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Suitable Design of Road Pattern for Kosti Town Based on TIN Analysis

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Abstract: Kosti town as one of the Sudanese towns suffers from floods and storm water particularly in the rainy season due to a number of reasons such as drainage system and design and construction of the road network in the town. This paper aims to study the phenomena, determines the causes, and analyzes the results to test the hypothesis that of "the problem is mainly due to unsuitability of the planning pattern followed in the road and drainage network with the city's topography". To conduct this research, contour and cadastral map, of Kosti town was compiled from field survey data carried-out in 2005. The map was studied and analyzed spatially to accept or reject the hypothesis. Alternative suitable design of the road network can be suggested. Geographical information systems (GIS), i.e. ArcGIS software, were used to build triangulated irregular network (TIN). Digital terrain model (DTM) was generated for the area of the study. Based on surface analysis, it became obvious that the network follows grid-iron pattern which is not appropriate for the town topography. The study proposes designing a new road network to follow semi radial concentric spatial pattern, which is believed to be better than the existing system.

Keywords: *Road Pattern; TIN; DTM; Lidar*

1. INTRODUCTION

Kosti town is located at the western bank of the White Nile River, about 350Km from the capital Khartoum (Fig1). The geographical coordinates of the town centre are 13°10′N, and 32°40′E. It is a harbor of the river transportation for trade off between Sudan and south Sudan. It is one of the major cities in the White Nile State connected with Sudan railway lines. The railway lines were used to link Darfur and Kordofan areas with the Khartoum, crossing the River Nile at Kosti town. This location makes Kosti one of the most import points in the country trade.

This study work was carried out to examine thoroughly the relationship between the topography and the spatial road pattern in Kosti town. The study will also assess impacts of this relation on the existing drainage system. The main objective of the study is to suggest a new design for road and drainage network suitable for the topography of the town.

A digital terrain model needs to be compiled either from contour map, elevation points, or other source i.e. airborne laser scanner's (Light Detection and Ranging-Lidar) data [3]. A further surface analysis such as slope, aspect, hill-shade and flow-direction can be performed. To conduct this research, contour and cadastral map of the town was compiled from field survey data carried-out in 2005.

The town experienced many flood and water storm disasters in rainy seasons in the last decade. The problem is serious and destructive having lots of consequences on the citizens such as loss of properties, diseases, transportation problems, etc. In addition, obvious impact on the environment can be observed. It is seldom to find a research considering this situation. Therefore this study aims at studying, analysis the phenomena, figuring out the causes and proposing effective solutions.

2. MATERIALS AND METHODS

The study was carried-out according to the work flow shown in Fig.2. The first step consists of identification of the problem and the description of the objectives of the study. The second step is concerned with data collection by different means and as a result a contour map and detailed map was prepared. The third step is concerned with the analysis by using GIS techniques so as to identify the topography and the spatial road patterns. In this step evaluation and assessment

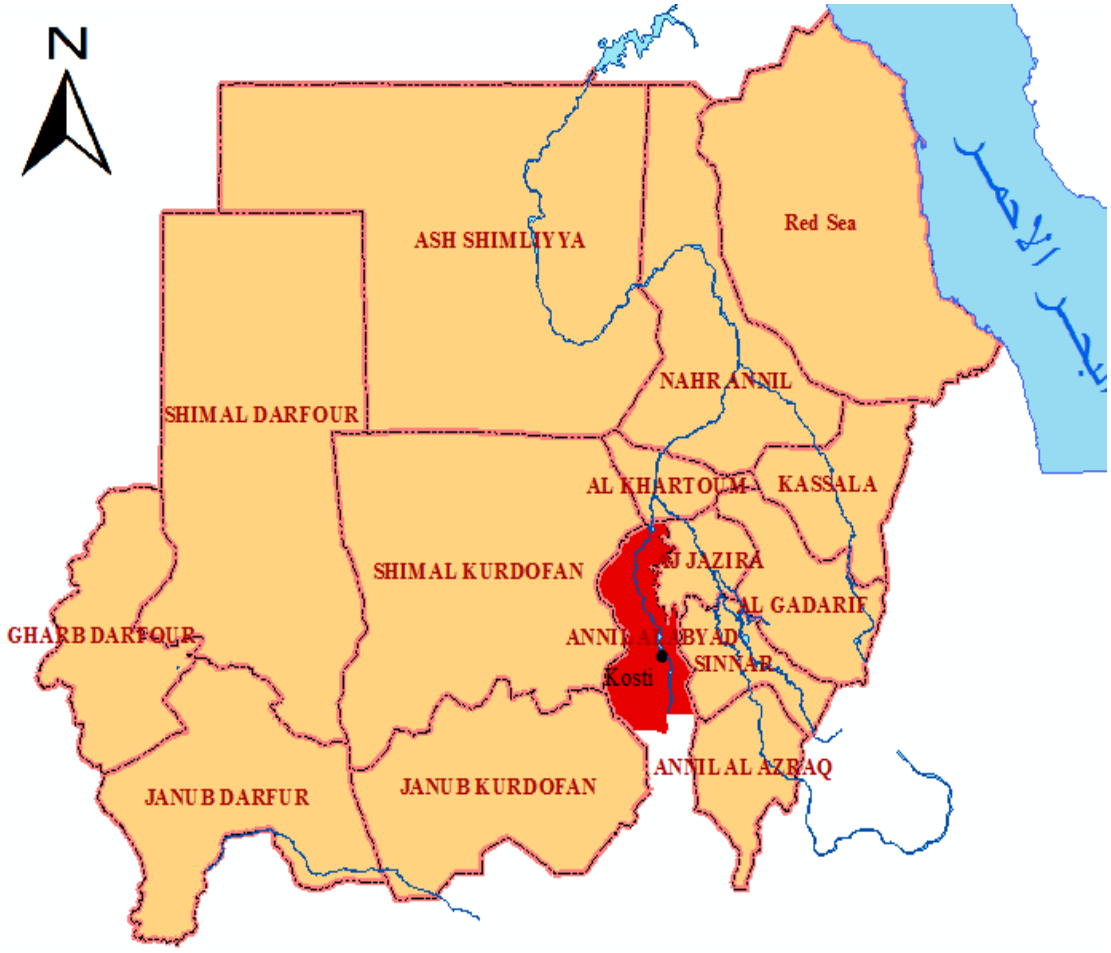

Fig. 1. Kosti Town Geographical Location

processes were carried out. The fourth step is concerned with verification of the relationship between topography, spatial pattern and the efficiency of the existing drainage network. Besides, designing of proper drainage network and finding the ideal spatial road pattern for the town To study and evaluate the topography of the area of interest, three-dimension (3-D) model of the Earth surface was used such as digital elevation model (DEM), digital terrain model (DTM) and triangulated irregular network (TIN) [1] and [2]. To construct such a kind of models, 3-D spatial data (i.e. data with x, y and z coordinates) need to be compiled in were several steps. The types of data that are normally used to compose the topography models include mass points, break lines, contour lines and or LIDAR data. Brief descriptions for these data and the 3-D models are given in [3].

