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Full Length Research Paper

Spatial assessment of urban flood risks in Aba Metropolis, using geographical information systems techniques

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This study applied Geographical Information System Technology in the spatial analysis of flood risks in Aba metropolis. Data on spot heights and elevation were collected with Global Positioning System and used to produce digital elevation model map in a 2-D format; the aspect map showed the natural direction of storm water flow; the slope map was used to indicate the overall rate of downward movement of water and the contour map showed elevations at intervals of 10m. The digital elevation model presents the study area as ranging from 35 – 70m above sea level. Water flowed from areas 70m to areas 35m above sea level. Areas 35-39m and 43-48m are prone to flooding, as runoff from the areas of higher elevations tends to flow towards areas of lower elevations. The percentage slope variation showed that slopes which ranged from 38.26% - 46.88% and areas 55.50% - 64.12% are more vulnerable to erosion but flood free. The areas with slopes ranging from 64.12% - 72.74% and areas 81.36% - 89.98% have critical and steeper slopes and certainly produce flood of greater velocity than moderate or lower slopes. The aspect map showed that in areas of 0 - 22.5 and 337.5 - 360 water flows to the north, while 67.5 - 112.5 flows to the east. All areas of 157.5 - 202.5 water flows in the southern direction, while areas from 247.5 - 292.5 water flows in the western direction. Elevation in the area ranged from 72m to 36m with an average of 54m and must be considered in storm water channelization projects.

Keywords: urban flood, geographical information system, spatial analysis, elevation

INTRODUCTION

Several manifestations and effects of climate change and variation have been studied (see for example, Ojo 1992; Obioh, 2002; FGN, 2003; NEST, 2003; Njoku, 2006). NEST (2004) indicated that current and future vulnerability include human settlements and health, water resources, wetlands, agriculture, food security, coastal zones and land degradation. Land degradation reduces the quality and productivity of land. One of the causes of land degradation which has been on the increase as a result of climate change is erosion and flood. It is as a result of this and the rising spate of occurrence of urban flooding and inundation, especially in coastal and humid regions that this study was carried out.

Ologunorisa, (2001) defined flood as any abnormally high water stage which may result in significant, detrimental effects such as property damage, traffic destruction, nuisance and health hazard. Flood also affects and damages agriculture, properties and public

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utilities, as well as economy of the affected area and may lead to loss of human lives. In urban areas in Nigeria, flooding has been known to be caused by a combination of excessive precipitation and inadequate flow channel capacity of sewer systems (Soba, 2008). Flooding may result when there is excessive rainfall or when natural or artificial channel is too small, relative to the discharge or when the land is too level and less permeable to the water that gathers on top of the ground surface. The physical dimension of flood shows that it leads to pollution of the human environment. Destruction of flora and fauna, damage to habitats, food chain, species diversity and stability, damage to endangered species, natural recreational resources, and archeological and historical resources are the environmental effects of flood. For example, waste that are generated from both domestic and industrial activities can be spread by flood.. Floods are linked to increases in communicable diseases, but studies show that certain endemic diseases, especially gastrointestinal diseases, rise to epidemic proportions where sanitation standards are low (Orji, 2010).Other health impacts are abundance of communicable diseases, shortage of food supply, dispersion of household wastes into the fluvial system and contamination of community water supplies and wildlife habitats with extreme toxic substances.

The occurrence of flood event usually elicits a response to alleviate losses and return society as quickly as possible to pre-disaster conditions (USNIOSH, 2008). After the flood event, many other environmental impacts can become apparent including, the volume of debris to be collected, the extent to which public utilities such as water supply systems and sewage operations have been damaged, and industrial pollutants entering fluvial systems, might present pressing problems. However, the environmental impacts of 1993 and 1995 floods in the Netherlands were assessed in terms of the suspended matter composition in the rivers and its eco-toxicological effects (Orji, 2010).

