An Investigation into the Flood Flow Pattern along University of Lagos Road Akoka, Yaba, Lagos State, Nigeria

By

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Abstract

Climate is fast changing and has brought about increase in the amount of rainfall in recent years. This increasing rainfall has been a major contributing factor to flood in most areas. The most common cause of flooding is prolonged rainfall aggravated by poor drainage system which could make rainwater not to be properly channeled into drains thereby leading to floods along the busy roads. This work aimed at assessing the causes of flood in the study area using Autodesk's AutoCAD civil 3D and GIS and ways to minimize its vulnerability of the area to floods. The drain architectural system, water discharge from adjoining roads, longitudinal and cross sectional profile along the road were under studied to predict the vulnerability of the road to flood. The longitudinal and cross sectional profile of the road that were prepared in Autodesk's AutoCAD Civil 3D was used to depict the configuration of the road surface. Flow direction, flow accumulation and flow length were determined using ESRI's ArcMap 10.2. The flow direction maps were used to help model how surface runoff contributes to flooding. Flow accumulation was used to generate a drainage network, based on the direction of flow of each cell. Findings showed that the study area is characterized by stagnation of rainfall waters on the road. Results showed that the stagnation of rain water led to the flooding and this is attributable to; lack of water outlets along the road to discharge excess rainwater into the drain; no significant difference between the height level of the top of the road and the drain at some points along the road; deposit of refuse in the drain. The study has shown the need for flood flow analysis in flood management and has demonstrated the importance of GIS as a spatial tool for road flood inundation.

Keyword: Flood, Flood flow pattern, flow accumulation, flow direction, GIS, Hydro tools.

1.0 INTRODUCTION

Floods are an important natural process that is becoming an integral part of the study area. The floods provide important ecological functions and values, which are essential for the Unilag population. These aspects should be taken into account, when planning and designing infrastructures in the study area. Rainfall is seen as a major cause of flooding, and this also includes human interference as a joint causative factor (Akintola, 1978). Flooding result when runoff streams inflows makes a stream full to capacity and also to low infiltration capacity.

During extreme flood events transport infrastructure can be directly or indirectly damaged, posing a threat to human safety, and causing significant disruption and associated economic and social impacts (Pregnolato, Ford, Wilkinson, & Dawson, 2017). The level of interactions between various measurable flood dimensions and transportation networks determines the potential impact of a flood. By determining interaction probabilities, the flood impact can be modelled, visualized, quantified and evaluated by developing a sophisticated GIS (Hossain & Davies, 2004). Thus, it is very important to identify sections of the road that are potentially vulnerable to flooding in order to prevent and/or be adequately prepared for flooding. However, recent studies have shown that interpretations of flood-related statistical variables basically depend on the accuracy of the initial data (Koutsoyiannis, 2013).

Roads can be damaged by floods and also can enhance hazardous flood conditions. The flooding of a road induces two levels of consequences: on the one hand, people may be injured and vehicles may be destroyed; on the other hand, the disruption of traffic may have severe indirect consequences (Rogelis, 2015). Flooding in a road network can occur if there is insufficient capacity in the drainage system, water on the surface collects in depressions in low-lying areas. The contributing drainage areas can be the surrounding areas as well as direct drainage on the road (Rogelis, 2015).

Several factors contribute to flood such as topography, drainage network, land use, meteorology etc. These factors are integrated into a geographic information system (GIS) environment that utilizes the curve number method of flood modelling for ungauged arid catchments (Gomaa, Meraj , & Khalid , 2012).

These factors are also identified and reclassified to flood risk values based on their suitability to retain waters, and then combined using weighted overlay tool in ArcGIS ArcMap to generate flood prone areas (Kursah, 2013).