The present authors explored the available topographic data of Kosti town during the data collection phase in year 2005. There was no useful available map. Therefore, a fieldwork was carried-out to collect elevation points for the research area. A plan for the fieldwork was prepared in March 2005 and accomplished in two stages. In the first stage, a leveling task was achieved. In the second stage, a controlled work was completed. For the leveling job, automatic level instrument was used. The work started by reconnaissance survey. Then the work was checked to examine the situation of the existing reference benchmarks. Then the points observed were located at the intersection of roads and on bed of drains. The distance interval used ranges were between 40 meters to 100 meters, according to the average dimensions of the planning units used (length = 100 m, and width = 40 m).

Afterward, fourteen control points were established using RTK- GPS (Real Time Kinematic GPS survey). The coordinate system used is UTM zone 36 and datum Adindan. Fig.3 shows the distribution of ground control points in Kosti town contour map. Table 1 depicts the coordinates of the

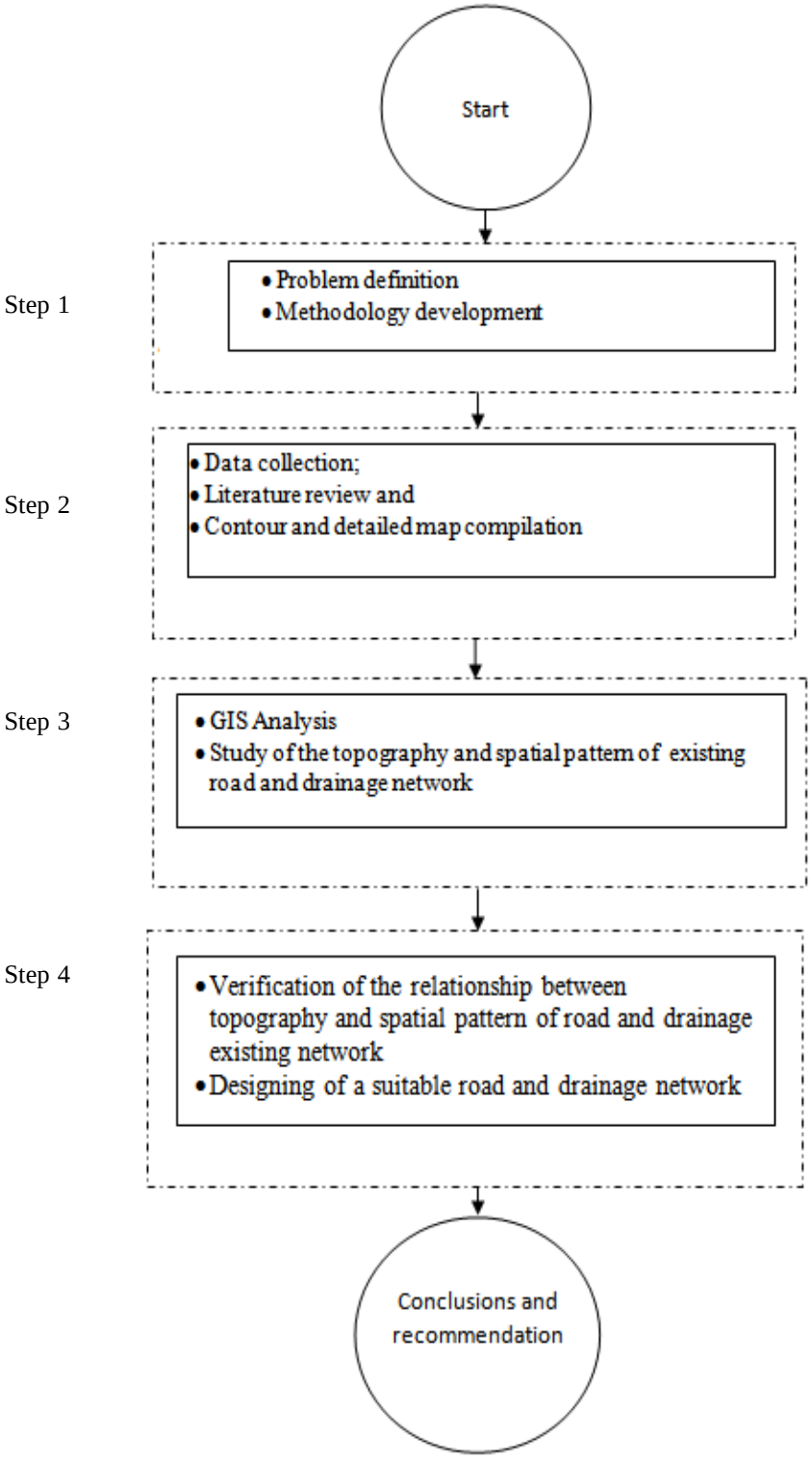

Fig. 2. Methodology workflow

ground control points. A detailed map for Kosti town was obtained from White Nile Sate, Survey Department, in hard-copy format. The paper map was scanned and geographically registered to its location. All the available features such as road, drainage networks, parcels, railways and river were digitized and stored in the GIS database. Afterward, all ground control points collected by field-survey were plotted on a detailed map which was adjusted accordingly. A contour map of 0.25-meter interval was produced from measured points by ArcGIS package using interpolation techniques existing in the software (A sample of the contour map is shown in Fig. 4. and a superimposed view of contour and parcel map were displayed in Fig.5.