Developing countries are presently characterized by rising flooding events being one of the effects of increasing urbanization. This ultimately alters the fluvial processes of the area because urbanization increases surface runoff due to increase in relative proportion of impervious surfaces. Odermerho (1988) further showed that land use and land cover in adjoining peri-urban areas, directions of slope and lack of drainage facilities also determine the timing, extent, magnitude and locations of floods in Nigerian cities. Similarly, Enakhimion, (1981) elaborately showed that these factors drive flood incidence in Benin City. To Soba (2008) the floods and flooded areas in rapidly urbanizing Owerri are potentially determined by the amount and intensity of precipitation, the texture of the soil, land use and cover types, gradient and direction of slope. The effects of these factors are more critical because cities in Nigeria evolve without well planned facilities and integrated sewage network (Njoku et al, 2010). Consequently, runoff associated with increasing proportion of impervious surfaces is ponded as pools on urban terrain.

Flood as a nuisance in Aba metropolis and environs is acute and rising. These followed the phenomenal growth of the city in recent years, marked by expansion of impervious surfaces as a result of spatial structures and infrastructural facilities/amenities, and the virtual absence of drainage and sewage systems. In Aba and environs the hydrologic environment is more complex than a pre-urban watershed due to the imposition of urban land use and land cover as well as the manipulated runoff disposal systems. Therefore, flooding in the city follows complications introduced by active urbanization and the near absence of adequate runoff disposal systems. This results to the ubiquitous pondage of runoff on street surfaces. As a result of the inconveniences of flood and the damages caused by ponded water, stakeholders are compelled to seek post-construction solution to the problems of flooding in the ever-urbanizing Aba metropolis and environs. This study provides spatial analysis of the flooding and flooded sites in Aba and environs using Geographical Information Systems (GIS) Technology. It seeks to solve the perennial flooding problem in the metropolis by identifying and mapping the flood zones and floodable areas. This study proposes the application of DEM in the control of flood in parts of Aba metropolis and harmonizes gradient, geological and environmental development, with specific emphasis on the natural sloping of the terrain, which is an integral component of the integrated urban flood planning of metropolitan areas.

The study area description

The specific study area, as presented in Figure 1, is Aba North Local Government Area. The area covers about 60% of the urban area of Aba, with a population of about 107,488 (FGN, 2006). It includes areas such as Ogbor Hill, Umuola Egbelu and Ariaria. It is located in southeastern Nigeria, on latitude 5^{0}7'N and longitude 7^{0}22'E.

The study area is within the humid tropical and rainforest zone of southeastern Nigeria. The rainfall distribution pattern is reminiscent of the scenario in southern Nigeria. The rainfall regime is bimodal and peaks in July and September with 'little dry season' known as 'August Break' in-between. The rainy or wet season begins about February or March and lasts till October or early November. The length of the wet season is at least 7 months including the period of August break. The dry season lasts from December to February. Long term rainfall trends show some evidence of swings or periodic variation; in the region and country (see Nnaji 1998, 1999; FGN, 2003; Njoku, 2006,). The mean annual rainfall of Abia State is between 2550mm and 2890mm.