Previous works have used GIS to deal with flooding from wide aerial coverage (water sheds) but this present work dealt with flooding on linear coverage (routes; roads) using GIS tools. By application of field data acquired from Total station equipment, these GIS hydrological tools model the flow of water across a surface of the road. Three hydrological tools from the Spatial Analyst Hydrology toolset were used in the bluespot models: Flow Direction, flood accumulation and flow length.

Geographic Information Systems (GIS)

Geographic Information Systems Geographic Information System is an application designed to perform various operations on geographic information (Darwin, Kombaitan, Yudoko, & Purboyo, 2018). Geographic information is defined as information about the location on or near the earth's surface, and can be organized in various ways (Goodchild, 2009). GIS presents the information in a graphical form by using the map as an interface. GIS is composed of the concept of multiple layers (layer) and relationships. Each layer in

GIS represent data and specific information according to the geographical location and the relationships that are defined (Hanifah, Isnanto, & Christyono, 2010).

The Study Area

The study area is section of University Road (one of the longest road network in Akoka, Yaba Local Council Development Area within the Shomolu/Bariga Local Government Area of Lagos State and most extensive). The length of road covers about 1.481km (figure 1) and it comprises two segments and four lanes.

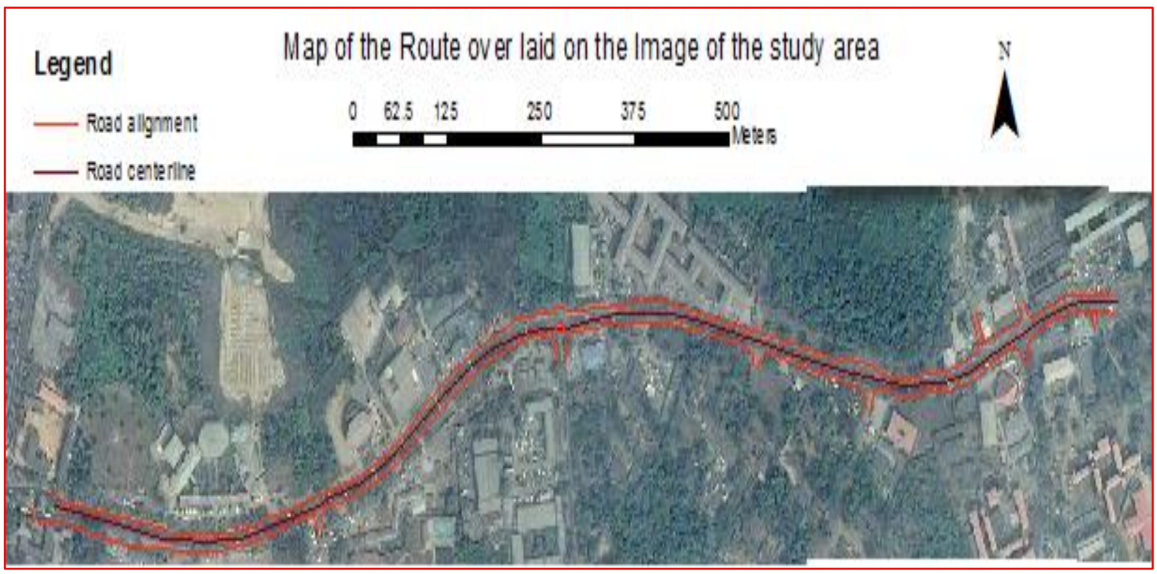

Figure 1: The Vector map of the Route overlaid on imagery of the Study Area

Various means of transportation ranging from motor cycle (Okada), Tricycle (Keke-Napep) and motor vehicles such cars, lorry, truck etc. plight this road. The road directly links to the University of Lagos main gate and Herbert Macaulay Road, the road is used majorly for those entering in and going out of the University of Lagos and all those going to Shomolu/ Bariga area, also those going to Obalende (to the right) and those going to Yaba under bridge (to the left) also use this road. The road is such a busy one especially during peak and off peak periods and most often there is usually traffic congestion during these periods, the situation on this road is usually very much critical whenever there is rainfall, which results into flooding along this route. As the number of users and vehicles plighting this road keep increases every now and then coupled with the vulnerability of this road to flooding, there is a need to carryout flood investigation along this route, hence the need for this study.

