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RETURN PERIOD ANALYSIS AS A TOOL FOR URBAN FLOOD PREDICTION IN THE NIGER DELTA: A CASE STUDY OF PORT HARCOURT CITY, NIGERIA

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The study examined return period analysis as a tool for flood prediction in urban areas. This technique enables us to know when an event is expected to occur, be equaled, or be exceeded. When floods occur, the effects are always very devastating, sometimes resulting in destruction of homes, villages, human life and property. Urban floods in most cases result from unplanned, uncoordinated urbanization projects, poor sanitary habits of dumping of refuse, and poorly maintained and insufficient drainage. These are well highlighted in this study. Results indicate that for thirty years of data, the return period is 10.3 years for a maximum 1-month rainfall of 804 mm with a maximum 1-year rainfall of 2,544 mm for same return period. The study recommends routing through specific drainages in flood prone areas of Port Harcourt to mitigate the impacts of flooding.

INTRODUCTION

The Niger Delta area is located in the most southerly part of Nigeria. It is one of the world's largest wetlands with a total land area of approximately 29,000 km^2 excluding the continental shelf (NDES, 1997). Port Harcourt, the capital of Rivers State with a population of about 1,356,000 (Federal Office of Statistics, 2003) is a major industrial city in the Niger Delta region (FEPA/ World Bank, 1998).

Port Harcourt suffers from urban flooding as a result of insufficient drainage capacity, and uncoordinated and poorly maintained drainages. The situation is worsened because of unplanned urbanization patterns leading to blockage of existing drainages, rapid population explosion and poor sanitary habits as a result of dumping volumes of refuse in gutters, drainage outlets and adjoining creeks (Ayotamuno and Gobo, 2004).

A direct consequence of the expansion in the built-up area is the increase in the extent of impervious surfaces which also increases surface runoff, causing floods in the city. Added to these effects are the indiscriminate canalization and the attendant creation of ingress channels for flood waters.

Human activities also aggravate flooding in urban cities. According to Akintola (1978) and Odemerho (1988), it is generally believed that urbanization, particularly when it encroaches on areas which were once farmlands or forests, causes the most remarkable flood-intensifying land use change. The removal of natural vegetation cover from a forested area during construction work can lower the infiltration capacity to a point where rainfall intensity significantly exceeds the water infiltration rate thereby causing floods (Dunne and Leopard, 1978). It is also argued that volume and timing of runoff are substantially modified by forest clearing.

Espey et al. (1966) found that the replacement of permeable by impervious surface through urbanization results in peak discharges which were from 100 to 300 per cent greater than those from undeveloped areas. Wolman and Schick (1967) and Alfesehi (1990) confirmed that changes in the urban landscape which aggravated flows have not only increased surface runoff but also sediment load in basins, along streets and storm channels resulting in change in channel morphology. Increases in urban floods are also related to building along runoff areas, impervious urban surfaces, inadequate storm drains and dumping of refuse in drains and drainage paths, uncoordinated physical development, and the absence of storm sewers.

The most useful approach to the prediction of flood flows is the statistical method of frequency analysis (Subramanya, 1991). This is because hydrologic processes such as floods are exceedingly complex natural events, and result from the interplay of a number of components/parameters that are very difficult to model analytically. For example, the floods in a catchment depend on rainfall and antecedent conditions, and each of these factors in turn depend upon a host of constituent parameters. Return period analysis becomes important because of its simplicity and ease of application. Return period values are important for designs of channels, bridges, culverts, waterways and spillways for dams and estimation of scour for hydraulic structures.

STUDY AREA

Port Harcourt is located within latitudes 6º58´N to 7º6´N and Longitude 4º40´E to 4º55´E (Figure 1). It falls almost entirely within the lowland swamp forest ecological zone and is flanked in the east, west and southern limits by mangrove swamp forest (Braide et al., 2004; Chindah, 2004). Port Harcourt constitutes the second largest port in Nigeria in terms of tonnage handling. It also constitutes an important terminal for connection to the outlying villages in the delta area. As the capital of Rivers State, Port Harcourt has become an important administrative center with regular air connections to other parts of Nigeria.