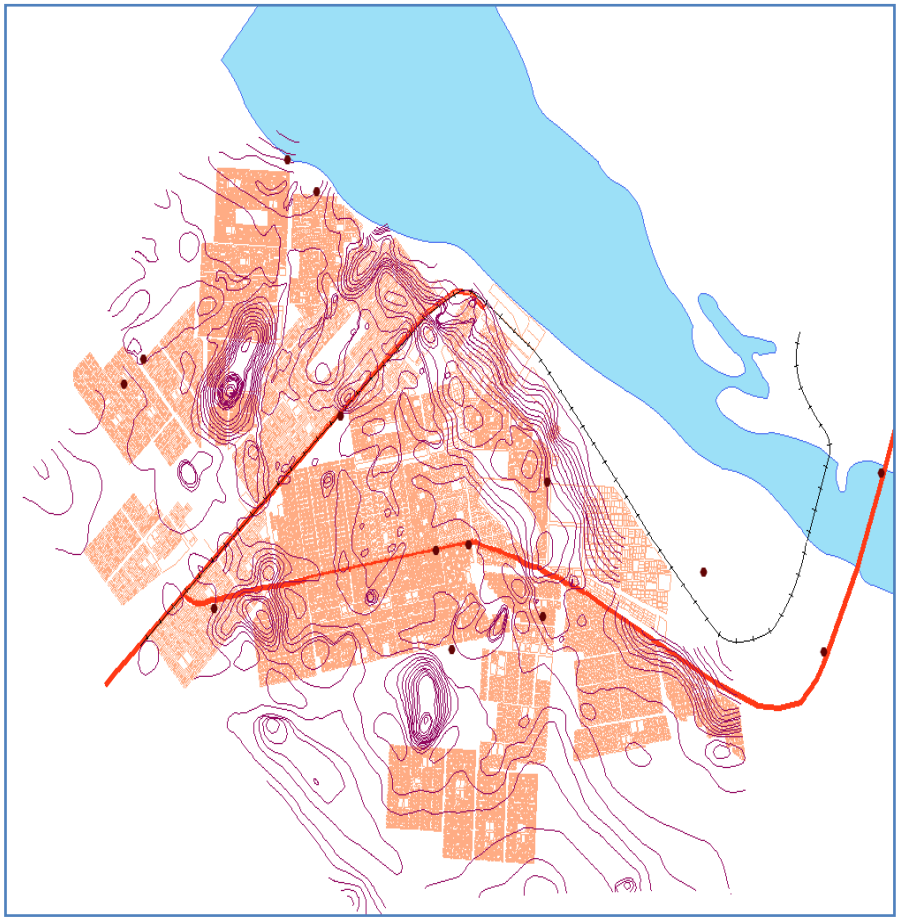

Fig. 3. Distribution of the control points

Table 1. Final coordinates of control points (in meters)

Point No.	X-value	Y-value	Z-value
k001	470562.1020	1450968.4900	380.501
k002	467025.8919	1451532.0449	384.253
k003	465889.1271	1453188.2063	384.252
k004	468525.9601	1452012.2153	380.504
k005	465817.8762	1451420.2164	383.753
k006	464280.8153	1450992.4347	384.504
k007	464556.0109	1452370.3956	384.502
k008	464013.9994	1452289.4726	384.504
k009	471530.1452	1453315.8253	380.503
k010	462390.2505	1454057.7032	384.012
k011	461993.6685	1457001.7595	383.504
k012	461499.7269	1457412.8297	383.503
k013	459067.3559	1454800.1750	384.504
k014	458738.3092	1454471.2217	384.502

