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Stormwater Assessment and Management Using Gis Modelling in The Urban Catchment of Port Harcourt, Nigeria

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Abstract: The management of storm water is a significant challenge in several urban areas in Nigeria. Urban areas often times have local flooding as storm water is channelled along streets as runoff may not be able to escape from the environment and may cause flooding (Bryan 2002). Thus, the period of heavy rains is known in Nigerian cities for flooding and associated damages The sustainable technique which is appropriate for storm water harvesting is from point source, water management and purification (treatment), this can make urban environments to be self-sustaining in terms of water resources. The study seeks to assess stormwater generation and management which involves the hard and soft engineering projects which involves the construction, operation, and maintenance approaches which includes dams, artificial levees, and channel straightening. The study adopted the correlational research design were data were analysed using hydrological modelling techniques using GIS to achieve the study objective. Thus a model to show the stormwater generation was done weighing and overlaying the DEM data in the pairwise comparism of stormwater runoff against rainfall intensity and terrain pattern using multi criteria evaluation. The result for the research and findings shows that the simulated sub catchments runoff in port harcourt metropolis whereby four catchments were used for the runoff generation, it is vividly shown that the total precipitation in each of the sub catchments is similar which was 1.57 inches while the total infiltration read 0.79 inches, the total runoff was 0.74 inches and 0.08x 106 gallon. Based on the findings, the study recommends that better planning of the city is required to manage the problem of stormwater through various engineering projects. The recommendations are as follow: Implement the port harcourt City Master Plan to guide, monitor, control and manage the areas designated as urban lands to achieve sustainable urban growth and development; [2] as a state policy and urgency, Storm Water Management Framework should be prepared for the city having Storm Water Master Plan to control, manage and monitor storm water – Model for Urban Stormwater Improvement Conceptualisation (MUSIC), 2002 Approach, Structural (engineering methods) and Non-structural (regulations and standards) Storm Water Management approaches should be employed to control and manage flooding challenges in the city;

Keywords: GIS, Stormwater, Urban, Catchment

Introduction

Globally the rate of loss and damage that are disaster related either anthropological or natural is alarming resulting in great economic loss and loss of millions of lives for the past three decades. Urban areas, where about one half of human population are presently residing and most of the world's human-made developments are concentrated are fast becoming the focal point for natural and human-induced disasters which have caused devastating destruction and losses (UN-HABITAT, 2007). However, rapid urbanization, coupled with global environmental changes, as a result of climate change and heavy human activities has resulted increased vulnerable or exposed areas (disaster hotspots) presently serving as human settlements(UN-HABITAT, 2007).

UN-HABITAT (2007) defined flood disaster as a situation where the resilience of the people is overwhelmed by the amount of stormwater/runoff generated in a place due to high rainfall intensity. These natural or human-induced disasters include; landslides, mudslides, flooding, droughts, earthquakes,

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tsunamis, volcanoes, avalanches, ecological damage, fire, etc. Though, the spotlight of this research is the assessment of storm water management and problems which cause pluvial flooding and environmental degradation in settlements especially in urban areas, and the strategy for effective storm water management in port harcourt City.

The management of storm water is a significant challenge in several urban areas in Nigeria. Urban areas often times have local flooding as storm water is channelled along streets as runoff may not be able to escape from the environment and may cause flooding (Bryan 2002). Thus, the period of heavy rains is known in Nigerian cities for flooding and associated damages. This human-induced disaster is a major problem and concern to the global communities, especially in urban areas, whose surface has grossly been paved and concretized through urban development. This has considerably caused environmental, social, health and economic problems in the built environment whether in developed or developing societies (Enger, et al, 2006) but more commonly in developing societies. In the past, many developed cities had single system to handle both sewage and storm water runoff, which during heavy precipitation, the runoff from streets could be so large for waste water treatment plants to handle the volume and these waters will be directed to any natural water bodies close without treatment. Currently the developed cities have separated sewage and storm water runoff for easy treatment and handling (Enger, et al, 2006).

