Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.4, 2013


# Mapping the Risk and Mitigation of Flood Occurrence in Calabar , Nigeria

Oluyemi Ayorinde Akintoye* , Asuquo Etim Okon , Elijah Etteobong Ekanem , Marcus Aja Idoko
Department of Geography and Environmental Science, Faculty of Social Sciences, University of Calabar, Calabar-Nigeria
*E-mail of the Corresponding Author : oluwayemijubilee@yahoo.co.uk

**Abstract**
The paper focuses on mapping the risk and mitigation of flood occurrence in Calabar south local government area in Cross River state of Nigeria. GPS points were taken at 100m intervals; along the major drainage channel from the beginning of the channel to the end of the floodplain in Calabar south and the different other points were taken at different location of Calabar considering the terrain. The procedure was to ascertain the variations in the terrain of the area. The analysis of data was carried out using the ArcGIS version 9.3 to digitally map the positions of the major drainage channels other points on each of the map layer that was generated. Contour, Risk and mitigation maps were generated from the coordinates collected from the field as well as risk categorization and their areal extent in relation to the built environment. The result shows that the increase in depth in flood water is greater nearer the beach locations adjacent to the rivers and creeks and decreases towards the northern axis of the study area. This follows the configuration of the terrain. Very high risk areas are close to the rivers and the wetlands which include Anantigha, Henhsaw town and Fishing Camps. More than 60 per cent of the built up area, are prone to flood. Also most built structures align the flood plain and the inland water channels. Retention pond and reconstruction of drainage facilities were modelled and recommended in suitable areas to avert flood disaster.
**Key words:** Mapping, Risk, Flood, Mitigation, Retention pond

## 1. Introduction

The rapid growth rate of many of the urban centres and cities in countries of the developing world is of great concern. When this is considered with huge population bases, the cities that are emerging are becoming huge with unprecedented sizes and environmental problems. The observation is that most of the world giant urban agglomeration seems to be emerging from the developing countries of the world (Sule, 2010).

The field of drainage basin analysis is very broad in scope, embracing such fields as hydrology, meteorology, geology, statistics, and others, in addition to the most often recognised field of hydrology. Whether it is subsurface water originating below the pavement, storm water falling upon the pavement and adjacent areas, or water courses intersected by projects, a systematic drainage design must be made in other to ensure adequate and lasting performance (Woods et al, 1988).

Since the 1980's, GIS coupled with multi-criteria analysis (MCA) has helped to enhance multi-criteria decision making associated with planning processes (Roy, 1996). The use of GIS and MCA, a decision making and mathematical tool allowing the comparison of different alternatives according to many criteria, has helped in the planning process and decision making in conflicting decisions (Anavberokhai, 2008). *GIS* makes use of satellite imagery, aerial photographs, base maps, graphs etc. from the geo-database to produce results. It is believed that with *GIS* and remote sensing a detailed perspective can be hinged on how to plan and manage drainage systems, anywhere in the world (Tomlinson, 1968; Meyer, 2009).

Environmental planners require solutions that address day-to-day work needs, while also fostering the ability to effectively predict and respond to chronic urban problems and future market fluctuations. The success of planners in combating chronic urban problems is largely determined by their ability to utilize effective tools and planning support systems that allow them to make informed decisions, based on actionable intelligence. Today, planners utilize GIS around the world in a variety of applications (ESRI, 2011).

Floodplain maps can be the most valuable tools for avoiding severe social and economic losses from floods. Accurately updated, floodplain maps also improve public safety. Accurate floodplain maps are the keys to better floodplain management (Siminovic, 1993). This research in Calabar South of Nigeria, thus demonstrates GIS applications for developing floodplain models and maps. Achieving flood control to safeguard lives and properties presupposes the understanding of the relationship between the terrain, land uses and the hydrologic systems. This will help t*o* identify the areas, within a development plan, that are at risk of flooding. The study therefore seeks to: collect available data on the various floodplains, land uses, terrain classes, flood characteristics and carry also, carry out risk identification.

