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Estimation of Flood Magnitude and Frequency of Escravos Bay in Delta State Nigeria using Log Pearson Type (iii) Distribution.

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Abstract
The climate of the world is changing and there are not enough rain/tidal gauges to record the hydrodynamics of water flowing in and out of the sub-tributaries of the western Niger Delta in Nigeria e.g., the Benin, Forcados and Escravos rivers. Flood in low lying coastal area of Ugborodo clan have been causing a lot of havoc, as a recurrence decimal it displaces the habitat and destroys properties especially during the raining season. This paper focuses on the estimation of magnitude on frequency of occurrence of return period 2years, 5years, 10years, 25years, 50years, 100years and 200years of flow using log Pearson type III probability distribution model fitted in fifteen years tidal record taken between 2000-2014 from Escravos bay and the results were 10,891m^3/s, 11,912 m^3/s, 12,376 m^3/s, 12,815 m^3/s, 13,068 m^3/s, 13,275 m^3/s, 13,447 m^3/s respectively. The predictions of these result as maximum possible flood is expected to assist coastal catchment managers in their planning because estimation of peak flood for a particular return period is the most valuable information for him to be able to design and construct safe hydraulic structures like gabions, sheet piles, dam, etc., also early warning measures can be put in place to prevent catastrophic scenario by developing flood maps and finally, this result can be used by decision makers as a guide to plan hydraulic structures in the clan.

Keywords- Coastal area, Tidal gauge, Peak flow, Return periods, Frequency of occurrence.

Introduction
As long as the earth exist there must be flood because it is a natural geological occurrence that is meant to shaping the earth like volcanoes, tsunamis, earthquake, weathering e.t.c. however, flood in coastal area have caused a lot of inconvenience to the habitats living around it especially as the sea levels are rising owing to climate change. Hinkel et al (2014) opined that without adaptation 0.2-4.6% of the global population may be flooded annually in 2100 with scenarios of 0.25-1.23m global sea level rise. Unfortunately most of these communities like Ugborodo Arutun, Okiemekpe, Forcados e.t.c are low lying catchments which makes them susceptible to flooding as every day the settlements in the catchment and river bank are increasing due to industrialization, agriculture and institutional development, Lochter et al (2010) expressed that the low elevation of coastal zones below 10m is home to 600million people and is vulnerable to the

effect of extreme sea level events and climate change, though precipitation can still cause flash flood in these communities as the nature of most hydrological events such as rainfall is erratic and varies with time and space Sathe et al (2012). Understanding the geomorphology of river network is one of the challenges that flood managers encounter in complex terrain of the coastal area of Niger Delta. The geomorphologic complexity of river network in many cities have been significantly altered which in turn greatly affect the flood frequency and probability in these cities Shixia et al (2015). Recently, the Niger Delta development commission drew a master plan to see that gradually most of these community shorelines are protected by designing and constructing walls like sheet pile, gabion e.t.c. Annually, a lot of funds are spent on flood effect reduction and protection using either structural (achieved by constructing storage dam, weir, reservoir, culvert e.t.c) or nonstructural achieved by flood forecasting, catchment enrichment, and rescue operation e.t.c. Okonofua et al (2013).

The water resources engineer needs to know the worse capacity of water that this designed structure will withstand during the life span of the structure as opined by Karim (2009) that water is viewed both as a valuable resources to be protected and a violent force to be respected. Schandel et al (2015) shared that the analysis of extreme event in hydrology is without doubt of crucial importance for engineering practice regarding water resources design and management, as shared by Duong et al (2016) that the information about the type of flood (River, coastal, lake and ground water), the probability of a particular flood event, the flood velocity and finally, the probable magnitude of damage (life properties economic activities) are vital information for flood managers. However, stream flow data are not always available at specific sites of interest (Unguaged sites) or the records may be too short to provide useful statistics Kuk – Hyun et al (2016) and Zakaullah et al (2012).

Design flood estimation is a difficult task to actualize, in the past, acquisition of historical flood data was gotten from two methods, the field investigation and detailed survey of historical literatures Cheng – Zheng (1987). Over the years, wrong forecast by meteorologist because of its timing has cost a lot of harm. However, this short term forecast can be used on various probabilistic models like Log Normal, Gumbel, Log Pearson III e.t.c to forecast a long term return period. Estimation of peak flood magnitude for a desired return period is often required for planning, design and management of hydraulic and other structures in a region Manas (2013) also Luna et al (2014) expressed flood frequency analysis as an important mathematical model technique used to determine the return period of the probability of witnessing a particular discharge in a river especially at its peak discharge.