The Encarta Dictionary (2009) defines storm water as the water channelled into a constructed or natural drain large enough to contain excess water overflowing the surface. Storm water is also defined as water that runs off streets and buildings and is often added directly to the sewer system and sent to the municipal wastewater treatment facility (Enger, et al, 2006).In the environment storm water can infiltrate into the soil, also held on the surface of the earth and evaporate, or overflow and emptied in nearby streams, rivers, or water bodies in the environment.Natural landscapes such as forests and grasslands, the soil absorbs much of the storm water and plants hold storm water close to where it discharges. In built-up environments, unmanaged storm water can cause two major problems such as the volume and timing of runoff water (flooding) and the other related to potential contaminations from pollutants that the runoff is carrying (water pollution) (Schueler, (2000); Alex and Robert (2005). Storm water is also a resource and important as the world's human population water demand exceeds readily available water for use as a result of rapid population growth especially in urban areas where most of the world population is concentrated. The sustainable technique which is appropriate for storm water harvesting is from point source, water management and purification (treatment), this can make urban environments to be self-sustaining in terms of water resources. Storm water has been shown to be one of the leading contributors to pollution of urban waterways since it can contain fertilizers, oil, pesticides, trash, sediment and animal wastes from human activities. Therefore, because of this condition, certain storm water discharges are regulated by Environmental Protection Agencies (EPAs) in developed countries (AHTD, 2015).The rapid increase in occurrence and intensity of extreme rainfall events has been severe in recent decades and it is evident also that both the frequency and intensity of floods have increased (Temi and Durowoju, 2014).In the wake of increased human developmental activities, runoff increases resulting in poor quality of surface and ground water resulting in growing concern on the handling methodology of treating and monitoring storm water and ensuring better quality of surface and ground water as a result of storm water through engineering solution (Bryan, 2000).

Environmental hazards attributed to water related hazards resulting from improper storm water management characterize coastal environments and Nigeria is not an exception. The Niger Delta region, which is a coastal region and a floodplain experiences storm water management challenges especially in the cities located in this region as they are convergent point for population. However, the increase in population and human reckless interference with the environment in the quest for industrialization, agriculture, urbanization and settlement development, etc have in addition to this geo-hazard resulted in serious ecological and socio-economic problems (Oyeleke, 2014). This study therefore seeks to examine the generation and management of stormwater/runoff across the catchments in port harcourt drainage basin

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Literature Review/Conceptual Framework

Storm Water generation and Management

Generally, rivers are major contributor to storm water problem which results to flooding incident. When they generate flood, their impacts are devastating which destroy livelihoods, cause economic damage and even kill people. This is why humans look for ways to handle them to prevent flooding in the first instance or reduce the impacts. Though, rivers are nature creations that are difficult to predict and they are very powerful dynamism. Man's ability to totally stop them from causing flooding is impossible but can control them to reduce impacts on human and the environment. However, to manage storm water not to cause flood, there are two basic storm water management strategies covering hard and soft engineering projects.

The soft engineering projects are centred on reducing and mitigating the impacts of storm water problems resulting to flooding incidents rather than preventing them. The major benefit of soft engineering is cost efficiency and effectiveness as they are cheaper to embark upon which developing countries can also undertake. The construction, operation and maintenance approaches low implication in education and technology requirements in implementation. Generally, they don't disturb the natural processes and ecological systems in river basin like their hard engineering project counterparts but integrate with the natural system to achieve environmental sustainability (Alex, n. y.).

Hard Engineering Techniques

Dams are super and hard engineering techniques with environment especially settlement along rivers and floodplains. The magnificent engineering edifies hold water as reservoirs and drain water slowly in a controllable manner as not to cause water surge. This helps keep discharge downstream of the dam low even during prolonged heavy rainfall for months. Apart from mitigating flooding occurrence it also provides hydroelectric power to many settlements that enhances socio-economic growth and development. The reservoir of the dam can also be used for provision water supply and recreational activities .

In spite of these enormous benefits, dams have many environmental challenges impacts. Dams are expensive and highly technological demanding of all hard engineering techniques in the world as many resources are required for its construction. The settlements behind a dam have serious flooding often times that can destroy habitats and properties, force the inhabitants to leave their homes. Dams disrupt the natural processes that take place within the river ecological systems by not allowing sediments from being transported to downstream of the river and this can destroy landforms and habitats of the deltas. Also, the chemical composition are affected which can reduce the survival of aquatic lives (Alex, n.y.).

Artificial Levees

Artificial levees are artificial versions of the river edges. They act as embankments just like their natural counterparts, and basically extend the channels height and increase their bank-full discharge. The primary benefit of an artificial levee is that it allows the floodplain to be developed upon which also have environmental consequences as it increases the risk of flooding from precipitation and river surge to the people that occupies the area and create ecological imbalances in the environment. However, if they fail, the consequences are overwhelming and even worse that if the levees did not exist at all (Alex, n.y.).

Channel Straightening

This method for flooding checking involves the blocking off meanders by constructing alternate and straighter routes across meanders, for the river to flow are faster and easy in movement. Like with wing dykes, this technique channel river water in a faster mode thereby preventing it from pooling at a point and causing flooding risk. A straightened channel is faster to navigate water and straightening channel. This technique has several problems, the downstream of a straightened section of a channel most times faces flood and erosion problems because of river dynamics (Alex, n.y.).

