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FACTORS THAT INFLUENCE THE FLOODING OF THE MIDDLE AND LOWER NTAMOGBA STREAM CATCHMENTS, PORT HARCOURT, NIGERIA

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The Ntamogba stream is one of the principal drainage rivers of the city of Port Harcourt; draining and evacuating flood/storm water from the New GRA, the northeastern portion of Diobu, and the whole of the D/Line Areas. Due to urban sprawl and land mismanagement, this all important stream has lost its flood conveyance capacity, especially in the middle and lower reaches. The overflowing of its banks has become a severe threat to life and property in the watershed. Several efforts including the dredging of the channel have not abated the problem. This paper evaluates the pattern of development, disturbance intensity and the contribution of runoff to the stream by analyzing urban status maps of 1975 and 2004, as well as stream discharge of each of the sub basins. It is shown that 90% of the watershed in the middle and lower reaches has been built up thereby increasing the disturbance intensity. This results in rapid onset of peak runoff which the receiving channel can seldom accommodate, leading to overflowing of the stream's banks.

INTRODUCTION

Urban streams are strongly influenced by their surrounding catchments, which is their primary source of organic materials, nutrients and sediments. (Hynes, 1975; Vannote et al., 1980; Ogbonna et al., 2007). Geology, land use, and other catchment characteristics affect the rate at which these substances are delivered to the streams (Omernik, 1976; Richards et al., 1996) because of the ubiquity of anthropogenic landscape modification (Vitousek et al., 1997; Hannah et al., 1994).

Urban and agricultural land uses often increase the inputs of sediments (Allen et al., 1997, Strayer et al., 2003; Odemerho, 1992). Urban and agricultural land uses include deforestation (Gutz et al., 1980; Kreutzweiser and Capell, 2001) and impervious covering (Amangabara, 2006). The effects of catchment disturbance can be particularly strong during storm events (Webster et al., 1990)

Several studies of the impacts of whole catchment deforestation/hydrologic connections on urban landscapes and streams have been conducted (Likens et al., 1970; Gutz et al., 1980; Amangabara, 2006). However, the effect of localized, intense soil and vegetation clearance, combined with concentrated impervious cover development in urban areas which ultimately leads to overflowing of stream banks in the middle and lower reaches, especially in the Niger Delta, Nigeria, are not well understood and they are the focus of this study.

STUDY AREA

The study area is the Ntamogba Stream catchment in the City of Port Harcourt (Figure 1). The city was established in 1912 as a railway terminal and as a seaport for the export of goods from the hinterland which triggered the movement of people to settle in the city (Anyanwu, 1979). However, it wasn't until oil was discovered in commercial quantities in the Niger Delta that there was a population explosion and its attendant consequences on the environment. One environmental consequence is population pressure which has led to the conversion of marginal areas such as stream channel corridors and floodplains for urban development (Amangabara, 2006).

The Ntamogba Stream is one of the three principal drainage rivers in the City of Port Harcourt. Others are the Nwaja River, and the Rumuogba-Woji Creek (Amangabara, 2006). Of these three River Systems, The Ntamogba has attracted much attention recently due to the continued overflow of its banks in the middle and lower reaches that has been taking place since the early 1990s (Amangabara, 2006; Abam, 2004; Gobo et al., 2006).

The stream is a 4.4 km single-channel, low gradient perennial fresh water body, which collects from a spring marsh in the Oroazi/Rumueme Area of Port Harcourt Metropolis [approximately between longitude $6^o58'$ to $7^o06'$E and latitude $4^o40'$ to $4^o55'$N (Gobo and Abam, 2006; Amangabara, 2006). It flows roughly northeast through the Government Reservation low density settlement Area (GRA) and the densely populated areas of D/Line and Diobu and on into the Amadi Creek (in the Amadi Flats Area it is influenced by saline water intrusion) and it drains the entire new GRA Phases I, II, III, the D/Line Area, and some sections of Diobu.