The town is therefore an important industrial and commercial center. Access to cheap energy from oil and natural gas, in addition to good communications, have created favorable conditions for Port Harcourt to become Nigeria's most important industrial town. The area experiences heavy rainfall averaging 2500 mm/annum. It rains for about eight months (March to October) during the year, and even the months considered as dry months are not free from occasional rainfall (Gobo, 1990). It has an almost flat topography and is underlain by superficial soil that consist of silty clays mixed with silty sand. The water table is less than 10 m below ground surface. The combination of excessive rainfall, inadequate and poorly maintained drainages, and low permeability of the superficial soils dispose the area to flooding on an annual basis whenever rainfall is in excess of 100 mm.

In spite of its economic importance, the city experiences intermittent flooding in a large number of areas. Some of the most affected areas include:

1) Waterline Junction (by College of Education bus stop)
2) Olu Obasancjo Road (Police Station) by Omoku Street
3) Diobu (Mile Three Building Material area)
4) Diobu (Mile One Market area)

Figure 1. Map of the study area showing the geographical location of Port Harcourt

5) Amadi Flats (Nzimiro Street)
6) Amadi Flats (Herbert Marculey by Yola street)
7) Diobu (Education Bus Stop area)
8) Civic Centre by Hospital Road
9) Azikiwe by Industry Road
10) Superboard Bus Stop by First Bank
11) Port Harcourt Main Post Office by Central Bank
12) Station Bus Stop (Round About) by Hospital Road

The spatial distribution of these locations is shown in Figure 2.