Effects of Climatic and Hydrological Factors on Storm Water Management

The magnitude and frequency of large rainfall events present significant challenges for stormwater management which most times the transporting system such as drainage are overwhelmed and filled beyond capacity and over flow and most coastal areas are exposed to risk of flooding (Liebl, 2011). For example, the U.S. Geological Survey (USGS) has created a synergy with the City of Charlotte and Mecklenburg County in North Carolina, and develop Flood Information and Notification System (FINS) used to check and address rapid flooding in the area by notifying future flooding occurrence in these urban areas where streams rise and fall rapidly(U.S. Geological Survey, 2003).

The FINS is based on a large network of stream flow-gagging and rainfall stations that will broadcast information recorded through radio telemetry. This system routinely notify the National Weather Service (NWS) and emergency agencies to respond rapidly in the region when rainfall and stream flow which indicate the eminent risk of flooding occurrence, for the agencies to issue warning signals to the people for evacuation and preparedness in the areas if necessary (Konrad, 2014; Carter, 1961) .

Water bodies such as streams, rivers, lakes, etc are naturally fed by runoff from rainfall and snowmelt moving overland or subsurface flow. Flood incidence may occur when large volumes of runoff flow rapidly into water bodies and overwhelm the banks of these water bodies causing inundations and rivers surge. The rapid discharge of water that causes flooding is influenced by many factors including the intensity and duration of rainfall and snowmelt, the topography and geology of natural water basins, level of vegetation in the environment, and the hydrologic conditions prior storm and snowmelt events (Konrad, 2014).

Modest storage capacity for water from rainfall and snowmelt in urban basins, generate more rapid runoff and urban water bodies rises more rapidly during storms and have higher peak discharge rates than do rural streams. For example, streamflow in Mercer Creek, an urban stream in western Washington, increases more quickly, because of higher peak discharge and volume during the storm in 2000, and decreases more quickly than in Newaukum Creek, a nearby rural stream in the same region. These differences cannot be attributed to landuse patterns in the various creeks but reflect differences in geology, topography, basin size and shape, and storm patterns (Konrad and Booth, 2002).

Hydrology affects of urban development and most time significant in small stream basins where before urban development, much of rainfall on the basin would have become subsurface flow, recharging aquifers or discharging to the stream network. Urban development can totally change or alter the landscape in a small stream basin, unlike in larger river basins where areas with natural vegetation and soil are likely to be retained because of the extent of land and water basin (Konrad, 2014; Leopold, 1968).

Developing along stream channels in floodplains may distort the capacity of water channel to transport water which may increase the height of the runoff. Buildings and other developments that encroaches on floodplain, such as bridges, can increase upstream flooding by narrowing the width of the channel and increasing the channel's resistance to flow. Since, the water is at a higher stage as it flows past the obstruction, it can cause backwater which may give rise that to inundation of upstream because of sediments and debris carried by the flood(Konrad, 2014; Bailey, et al, 1989). Small stream channels also can be filled with sediment and cause clogging because of the size of the culvertin the stream. However,such channels can be engineered through the conveying of floodwater and debris quickly downstream, which may benefit the area and balanced against the possibility of flooding in downstream (Konrad, 2014).

Erosion is another consequence of urban streams as it effects urban development. The frequent development in urban water bodies increases flooding and causes bank erosion along the water channel path. Where river channels have been altered and vegetation has been removed from channel banks, streamflow velocities will increase and enhance the transportation of sediment along the river rapidly. In many urban areas, stream bank erosion continue to be threat to roads, bridges, and other structures which is difficult to control even by hardening stream banks (Konrad, 2014).

Materials And Methods

This study adopts the correlational research design. The correlational design approach is being used in this study to measure the strength of the relationship between runoff (stormwater) and the associated risk of vulnerability on flood prone areas in the study area. Hence, data for the study was the secondary data acquired from Landsat imageries of the study area showing the digital elevation of the area and the water shed pattern. *The data for this study was analyzed using hydrological models and modeling techniques to achieve the objective of the study. The volume of Water generated was plotted against the intensity of rainfall to get the stormwater generation as showed in the hydrograph.*

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Thus a model to show the storm water generated was done by Weighing and overlaying the DEM data in the principle of pair-wise comparison of storm water runoff against rainfall intensity and terrain pattern using multi criteria evaluation techniques.Thus, the enhanced Digital Elevation Model (DEM) developed for the small catchment across cities was used. This technique was adopted by Amro et al (2019) in assessing flash flood risk in urban environment of Taibah and Islamic University Campuses of Kingdom and Lian et al, (2017) on flash flood vulnerability assessment for small catchment with material flow approach to show the relationship between exposure, sensitivity and adaptive capacity in a small catchment and it is replicated in this study . Adopting the procedure of Amro et al (2019) and Lian et al, (2017), a flood hydrograph for the small catchment across the city of Port Harcourt was generated using enhanced DEM and acquired to model the approach of runoff/storm water generated.