Therefore, for this particular study, with the use of *GIS* applications, relevant data were collected scientifically and processed to give results that will help to arrive at conclusions, which could form the basis for decision making by planners, and are acceptable for an urban area like Calabar south.

## 2. The Study Area

Calabar, the capital of Cross River state of Nigeria lies close to the Gulf of Guinea and on the south eastern part of the Niger-Delta region of Nigeria. The study area lies between $8^0$ 18' 59" and 80 21' 44" East of the Greenwich meridian and between latitude $4^0$ 54' 59" and $4^0$ 59' 59" North of the equator. Calabar is characterized by humid tropical climate, with annual rainfalls of 3500 to 4000mm.The temperature ranges between $23^oC$ - $33^oC$. A relative humidity of 80 – 90 percent, as well as hydromorphic (water logged) soils is typical.

Located on a fan shaped alluvial formation of sedimentary basin with fluvial deposit, Calabar is drained by three rivers, including Cross River as the major channel, while the remaining include both Calabar River and Great Qua River, with networks of creeks as shown in Figure 1. Calabar is known for its “clean and green” slogan which has attracted many tourism investors over the years. Calabar is located on an undulating plain, particularly in areas closer to the coast. This area is a low lying plain, with average altitude of 10m above sea level. The area also consists of mud flats and sandy beaches. They are influenced by semi-diurnal tides, with tidal heights of 3 meters.

Calabar south which has an estimated population of 191,515 inhabitants is surrounded by water on both the eastern and western flanks, with rich mangrove forests that makes Calabar and its environs rich in biodiversity. Figure 1 presents a map of the study area, showing the land area, Calabar River and the Great Qua River.

## 3. Method of Study

The study relies largely on the use Geographic Information System (GIS) , using a remotely sensed data supported with high end Global positioning system (GPS).

### 3.1. Data Set and Software

Data used for the study were sourced from thematic maps, combined with satellite imageries of the current land use classes. Data from the thematic maps were collected, based on information on surface hydrology. Arc GIS 9.3 software was used to processed data from the different data sets.

### 3.2. Field Data Collection

GPS device was used to take the coordinates and elevation readings at different points within Calabar south LGA. The points were taken at 100m intervals, along the major drainage channel, from the beginning of the channel to the end of the floodplain that terminates at the Great Qua river in Calabar south. Moreover, the coordinates and elevations were taken at different locations in Calabar considering different terrains.

Also, point readings were taken at the ends of the capillary drainage facilities, feeding the major channel and also randomly within the study area. These are meant to determine the overall elevation of the study area. It included the inspection of the major and minor drainage channels to ascertain depth and construction or design .The data were used to generate different map models for the study area.

## 4. Data Analysis

The analysis of data was done using the ArcGIS version 9.3. The 3D analyst of ArcGIS version 9.3 was used to digitally map the positions of the major drainage channels, as well as other points on each of the map layer that was generated. Contour, risk and mitigation maps were generated from the coordinates collected from the field. The map of the study area was scanned, geo-referenced and used to generate other layers, digitized to produce different maps , and are referred to as thematic layers. Digitization of the various classes was done to create the coverage for each of the flood risk classes and their areal extent. The maps were digitized in their various themes, with calculations of the coverage of the various thematic layers.

The thematic maps were geo-referenced, integrating all maps into a common digital framework , that enabled geospatial analytical operations. Geometric intersections were carried out with each of the composite thematic layers. A contour interpolation using nearest neighbour and Euclidean distance function algorithm were applied to allocate height values, to every area and to automate areas prone to flood, as well as suitable areas for mitigation. This gave a progressive pattern to the elevation of the area and the categorization of the flood risk and mitigations.