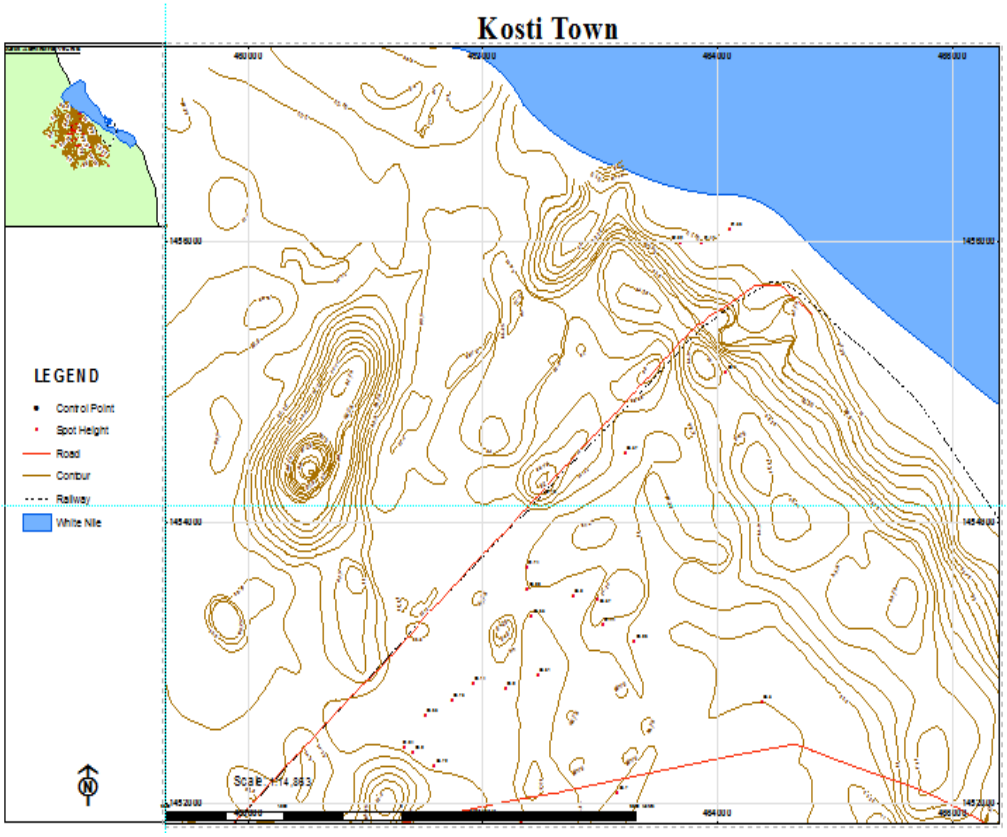

Fig. 4. Kosti town contour map

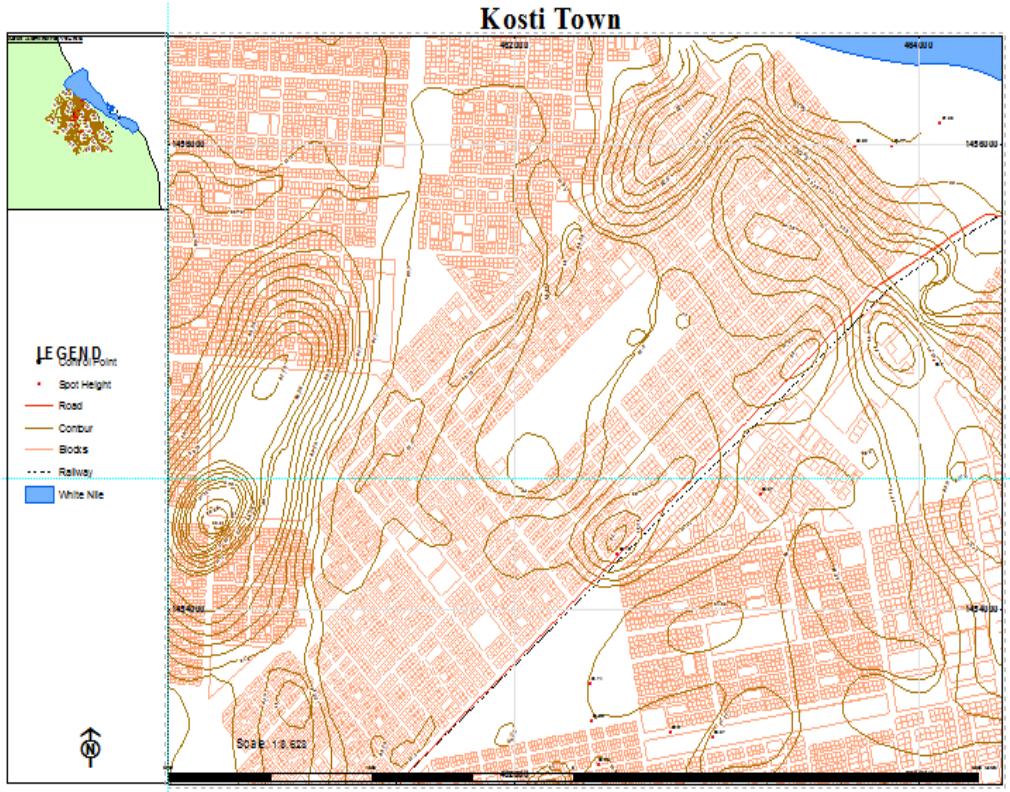

Fig. 5. Kosti town detailed map with contour

The next step that is following data preparation in GIS environment is digital terrain analysis. This part of the work was accomplished using ArcGIS 3D-Analyst extension. The extension provides tools and functions to perform the following tasks:

- Profile;
- Hill shade;
- Slope;
- Steepest descent path;
- Aspect; and
- View shade/Line-of-Sight.

Terrain analysis and contour lines were generated for Kosti town. They were converted from two dimensions (2D) features into three-dimension (3D) features using 3D tool. Then a TIN view was made for the area. The portion of the TIN scene is shown in Fig. 6.

Following the TIN establishment, all the terrain surface analysis tasks, such as profiles, hill shades, slopes, steepest descent paths, aspects; and view shade/line-of-Sight were carried-out in the area of the study. The purpose of this surface analysis was to assess the situation of the existing drainage networks and to see how it was sufficient to drain storm water. Figs 7 to 12 show samples of the results.

3. RESULTS AND DISCUSSION

The study came up with a number of very interesting results. First, urban spatial pattern of the town as can be seen in Fig.12 appeared to have followed grid iron pattern in its design. Second, the topographic analysis of the area reflects that the terrain was found to be almost flat. The terrain average height is about 382 meter above the mea sea level (MSL). The elevation changed obviously in small portion of the area in Goz Abu Sharif (Fig.9). Height point was found to be about 388 meter above MSL. In Fig.11 the color code in the legend represents graduations of the height. The red color shows the highest elevation and the semi-grey color shows areas of medium elevation. While the blue color represents the lowest value of the elevation. Third, the drainage network seems to follow the road network which is grid iron spatial pattern design (not covered in the entire town). The existing drainage system was developed in two stages between 1950 and 1970. Finally, the surface analysis (i.e. profile, slope and aspect) proof that the flow of the water is almost sating and this due to topography effect. This is because the design of the network doesn't consider the characteristics of the area as should be. The view in Fig.13 shows the drainage network and direction of the slope in each part of area. In addition, the grid iron pattern adopted for the town is not the best choice for such kind of topography.

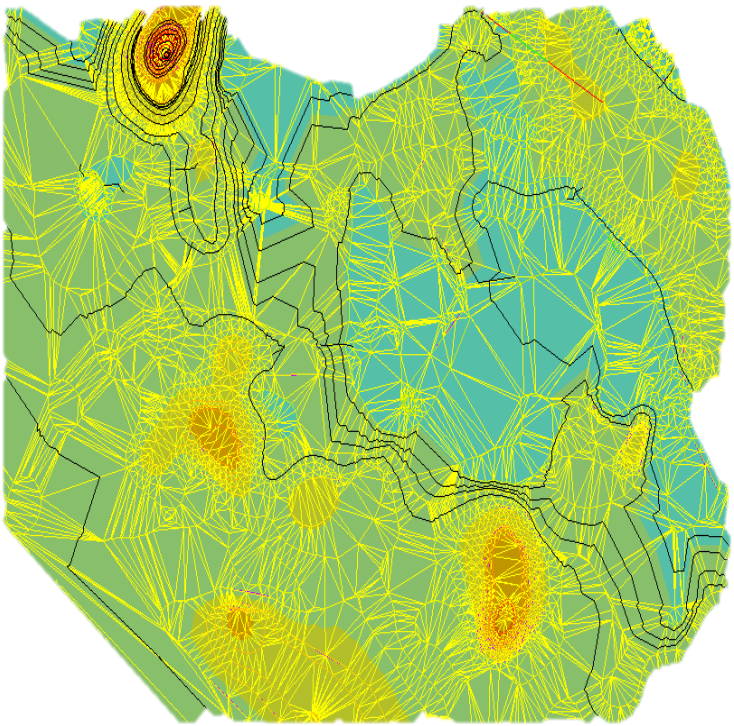

Fig. 6. Kosti-Triangulated Irregular Network (TIN)