Results And Discussion

This involves the results presentation and discussions of findings in the study areas.to be presented in the light of the study aims and objectives which involves to analyze the probability and occurrence/variation of stormwater generation across the cities in the study area

Table 4.1: Stream Parameters

Stream Parameters	***Port Harcourt***
Total Stream Length (m)	*339991.67*
Average Stream Length (m)	*1086.24*
Number of Streams	*313*
Standard Deviation	*886.39*
Minimum (m)	*46.08*
Maximum (m)	*5771.86*
Highest Flow Length (m)	*0.17*

Storm-water generation in Port Harcourt Metropolis

The descriptions of stream parameters in Port Harcourt Metropolis is shown in Table 4.1. In Port Harcourt, the analysis showed that the total length of streams was 339991.67m and the mean length was discovered to be 1086.24m. In total, there were 313 streams in Port Harcourt Metropolis and the highest flow length was 0.17m. There were 251 streams that were found in Port harcourt Metropolis and the highest flow length was 0.14m. From the analysis, it can be deduced that there are more streams in Port Harcourt the average length of streams was higher in Port Harcourt.

The sub-catchment analysis in the study areas revealed that Port Harcourt had more basins 654 sub basins (Table 4.2, Figures 4.2, 4.3, 4.7). The total area of basins in Port Harcourt was 446101922.54 sq m . In Port Harcourt, the area ranged between 5456.12 sq. m to 68591447.12 sq m. with the mean value of 1388006.17 sq.m.

Table 4.2: Sub Basin Parameters

Sub Basin Parameters	**Port Harcourt**
Total Number of Basins	654
Total Area (Sq. m)	446101922.54
Minimum (Sq. m)	5456.12
Maximum (Sq. m)	68591447.12
Average Area (Sq. m)	1388006.17
Standard Deviation (Sq. m)	4246555.79

Source: Researcher’s Analysis, 2020

The digital elevation model of Port Harcourt was found to range between -6m to 39 m in Figure 4.1 and there are quite sub basins of varying sizes in Port Harcourt Metropolis (Figure 4.3). The flow length of streams in Port Harcourt Metropolis ranged from 0m to .174054m (Figure 4.4). This shows that the topography of Port Harcourt is more higher. The flow length of streams in sub basins ranged from 0m to 0.144281 (Figure 4.7). Thus the flow length of streams in Port Harcourt is higher Metropolis.

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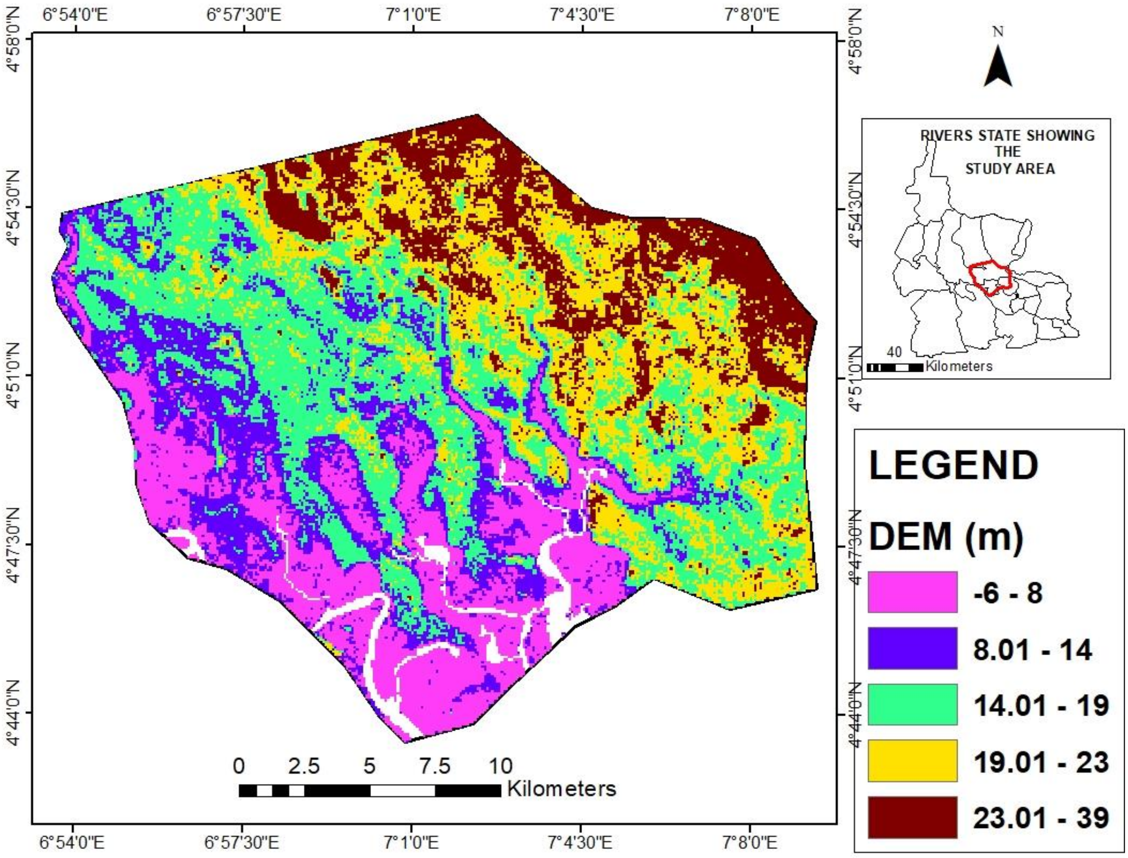