The chosen design discharge (magnitude) must be able to meet it serviceability limit i.e. it estimation must be able to be sustained by the structure, so that there will be no amount of flood in the life of the structure that it cannot carry, in this regards all factors of safety must be met. Researchers have tested different probabilistic distributions and found that log Pearson (III) gives a better result e.g, Singo et al (2013) used different probabilistic approach but found out that log Pearson type (III) best fits model to find the flood intensity of different return period in prone Luvuvhu River Catchment (LRC) of South Africa. In the log Pearson (III) model the return periods which is an expression of the highest frequency of occurrence are analyzed by getting basically three terms, the mean, the standard deviation and the skewness coefficient which are interpolated from the frequency factor. The objective of this paper is to model the flood frequency analysis of Escravos river using existing fifteen years annual peak discharge data obtained from the Escravos bay in Ugborodo from 2000- 2014. The maximum discharge for return period of 2yrs, 5yrs, 10yrs, 25yrs, 50yrs, 100yrs and 200yrs where estimated.

Description of the Study Area

Ugborodo is a riverine kingdom located between the Escravos river with a distance of 29km and drains into the Atlantic Oceans. It is an Itsekiri clan with different communities represented by chief and headed by a King. The community lies between longitude E5.15^{0} and latitude N5.57^{0}. it is bounded at the North by Okiomekpo and Ogidigben by the south eastern flank. There is population migration to the community because of the presence of oil facilities although the common occupation in the area is fishing, lumbering, hunting, palm oil farming e.t.c. About 177,000 people live in this flood plan and the land area of the study area is about 80km^{2}. This region, because of its low lying nature has experienced coastal flooding due to sea level rise and tidal effects which has resulted to lose of properties but no known loss of life, this is because most of the indigenes are fishermen.

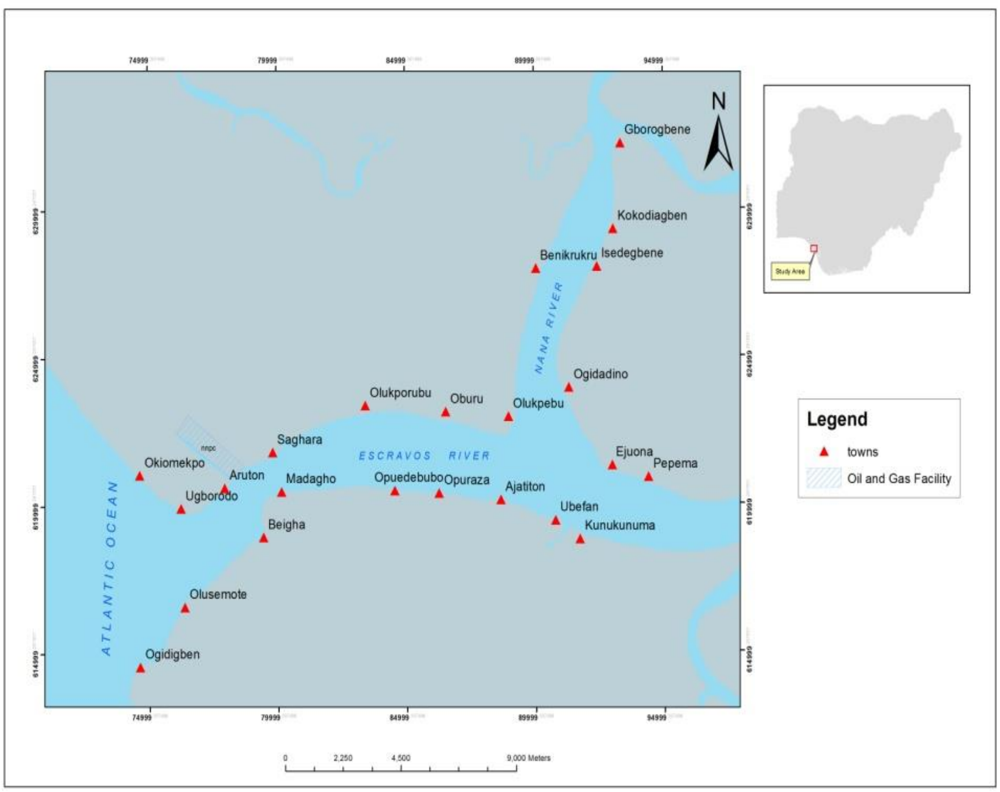

Fig 1. : Digital map of the study area

Data and Method: The data used in this paper was collected from the Escravos record gauge in Ugborodo, it is a 15years record from 2000-2014 and was validated with the data from Ibitola (2009) on the hydrodynamic fluxes of the Escravos and Forcados rivers.