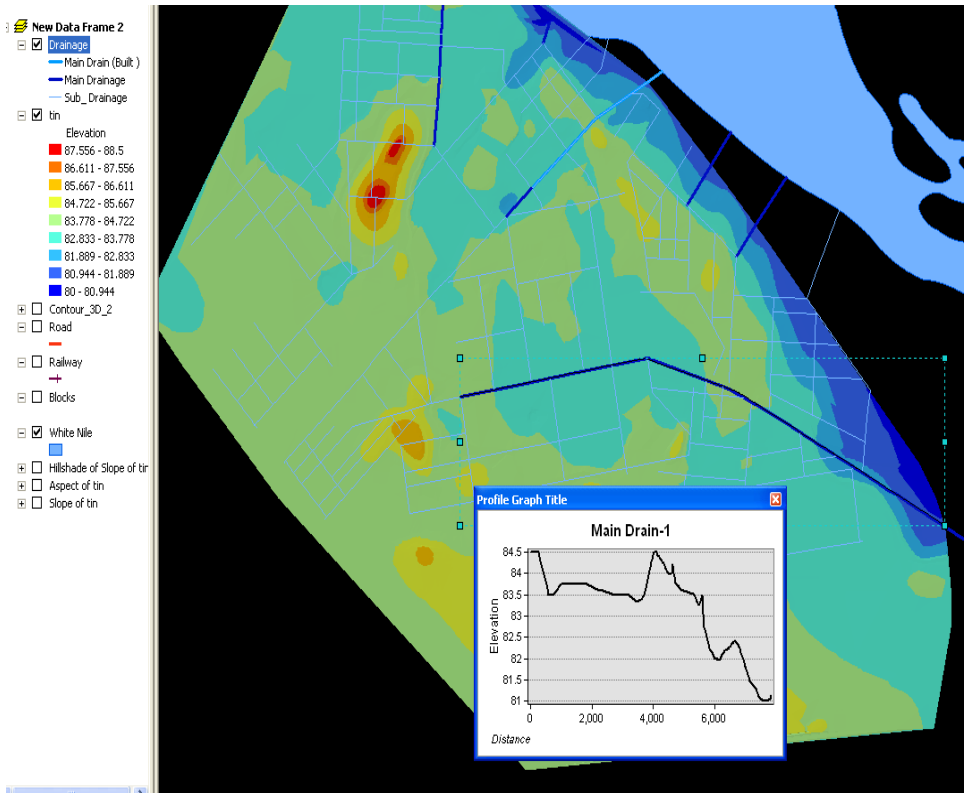

Fig. 7. Main drain profile generated from TIN - Kosti Town

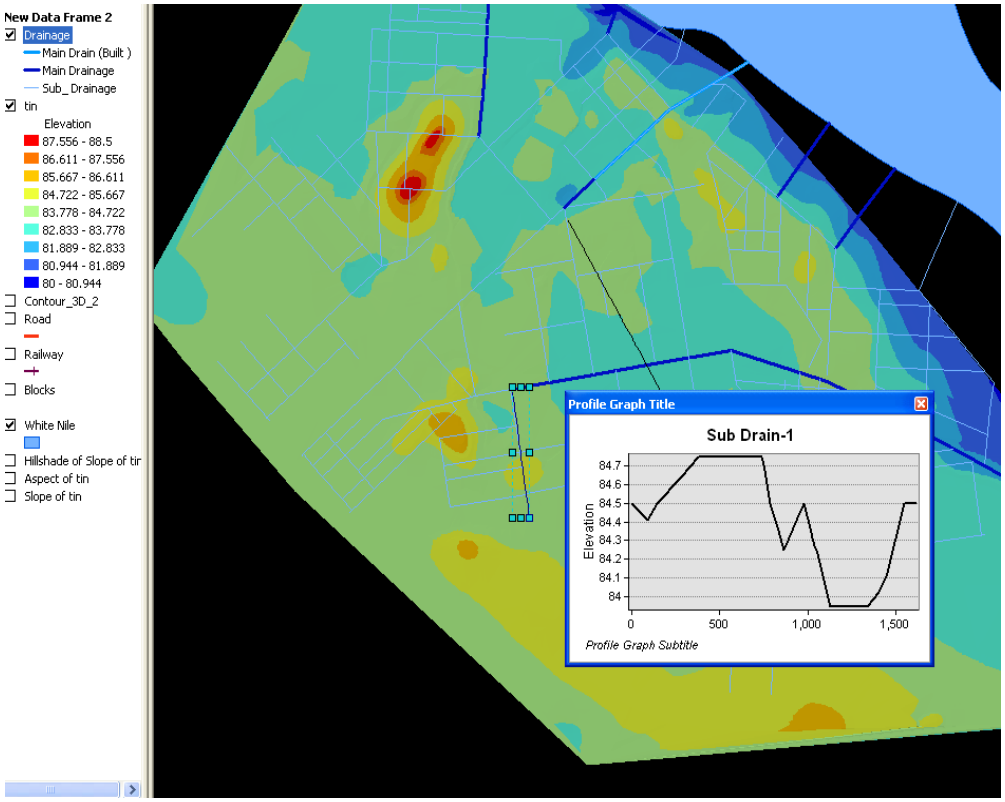

Fig. 8. Sub-drain profile generated from TIN - Kosti Town

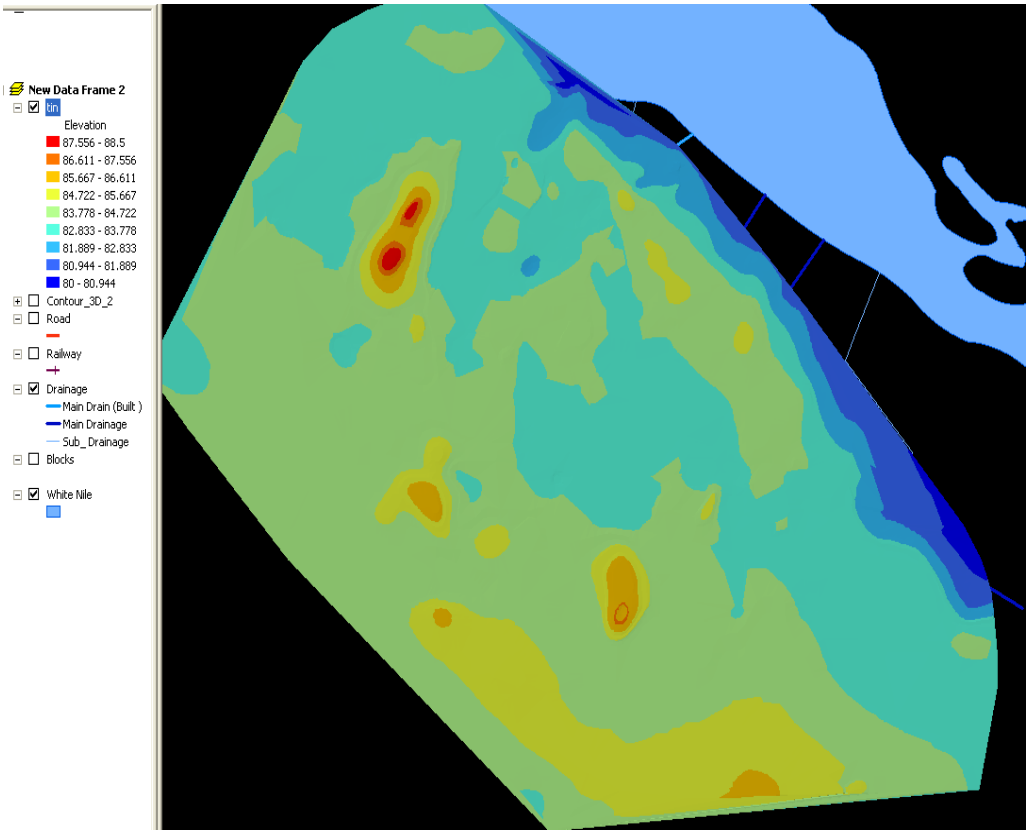

Fig. 9. TIN hill shaded generated from contours - Kosti Town