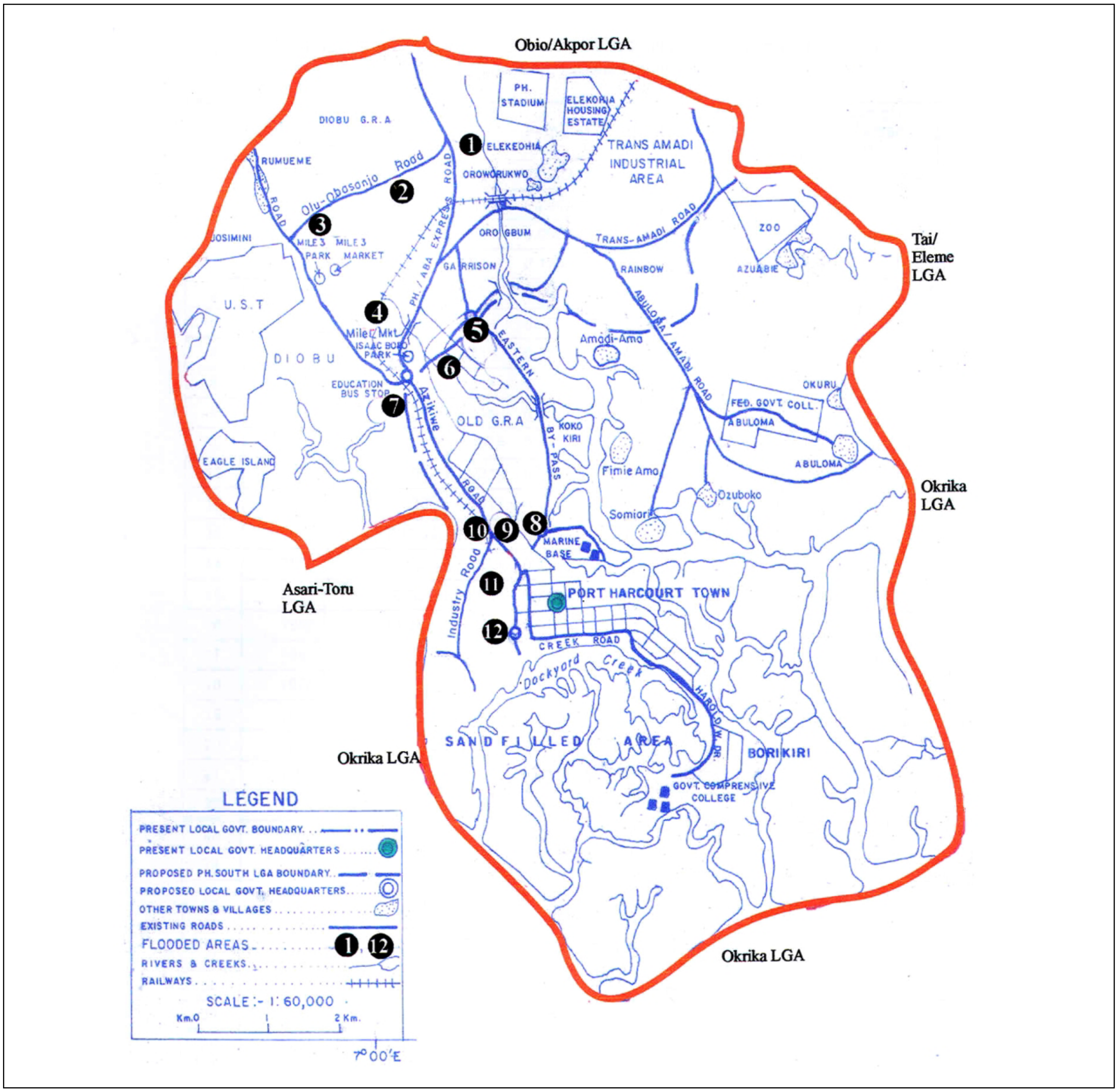

Figure 2. Map of Port Harcourt Government Area showing areas prone to flooding.

METHODOLOGY

The data include maximum daily rainfall data from 1975-2004 (30 years inclusive). This finds justification in climatologists adoption of the practice of forming climate change estimates from a thirty-year reference period (Miller, 1961). Maximum daily rainfall values were used since flood problems are always considered in terms of worst or extreme situations.

Recurrence predictions are often calculated in terms of return periods. The return period of a given event is the average number of years within which the event is expected to be equaled or exceeded (that is, the expected average frequency of occurrence of an event over a longer period of years) (WMO 1983).

The data are arranged in descending order and the probability (P) and recurrence intervals of various events are calculated as indicated in the Tables 1 and 2 (Where n = 30 and n + 1 = 31).

Table 1. Maximum 1-month rainfall values (mm) for Port Harcourt [1975-2004] (30 Years inclusive).

M	Year	Rainfall (RR)		P=m/n+1	RT = $\frac{1}{p}$	Log of RT	Log of Rainfall (RR)
1	2000	1036.011	1/31=	0.032258	30.9981	1.4913	3.0154
2	1997	826.648	2/31=	0.06452	15.4991	1.1903	2.9173
3	1998	803.727	3/31=	0.09677	10.3338	1.0143	2.9051
4	1995	757.134	4/31=	0.129	7.7519	0.8894	2.8792
5	1993	712.519	5/31=	0.1613	6.1996	0.7924	2.8528
6	1979	701.3	6/31=	0.1935	5.168	0.7133	2.8459
7	1994	680.043	7/31=	0.2258	4.4287	0.6463	2.8325
8	1987	663.1	8/31=	0.2581	3.8745	0.5882	2.8216
9	1992	645.892	9/31=	0.2903	3.4447	0.5372	2.8102
10	1980	637.82	10/31=	0.3226	3.0998	0.4913	2.8047
11	1975	622	11/31=	0.3548	2.8185	0.4500	2.7938
12	1991	615.285	12/31=	0.3871	2.5833	0.4122	2.7891
13	1977	607.64	13/31=	0.4194	2.3844	0.3774	2.7836
14	2003	602.6	14/31=	0.4516	2.2143	0.3452	2.7800
15	2002	596.9	15/31=	0.4839	2.0665	0.3152	2.7759
16	1990	587.903	16/31=	0.5161	1.9376	0.2873	2.7693
17	1988	576.61	17/31=	0.5484	1.8235	0.2609	2.7609
18	1978	570.2	18/31=	0.5806	1.7224	0.2361	2.7560
19	1981	566.9	19/31=	0.6129	1.6316	0.2126	2.7535
20	1982	534	20/31=	0.6452	1.55	0.1903	2.7275
21	1996	521.415	21/31=	0.6774	1.4762	0.1691	2.7172
22	1984	520	22/31=	0.7097	1.409	0.1489	2.7160
23	1986	519.6	23/31=	0.7419	1.3479	0.1297	2.7157
24	2001	511.6	24/31=	0.7742	1.2919	0.1112	2.7089
25	1976	508.4	25/31=	0.8065	1.24	0.0934	2.7062
26	1999	507.913	26/31=	0.8387	1.1923	0.0764	2.7058
27	1989	506.1	27/31=	0.87096	1.1482	0.0600	2.7042
28	2004	469.3	28/31=	0.9032	1.1072	0.0442	2.6715
29	1985	491.02	29/31=	0.9355	1.0689	0.0289	2.6911
30	1983	382.2	30/31=	0.9677	1.0334	0.0143	2.5823
Total		18281.78		14.9999	123.8453	12.3174	83.2932