There are two season in the study area (Rainy and dry season) however the peak discharge recorded for each year was used for the analysis.

Method

Calculation of flood frequency analysis tend to estimate three values

1. Probability of exceedence
2. The relative frequency
3. Recurrence interval

Table 1 Annual peak discharge of Excravos river (2000-2014)

S/NO	YEARS	Q (ESCRAVOS) m^3/s
1	2000	10,421
2	2001	10,850
3	2002	11,210
4	2003	10,970
5	2004	8,535
6	2005	8,710
7	2006	10,918
8	2007	11,010
9	2008	10,111
10	2009	9,720
11	2010	12,003
12	2011	11,789
13	2012	12,516
14	2013	10,979
15	2014	11,863

Log Pearson type (III) was used to predict design flood of different return periods.

The calculation procedures – there are twelve steps to calculating the flood discharge quantity.

1. The flood data (q) has to be ranked (r) (arranging the quantity of flood data from highest to the least). All working is first converted to logarithms of base 10.
2. The log of each quantity are gotten B = log q
3. The mean of the log quantity value is gotten Bm
4. Subtract the mean log value Bm from the log value and square = $(B - Bm)^2$
5. Cube the value of $(B - Bm)^3$
6. Get the period T = $\frac{r+0.2}{t-0.4}$ where r is the rank and t ishe number of data value (years)
7. The probability P = $\frac{100\%}{Return\ Period}$,
8. The standard deviation $\sigma = \sqrt{\frac{\in(B-B_m)^2}{r-1}}$
9. The skewness coefficient g = $\frac{\in(B-B_m)^3}{(r-1)(r-2)\sigma^3}$
10. The skewness coefficient value is checked up from the frequency factor (k) table for each of the return period through interpolation method.
11 Water quantity factor q_2 = Bm +k σ = mean value (Bm) + frequency factor K x the standard deviation

12 The anti-log of q_2 = Q in m^3/s.

Table 2. Log Pearson III Computational analysis of data

Rank(m)	**Water year**	**Flood flow (x) (m^3/s)**	**y = log x**	**$(y-ym)^2$**	**$(y-ym)^3$**	**T = (n + 0.2)/(m - 0.4)**	**P= 100/T**
1	2012	12,516	4.0975	0.00455	0.00031	25.333	3.947
2	2010	12,003	4.0793	0.00243	0.00012	9.500	10.526
3	2014	11,863	4.0742	0.00195	0.00009	5.846	17.105
4	2011	11,789	4.0715	0.00172	0.00007	4.222	23.684
5	2002	11,210	4.0496	0.00039	0.00001	3.304	30.263
6	2007	11,010	4.0418	0.00014	0.00000	2.714	36.842
7	2013	10,979	4.0406	0.00011	0.00000	2.303	43.421
8	2003	10,970	4.0402	0.00010	0.00000	2.000	50.000
9	2006	10,918	4.0381	0.00007	0.00000	1.767	56.579
10	2001	10,850	4.0354	0.00003	0.00000	1.583	63.158
11	2000	10,421	4.0179	0.00015	0.00000	1.434	69.737
12	2008	10,111	4.0048	0.00063	-0.00002	1.310	76.316
13	2009	9,720	3.9877	0.00179	-0.00008	1.206	82.895
14	2005	8,710	3.9400	0.00809	-0.00073	1.118	89.474
15	2004	8,535	3.9312	0.00976	-0.00096	1.041	96.053
	Mean	10,774	4.0300				
	Standard deviation (δy)		0.0477				
	Skewness coefficient (g)		-0.8996				

Table 3. Results from computation

Return period T(yrs)	Probability P(%)	Frequency factor K (g = -0.8996)	q = Bm + Kδ	q_2 =Q(m^3/s) = Antilog (q)
2	50	0.148	4.037	10891
5	20	0.963	4.076	11912
10	10	1.311	4.093	12376
25	4	1.628	4.108	12815
50	2	1.806	4.116	13068
100	1	1.949	4.123	13275
200	0.5	2.066	4.129	13447