METHODOLOGY

Federal Survey Aerial Photos of 1971; 1975 and 2004 urbanization maps of Port Harcourt (scale 1:60,000) were sourced from the Land and Survey Bureau of the Governor's office, Port Harcourt, Nigeria. The maps were reduced by the square methods (Olomo, 1997) to scale 1:10,000 to determine historical changes of the Ntamogba stream watershed - e.g. pattern and degree of disturbance, total built up area (total impervious area) as well as pattern and trend of urbanization in the watershed. Discharge per unit area were also determined

Discharge was determined by the method described by USEPA Field Operation Manual (2004) and the Handbook and Method sheet (2005). At base flow, the salt dilution gauging method using a continuous NaCl injection was used to compare results. Background conductivity was recorded before injection. A coring grab sampler was used to collect bed materials from the center line of the stream at low flow conditions. A staff gauge was used to determine height of sediment/debris during the period of the study, January 2005 to March 2006.

RESULT AND DISCUSSION

Percentage Urban Land Use

The Federal survey aerial photograph of 1971 (Air Photo No. 7181835-47) and that of the Rivers State Land and Survey Bureau map of 1975 and 2004 of Port Harcourt (Figures 1, 2, and 3) show the urbanization status of the study area. From the two maps Table 1 was drawn which shows that more than 90% of the watershed was intact as of 1975. The 1997 Federal Survey Urbanization index for the same area shows that 56.9% of the area has been built up, thereby reducing the watershed with attendant multiplier negative impacts. By 2004 the watershed had been severely constricted as the area was continuously built up without adequate watershed planning, especially in the middle and lower reaches. The number of hydrologically connected impervious cover areas indicates the intensity of urban land use or disturbance. Table 1 shows that in the middle reaches the urban land use is 56.2% while that of the lower reach is 85.7%

Figures 1, 2 and 3 in conjunction with Tables 2, 3 and 4 show the patterns of urbanization intensity of land use over time. As the city grows, so does the total impervious cover (the total area covered by roof tops, roads, culverts and bridges). These impermeable surfaces prevent rainwater from seeping into the ground, and instead tend to channel water quickly to the stream. Around the Okija-Afam Street zone of the D/Line axis of the stream, a small amount of rain can cause a rapid rise in flow, whereas the same amount of rain may have caused an imperceptible change in stream flow previous to the development of impervious cover in the area. This change has influenced the discharge pattern. For example the average discharge for Station 1 (Table 4) with an approximate area of 415.5 acres (with low impervious cover) generated 28.04 m^3/s for 15 months whereas Station 3 with an approximate area of 659.5 acres (with high impervious cover) generated an average of 109.35 m^3/s between January 2005 and March 2006. The implication from the discharge pattern is that areas with “green cover” (e.g. the GRA) have more capacity for infiltration and the entrapment of surface runoff leading to less discharge compared to areas with high impervious cover in the form of roads, rooftops, bridges and paved lawns (e.g. D/Line areas). Generally, round shaped basins tend to produce larger, shorter peak discharge than linear basins. The Ntamogba drainage basin can be described as an round shaped basin (Figure 2) and may account for the quick flood events around the Afam street area

We can therefore infer that when there is high velocity/discharge value, it is an indication that:

1) The contributing drainage area is large or

2) There is a considerable impervious cover which reduces the amount of infiltration and percolation leading to peak flows and surface runoff, and

3) The condition of the soil is such that it is saturated and cannot accommodate more precipitation and therefore increases the runoff to the stream

