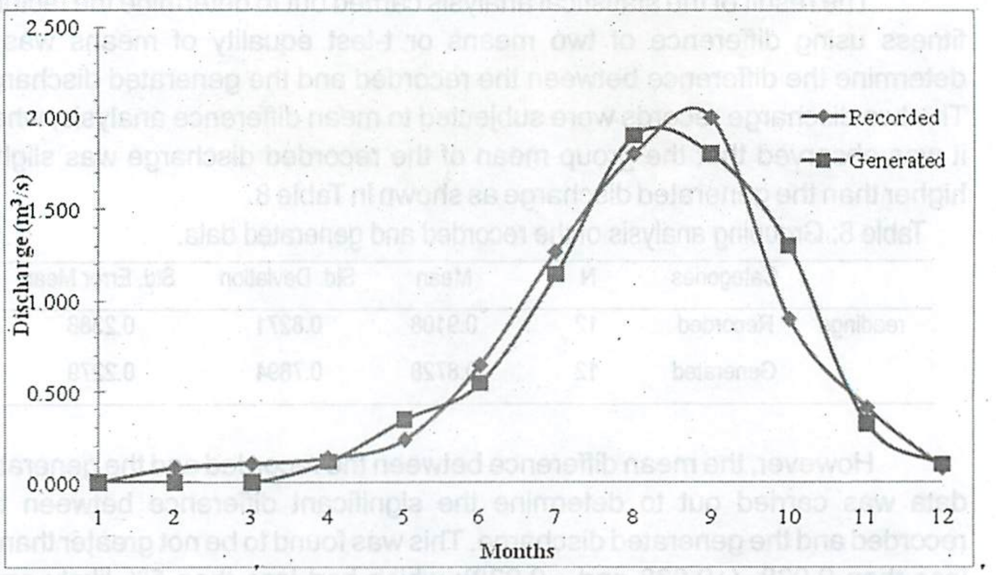

Fig. 4: Graph of the Recorded and Generated discharge of River Oyun in 2010.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The results obtained from this research shows that with enough recorded hydrological data and soil characteristics of the catchment, the computer program can generate accurate discharge of the catchment area.

The generated discharge can be used for the construction of any hydraulic structure in and around the catchment across Oyun River and other catchments with similar hydrological and soil characteristics, provided an appropriate factor of safety is considered.

REFERENCES:

Ahaneku, I.E. (1997). Soil degradation and water balance studies under different tillage systems, (unpublished Ph.D Thesis, University of Ibadan, Nigeria.

Chow, V.T. Maidment, D.R, and Mays, L.W. (1988). Applied Hydrology. McGraw-Hill Book Company, Singapore.

Fapohunda, H. O. and Ude, I. C. (1992). Estimating potential evapotranspiration from tropical climatological data. The Nigeria Engineer, vol. 27(1): 23 - 29.

Jimoh, O.D. and Ayodeji, O.S. (2003). Impact of Gurara River (Nigeria) interbasin water transfer scheme on the Kaduna River at Shiroro Dam. Proc. of symposium IUGG@))# - Hydrological Risk and Management and Development No. 281, pp. 277 - 286, IAHS Publication, Saporo.

Linsely R. K. and Frazini M., (1992). Water Resources and Environmental Engineering. McGraw-Hill, Inc., Singapore.

Metrological Station Report (2009), Ilorin International Airport Meteorological Station yearly report, Ilorin, Kwara State.

NCAM Meteorological Station

Peter J. W. & Robert G. (2009), Forecasting River Discharge into Bangladesh on Short, Medium and Long Time Scales, Georgia Institute of Technology, Atlanta, Georgia, USA.

WMO Report (2005), Climate and Land Degradation, WMO No. 989 2005.