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Evaluation of Natural Drainage Flow Pattern, Necessary for Flood Control, Using Digitized Topographic Information: A Case Study of Bayelsa State Nigeria

Collins C. Chiemeke

***Abstract*—**The need to evaluate and understand the natural drainage pattern in a flood prone, and fast developing environment is of paramount importance. This information will go a long way to help the town planners to determine the drainage pattern, road networks and areas where prominent structures are to be located. This research work was carried out with the aim of studying the Bayelsa landscape topography using digitized topographic information, and to model the natural drainage flow pattern that will aid the understanding and constructions of workable drainages. To achieve this, digitize information of elevation and coordinate points were extracted from a global imagery map. The extracted information was modeled into 3D surfaces. The result revealed that the average elevation for Bayelsa State is 12 m above sea level. The highest elevation is 28 m, and the lowest elevation 0 m, along the coastline. In Yenagoa the capital city of Bayelsa were a detail survey was carried out showed that average elevation is 15 m, the highest elevation is 25 m and lowest is 3 m above the mean sea level. The regional elevation in Bayelsa, showed a gradation decrease from the North Eastern zone to the South Western Zone. Yenagoa showed an observed elevation lineament, were low depression is flanked by high elevation that runs from the North East to the South west. Hence, future drainages in Yenagoa should be directed from the high elevation, from South East toward the North West and from the North West toward South East, to the point of convergence which is at the center that flows from South East toward the North West. Bayelsa when considered on a regional Scale, the flow pattern is from the North East to the South West, and also North South. It is recommended that in the event of any large drainage construction at municipal scale, it should be directed from North East to the South West or from North to South. Secondly, detail survey should be carried out to ascertain the local topography and the drainage pattern before the design and construction of any drainage system in any part of Bayelsa.

***Keywords*—**Bayelsa, Digitized Topographic Information, Drainage, Flood.

I. Introduction

BAYELSA State is a state in southern Nigeria in the core Niger Delta region, between Delta State and Rivers State. Its capital is Yenagoa. The four main languages spoken are Izon, Nembe, Epie-Atissa and Ogbia. Like the rest of Nigeria [2].

Bayelsa state where this research was carried out is a flood prone region, with annual rainfall that last for at least 10 months. There are several previous drainage constructions that ended abruptly (Fig. 1), thereby introducing more complication to the environmental flooding than it is trying to solve. The existing drainage pattern revealed an obvious fact that, the developers do not have adequate and detailed knowledge of the environment topography, which controls the flow pattern, before embarking on such construction work. Hence this research work was carried out to ascertain the nature of the topography and model the flow pattern, which will enhance the construction of an effective drainage pattern that will help curtail the menace of flooding (Fig. 2) in Bayelsa state. The instrument used for this research work includes; Global positioning system, Google Earth imagery Map [5]., and dedicated geo software for 3D surface modeling.

Fig. 1 Abrupt truncation of drainage, that resulted in flooding

Fig. 2 Menace of flooding in Bayelsa due to poor drainage and wrong Town planning, in 2012, [4]

Collins Chiemeke is with Physics Department Federal University Otuoke, Yenagoa, Bayelsa State, Nigeria (Phone: +2348035780638 e-mail: chiemekecc@fuotuoke.edu.ng).

Bayelsa would continue to experience flood, owing to the vulnerability of the topography. The devastation of last year's flood (2012) cannot be quantified, as it brought poverty, developmental challenges, lives were lost, institutions (Federal University, Otuoke) shut down, amongst others, [1].

II. Location of the Study Area

The study area is Bayelsa state (Fig. 3), located in the Southern part of Nigeria, in the oil rich Niger Delta. It is bounded by latitude 5° 05' 46.36'' N, longitude 5° 23' 51.01'' E and 4° 18' 10.56'' N, longitude 6° 05' 11.83'' E.

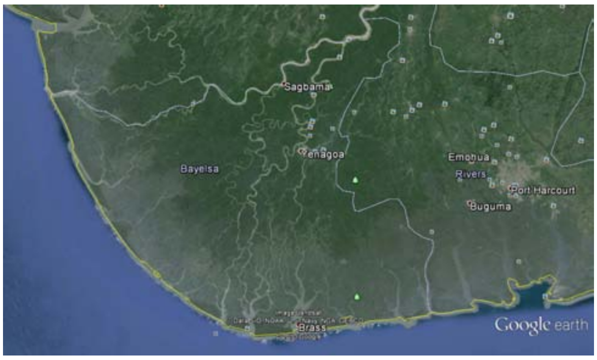

Fig. 3 An imagery map showing the location of the study area

III. Geology of the Study Area

The study area is Bayelsa and it lies within the fresh water and meander belt geomorphic unit of the Niger Delta, [7]. The formation of the present Niger Delta started during Early Paleocene as a result of the built up of fine grained sediments eroded and transported to the area by the River Niger and its tributaries. The regional geology of the Niger Delta consists of three lithostratigraphic units, Akata, Agbada and Benin Formations, overlain by various types of Quaternary Deposits [9], [6], [3]. These Quaternary Sediments, according to [8] are largely alluvial and hydromorphic soils and lacustrine sediments of Pleistocene age.