Figure 4.1: DEM of Port Harcourt Metropolis

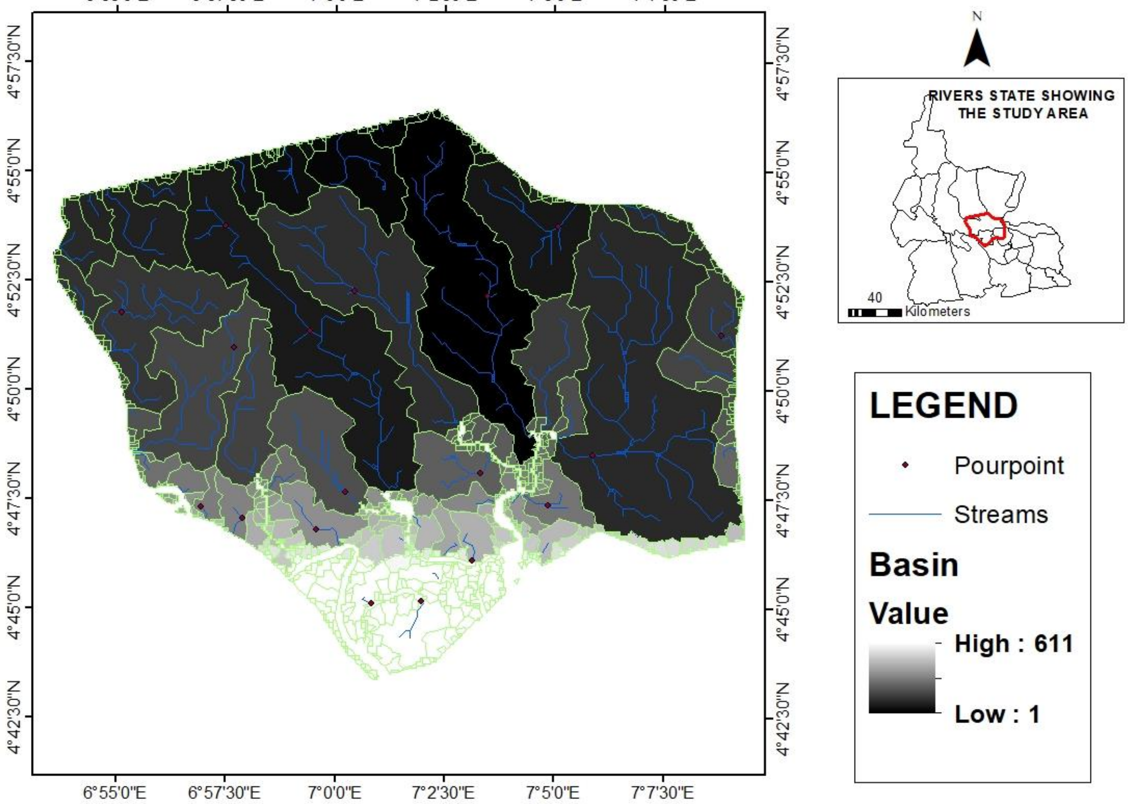

Figure 4.2: Basins and Streams in Port Harcourt Metropolis

Storm water attributes in the Study Areas
Storm water attributes in the Port Harcourt

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Based on the study aims and objectives which involves to analyze the occurrence and variations of stormwater generation across the study areas.