## 5. Result

Representation of the results, such as flooding extent, depth, flow and flood hazard levels in a GIS environment is a very effective way of conveying flood risk and flood hazard.

a. Terrain/ Drainage Characteristics

The overall surface form of Calabar depict an undulating terrain, with variations in some areas .These variations with other factors have compounded flood situations in such places (Figure 2 and 3). Also we discovered that though there are concrete pillars at some positions, where the major channel passes underneath a road. These pillars do not cause floods, at all the points they go underneath the road. Further findings showed that some portions of the drainage channel are clogged with sand, while some occur at a depression, where much capillary drainage meet and the runoffs are too large to be evacuated immediately. This was in the form of a basin as in the case of Goldie/target roads. The two ends of Goldie road had elevations of 130feet and 145 feet at each end, while Target Street is characterized by 127feet and 135feet at each end. The point of intersection of the two roads has a value of 89feet. The intersection forms a basin and with the paved surfaces everywhere rain water collects easily at the intersection (Figure 7 and 8).

Moreover, the drainages are not well sloped, too narrow for the load they carry and thus form a poor network. The poor network arises in the sense that three (3) to five (5) drainages are linked to the sixth ($6^{th}$) one, which is usually all of the same size. These often results in a sharp rise in runoff load, while the drainage is not equipped to handle such loads. These were revealed in the land use map. Also, the land use map showed that some infrastructure was built along the channel. Also the channel has collapsed at some points, usually causing a spill-over, which leads to flooding. Moreover, the contour and Digital Terrain Model (DTM), both revealed that the variations can trap surface water, since no fluid can flow uphill.

b. Flood Risk Analysis

The study area is enclosed by undulating configuration (See Figure 3), it is highly disposed to seasonal inundation from the ocean due to sea level rise consequent upon tidal dynamics, rainfall and the phenomenal global climate change. The increase in depth of flood water is greater nearer the beach locations adjacent to the rivers and creeks and decreases towards the northern axis of the study area. This follows the configuration of the terrain (Figure 2).

The extent of flooding under the different risk categories shows that the very high risk areas, which are close to the rivers and the wetlands (Anantigha, Henhsaw town and Fishing Camps which include , but is not limited to Ine ube, Asiak obufa and Nkanwagha) cover an area of about 5.9sq.km, which is 18.4 per cent of the total built up area (See Table 1). The depth of flood water can be as high as above 2 meters.

Areas under high flood risk cover an area of 8.62sq.Km (26.9 per cent of the total built up area). Moderate flood risk Stretch along Atamunu to Mbukpa axis covering 19.6 per cent of the built up area. Low risk covers an expanse of 35.1 per cent. Hence, 64.9 per cent of the area are prone to flood (see Figure 6).

Increase in population and urban expansion has altered land use and land cover and have ensued rapid conversion of vegetated areas to paved and impervious covers. This situation affected the infiltration capacity of the soil after rainstorm leading to high rate of overland flow, over flooded bank and areas close to the main flood channels thereby complicating flood water management in the city and the surrounding suburbs. Most structures are situated in flood plains, thereby exacerbating flood risk in the area. The fact that more than 60 per cent of the built up area are prone to flood, shows cleanly that most structures align the flood plain and the inland water channels.

The model used to explain Goldie/Target situation is represented in figure 9 & 10 below. The suitable areas for flood mitigation, such as drainage channels and detention for confinement of the flood water can be created in low areas within the city centre (Figure 8). Areas with configuration that can easily drain to the water bodies, such as great Qua river and Calabar river are earmarked for channel delimitation and construction (Figure 7)

## 6. Conclusion

GIS was used to develop a flood Management Plan in the study area. The analysis exposes the various areas under different categories of flood risk in Calabar south. The large area prone to flood, begs for urgent attention for mitigation. Utilization of the flood plains for construction and land cover changes, as well as the destruction of the mangroves in the coastal areas need, to be halted. By creating retention ponds, dredging of flow channels and construction of new ones, the protection of life, properties and environment can be achieved.

