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# GIS & Remote Sensing Based Morphometric Parameters and Topographic Changes of the Lower Orashi River in Niger Delta

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ABSTRACT

In watershed hydrology, the morphometric features of a river basin are vital to examine the lower Orashi River basin morphological and hydrological aspects, as well as its flood potential, based on their morphometric characteristics using remotely sensed SRTM data that was analyzed with ArcGIS software. The areal, linear, and relief aspects of the Orashi River basin were examined as morphometric parameters. The lower Orashi river basin, according to the findings, has a total size of 625.61 km<sup>2</sup> and a perimeter of 307.98 km, with a 5th order river network based on Strahler categorization and a dendritic drainage pattern. Because of low drainage density, the drainage texture is very fine, the relief is low, and the slope is very low. Bifurcation ratio, circularity ratio, drainage density aspect ratio, form factor, and stream frequency values indicate that the basin is less elongated and would produce surface runoff for a longer period, while topographic changes show that the river is decreasing with depth in the land area at about the same elevation as a result of sand deposited due to lack of maintenance by dredging, which implies that the basin is morphometrically elevated and sensitive to erosion and flooding. To understand geo-hydrological features and to plan and manage watersheds, morphometric analysis based on geographic information systems and remote sensing techniques is beneficial.

## 1. Introduction

The quantitative assessment and measurement of a landform's shape, surface, and extent is known as morphometrics<sup>[1]</sup>. In most case, an extensive watershed development plan begins with a thorough morphometry understanding of the streams or drainage basins. Modelling various hydrological processes of a river or

canal basin relies heavily on geomorphological attributes or qualities of a stream or river basin. Traditionally, morphometric analysis entails determining the length of streams, the bifurcation ratio, and the stream density per unit drainage area, as well as the difference in elevation, perimeter, and drainage basin area. The drainage basin or watershed is viewed as a basic tool in the examination of some parts of the hydrological cycle and can likewise be

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portrayed as an open framework [2]. The morphometric research of the drainage basin and channel network serves an important role in comprehending the drainage basin geo-hydrological vital function and expresses the climate, geology, geomorphology, and structural conditions. Consequential environmental impacts such as flooding, erosion, etc. have been detected and monitored using remote sensing and geographic information system (GIS) technologies [3]. This study focuses on the morphometric evaluation of the Lower Orashi River to comprehend the drainage basins by assessing their morphometric values, which incorporate the state of the morphometric framework including the shape of the basin, the length of the stream, the area, the stream order, the length of stream segments, bifurcation ratio, density of drainage, and frequency. Furthermore, to join the geomorphologic and hydrological characteristics of the drainage basins.

## 2. Materials and Methods

### 2.1 Study Area and Geology

The lower Orashi River, which flows through Ahoada West LGA in Rivers State, Nigeria, is subjected

to investigation, and the area is fast becoming one of the increasing urban centers in Nigeria's South-South geopolitical region. Communities sounding the area are Jorkarima 1,2,3,4, Akinima, Mbiama, Ushie, Akiogbolgbo, Okarki, Ikodi, Ogbogoro in Ahoade West Local Government Area, Rivers State. in addition, the area is accessible by roads and the river and lies between longitude 006° 20'0 and 006° 40'0 "East and latitude 04° 50'0" and 05° 10'10" North in the Niger Delta (Figure 1), with altitude below sea level on the region 39 m further inland [4]. The average rainfall and temperature of the area are 2,899 mm and 26.7°C [3]. Several settlements in the area are close to hydrocarbon flow stations owned by the SPDC and NAOC, and the area is drained by tributaries that connect to the lower Orashi River [5] geologically described the research area as the south-western flank of the Niger Delta Region. The Niger Delta Basin was formed when the South American plate separated from the African plate and a failed rift (Aulacogen) junction developed. The rifting in the basin began in the late Jurassic and ended in the mid-Cretaceous epoch. There are several thrust faults that arise. The delta has a land area of more than 105,000 km<sup>2</sup> [6].