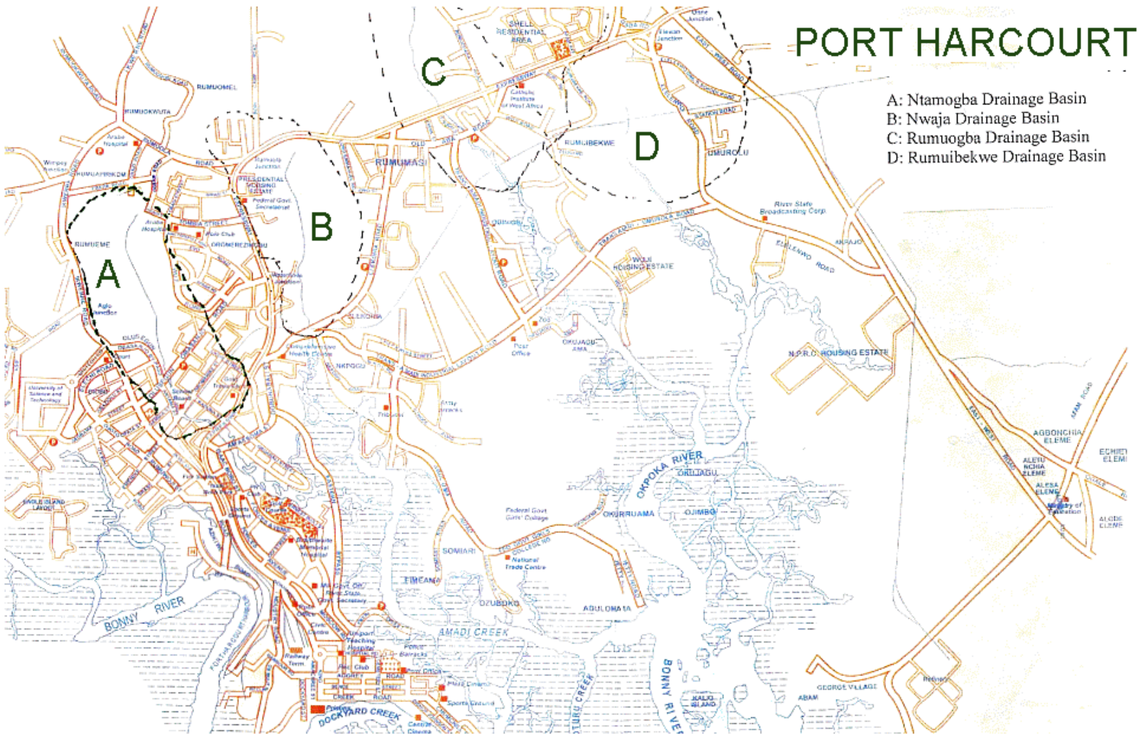

Figure 1. Map of Port Harcourt showing the drainage river systems.