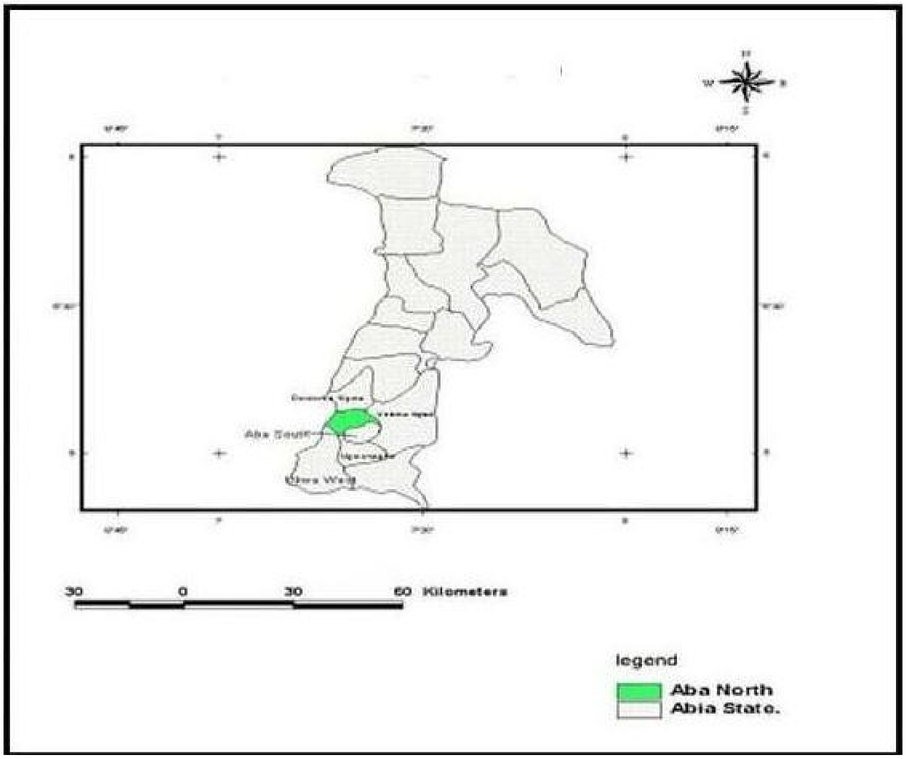

Figure 1. Map of Abia State showing Aba, the study area

However, increasing spatial and temporal variation and decline in rainfall trend, has also been reported by Njoku (2006) and Ulor (2007).

Temperature regime for Aba is also identical to the regional pattern, and is generally high and uniform throughout the year. Njoku, (2006) reported that temperature showed a rising trend for southeastern Nigeria (especially towards the end of the last decade). Temperature of Southeastern Nigeria rose, as 1970 – 1979 is 22.0^{0}C, 1980 – 1989 is 26.7^{0}C and that of 1990 – 1999 is 27.3^{0}C. The mean minimum air temperature [T_{min}] of the area is 22.8^{0}C, while the mean maximum [T_{max}] for the period is 32^{0}C. The hottest months are January and March. The cooling influence of the *Harmattan* winds last from December to February.

The study area is bisected by the Aba River, a tributary of the Imo River. The river water have been degraded by the introduction of effluents from industries situated adjacent the river. Generally, the topography of Aba is between low lying and uniform, with a gently tilted plain slopping towards the Aba River. The highest elevation of 72mabove sea level is around the north-central part of the study area, while the lowest of 36m is on the Aba River valley (Orji, 2010). Thus, the average relief is 54m. The soil is predominantly loamy containing brown to dark brown sandy soils and ferralsols.

It is an important regional trade centre, particularly for food stuffs, clothing, palm oil and other industrial goods.

MATERIALS AND METHODS

Data on spot heights, slope direction and coordinates measurements were obtained in degrees from locations randomly distributed throughout the study area, using Global Positioning System (GPS) Map 76, during the rainy season of 2009. Specifically, data were collected from Eziama Rail, Faulks Road, Osusu Road, Okigwe Road, Ariaria, Samek, Road, Ogbor-hill, Ferguson Street, Nwamkpa Street and Aba River Bridge, using GPS Map 76, record sheet and a map of the study area. These locations were selected as result ofobserved changes in terrain elevation and slopes, and so, are critical to natural runoff direction and determination of floodable and flooded sites. These data were converted to appropriate formats and analyzed with Arc View 3.2a extension, Spatial Analyst and Microsoft Excel for the generation of point and contour maps. Grid interpolation was carried out to get Digital Elevation Model (DEM). This DEM was used to create Slope map, Contour map (which was interpolated at 10m intervals in 2-D formats to show the variations in height and coordinates), and Aspect map of the DEM to define and show the directions of runoff in the metropolis.