IV. Data Acquisition

The data acquisition started by making use of global positioning system (GPS) equipment to acquire the preliminary data (Elevation, Latitude and Longitude) in strategic positions that will act as baseline data for location and digitization of the survey area in the imagery map. The goggle Earth imagery map was activated online, when the best resolution was achieved, data were digitized along rectangular flight lines as shown in Figs. 4 and 5, at an interval of 10 km for the regional survey and at interval of 500 m for detail survey. Among the data extracted include elevation, latitude and longitude co-ordinates of each point sampled. A part of the collected sampled raw data is shown in Table I. A total of 95 sample points were digitized for Bayelsa in general to view it on a regional scale, while a total of 465 data point were digitize for Yenagoa, the capital city of Bayelsa that forms part of the study area.

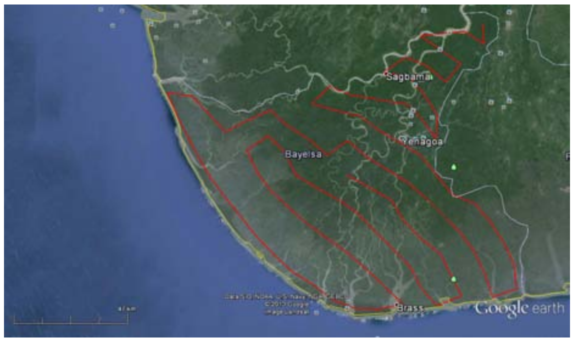

Fig. 4 Digitization flight lines for the regional survey

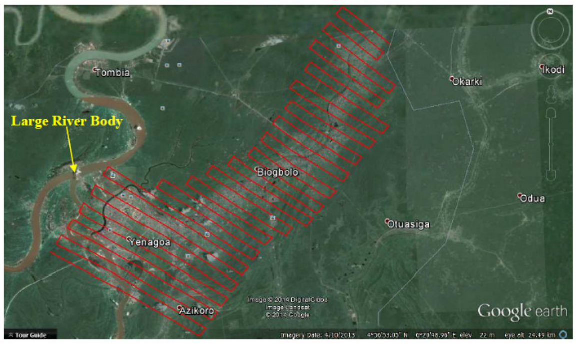

Fig. 5 Digitization flight lines for the detail survey of Yenagoa and Its Surroundings

TABLE I
DIGITIZED RAW DATA

Latitude			Longitude			Elevation (m)
Degree North	Minutes North	Seconds North	Degree East	Minutes	Seconds East	
4	44	58.51	6	8	17.09	9
4	42	6.05	6	13	9.94	10
4	30	10.2	6	24	7.83	5
4	25	27.59	6	26	23.94	6

V. Data Processing

The data processing started with converting the digitized longitude and latitude values in minutes and seconds into the appropriate values in degree. The converted values where arranged in three columns, starting with the longitude values in degrees, followed by latitude in degrees and ending with the elevation value in meters, forming x, y, z coordinates as shown in Table II. The processed data were exported to the processing software, where it was grided and contoured into 3D surfaces. The colour scale bar that will aid the interpretation was generated. The vector map surfaces that also depict the flow pattern were also generated. Elevation analysis was carried out using the "Elevation Profile Analysis" to determine the highest and lowest point in the survey area for the regional survey and detail survey.

TABLE II
The Coordinate Point and Elevation Used to Develop 3D Surface

East (Degree)	North (Degree)	Elevation (m)
6.058588889	4.799194444	12
6.138080556	4.749586111	9
6.219427778	4.701680556	10
6.268111111	4.62275	7
6.326758333	4.559638889	6
6.402175	4.502833333	5
6.439983333	4.424330556	6

VI. Results and Discussion

The result of the Elevation Profile analysis on a regional scale, Figs. 6 and 7 revealed that the highest elevation in Bayelsa is placed at 28 m, while the lowest elevation is placed at 0 m, along the coastline. The average elevation for Bayelsa in general from the Elevation Profile analysis is 12 m, which is almost equivalent to the difference between the highest elevation and lowest elevation divided by two.