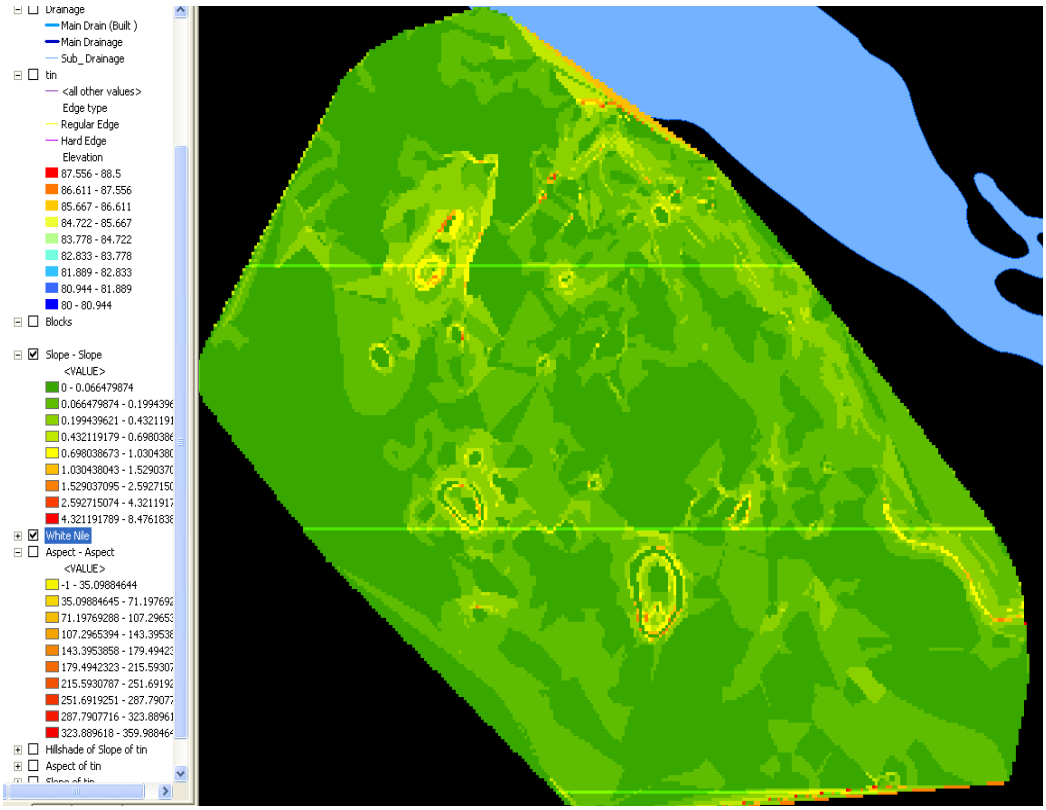

Fig. 10. Slope analysis- Kosti Town

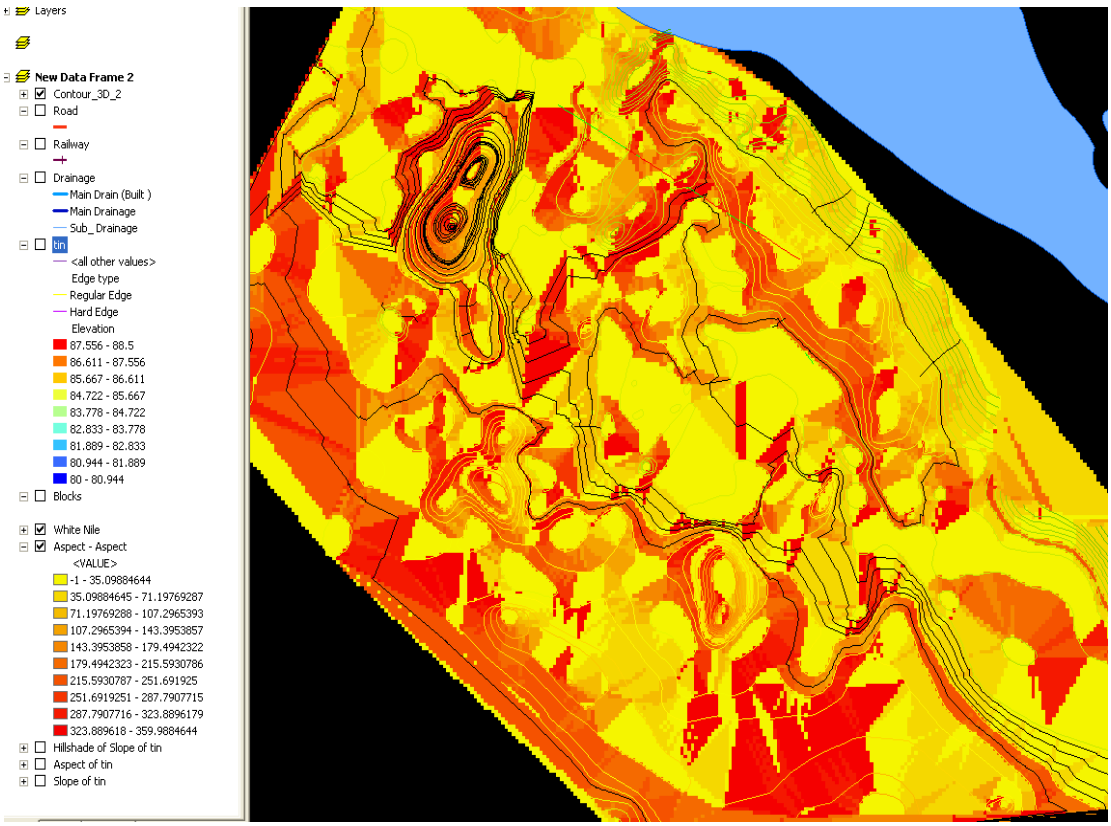

Fig. 11. Aspect analysis - Kosti Town

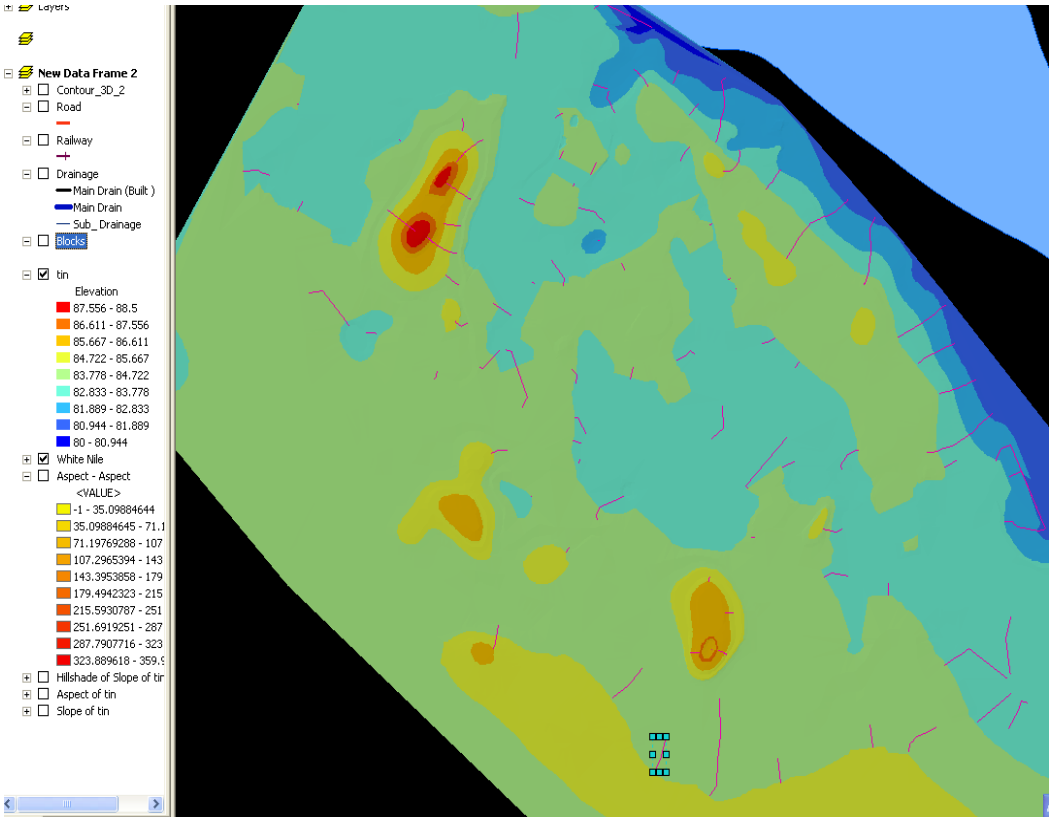

Fig. 12. The steepest path analysis (Kosti Town)