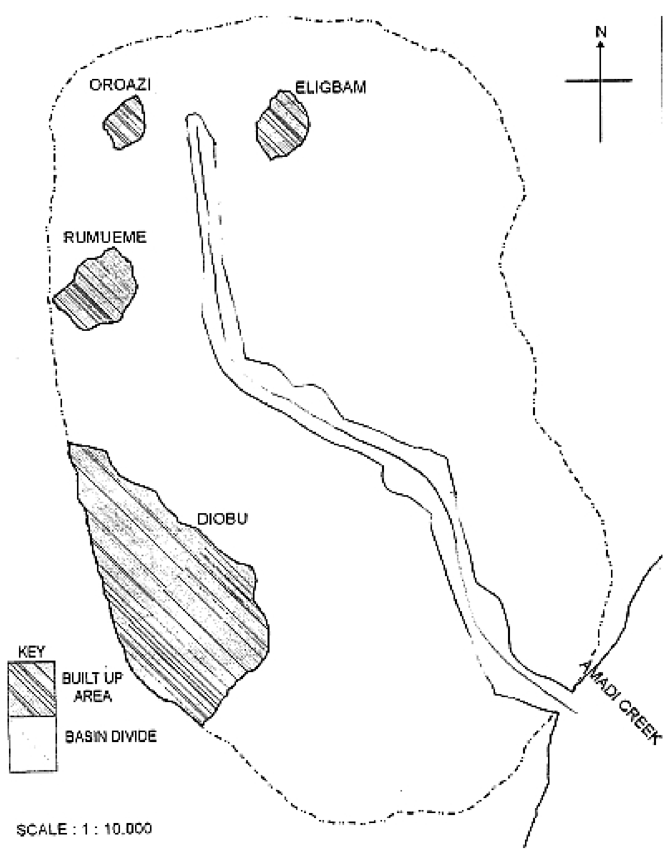

Figure 2. Map of Ntawogba Creek catchment, urbanization status 1975.