The result of the elevation profile analysis in Yenagoa the capital city of Bayelsa (Figs. 8 and 9), revealed that, the highest elevation is put at 25 m. While the lowest elevation stands at 3m. The average elevation in Yenagoa the capital city was determined to be 15 m.

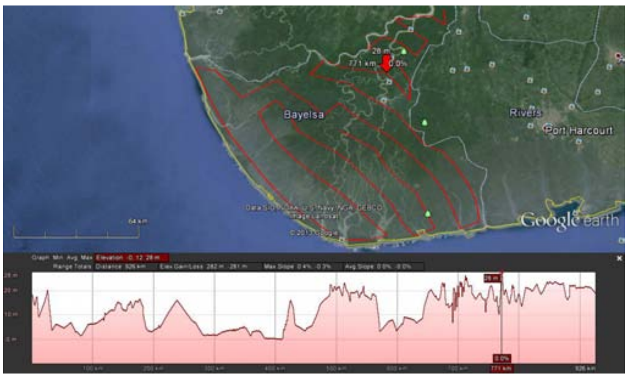

Fig. 6 Elevation profile analysis to determine the highest point on the in Bayelsa on a regional scale

Fig. 7 Elevation profile analysis to determine the lowest point in Bayelsa on a regional scale

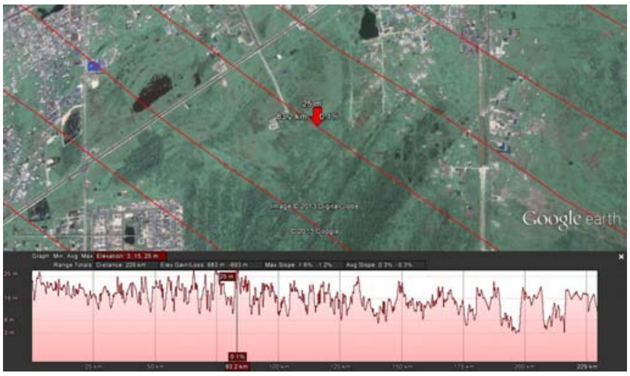

Fig. 8 Elevation profile analysis to determine the highest Elevation point at Yenagoa on a regional scale

Fig. 9 Elevation profile analysis to determine the lowest Elevation point at Yenagoa on a regional scale

The 3D topographical surface generated from the digitized regional scale data for Bayelsa is shown in Fig. 10. The 3D surface is displayed in a shade of rainbow colour, with a scale bar attached by the side for ease of interpretation. Like the elevation profile analysis of Figs. 6 and 7, the elevation ranges from 0 to 28 m.

Note that, in all cardinal points (North, South, East and West) observations, it is assumed the observer is standing at the center of 3D surface. A careful qualitative analysis of the 3D topography map showed that, there is a gradational decrease in elevation from the North Eastern part to the South Western part of Bayelsa.

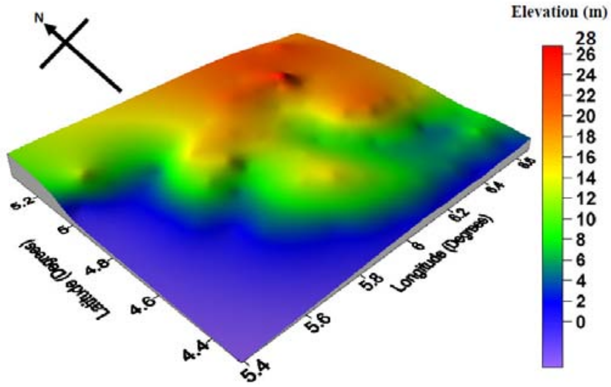

Fig. 10 Regional 3D topographical surface view of Bayelsa

The 3D topographical view generated from the digitized data for Yenagoa is shown in Fig. 11. The 3D surface is also displayed in shade of rainbow colour, to highlight differences in elevation. In line with the profile elevation analysis, the range of elevations were determine to be between 3 m to 25 m. Qualitative observational view showed there is an elevational lineament that runs from North East to South West. This can be described with a depression at the center that is flanked by relatively high lands. Moving from North East to South West, there is no much difference in elevation, except in some location in the South East that stands out very prominently.