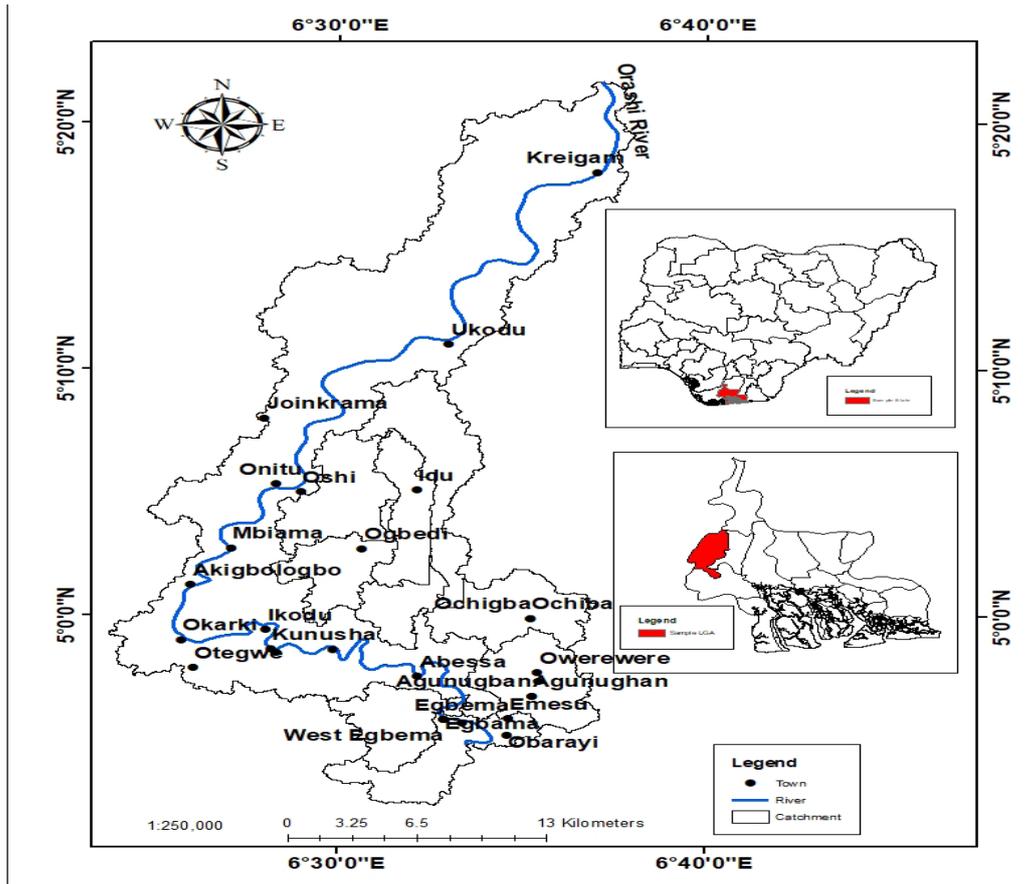


Figure 1. Location of Study Area

## 2.2 Data Source

The United States Geological Survey (USGS) earth explorer <sup>[7]</sup> provided the Shuttle Radar Topography Mission (SRTM) data, and administrative shape file.

## 2.3 Data Processing

The utilization of ArcGIS software and Arc hydro extension tools were to process the Digital Elevation Model data, by keeping the setting on projected coordinate system using WGS UTM zone N32, which depicts to process for spatial variation of elevation values at every geographic point/location within the area, we first use the Arc hydro tools to process the Digital Elevation Model image. It makes it possible to analyse and delineate drainage basin parameters derived from elevation information. The Strahler's method of stream ordering was used to obtain drainage basin morphometric parameters and stream order characteristics from the digitized data <sup>[8]</sup>.

## 3. Results and Discussion

The Evaluation Parameter for Morphometric according to Clarke <sup>[9]</sup>, is the measurement and mathematical analysis of the earth's surface configuration, including the shape and dimensions of its landforms. Measurements of the basin linear, areal, and relief aspects, as well as slope contribution, are used in the morphometric analysis <sup>[10]</sup>. Presented below.