Table 2. Maximum yearly (1-year) rainfall values (mm) for Port Harcourt [1975-2004] (30 years inclusive)

M	Year	Rainfall (RR)		P=m/n+1	RT = $\frac{1}{p}$	Log of RT	Log of Rainfall (RR)
1	1998	2569.3	1/31=	0.03226	30.9981	1.4913	3.4098
2	1995	2569.3	2/31=	0.06452	15.4991	1.1903	3.4098
3	1980	2544.9	3/31=	0.09677	10.3338	1.0143	3.4057
4	1993	2542.4	4/31=	0.129	7.7519	0.8894	3.4052
5	1999	2499.6	5/31=	0.1613	6.1996	0.7924	3.3979
6	1975	2491.5	6/31=	0.1935	5.168	0.7133	3.3965
7	1988	2420.9	7/31=	0.2258	4.4287	0.6463	3.3840
8	2003	2407.7	8/31=	0.2581	3.8745	0.5882	3.3816
9	1985	2395.6	9/31=	0.2903	3.4447	0.5372	3.3794
10	1994	2374.2	10/31=	0.3226	0.0998	0.4913	3.3755
11	1979	2342.5	11/31=	0.3548	2.8185	0.4500	3.3697
12	1996	2339.4	12/31=	0.3871	2.5833	0.4122	3.3691
13	1997	2329.4	13/31=	0.4194	2.3844	0.3774	3.3672
14	1976	2321.8	14/31=	0.4516	2.2143	0.3452	3.3658
15	1978	2291.2	15/31=	0.4839	2.0665	0.3152	3.3601
16	1986	2283.1	16/31=	0.5161	1.9376	0.2873	3.3585
17	1978	2261.3	17/31=	0.5484	1.8235	0.2609	3.3544
18	1977	2235.5	18/31=	0.5806	1.7224	0.2361	3.3494
19	2002	2166.2	19/31=	0.6129	1.6316	0.2126	3.3357
20	1989	2160.2	20/31=	0.6452	1.55	0.1903	3.3345
21	1981	2158.3	21/31=	0.6774	1.4762	0.1691	3.3341
22	2001	2153.5	22/31=	0.7097	1.409	0.1489	3.3331
23	1984	2126.8	23/31=	0.7419	1.3479	0.1297	3.3277
24	1991	2094.4	24/31=	0.7742	1.2919	0.1112	3.3211
25	1990	2073.3	25/31=	0.8065	1.24	0.0934	3.3167
26	2000	2068.9	26/31=	0.8387	1.1923	0.0764	3.3157
27	1982	1991.5	27/31=	0.8709	1.1482	0.0600	3.2992
28	1992	1962.2	28/31=	0.9032	1.1072	0.0442	3.2927
29	2004	1877.5	29/31=	0.9355	1.0689	0.0289	3.2736
30	1983	1632	30/31=	0.9677	1.0334	0.0143	3.2127
Total		67684.4		14.9999	90.8453	9.3331	100.5364

RESULTS AND DISCUSSION

Table 1 and Figure 3 give the return period for a maximum total 1-month rainfall (mm) using values from 1975 to 2004 (30 years inclusive) for Port Harcourt. The results indicate that the period is 15.5 years to obtain maximum 1-month rainfall (mm) value of 826 mm. Furthermore, the results suggest that the period is 2.0 years for maximum 1-month rainfall (mm) of 587 mm to occur while a maximum 1-month rainfall (mm) of 382 mm could occur every year. These relationships can be numerically expressed as $y = 0.2229x + 2.6849$ with a coefficient of determination of $R^2 = 0.9250$. Table 2 presents maximum yearly rainfall in Port Harcourt. The return period