**REFERENCES**


Anavberokhai, I. O. (2008): Introducing *GIS* and Multi-criteria Analysis In Road Path Planning Process in Nigeria. *Retrieved at http://hig.dwa-portal.org/*

GIS Best Practises; GIS for Urban and Regional Planning by ESRI 2011, NEW YORK. Retrieved at http://esri.com/planning

Iliffe, J. (2005) African: The History of a Continent (illustrated, reprinted).Cambridge University Press P149 ISBN: 0 – 521 – 48422 – 7

Woods, K. B. Donald, s. B., Goetz, W. H. (1998): Highway engineering handbook. 1st ed. London: McGraw Hill Book Company

Sule, R. O. (2010) : Thematic Issues of Urban and Regional Development Planning in Nigeria_2010.. Calabar: Thumbprints International company

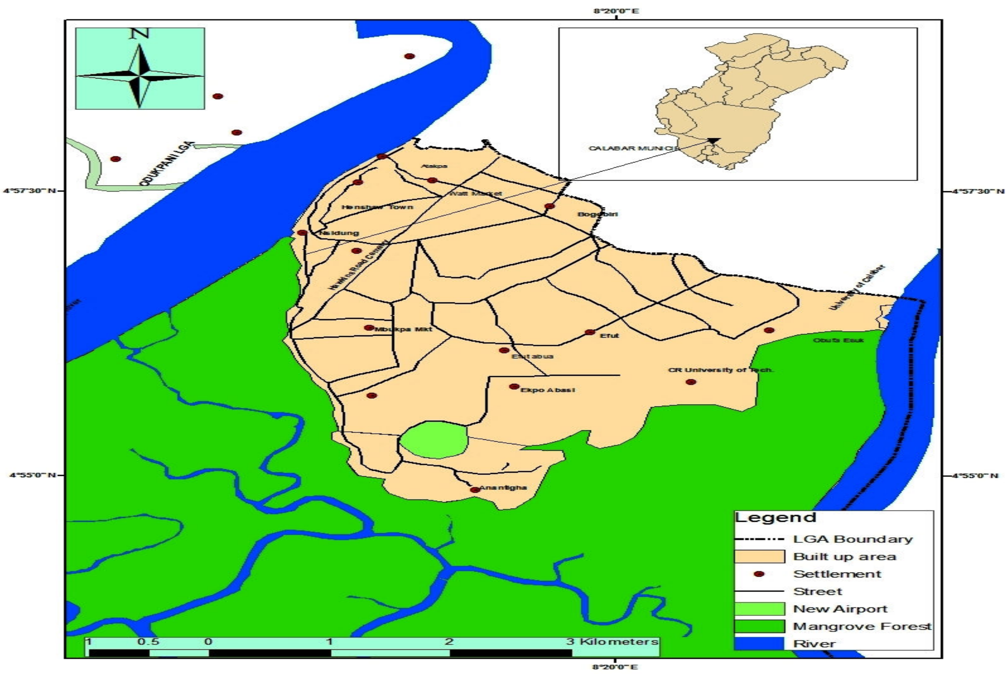
Tomlinson, R. F. (1968): "A geographic Information System for Regional Planning" in G. A. Stewart (ed) Land Evaluation: Papers on the CSIRO Symposium, Canberra, Victoria Australia.

Mason, S.J,; Waylen, P.R; Mimmack, G. M; Rajaratnam, B and Harrison, J.M (1999). 'Changes in Extreme rainfall events in South Africa',*Climate Change,* 41(2): 249–257.

Meyer, V; Scheuer, S. and Haase, D. (2009). 'A multi-criteria approach for flood risk mapping exemplified at the Mulde river, Germany',*Natural Hazards*,.48(1): 17–39.