	Return Period T(y)									
	1.05	1.11	1.25	2	5	10	25	50	100	200
	Probability of exceedence P (percent)									
C_s	95	90	80	50	20	10	4	2	1	0.5
3.0	-0.665	-0.660	-0.636	-0.396	0.420	1.180	2.278	3.152	4.051	4.970
2.8	-0.711	-0.702	-0.666	-0.384	0.460	1.210	2.275	3.114	3.973	4.847
2.6	-0.762	-0.747	-0.696	-0.368	0.499	1.238	2.267	3.071	3.889	4.718
2.4	-0.819	-0.795	-0.725	-0.351	0.537	1.262	2.256	3.023	3.800	4.584
2.2	-0.882	-0.844	-0.752	-0.330	0.574	1.284	2.40	2.970	3.075	4.444
2.0	-0.949	-0.895	-0.777	-0.307	0.609	1.302	2.219	2.912	3.605	4.398
1.8	-1.020	-0.945	-0.799	-0.282	0.643	1.318	2.193	2.848	3.499	4.417
1.6	-1.093	-0.994	-0.817	-0.254	0.675	1.329	2.163	2.780	3.388	3.990
1.4	-1.168	-1.041	-0.832	-0.225	0.705	1.337	2.128	2.706	3.271	3.828
1.2	-1.243	-1.086	-0.844	-0.195	0.732	1.340	2.087	2.626	3.149	3.661
1.0	-1.317	-1.128	-0.852	-0.164	0.758	1.340	2.043	2.542	3.022	3.489
0.8	-1.388	-1.166	-0.856	-0.132	0.780	1.336	1.993	2.453	2.891	3.312
0.6	-1.458	-1.200	-0.857	-0.099	0.800	1.328	1.939	2.359	2.755	3.132
0.4	-1.524	-1.231	-0.855	-0.66	0.816	1.317	1.880	2.261	2.615	2.949
0.2	-1.586	-1.258	-0.850	-0.033	0.830	1.301	1.818	2.159	2.472	2.763
0.0	-1.645	-1.282	-0.842	0.000	0.842	1.282	1.751	2.054	2.326	2.576
-0.2	-1.700	-1.301	-0.830	0.033	0.850	1.258	1.680	1.945	2.178	2.388
-0.4	-1.750	-1.317	-0.816	0.066	0.855	1.231	1.606	1.834	2.029	2.201
-0.6	-1.797	-1.328	-0.800	0.099	0.857	1.200	1.528	1.720	1.880	2.016
-0.8	-1.839	-1.336	-0.780	0.132	0.856	1.166	1.448	1.606	1.733	1.837
-1.0	-1.877	-1.340	-0.758	0.164	0.852	1.128	1.366	1.492	1.588	1.664
-1.2	-1.910	-1.340	-0.732	0.195	0.844	1.086	1.282	1.379	1.449	1.501
-1.4	-1.938	-1.337	-0.705	0.225	0.832	1.041	1.198	1.270	1.318	1.351
-1.6	-1.962	-1.329	-0.675	0.254	0.817	0.994	1.116	1.166	1.197	1.216
-1.8	-1.981	-1.318	0.643	0.282	0.799	0.945	1.305	1.069	1.087	1.097
-2.0	-1.996	-1.302	-0.609	0.307	0.777	0.895	0.959	0.980	0.990	0.995
-2.2	-2.006	-1.284	-0.574	0.330	0.752	0.844	0.888	0.900	0.905	0.907
-2.4	-2.011	-1.262	-0.537	0.351	0.725	0.795	0.823	0.830	0.832	0.833
-2.6	-2.013	-1.238	0.499	0.368	0.696	0.747	0.764	0.768	0.769	0.769
-2.8	-2.010	-1.210	-0.460	0.384	0.666	0.702	0.712	0.714	0.714	0.714
-3.0	-2.003	1.180	-0.420	0.383	0.836	0.660	0.666	0.666	0.667	0.667

Source: (Jagadesh and Jayaram, 2009)

FIG 3: Frequency Factor Computation k

Result and Discussion

From the given information, the annual peak discharge was recorded during the rainy season of year 2012 with a value of 12,516 m^3/s, while the lowest value was recorded in 2004 with 8,535 m^3/s. Considering the ranking as given in table 3, the peak discharge has been estimated for return period of 2, 5, 10, 25, 50, 100, 200 years as 10,891m^3/s, 11,912 m^3/s, 12,376 m^3/s, 12,815 m^3/s, 13,068 m^3/s, 13,275 m^3/s, 13,447 m^3/s respectively and their values where plotted with the return period, frequency factor k and flood probability. A mathematical model was developed for the estimation of flood for each year as y = 1312.8ln(x) + 10942, where x is the number of year and y is the flood discharge.