RESULTS DISCUSSION AND PRESENTATION

The results of the analyses were presented as DEM map,

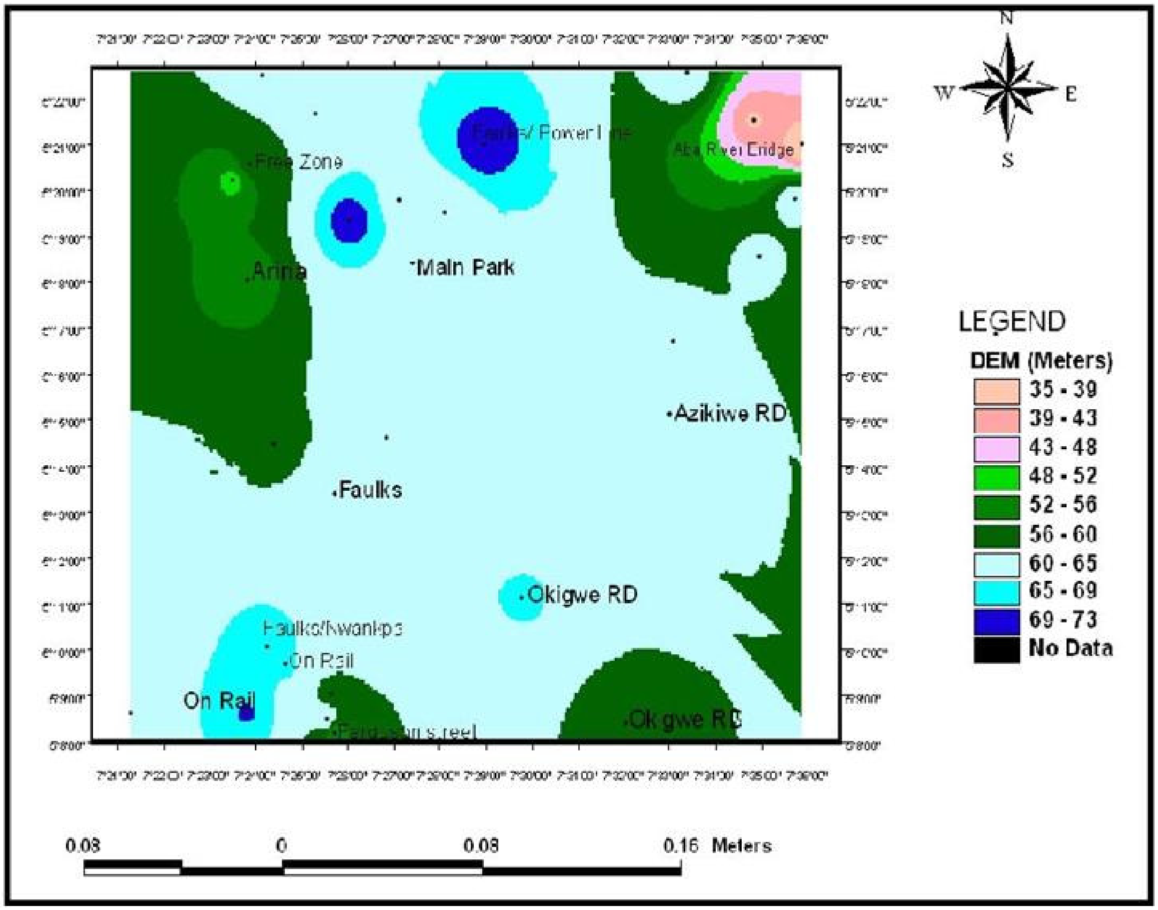

Figure 2. DEM map of Aba North, Abia State

Slope map, Aspect map and Contour map.

DEM map of the study area

From the DEM map in Figure 2, the variations in heights are shown in 2-D format. The DEM presents the study area as ranging from 35 – 70m above sea level. In other words, the flow of water must be from areas 70m above sea level to areas 35m above sea level. Thus, areas 35-39mand 43-48m are prone to flooding as runoff from the areas of higher elevations tends to flow towards areas of lower elevations. The areas with lower elevations include Aba River Bridge and Ogbor Hill areas. Areas ranging from 48-52m to 69-73mare likely to experience erosion because the runoff velocity towards the areas of lower elevations are higher for greater erosivity index, showing greater propensity for increased destruction and degradation of the top soil. The legend further showed that Aba metropolis is generally, relatively flat, irrespective of variations in heights. Therefore, it may be assumed that the flood problem in Aba metropolis is as a result of absence of adequate elevation drainage system, soil type and climate among other factors.

Slope map of the study area

The slope map identifies the overall rate of downwards movement of water. This implies the higher the elevation, the faster the downward flow of water. Figure 3 show the slope percentage variation and indicated the rate and velocity of storm water flow changes with gradient in the study area. In areas where the slope is steep, sink basins may be required to reduce storm water velocity and speed of flow. From the legend, the areas ranging from 12.41%-21.03%and from 29.65%-38.26%are flood prone areas, and to a lower extent erosion prone areas. This is because of the apparent slow movement of the runoff during precipitation. The water tends to flow faster from areas of higher elevation to the areas of lower elevation because of variation in height which affects the slope of the terrain. The areas ranging from 38.26% - 46.88% and areas 55.50%-64.12%are more vulnerable to erosion but flood free areas.