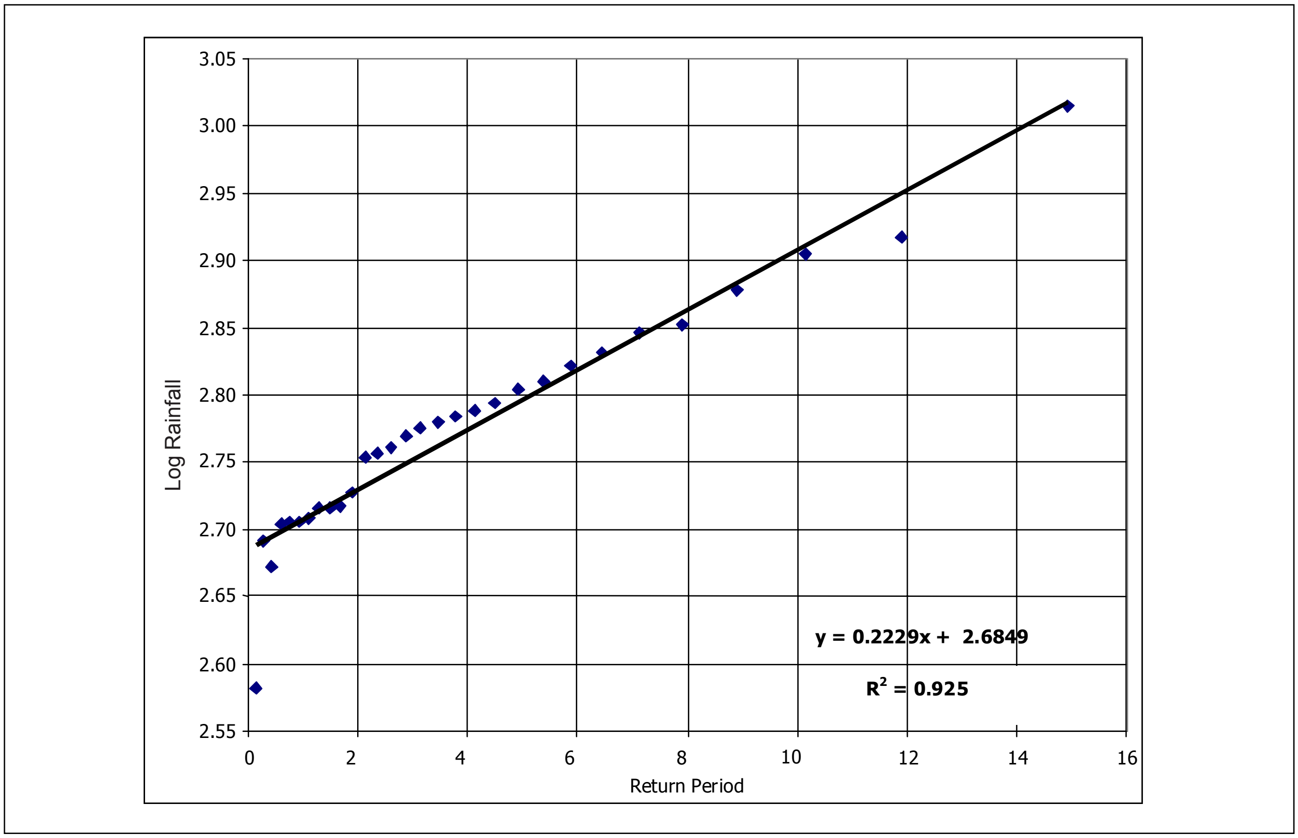

Figure 3. Return Period for maximum 1-month rainfall for Port Harcourt.

computation based on the annual maximum rainfall is presented in Figure 4. As regards Table 2 and Figure 4, it will take 10.3 years for maximum 1-year rainfall (mm) of 2,544 mm to occur. Furthermore, to obtain maximum 1-year rainfall (mm) of 2,291 mm, it will take 2.1 years while the value of 1,166 mm rainfall could be obtained in every year. The regression equation for this relationship is: $y = 0.0995x + 3.3104$ with $R^2 = 0.6747$. The coefficient of determination, R^2, indicates the strength of the relationship.

These values give the threshold or critical values that must be obtained and used for engineering designs for flood control works in Port Harcourt and its environs. Also Figure 2 shows that the Northwesterly (NW) through the Southwesterly (SW) sides of Port Harcourt lie at lower elevations and are more prone to flooding than the Northeasterly (NE), through the Southeasterly (SE) axes. The Trans-Amadi Axis (Figure 2) also suggests that drainages around the areas marked numbers (1) to (7) should be constructed and channeled into Abonnema Wharf Creek; while for the areas labeled (8) to (12) drainage should be constructed to run through the Eastern Bye Pass, through NEPA waterside, and into the Amadi-Amd/Abuloma Town Creeks.