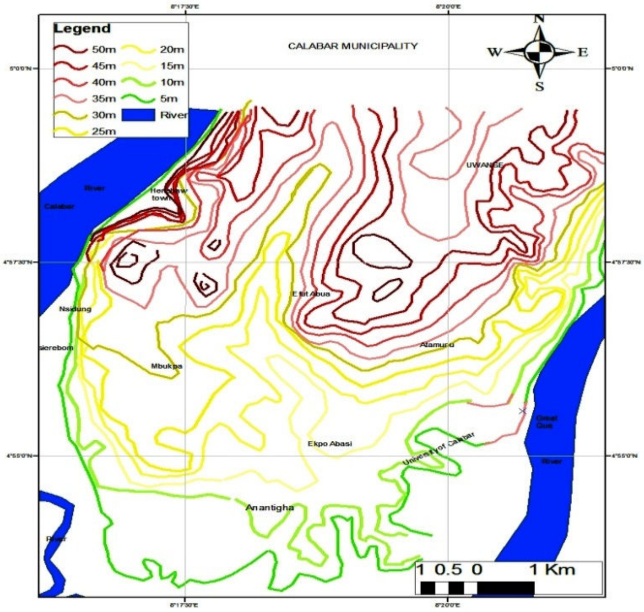
Yahaya, S, Ahmad, N. &Abdalla, R. F. (2010). 'Multi-criteria analysis for flood vulnerable areas in Hadejia-Jama'are River basin, Nigeria',*European Journal of Scientific Research,* 42(1). 71–83.

Simonovic, S. P. (1993). Flood control management by integrating GIS with expert systems: Innipeg city case study. A paper presentation in HrydroGIS Conference ,Vienna.


**Source:** Adopted from Arc*GIS*geo-database

**Figure 1: Landuse Map of Calabar south in Cross River State of Nigeria** .



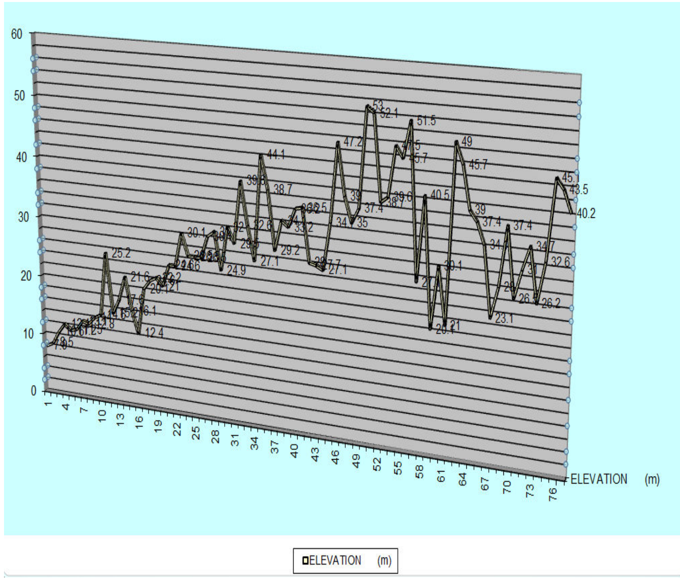
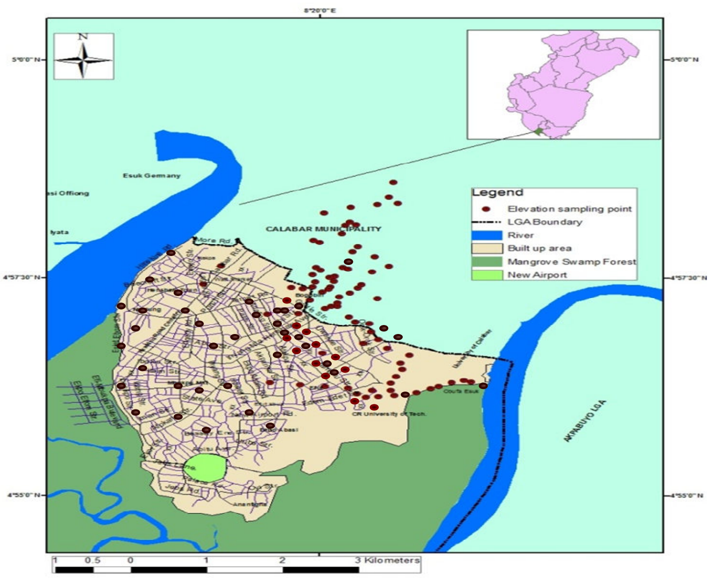