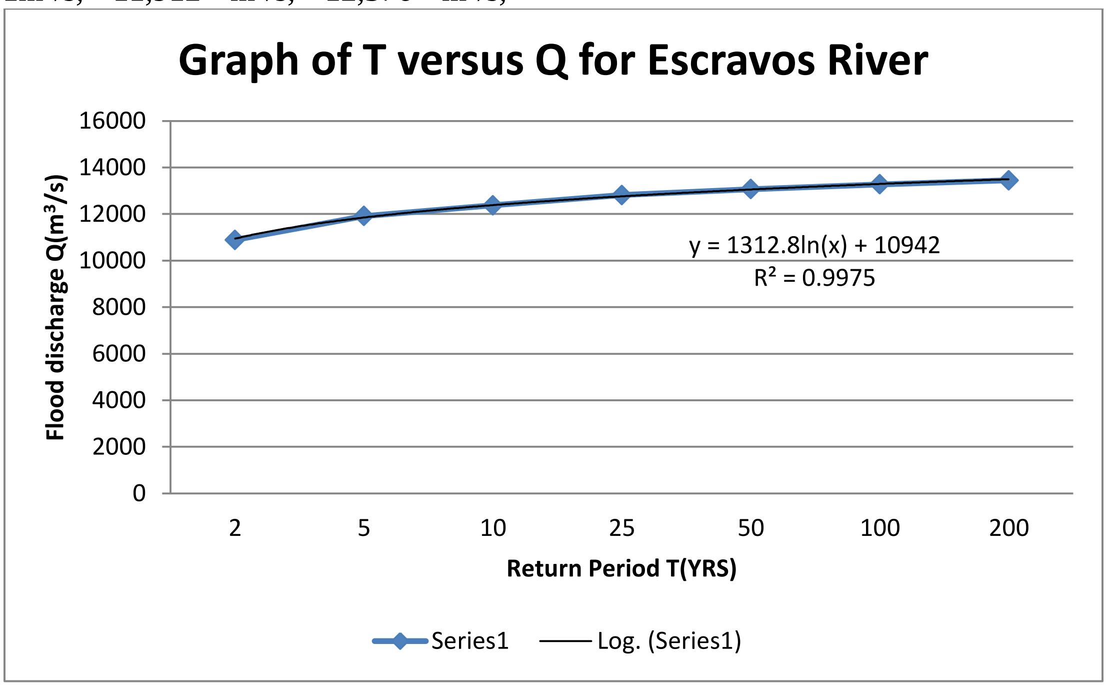

FIG 4 Graph of return period against discharge of Excravos river

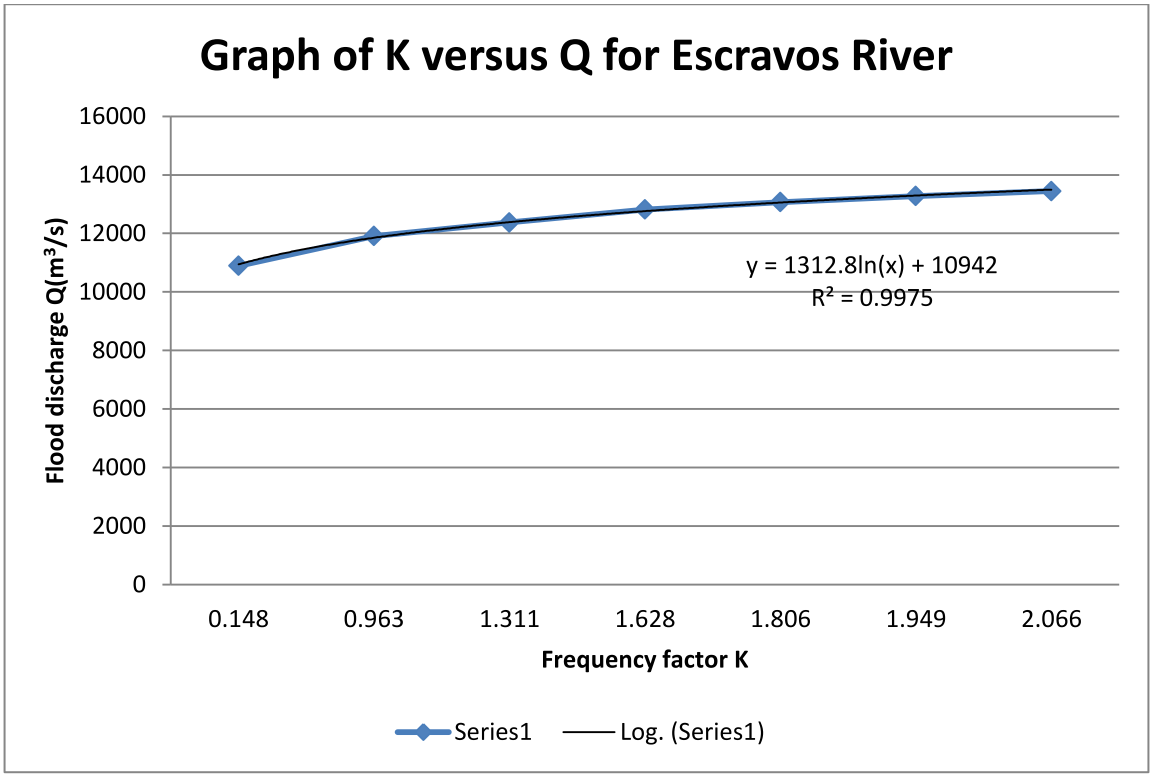

FIG 5 Graph of Frequency Factor against Discharge of Excravos River

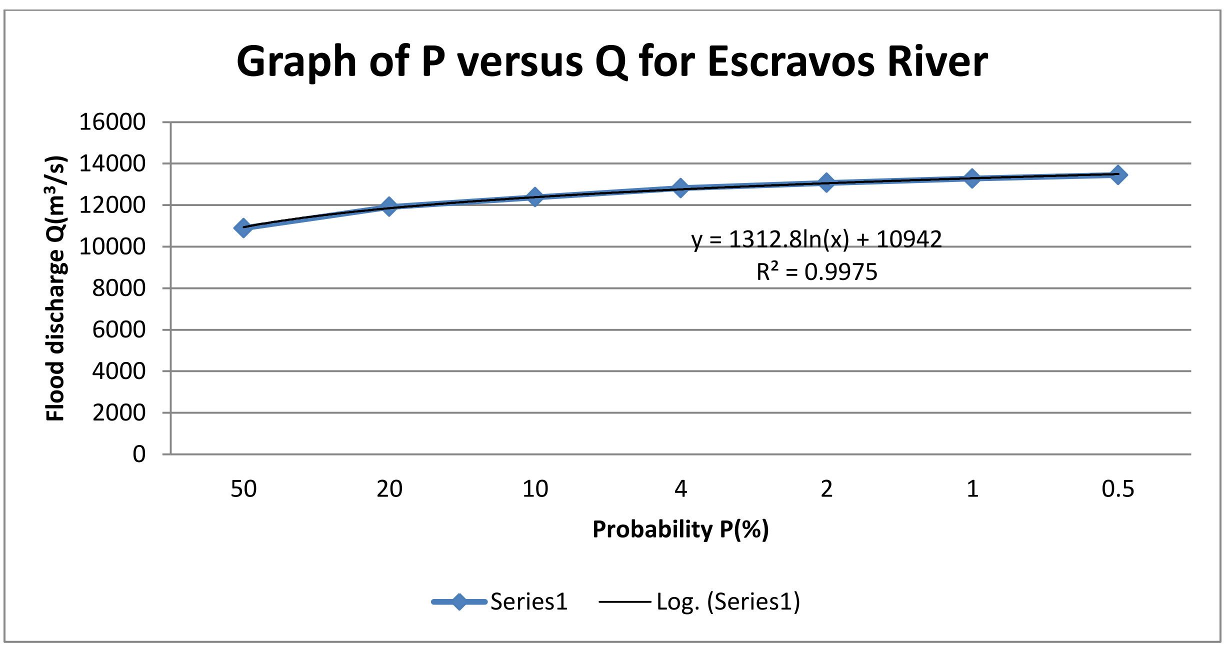

FIG 5 Graph of probability p% against discharge of Excravos river

Conclusion

The findings from this probabilistic model has forcasted the magnitude of flood with it frequencies. Floods are widespread threat to coastal communities and sea level rise is increasing the probability of such event (Wadey et al 2015). Ugborodo, Aruton, Okiemekpe, Forcados e.t.c are communities sharing boundary with the Atlantic Ocean and with the scarce hydrological data for hydraulic engineers to utilize the result from, this paper can be of immense importance as it's the extreme discharge that the designer is interested in. Finally, the study has been carried out with the available data in the Ugborodo clan, the flood magnitude of each return period can be calculated with the relationship $y = 1312.8\ln(x) + 10942$ therefore a robust flood warning plan can be put in place, also adequate shore protection can be provided to save the built up community from loss of lives and properties.

References

1. Zakaullah, M. Mazhar Saeed, Iftikhar Ahmad and Ghulam Nabi (2012) Flood frequency analysis of homogeneous regions of Jhelum River Basin. International Journal of water resources and environmental Engineering Vol. 4(5),pp 144 – 149, May (2012).