Finally, the areas ranging from 64.12%-72.74%and 81.36%-89.98%arecritical and steeper slopes and certainly produce flood of greater velocity than moderate slopes of 55.50% - 64.12%. These areas are highly vulnerable to erosion, butare flood free zones, because of

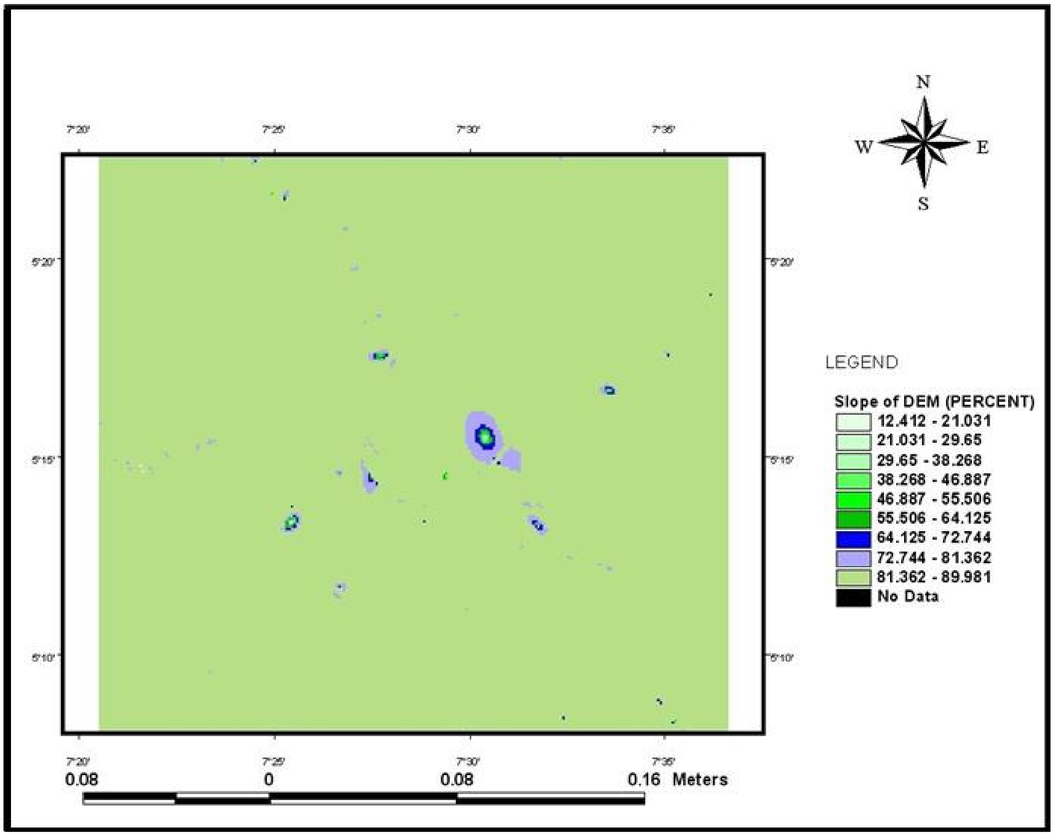

Figure 3. Slope Map of Aba North, Abia State

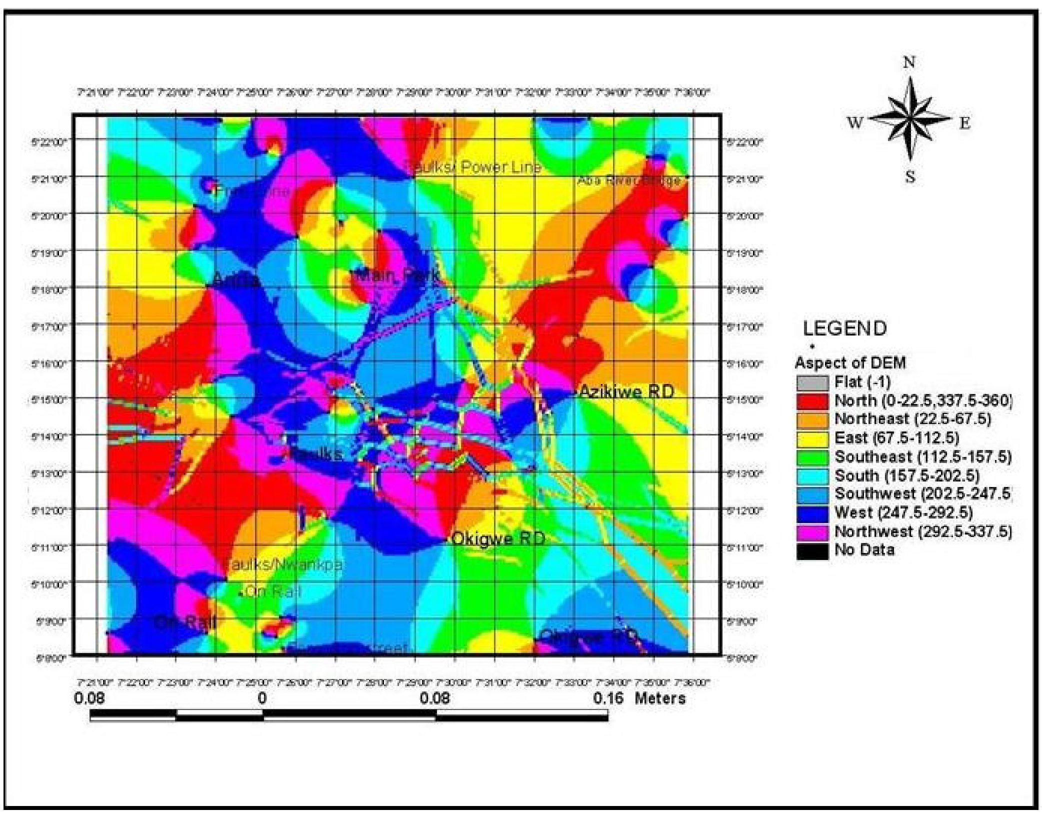

Figure 4. Aspect Map of Aba North, Abia State, showing direction of flow

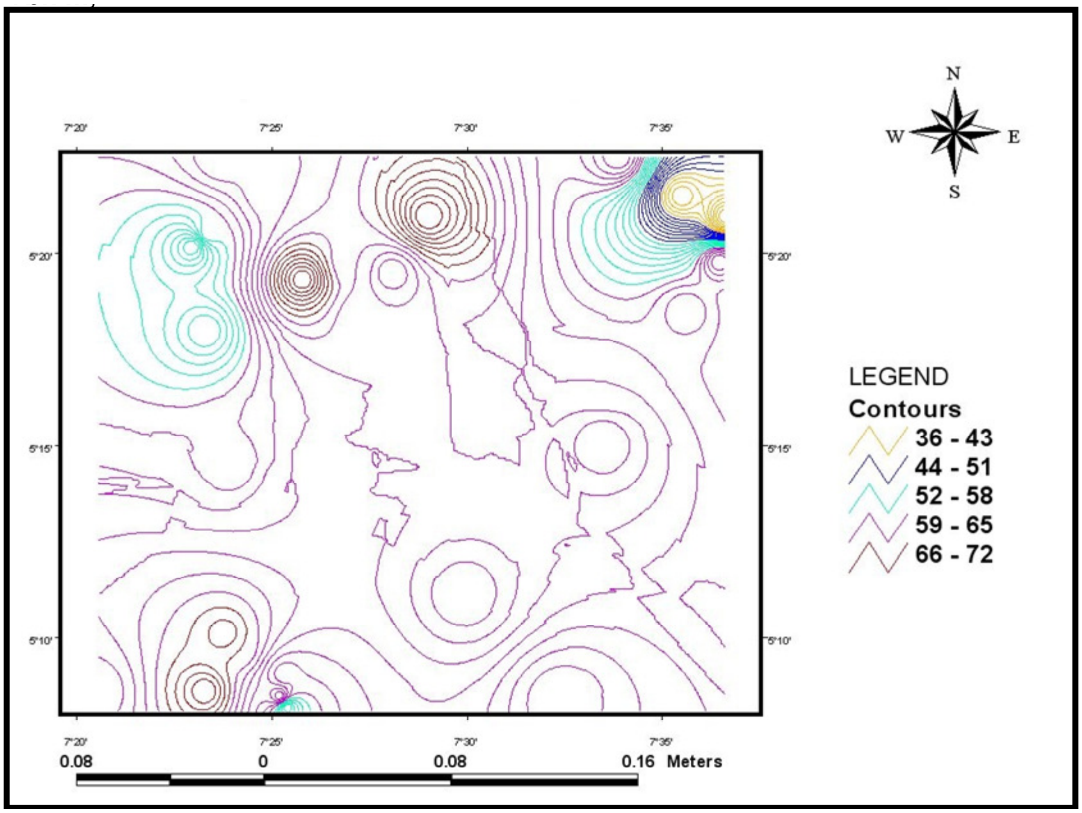

Figure 5. Contour map of Aba North, Abia State.