**Figure 2& 3: Maps showing reading points and the Digital Terrain Model for Calabar South**

**Source:** Generated by the researchers using Arc*GIS* with data from the field.



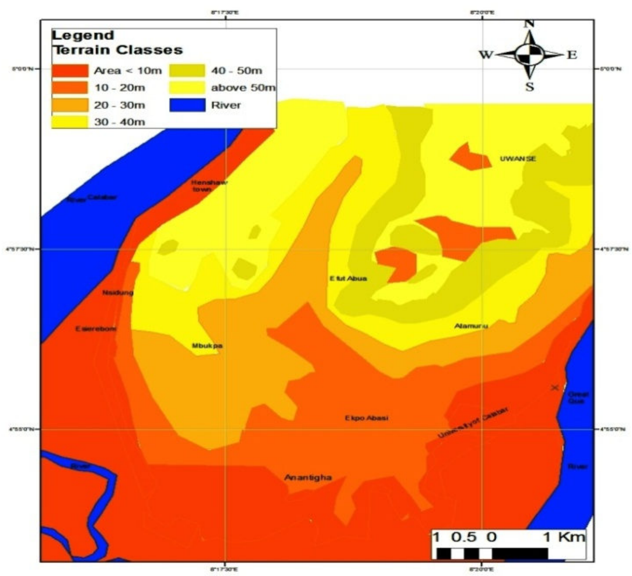




**Figure 4 & 5: Built environment and terrain coverage**

**Source: Generated by the researchers using Arc*GIS* with data from the field**

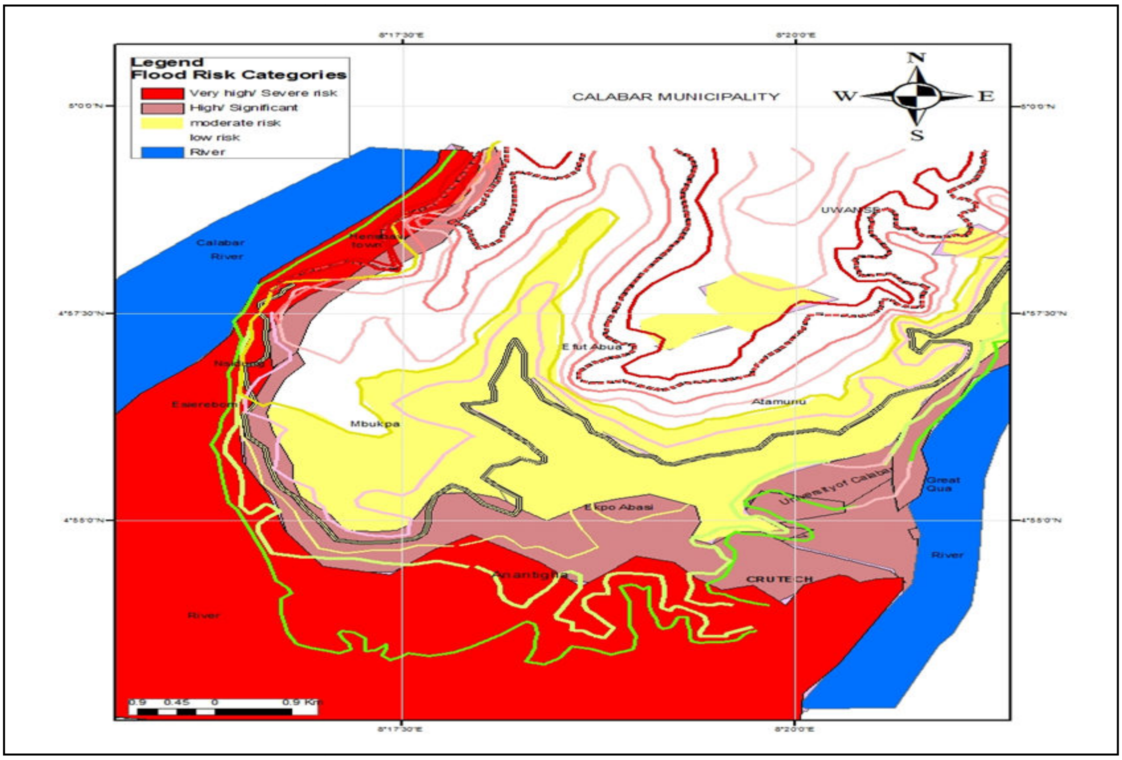



**Figure 6: Flood risk area analysis**

**Table 1: Flood risk analysis**.

| **Flood risk categories** | **Projected depth at apeak of rainfall** | **Area coverd (Sq. Km)** | **Percent age of built up area** | **Areas affected** |