### 3.1 Linear Morphometric

This means that the drainage network's channel patterns

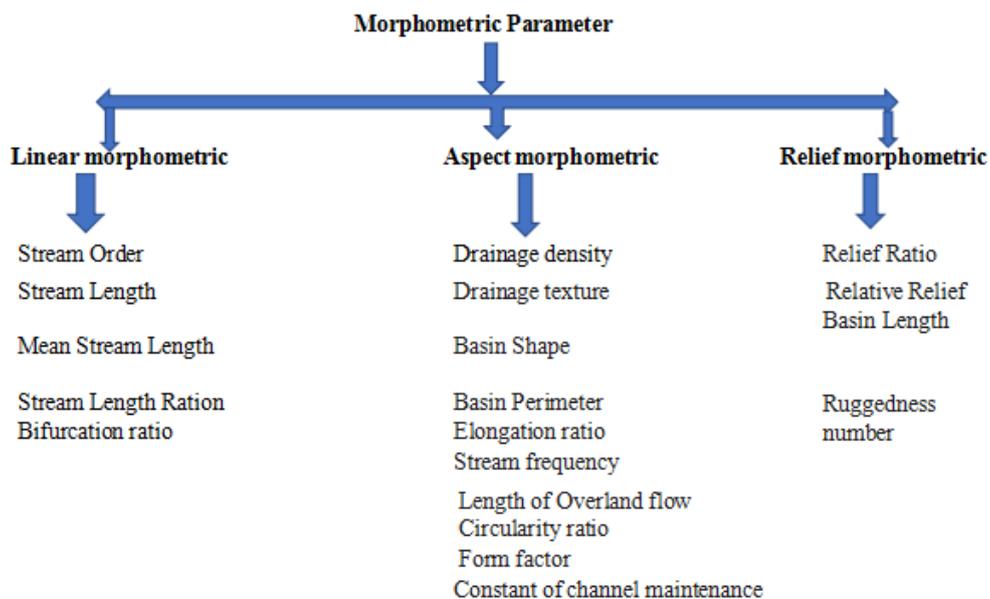
follow the stream segments' morphological characteristics, and the analysis is based on the stream network open linkages such as Stream Order, Stream Number, Stream Length, Bifurcation Ratio.

#### 3.1.1 Stream order (U)

Stream order analysis has been established as a measure of a stream's location in the hierarchy of tributaries <sup>[11]</sup>. The lowest fingertip tributaries are categorized as first stream order, according to Strahler <sup>[8]</sup>. A second stream order is generated when two first stream orders meet; a third-stream order is formed when two second stream orders meet, and so on. The Orash River has up to 5th order tributaries, according to Table 1, with 1st, 2nd, 3rd, 4th, and 5th streams depicted in Figure 3 and Table 1.

**Table 1.** Morphometric Characteristics for catchment area (Linear)

Stream Order	Stream No (Nu)	Stream Length (Lu)	Mean Stream Length (MLu)
1st Order	5432	810.73	0.15
2nd Order	742	273.82	0.37
3rd Order	232	113.31	0.49
4th Order	87	43.37	0.50
5th Order	28	12.63	0.45
$\Sigma Nu = 6521$		$\Sigma Lu = 1253.86$	