2. Thomos Schendel and Rossukon Thongwichian (2015). Flood frequency analysis: confidence interval estimation by test inversion bootstrapping. Advance in water resources 83 (2015)1-9.
3. Okonofua Solomon and Ogbeifun Prince (2013). Flood frequency Analysis of Osse river using Gumble's Distribution. Civil and Environmental Research. Vol.3, no 10, 2013.
4. Shixia Zhang, Yakun Guo, Ziwen Wang (2015), Correlation between flood frequency and geomorphologic complexity of rivers network – A case study of Hangzhous china. Journal of hydrology 527 (2015) 113 – 118.
5. Singo L.R, Kundu P. M, Odiyo J.O, Mathivha F.L, Nkurna T.R (2013). Flood frequency analysis of annual maximum stream flows for Luvuvha river catchment Limpopo province, South Africa, University of Venda, Department of Hydrology and Water Resources, Thohoyandou South Africa, pp 1-9.
6. Manas Kumar Mukherjee (2013), Flood frequency analysis of River Subernarekha, India, using Gumbel's extreme value distribution. International journal of computational engineering research vol. 031 issue 7.
7. Lichter M, Vafeidis A.T, Nicholls R.J, Kaiser G. (2010). Exploring data - related uncertainties in analyses of land area and population in the low – elevation coastal zone (LECZ) coastal res. 757 – 768.
8. Hinkel J, Lincke D., Vafeidis, A.T, Perrette M., Nicholls R.J, Tol, R.S Marzeion B., Fettweis X, Ionescu C, Levermann. A, (2014) Coastal flood damage and adaptation cost under 21st century sea level rise. Proc. Natl. Acad Sci 111 3292 – 3297.