2.0 METHODOLOGY

Spatial Data Acquisition

Traverses were run for the purpose of coordinating the alignment of the road and to establish subsidiary points that were used for fixing all noticeable features along the road corridor using the Leica Total station equipment. For cross sectioning, spot height leveling was performed at 2m across the road and 25m interval along the road center for longitudinal profiles. This gives the nature of the undulation of points along the center line of the road. These data were processed in Microsoft excel. The road alignment was prepared in AutoCAD and exported to ArcGIS.

Triangulated Irregular Network (TIN)

The spot heights obtained from field measurements were added in ArcMap and converted to raster (TIN) by krigging, using the spatial analyst tool in the Arc toolbox. This is in order to show regions with height differences along the road (figure 2). The extent of the road was clipped out from the TIN for better analysis.

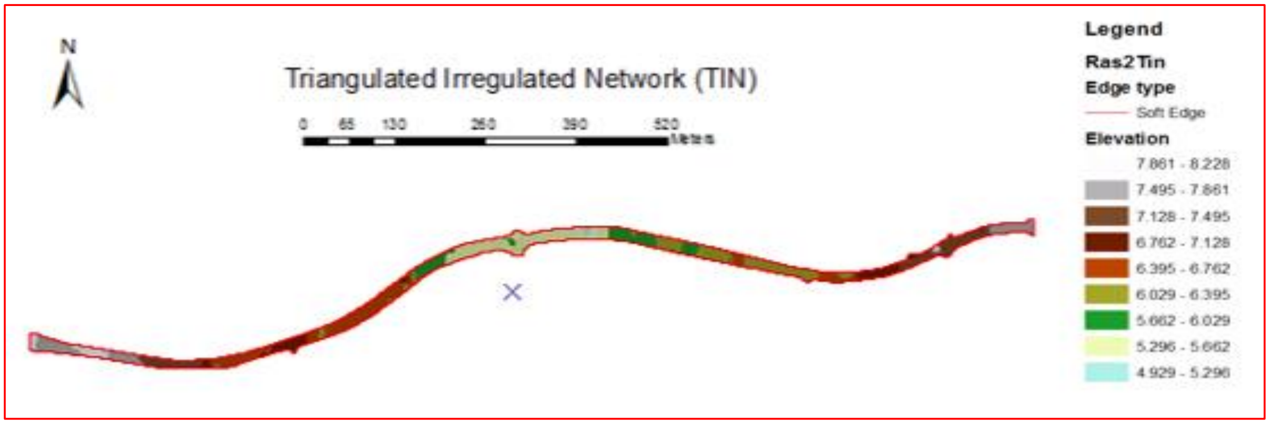

Figure 2: Triangulated Irregular Network of the study area.

Flow Direction

Flow direction determines which direction water will flow in a given cell. This helps in deriving hydrologic characteristics of road surface. This spatial analysis creates a raster of flow direction from each cell to its steepest downslope neighbor. This is calculated as follows:

maximum_drop = change_in_z-value / distance * 100

This tool takes the kriging surface as input and outputs a raster showing the direction of water out flow from each cell. There are eight valid output directions relating to the eight adjacent cells into which flow could travel. This approach is commonly referred to as an eight-direction (D8) flow model (figure 3).