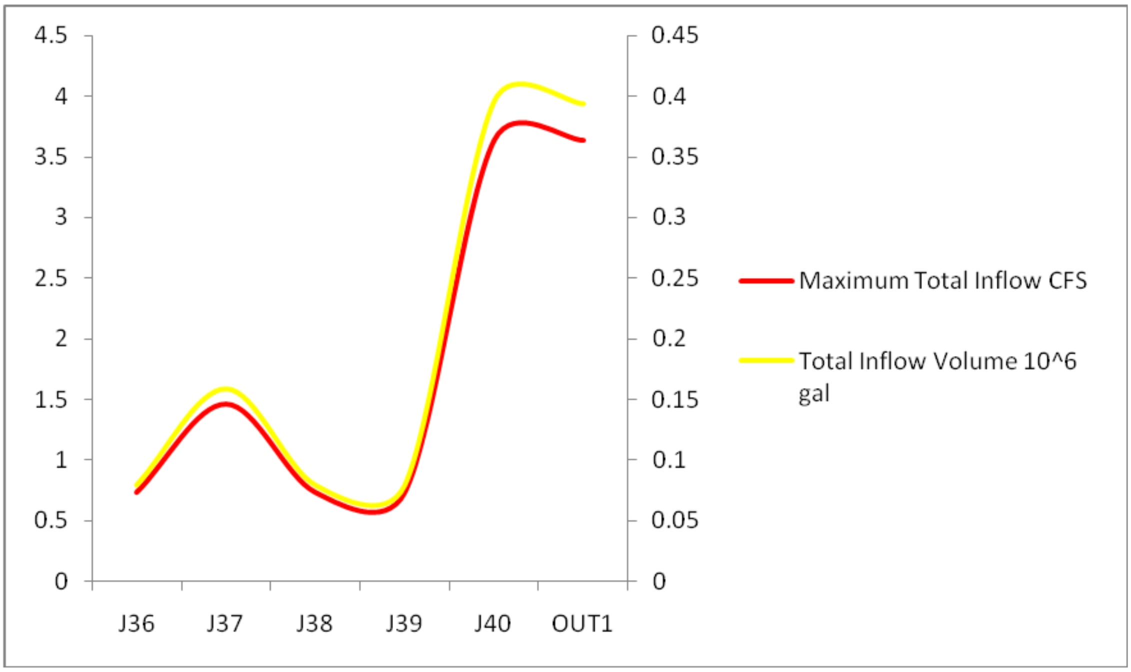
Table 4.3 summarised the simulated sub catchment runoff in Port Harcourt Metropolis whereby 4 sub catchments were used for the runoff generation (Figure 4.8). It is vividly shown that the total precipitation in each of the sub catchment is similar which was 1.57 inches while the total infiltration read 0.79 inches. The total runoff was 0.74 inches and 0.08 x 10^6 gallons.

The link flow analysis through the conduit or pipe as shown in Table 4.4 reveals that the range of maximum flow of the conduit was from 0.73 CFS to 3.64 CFS while hours of flow was 6 hours. It is thus observed that the conduit C36, C38 and C39 having similar maximum flow still exhibited different rates of maximum velocity. Thus, C36 had 3.56 ft/sec, C38 had 4.22 ft/sec while C39 had 3.92 ft/sec. The other two conduits namely C37 and C40 with higher flow maintained higher velocity as they had 5.26 ft/sec and 9.35 ft/sec respectively. It is equally discovered that the maximum full flow was higher in the conduits with higher flo velocity. The maximum full depth of the conduit appeared to range from 0.11 ft (C38) to 0.26 (C40). Generally, it is shown that flow; velocity of flow, full flow and full depth of conduit followed almost the same pattern against each of the conduit (Figure 4.9).

The nodes or junctions of inflow in Port Harcourt Metropolis in Table 4.5 were seen to have equal maximum of lateral inflow of 0.73 CFS. It is however discovered further that the maximum total inflow ranged from 0.73 CFS in J36, J38 and J39 to 3.64 CFS in J40. The Outfall was also having 3.64 CFS total inflow. Although the lateral inflow volume in all the nodes was similar (0.0796 x 10^6 gal) but the total inflow volume of the nodes varied and ranged from 0.0796 x 10^6 gal to 0.396 x 10^6 gal; whereas the outfall had 0.394 x 10^6 gal. It could be deduced from the analysis that total inflow is proportional to the total inflow volume in the nodes or junctions (Figure 4.10).

The node depths in Port Harcourt Metropolis are given in Table 4.6 had varying depths ranging from 0.12 ft in J38 to 0.27 ft in J40 and Out1. The maximum depth among the nodes was highest in J40 and Out 1 (0.39 ft) while the minimum was found in J38 (0.17 ft). The maximum HGL ranged from 13.39 ft in J40 to 23.2 ft in J36. The maximum HGL in Out 1 was 3.39 ft.