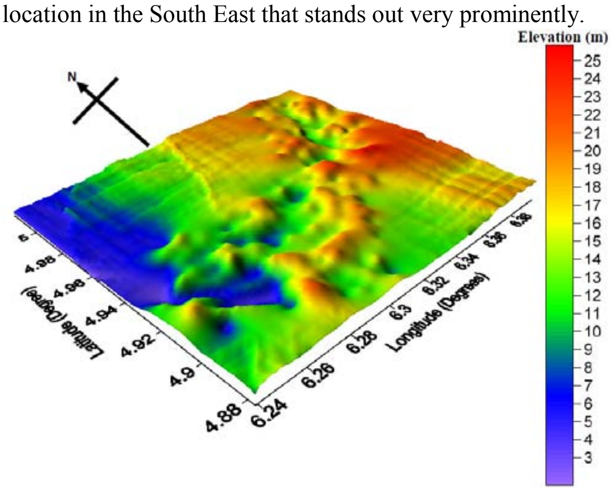

Fig. 11 3D topographical surface view of Yenagoa

With a bid to have a better and detailed view of the topography of the study area, the sampled area was divided into three segments (Fig. 12). Separate 3D surfaces were generated with their vector map from the three sections, as shown in Figs. 13-15.

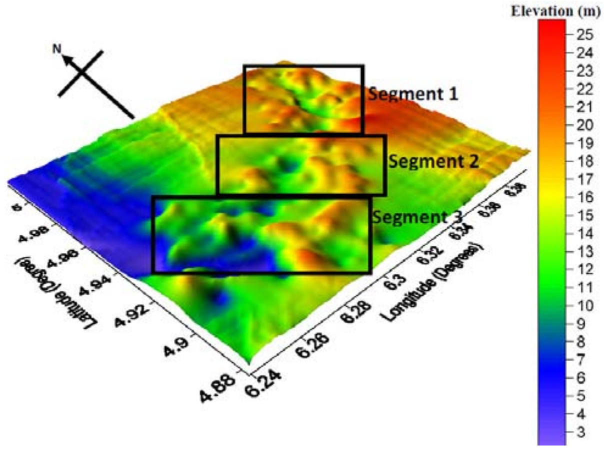

Fig. 12 3D topographical surface view of Yenagoa divided into three Segments

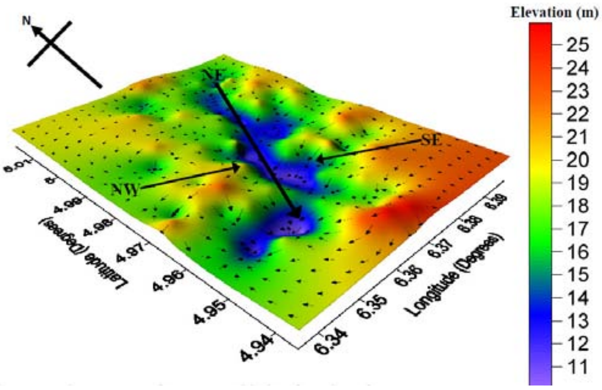

Fig. 13 First Segment of 3D topographical surface view of Yenagoa

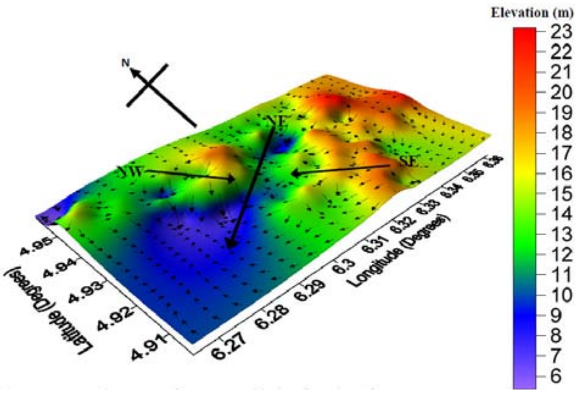

Fig. 14 Second Segment of 3D topographical surface view of Yenagoa

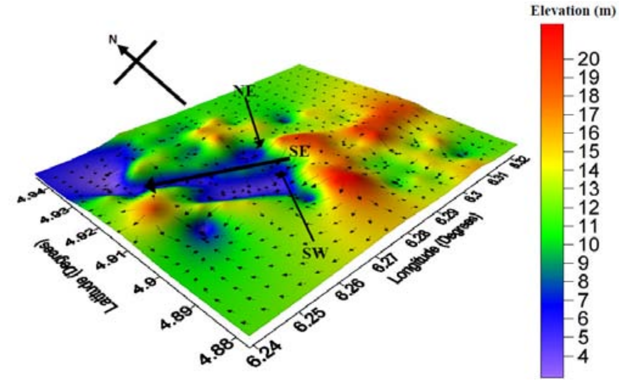

Fig. 15 Third Segment of 3D topographical surface view of Yenagoa

A close examination of the first segment topography in Fig. 13, confirmed a depression with an average elevation of 12 m above sea level that is flanked by relative high elevation with an average value of 21 m above sea level. The topography also conforms to the North East and South West trend. A vector map analysis which was carried out to ascertain the drainage pattern (Direction of water flow), revealed that the drainage direction is such that, it point toward the direction of the depression at the center, that is flanked by the relative high elevations. This has shown that any drainage that is to be constructed within this vicinity bounded by latitude 5.01^o N, Longitude 6.34^o E and Latitude 4.94^o N, Longitude 6.39^o E, should be directed from the South East toward the North West, and from the North West toward South East, to the point of convergence, which is at the center, as indicated by the two arrows in Fig. 13. This will flow generally from North East toward South West through the main natural drainage, as indicated by the main arrow at the center (Fig. 13).