|---|---|---|---|---|
| Very high/Severe | above 2m | 5.9 | 18.4 | Anantigha, Henshaw town and Fishing camps |
| High/Significant | 1-2m | 8.62 | 26.9 | Unical/Crutech areas |
| Moderate | 0.51-1m | 6.29 | 19.6 | Atamunu/ Mbukpa |
| Low | 0-0.5m | 11.25 | 35.1 | Watt market |
| Total | | 32.06 | 100.0 | |

Source: Researchers analysis

**Modelling Suitable Areas for Flood Mitigation**

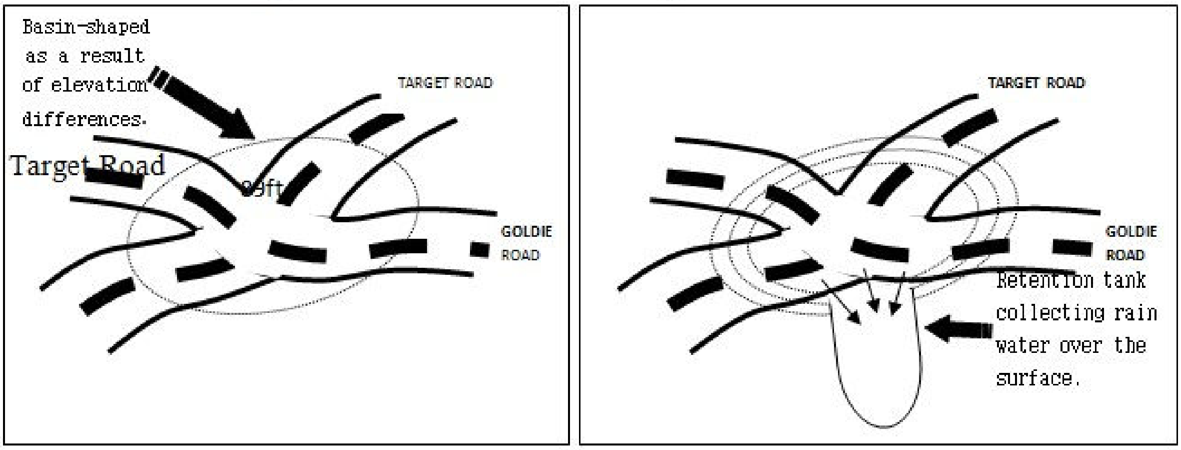



**Figure 7 and 8: Diagram showing the basin-shaped situation of Goldie by Target road junction and retention drainage for mitigation.**


**Figure 9: Flood plain mapping**