The outfall loading shown in Table 4.7 revealed that the flow frequency was 82.36% while the average flow was 2.97. The maximum flow was 3.64 CFS and total volume of storm water was 0.394 x 10^6 gal in Port Harcourt Metropolis.



Maximum Total Inflow and Total Inflow Volume in the Nodes in Port Harcourt Metropolis

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Sub Catchment Runoff, Node Flooding, and Linking Volume

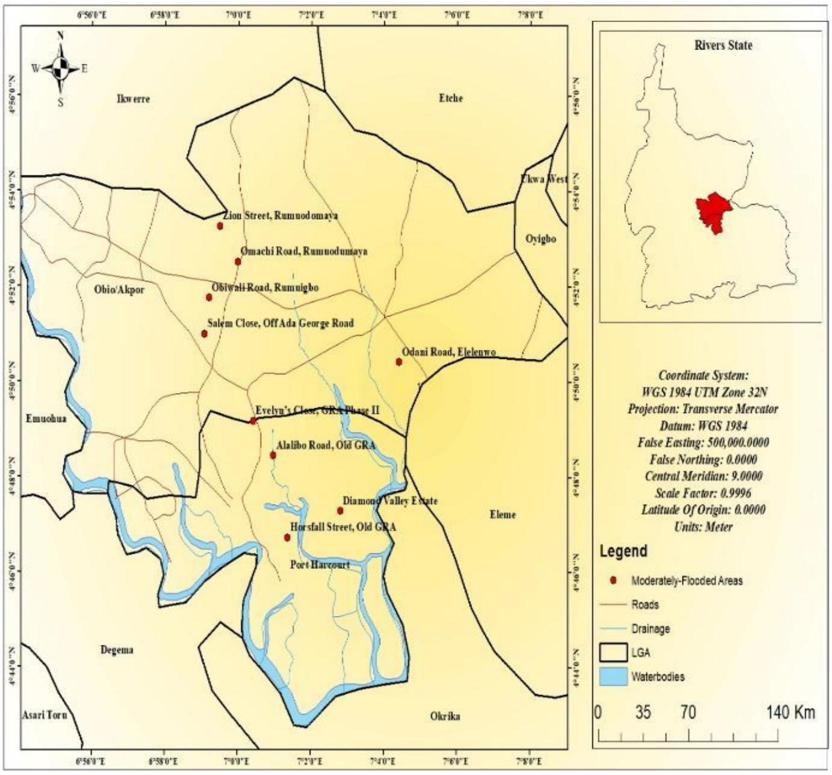
The sub catchment runoff, node flooding and linking volume of Port Harcourt Metropolis is observed here. The situations at different times of the day are shown in Figures 4.20 (0.00-01.00mins), 4.21 (01.15-01.30mins), 4.22 (01.30mins-01.45mins), 4.23 (01.45mins-05.15mins), and 4.24 (05.15mins-06.00mins) in Port Harcourt Metropolis. In Table 4.15, the analysis revealed that the catchment runoff, node flooding and linking volume increased with increasing time of the day. The sub catchment runoff ranged from 0 in to 0.73 in; node flooding ranged from 25 to 100 CFS while link volume ranged from to 100 ft^3 to 460 ft^3. The simulation of the sub catchment runoff, node flooding and linking volume was not deduced.

Nature of Water Elevated Profiles/Hydrographs in the Study Area

The nature of water elevated profiles or hydrographs though the conduit between different nodes and the outfall in the study area are discussed in this section.. For Port Harcourt Metropolis, the water elevation profile included from Node 36 to Out 1 (Figure 4.31); and that of Node 38 to Out 1 (Figure 4.32).

Storm water/ Flood Vulnerability in Port Harcourt

Figure 4.38: Lowly Flooded Areas in Port Harcourt Metropolis



Discussion of Findings

The study compared the storm water generation and flood vulnerability between Port Harcourt. Due to devastating effect in Urban areas resulting to destruction of Property and displacement of millions of people, sporadic urbanization ,human attraction, Landuse/landcover changes. uncontrolled development, encroachment of floodplains which occurs as a result of flash flood, blockage of river channels, drainages. shoreline inundation, devastating human impact on the hydrological cycle, The Findings of the study showed that Port Harcourt the total stream length, number of streams and the flow length was higher in Port Harcourt. However, the average stream length was higher in Port Harcourt Metropolis. Considering the number of sub basins in the study area, findings showed that Port Harcourt had more (654) sub basins.