In the same vain the second segment (Fig. 14) conforms to the same pattern, but with a prominent low elevation in the south West, with an average elevation of 8 m above sea level. The second segment also followed the general trend of North East, South West lineament. A vector map analysis carried out to ascertain the drainage pattern also revealed the direction of flow to be South East toward North West and North West toward South East, to converge at the center (Fig. 14). Any drainage constructed within Latitude 4.95^o N, Longitude 6.27^o E and Latitude 4.91^o N, Longitude 6.36^o E, should be directed from the South East toward the North West, and from the North West toward the South West, to converge at the center. The main natural drainage which all the drainage collates into will naturally flow from the North East to the South west direction, as indicated by the three arrows in Fig 14.

The third segment (Fig. 15) followed a slightly different pattern. It has a depression that is flanked by relatively high elevations that points from South East to North West. The vector map, which comes in the form of an arrow, generated to ascertain the direction of flow, indicates the direction of flow to be from North East toward South West, and from South West toward North East to collate at the center (Fig. 15). Therefore any drainage constructed within Latitude 4.94^o N, Longitude 6.24^o E and Latitude 4.88^o N, Longitude 6.32^o E should be directed from the North East toward the South West and from the South West toward the North East, to collate at the center. The main natural drainage which every other drainage will collate into will flow from South East toward the North West, and empty into a large river body as depicted in Fig. 5.

The vector map analysis (Fig. 16) of the entire Bayelsa State was also carried out to ascertain the direction of the regional drainage system. The result revealed that the trend pattern of flow is from the North East to the South West. This is also in conformity with the realities on ground, as regard to the natural drainage pattern of the rivers that flow from North East to the South West, although being in a delta region some tributaries still flow from North to South, which is also depicted to a very large extent in Fig. 16. Hence any regional Municipal drainage to be constructed within 5.2^o N, 5.4^o E and 4.4^o N, 6.6^o E should be directed either from North East to the South West or from North to South.

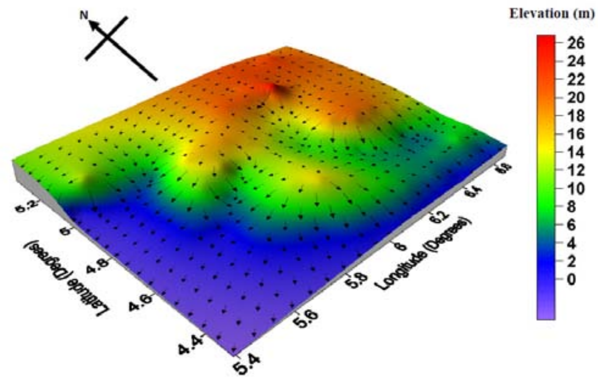

Fig. 16 Regional 3D topographical surface view of Bayelsa

VII. Conclusion

It has been established that the average elevation in Bayelsa is 12 m, above mean sea level, the highest elevation is 28 m and the lowest is 0 m along the coastline. In Yenagoa the Capital city of Bayelsa where the detail survey was carried out, the average elevation was place at 15 m, above mean sea level, the highest at 25 m while the lowest is 3 m above sea level. The regional elevation in Bayelsa, showed a gradation decrease from the North Eastern zone to the South Western Zone. Yenagoa showed an observed elevation lineament that runs from the North East to the South west. It can be concluded that, the future drainages in Yenagoa should be directed from the high elevation from South East toward the North West and from the North West toward South East, to the point of convergence which is at the center that flows from South East toward the North West. It is recommended that the main drainage in Yenagoa which runs South East toward the North West should be dredged, to be shallower in the South East and deeper toward the North West. Considering Bayelsa on a regional Scale, the trend of pattern of flow is from the

North East to the South West, and also North South. It is recommended that in the event of any large scale drainage construction at municipal level should be directed from North East to the South West or from North to South. Also detail survey should be carried out to ascertain the local topography and the drainage pattern before the design and construction of any drainage system in any part of Bayelsa State.

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