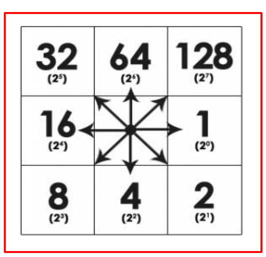

Figure 3: Flow Direction: Eight Direction Pour-Point Model

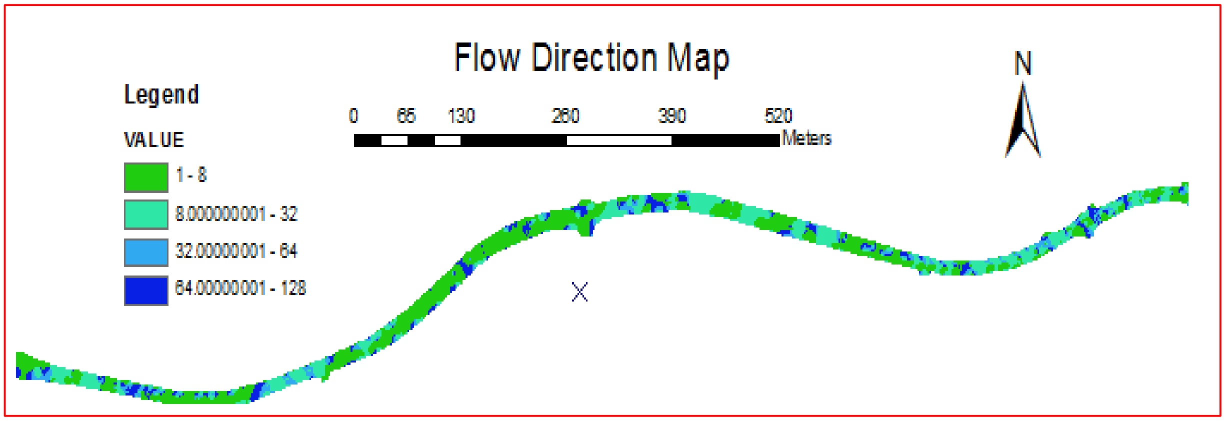

Figure 4: Flow Direction map of the study area

Flow Accumulation

Flow accumulation in its simplest form is the number of upslope cells that flow into each cell (ESRI, 2013). Accumulated flows are calculated as the accumulated weight of all cells flowing into each downslope cell in the output raster. If no weight raster is provided, a weight of 1 is applied to each cell, and the value of cells in the output raster is the number of cells that flow into each cell. In the graphic below (figure 5), the top left image shows the direction of travel from each cell and the top right the number of cells that flow into each cell (ESRI, 2013).

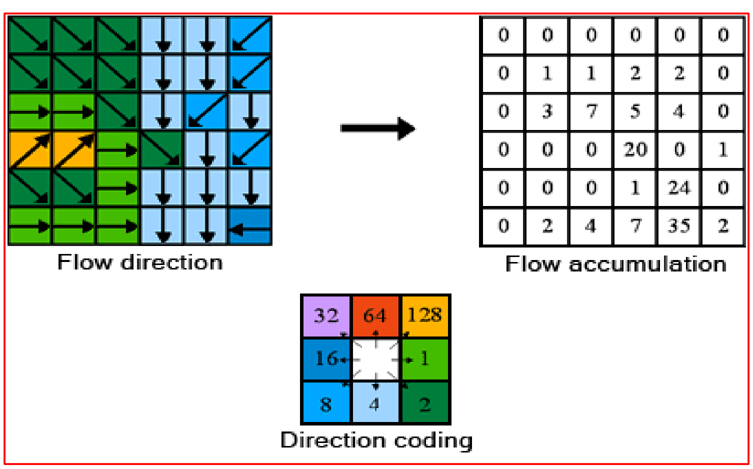

Figure 5: Principle of Flow Accumulation

Cells with a high flow accumulation are areas of concentrated flow and may be used to identify flood paths.