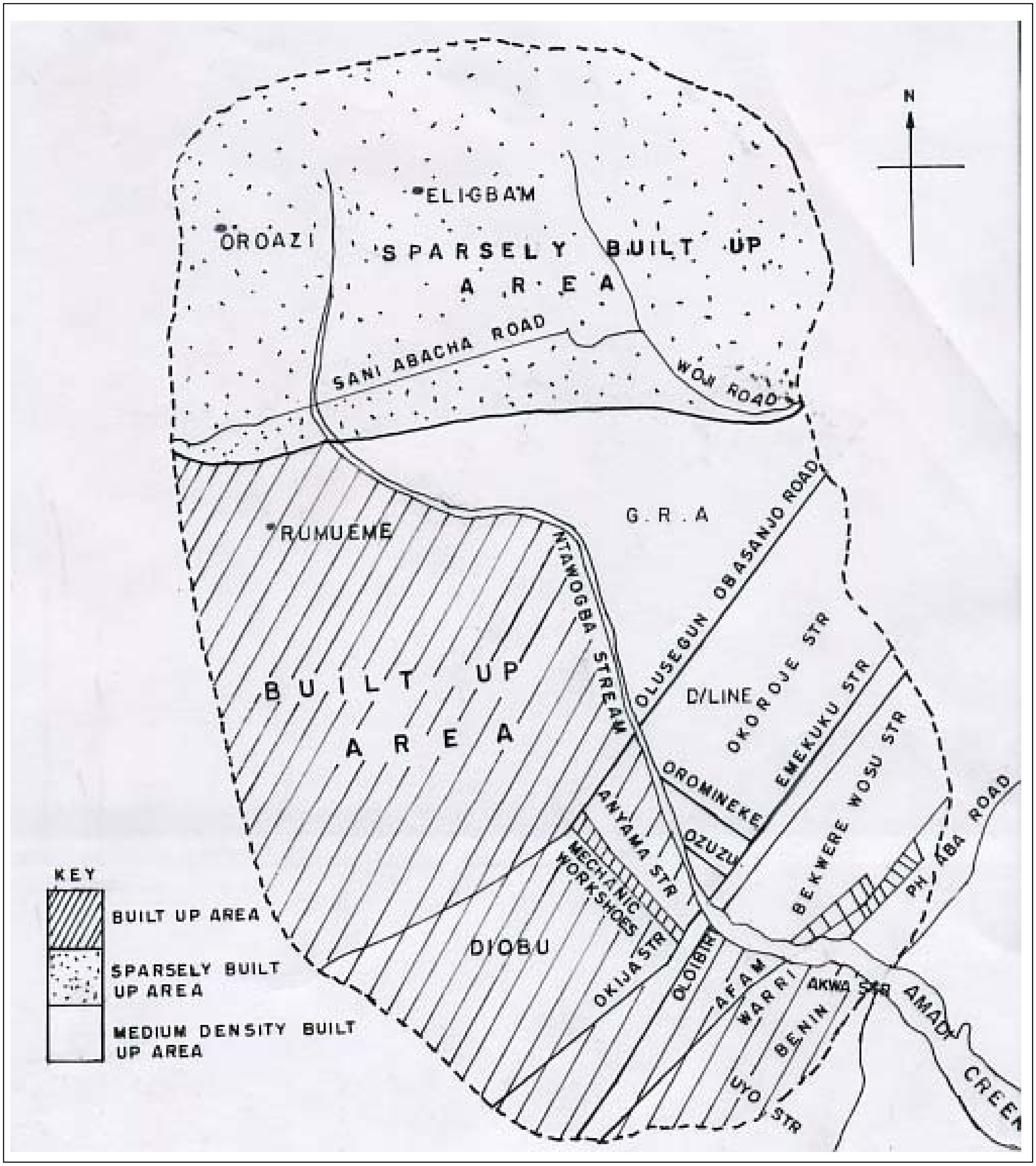

Figure 3. Map of Ntawogba Creek catchment, urbanization status 2004. Source: Cartography Section, Land and Survey Bureau, Port Harcourt.

Siltation/Bed sedimentation: Disturbance Intensity

Bed loads in the Ntamogba stream are dominated by the land use activity in each of the sub basins. The texture of the streambed sediments was significantly different between the various reaches in the upper section and the middle and lower reaches. Multiple comparisons show that the upper reaches have larger quantities of sand-size particles than the lower reaches. The soil samples collected in the upper reaches appear white, sharp and angular compared to those in the lower

Table 1. Percentage of urban land use.

Catchments	Approximate areas (Acres)	Percentage of urban land use	Percentage of urban non-use	Approximate length of road (km)
Upper Reach				
GRA (from Woji Road down to the Ntawogba Channel)	415.5	62.8	35	4.925
Middle Reach				
Ozuzu, Emekuku; Oromineke; Okorojie Streets	659.5	56.2	28	1.675
Lower Reach				
Afam; Anyama; Olu-Obasanjo; Warri; Benin; Uyo; Awka; Oloibiri; Okija Streets	1,404.5	85.7	14.3	5.042

Table 2. Percentage composition of bed material.

Reach No	Reach/Segment Name	Grain Size			
		%sand	%Silt	%Clay	% others
1	Upper Reach/Segment GRA	60	33	7	-
2	Olu-Obasanjo Culvert Middle/Lower Reach	22	69	9	-
3	Okija Street/Emekuku Street Culvert	30	67	3	-
4	Afam Street/Kaduna Street culvert	32	-	-	Rags, woody debris, general household waste
5	Aba Road Overhead Bridge	40	-	-	Plastics, glassware, household wastes etc

Table 3. Height of sediment/debris from bed floor

Station	Sediment accumulation (m)			
	Q1	Q2	Q3	Q4
GRA Link Road	0.5	0.8	0.6	0.9
Olu-Obasanjo Culvert	1.1	2.0	5.0	5.8
Okija Street Culvert	1.1	2.2	4.3	6.0
Rehoboth Clinic /Afam Road	2.1	4.0	6.8	7.2
Aba Road Bridge Junction	2.0	3.3	5.5	7.2

Table 4. Discharge / streamflow data.