9. Wadey M.P, Nicholls R.J., Hutton C.,(2012). Coastal flooding in the solvent; An integrated analysis of defence and inundation. Water , pp430 – 459.
10. B.K. Sathe, M.V Khire, R.N. Sankhua (2012). Flood frequency analysis of upper Krishna river Basin catchment area using log Pearson type III distribution (IOSR Journal of engineering (ISSN 2250 – 3021 Vol. 2 Pp 68 - 77 .

11. Luna Moni Das and Zahid Husain Qureshi (2012). Flood frequency analysis for Jiya
Dhol River of Brahmaputra Valley. International Journal of science; Basic and

Applied Research (IJSBAR) (2014) Volume 14 No. 2 Pp 14 – 24.
12. Kuk –Hyun Ahn and Richard Palmer (2016). Regional flood frequency analysis using spatial proximity and basin characteristics; Quantile regression vs Parameter regression technique. Journal of hydrology 540 (2016) 515 – 526.
13 Matthew P.Wadey,Samantha N. Cope, Robert J. Nicholls,Karen McHuge Gareth Greweock, Travis Manson (2015). Coastal flood analysis and visualization for small town. Ocean and coastal management 116(2015) 237-247 (Elsevier)
14 Ibitola Mayowa Philips (2009). The hydrodynamic fluxes of Escravos and Forcados rivers: Implications for transport and circulation patterns of the western Niger Delta. Report from project on a Master of Science physical oceanography and applications, Faculty science and technique university of Abomey Calavi, Cotonou, Republic of Benin.
15 Jagadesh, T.R. and Jayaram, M.A. (2009). Design of bridge Structures. 2nd Edition. PHI Learning PVT Ltd, New Delhi India.