CONCLUSION AND RECOMMENDATION

This study has highlighted the need for basic statistical analysis of hydrometeorological data and application of the results for engineering design works to achieve desired flood control objectives. The results indicate that the return period is 15.5 years for maximum 1-month rainfall of 826 mm and maximum 1-year rainfall of 2569 mm to occur. In this era of frequent collapse of bridges, houses, dams and drainages as result of improper design, it is necessary for engineers to take all necessary statistical inputs into design process for effective works. Various routes and channels through which flood drainages could be channeled are also recommended.

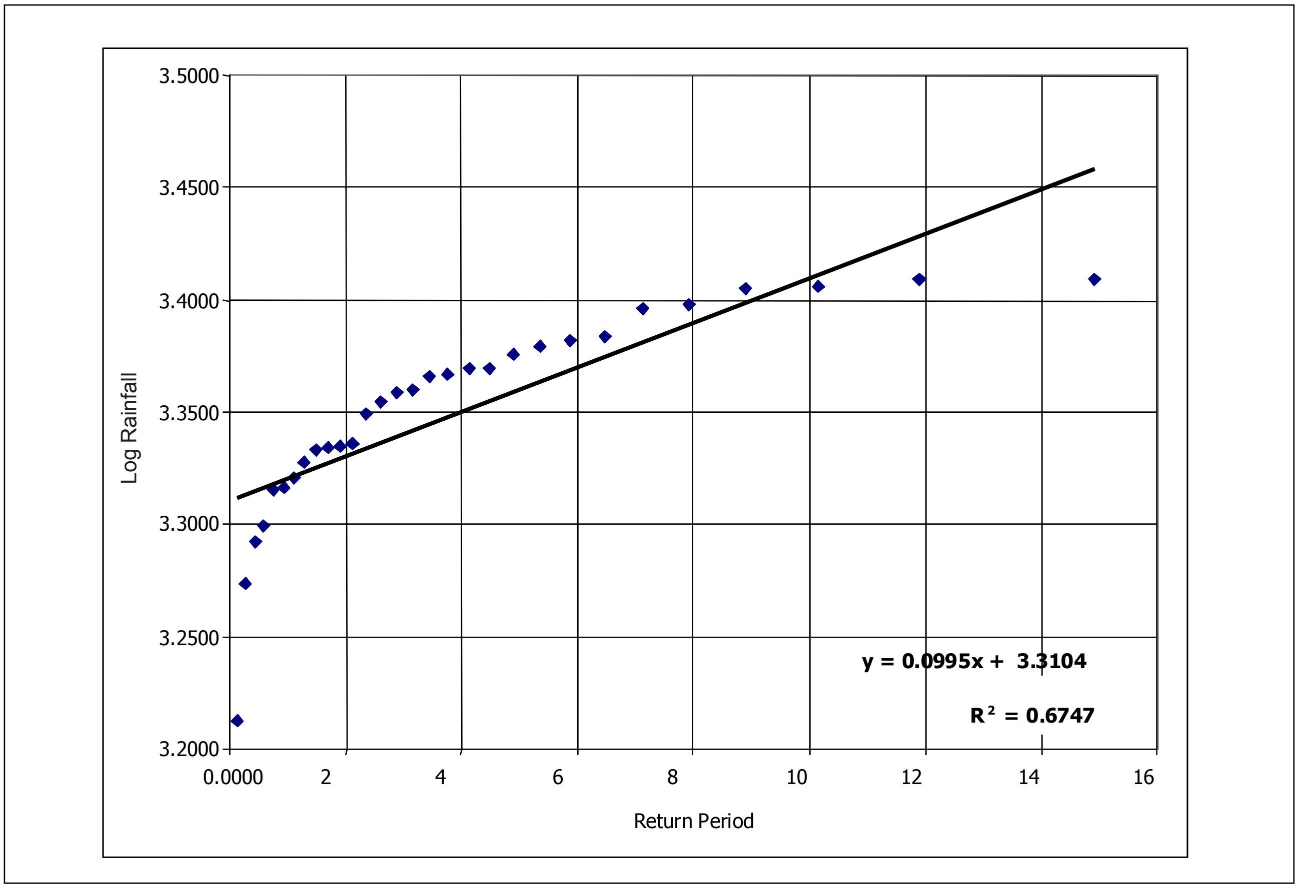

Figure 4. Return Period for maximum 1-year rainfall for Port Harcourt.

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