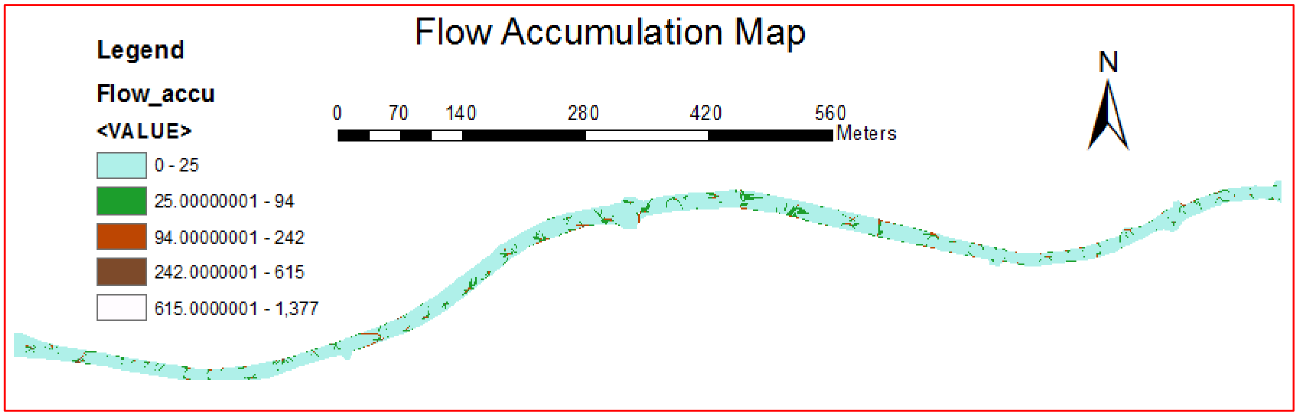

Figure 6: Flow Accumulation map of the study area

Flow Length

Finally, the flood flow pattern and analysis was done using the flow length tool in Arc toolbox. The flow length displays regions with low and high flood flow and also regions liable to flood (figure 8).

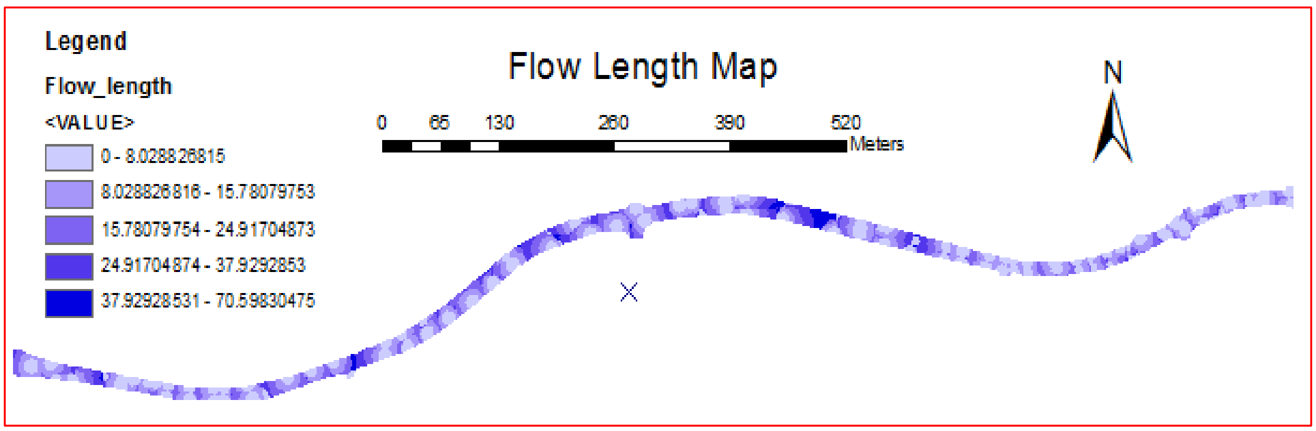

Figure 7: Flow Length map of the study area

3.0 RESULTS AND DISCUSSION

As the population of road users' pressures on roads increase, road managers are continually looking for new methods of managing and monitoring road "health." In order to analyze the properties of a road, it is necessary to identify the source/entry point, the accumulation areas and the direction of flow of the flood.