Date	Wetted Perimeter				Surface Velocity (m/s)				Average Velocity (Surface/Mid depth Velocity)				Discharge (m3/s)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Jan'05	5.0	0.93	3.90	1.63	2.29	1.40	2.29	1.66	1.94	1.19	1.96	1.45	9.72	1.10	7.63	2.35
Feb'05	3.83	2.06	3.58	1.95	2.18	2.00	2.01	1.57	1.84	1.71	4.76	1.36	7.08	3.51	17.06	2.65
Mar'05	5.89	2.32	3.90	2.44	2.41	2.29	2.34	2.29	2.04	1.95	5.44	1.96	12.04	4.53	21.22	4.77
Apr'05	7.36	2.32	3.90	2.59	2.61	2.77	3.05	2.64	2.22	2.34	6.55	2.21	16.34	5.43	38.54	5.72
May'05	9.12	3.02	7.81	3.32	3.05	3.26	3.81	3.26	2.59	2.77	7.74	2.81	23.63	8.36	60.39	9.07
Jun'05	11.78	9.05	23.42	11.13	4.57	6.09	6.52	5.08	3.89	5.18	14.45	4.34	45.76	46.89	338.48	48.25
Jul'05	10.89	11.61	25.34	10.49	4.16	9.14	11.43	9.14	3.53	7.77	21.68	7.74	38.46	90.26	549.33	81.17
Aug'05	12.07	6.97	11.70	5.30	4.57	7.62	8.32	6.10	3.89	6.49	18.11	5.19	46.89	45.23	211.91	27.48
Sep'05	13.24	11.13	18.69	7.74	5.38	6.52	7.04	5.37	4.57	5.54	15.47	4.59	60.54	61.63	289.10	35.52
Oct'05	13.54	4.65	7.80	6.41	6.10	3.05	2.86	2.61	5.18	2.59	7.23	2.22	70.18	12.03	56.38	14.22
Nov'05	9.42	1.39	2.34	1.78	3.98	2.53	2.68	2.40	3.38	2.16	6.04	2.04	31.82	3.01	14.14	3.62
Dec'05	5.59	0.93	1.54	1.62	2.69	1.45	1.52	1.58	2.29	1.22	3.40	1.36	12.78	1.13	5.22	2.20
Jan'06	4.12	0.69	1.54	1.59	2.41	1.43	1.58	1.57	2.05	1.22	3.40	1.36	8.43	0.84	5.22	3.75
Feb'06	5.00	0.93	2.34	0.97	2.86	1.53	1.64	1.41	2.43	1.31	3.66	1.19	12.15	1.22	8.56	1.15
Mar'06	7.65	2.09	3.95	0.53	3.81	1.83	1.84	1.60	3.24	1.55	4.34	3.91	24.78	3.24	17.11	0.72

Key: 1, 2, 3, and 4: Measurement Stations.
Station: GRA – Mile 3 Link Bridge, Station 2: Okija/Emekuku Streets link Bridge, Station 3: Afam – Kaduna Street link Bridge, Station 4: Aba Road Over Head Bridge

reaches. Station 1 had 60% sand while Station 2 had 22% (Tables 2 and 3). The land use activity in the GRA area is mainly housing and road construction as well as grading of the upper reaches of the Ntamogba stream. These activities account for the large percentage of sand particles in this reach.

The texture of the streambed sediment in the lower reaches is finer than upstream. It contains less sand (mean 35%) and greater quantities of silt (50%) with mixture of woody debris (15%). A single factor ANOVA determined a significant difference in only the percent weight of sand. The last two stations (Stations 3 and 4) have mainly rags, broken pieces of bottles and wood/furniture and nylon. The composition reflects the fact that the stream serves as a refuse dump. This agrees with Ayotamuno and Gobo (2004). These materials act as barriers, especially on the struts of the culverts causing local swelling/pooling resulting in the deposition of other materials, and generally increase the volume of the water without a corresponding increase in the velocity of the stream in the channel. This creates an artificial settling velocity. It also creates sediment and organic material storage sites which enhance substrate diversity - flow energy is dissipated which reflects the stability of these materials and enhances in-stream vegetation which further hinders flow (Table 3). In-stream vegetation may increase photosynthesis, which may produce secondary water quality impacts such as changes in dissolved oxygen and pH leading to eutrophication. It is at the Afam street culvert that we have a high concentration of urban waste (plastic, tires, broken pieces of furniture etc.) mounting up and blocking the culverts and increasing flooding.

In-stream vegetation reduces the effectiveness of erosion, stabilizing sediment and providing an obstacle to flow. Sediment deposited as velocity drops is trapped by vegetation. The result is that in vegetated reaches, sediment transport is lower and bed stability improved. Where an obstacle causes the rate of sediment supply to approach zero, the bed will scour immediately downstream as the 'clear' stream picks up a new equilibrium load. Further downstream, this load becomes the supply for the succeeding section of the channel. Between Abacha Road and Olu Obasanjo culvert (Table 4), the stream power appears high allowing entrapment of sediment. Conversely wider, shallower channel reaches have lower stream power resulting in the deposition of sediment, e.g. between Olu-Obasanjo culvert and Okija/Emekuku Streets culvert up to Afam Street culvert.