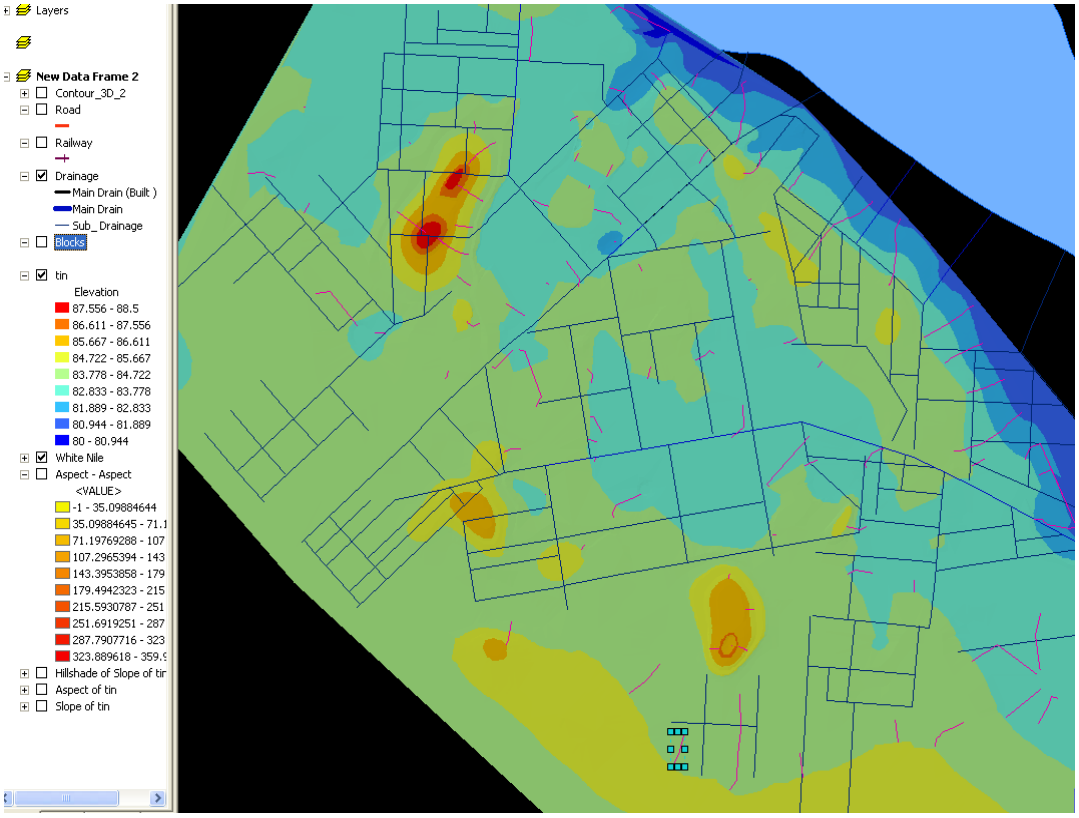

Fig. 13. The existing drainage system with the steepest path - Kosti Town

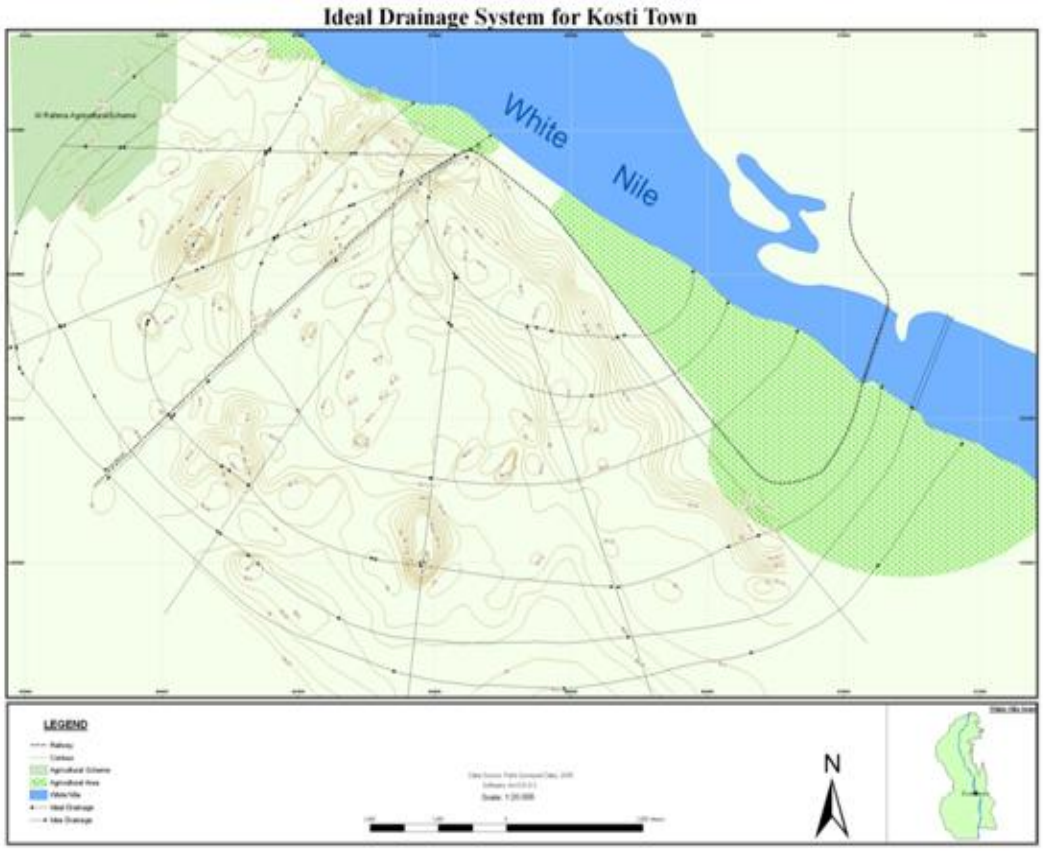

Fig. 14. The proposed Semi- Natural Drainage Network for Kosti Town

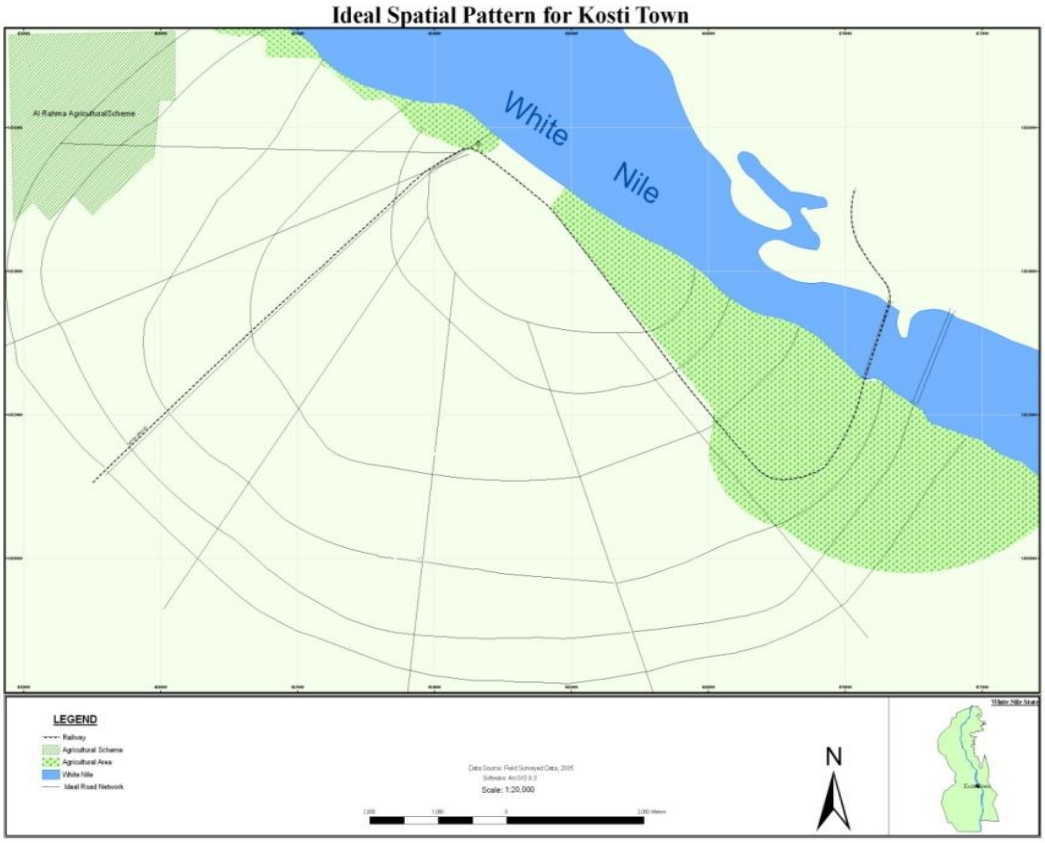

Fig.15. The proposed road pattern for the town - Semi Radial Concentric

Water-flow in the town needs to be directed to the north and to the north east towards the White Nile course. Therefore, for flat areas such as the study area, another road network spatial pattern needs to be developed and adopted to eliminate the effect of topography in the drain process. Based on the information provided by the GIS and surface analysis, an alternative road and drainage network design were suggested. The networks suggested could take a form of half-radial concentric pattern. The authors studied and analyzed each part of the area carefully (Figures 14 and 15 illustrate the proposed networks).

4. CONCLUSIONS

Kosti town suffers from storm water flood during the autumn season. This problem became an issue to the local authorities. The present work was carried-out to study closely the relationships of this problem to urban planning. The study focused on the existing road, drainage networks, and the topography of the area. Field data were collected to measure the terrain elevation to produce digital terrain model. A large scale parcel and road network map was obtained from the State Survey Department. The map was converted to digital form and then DEM is generated from the field survey data. Both maps were combined in GIS environment to conduct 3-D surface analysis. Many outputs were generated such as TIN, slope, aspect, hill shade, etc. Profiles of the main drain lines and sub-drain lines were performed.

The town followed gridiron urban planning model, its topography is almost flat and drainage system is found to be affected by this condition. The analysis also shows a significant correlation between the environment deterioration and silent storm water in the area due to in sufficiency of storm-water network. Based on the analysis of the present research data and the results generated by GIS tools the authors concluded that gridiron pattern is not suitable for the town's topography. Therefore, semi radial concentric pattern was recommended. A newly designs of the road and drainage networks were proposed.

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