The results obtained in the study were analysed in detail and inferences drawn from the analysis of the results. A Study of the flood flow patterns (flow direction; figure 4, flow accumulation; figure 6 and flow length; figure 7) indicated that areas with high elevation tend to have low flood. Thus, all water tend to flow to places of low elevations. The Flow Accumulation tool identifies how much surface flow accumulates in each cell; cells with highest accumulation values are the mostly flooded areas (figure 7).

During decision-making phase, flood experts can further process the flow accumulation surface with a Map Algebra Conditional (Con) statement in Arc Map to capture only those cells with high flow accumulation values, such as: con (flowacc > 200).

All road floods that flow have entry points and exits points. Flow direction is important in hydrologic modeling because in order to determine where a landscape drains, it is necessary to determine the direction of flow for each cell in the landscape. This is accomplished with the Calculate Flow Direction menu choice. For every cell in the surface grid, the ArcGIS grid processor finds the direction of steepest downward descent. Establishing the flow direction in a flood road determines the direction in which flood flows along the road (figure 4). The ability to determine the direction of flow from every pixel in the raster is one of the keys to deriving hydrologic characteristics of a surface. The direction of flow of the flood water will aid in the rehabilitation of the road, i.e rechanneling the flood water through an exit route. A model (Flow direction) of how surface runoff contributes to flooding in the study area is shown (figure 4). This is important in hydrologic modelling because in order to determine where flood water drains, it is necessary to determine the direction of flow for each cell in the landscape.

The spot heights of points also show that the height of the top of the road is at the same level with the invert of drainages. This is as a result of deposits of sand sediments at the bottom of the drain. The implication of this is that rainfall water stagnates on the roads thereby resulting in flooding. There are also no outlets at some portions along the road to channel rain water to the drains. Drains around the canal do not support flow of water because they have low elevation, thus hindering the free flow of water into the canal during rainfall.

By using hydrological tools like flow accumulation and direction, GIS has helped in understanding the flow of water during floods in the study area.

The next step in hydrologic modeling after flow direction is the flow accumulation. Flood paths are defined spatially by the geomorphological property of drainage. In order to generate a drainage network, it is necessary to determine the ultimate flow path of every cell on the landscape grid. The principle of flow accumulation (Figure 5) was used to generate a drainage network, based on the direction of flow of each cell. By selecting cells with the greatest accumulated flow, we were able to create a network of high-flow cells (Figure 7). The flood flow pattern is the result of the geoprocessing of the flood flow length, flow accumulation and flow direction. This flood flow pattern was validated by confirming that the analyzed flood matched with the actual flood event at the different flood locations.

4.0 CONCLUSION

Findings revealed that not only the surface configuration of roads is the cause of water logging and flooding on roads, rather it is due to the blockage of the drainage systems (canal, gutter etc). This is evidenced in the study area. All things being equal, some regions in the area are also liable to more flooding in the future, such as the front of Emerald Hall (Akoka Road) if adequate attention to evacuate the sand deposits and refuse in the drains is not considered. This study advocates the inclusion of the use of GIS as a spatial tool to carry out flood flow analysis in the management of road floods.

5.0 RECOMMENDATIONS

Flooded roadways are the second leading cause of weather related fatalities. A flood detection system that is both reliable and cost effective are key to keeping motorists safe. This paper advocates an alerting solution for roadways prone to flooding. The flood data and flow analysis from this present study can be used as a base for subsequent flood research and developing an alert system for related flood areas. The following recommendations are hereby proposed:

i. There should be some personnel in charge of proper cleaning of drainages and checking indiscriminate dumping of refuse into the drainages.
ii. There should be a monthly check on the status of the drainage and canal, to checkmate the growth of weeds around this canal which leads to stagnation of water and flood along this route.
iii. The drains at some location along the road should be rehabilitated for proper channelling of water.
iv. The drains should be properly covered.

v. Regular Engineering surveys should be encouraged by the Government/Departments for proper management and maintenance of roads and its environment.

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