The sub catchment runoff, Node flooding and link velocity of both Port Harcourt metropolis as presented in Table 4.16, figure 4.25 (0.00 mins – 01/15mins), figure 4.26 (1.15mins – 1.30 mins) and figure 4.27 (1.30mins – 6.00mins) present the sub catchment runoff, Node flooding and link velocity a Port Harcourt metropolis. Similar to other analysis and findings, the runoff, and flooding increased with increasing time of

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the day while the velocity increased from 0.01ft/sec to 2ft/sec at 1.30mins, and begin to reduce and stayed at 1ft/sec. The analysis/findings in figure 4.28/0.00mins – 03.30mins, 4.29 (03.30mins – 0.400mins) and 4.30 (04.00mins) – 06.00mins indicated three different major changes during the simulations in any of the combined parameters (runoff, flooding or velocity).
Table 4.17 revealed according to finding that the sub catchment run off and node flooding remained unchanged throughout the hour considered. While the link velocity fluctuated from 10.01ft/sec to 0.78ft/sec at 3.30mins and later increased at 4.00mins for the remaining hour of the day.The nature of water selected profiles/flood hydrograph of the study areas. In Port Harcourt metropolis were the water elevation profile included from node 36 to out 1 (figure 4.31) and that of node 38 to out 1 (figure 4.32). The one from node 36 to out 1 has increasing in elevation with increasing distance to the outfall while the one for node 38 to out 1 outlined to decrease. Analysis and findings for flood vulnerability in Port Harcourt metropolis revealed that the landuse map vulnerability to flood according to each landuse identified in the study area. looking at Table 4.18, figure 4.36 and figure 4.37 explained the types of landuse discovered and the spatial extent of each of them. The analysis further showed that the spatial extent of the area for moderate flood vulnerability was 48.7% while high flood vulnerability was 51.3%.
According to Table 4.24, Figure 4.45 and figure 4.46 explained the types of landuse discovered and the spatial extent of each of them, buildup area (141783308.91m^2) vegetation patches (50813320.29m^2). The findings revealed farmland /space vegetation recorded 35785889.00m^2 while water bodies and vegetation patches 10.37% and 19.94% respectively. The findings also showed that spatial extent for moderate flood vulnerability was 33.98% while high flood vulnerability was 66.02%.

Summary

The study compared the storm water generation and flood vulnerability between Port Harcourt Metropolis. Findings showed that Port Harcourt the total stream length, number of streams and the flow length was higher in Port Harcourt. However, the average stream length was higher in Port Harcourt Metropolis. Considering the number of sub basins in the study area, findings showed that Port Harcourt had more (654) sub basins. although the average area of the basin was higher in Port Harcourt. The digital elevation in Port Harcourt was lower in range. For Port Harcourt, it ranged between -6m to 39m. The total runoff in Port Harcourt Metropolis was higher in Port Harcourt Metropolis (0.74) inches, the maximum flow was 3.64 CFS and total volume of storm water was 0.394 x 10^6 gal. The analysis revealed that rate of change of catchment behaviour The catchment precipitation, node flooding and runoff in both study areas continued to increase with increasing time of the day, although the rate of change of the volume of runoff varied slightly between Port Harcourt. The width of the hydrograph in Port Harcourt was wider. The areas prone to moderate and high flood in Port Harcourt was higher (95.03%) .

Conclusion

The study can be concluded that the runoff generated in Port Harcourt was higher. Also the flood vulnerability level of Port Harcourt is higher in Port Harcourt considering the landuse, elevation, proximity to river and soil texture.

Recommendations

Based on the findings, the study suggested the following recommendations.

1. Government should be fully prepared against flood intensity because of the level of vulnerability to flood in Port Harcourt is found
2. The area liable to moderate and high flood vulnerability should be well guided and guarded to minimize the destruction of lives and properties
3. Better planning of the cities is required to regulate the effect of flooding in the study area

[4] implement the port harcourt City Master Plan to guide, monitor, control and manage the areas designated as urban lands to achieve sustainable urban growth and development; [2] as a state policy and urgency, Storm Water Management Framework should be prepared for the city having Storm Water Master Plan to control, manage and monitor storm water – Model for Urban Stormwater Improvement Conceptualisation (MUSIC), 2002 Approach,Structural (engineering methods) and Non-structural (regulations and standards)

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Storm Water Management approaches should be employed to control and manage flooding challenges in the city;

I. Proper planning and layout of residential, commercial and industrial areas for easy construction of drainages and channelling of storm waters to natural drainage systems in the city;[5] HEC-1 and HEC-RAS softwares should be used to analysis and estimate natural drainage systems hydrology, hydraulic and flow systems of channels;
II. Detailed topographical and geological surveys and analyses of the study area should be carried out before storm water infrastructure should provided for proper flowing and channelling of storm water;

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