It can also be argued that the amount of sediment in the middle and some portions of the lower reaches is a function of the stream velocity, which in turn gives power to the stream for sediment transport. Figure 2 shows that the pattern of housing development in the GRA is sparse (and it's about 415.5 acres) while that of the D/Line is nucleated with very few open areas with lots of the areas being made impervious (1404.5 acres). This impervious nature of the area, and not the impermeable nature of the soil of Port Harcourt as posited by Akobo (2005), results in increased volume of runoff during rainfall. Water remains above the surface for a longer time and runs off in large amounts when threshold is reached. This strength erodes stream banks and carries loose particles and other urban waste debris into the stream. At this rate the channel receives a high amount detritus in a very short time. This lowers the channel depth and increases the sediment load in the dry season leading to more settlement of detritus. During the rainy season this gives rise to higher than normal water levels leading to overflow of the river banks.

Another source of sediment input to the stream that induces flooding is urban housing and road construction and this agrees with the conclusion of Knighton (1984). Excavation for building foundations, foundations for culvert piling and sand bags brought in for grading into artificial channels are the major contributors to the sediment load from Sani Abacha road. Presently engineering solutions to the problems of aggradation of the channel and flooding employ grade control structures and bank protection. Flood mitigation works such as channel improvements (straightening, removal of vegetation, de-silting, lining with rocks and concrete) accelerate flows, so that they arrive at downstream locations more quickly. Enhanced levees deprive floods the opportunity of engaging extensive floodplain storage and thus greater volumes of floodwater find their way downstream. The net effect is that flooding downstream of the mitigation is often intensified. This has been a major problem to residents of D/Line Area adjoining the Okija/ Emekuku Street - Afam Street culverts zone. Furthermore, the effectiveness of mitigation work is often negated by on-going housing development. For instance upstream urbanization would result in greater volume of runoff being transported downstream. Channel encroachment caused by housing development on banks or levees would cause flood levels to rise locally, with the impact being propagated significantly upstream.

While the processes of urbanization are linked to unstable streams, they are by no means homogenous or uniform in terms of their explicit spatial patterns or implications. In this study, we postulate that urbanization can be characterized according to land-use intensity and landscape composition.

CONCLUSION

This paper found that the entire watershed has been demarcated into three zones or reaches – upper, middle and lower. Housing and road construction is greater in the middle and lower reaches and accounts for peak runoff of shorter duration; runoff carries sediments and other urban loads characteristic of the catchment area, and as a result there is a net effect in two ways – first, during raining periods, quickflow results in flood and second, in dry seasons, sedimentation/bed aggradation take place. We therefore conclude the basic factors influencing the flooding of the middle and lower reaches include urban land use intensity, pattern of housing and road development and hydrologically connected impervious areas. Unplanned urbanization leads to increased and localized total impervious cover generating high peak runoffs. The conversion of the channel into a refuse dump accelerates aggradations and reduces the stream depth and as a result the flood conveyance capacity of the stream in the middle and lower reaches is impaired and unable to accommodate the peak runoffs generated by the total impervious cover.

RECOMMENDATIONS

An effective urban renewal policy that will address indiscriminate housing, and encroachment into marginal areas should be put in place. Efforts should be made to hydrologically disconnect the impervious areas. There should be effective legislation to stop dumping of refuse into the stream. We also want to suggest here that a team of experts comprising, hydrologists, civil engineers, environmentalists, and all stake holders in urban watersheds be engaged to critically evaluate the various issues raised in order to achieve a meaningful watershed management policy.

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