Their higher elevation. The map contains all topographicand physiographic features that are important in drainage design, erosion control and flood control features, including knowledge of the lowland and highland areas.

Aspect map of the study area

The Aspect map which defines the direction of the flow of water is presented on Figure 4. In the areas ranging from 0-22.5 and 337.5-360 water flows to the North, 22.5-67.5 flow to the Northeast direction, while 67.5-112.5 water flows to the East. All areas 112.50 - 157.5 water flowsin the Southeast direction, while 157.5-202.5 flows in the southern direction, but 202.5-247.5 flows in the southwest direction. The map further shows that areas from 247.5-292.5 water flows in western direction, whileall the areas from 292.5-337.5 water flows in the Northwest direction where the slopes are steeper. Channelization of water should follow these natural directions.

Contour map of the study area

Figure 5 shows Contour map as spot in the study area having equal elevation above or below sea level as generated at 10m intervals. The spot height tells the direction in which water flows. From the map on Figure 5 the contour lines joining locations from 36-43 has higher probability and concentration of flood and floodable areas. From the legend, contour lines of spots from 44-51 and 52-58 have high concentration of flood. All other areas have moderate and no probability of flooding. It may be that the presence of excess, ponded water may be due to inadequacy of storage capacity of natural water courses which obstruct the flow and deregulate topography, thereby leading to local depressions. Thus, design of surface drainage systems depend on amount of rainfall expected within the locations, at a particular period of time and the type of land use and land cover.

CONCLUSION

The study applied the concept of integrated data analysis, using GIS to determine the implications of flooding in Aba metropolis. The DEMin Figure 2 shows the variation in height as the areas ranging from 35-39 and 43-48 are likely to be prone to flooding, being that runoff from the areas of higher elevations tend to concentrate around the areas of lower elevations. The areas with lower elevations include Aba River Bridge and

Ogbor Hill.

The Slope map defined the rates of downward movement of water from a particular point to another. This provides insight on the acceleration and deceleration of water movement which influences flooding, erosion and deposition of organic and inorganic materials. In Figure 3, the areas ranging from 12.412-21.031 and 29.65-38.268 are prone to flooding and less prone to erosion. This implies that deposition of particulate matter, organic and inorganic compounds may occur at these points. The Aspect map defines the direction of the flow of water. The areas shown in Figure 4, from 0-22.5 and 337.5-360, have the direction of natural flow towards the North. During construction of drainage systems, mapping and project analysis should include aspect and contour mapping.

The study was carried out as a response to the observed frequent and perennial flooding of Aba North and environs. The result of the prevailing situation is frequent pondage of surface runoff with increasing retention time. These causes destruction of traffic infrastructure and traffic jam, destruction of flora, fauna, damage to habitats, food chain, species diversity and stability, damage to endangered species, damage to natural recreational resources, and damage to archeological and historical resources as well as destruction of the aesthetic value and scenic beauty of the city. The health impacts include abundance of communicable disease, shortage of food supply, dispersion of low level household wastes into the fluvial system and contamination of community water supplies and wildlife habitats with extreme toxic substances. Consequently, the study suggests solution to the age long problem of floods in Aba North and environs which has defied all adhoc measures. The study also demonstrated that the study area is situated on a relatively flat terrain, and so, natural storm water flow should be as suggested in the study. Thus, storm water channelization and routing should naturally follow the direction of north, northeast, east, southeast, south, southwest, west and northwest in the various locations and zones. This study therefore recommends some re-routing of the storm water routes. Unless this is done, the perennial pondage of storm water and water retention time may continue as long as the rainy season lasts. Government and stakeholders should provide resources for the achievement of the recommendations. And, here as well as elsewhere, construction activities should consider the landscape and geomorphology of the site in order not to block the direction of the flow of runoff.

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