**Figure 2.** Flow diagram

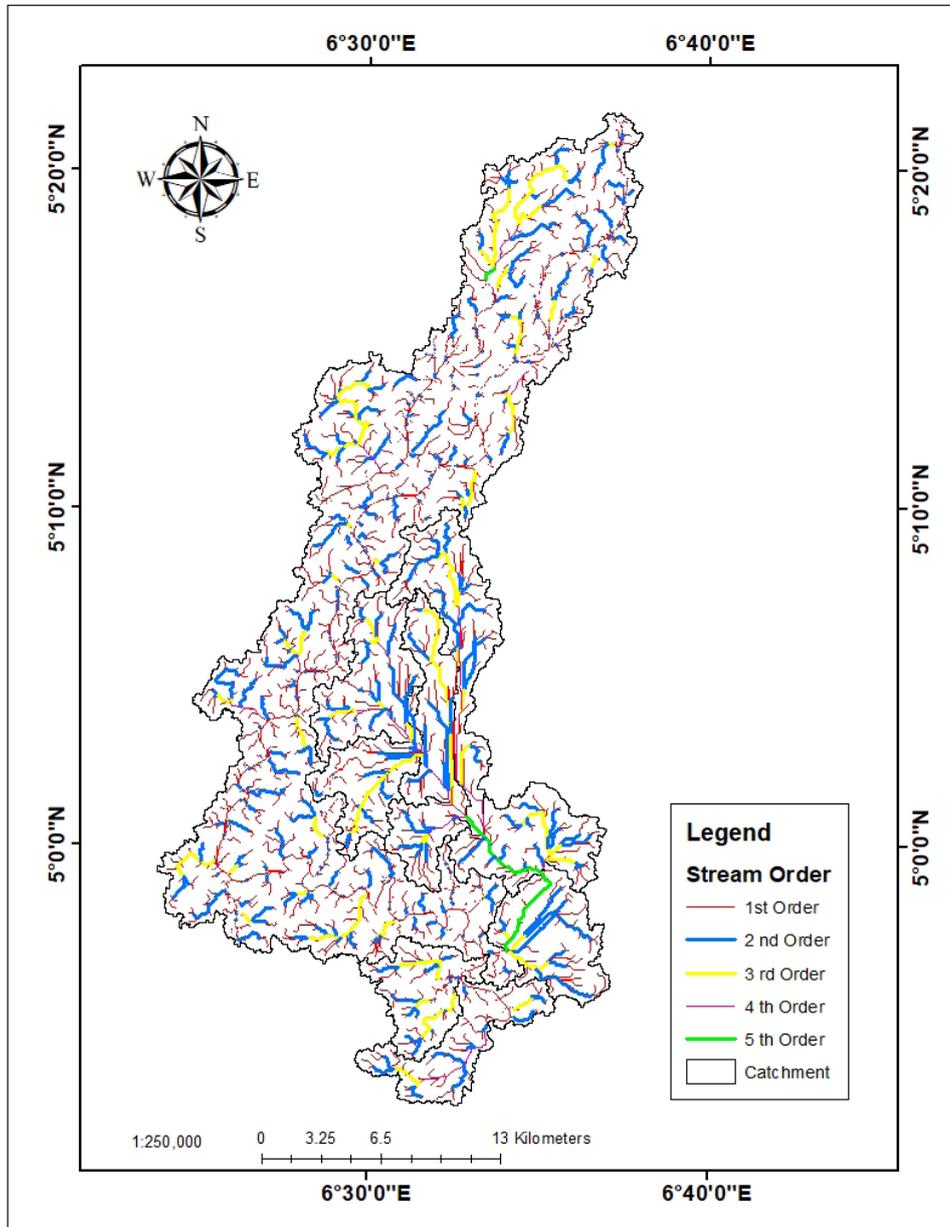


Figure 3. Stream Order

The total number of streams evaluated in the assessment of stream number is 6,521, with dendritic drainage present in the area. Horton <sup>[12]</sup> observed that when a basin has a large number of stream segments of progressively decreasing orders, the number of segments tends to form a geometric series, beginning with the single highest-order segment and rising in proportion to the constant ratio. When the relationship is plotted on the logarithmic and arithmetic scales on the Y-axis and X-axis, it creates a negative linear pattern on the Y-axis (Figure 4).

### 3.1.2 Stream Length (Lu)

The length of a stream is one of the most important hydrological properties of a basin since it indicates the characteristics of surface runoff. Streams with shorter lengths are more common in locations with steeper slopes and finer textures. Longer streams typically have smoother surfaces with lower slopes. The total length of stream segments is usually greatest in the first stream orders and gradually reduces as the stream order increases. When plotted against the corresponding order, the logarithms

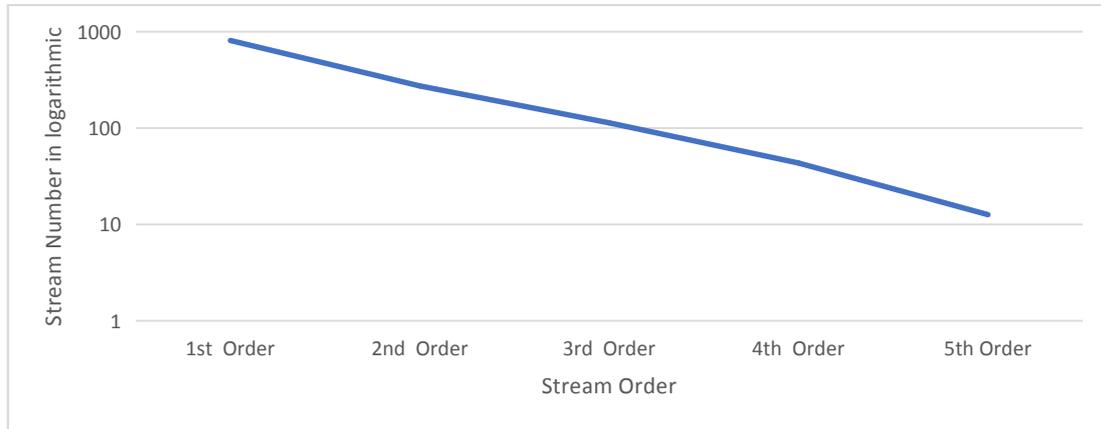


Figure 4. Stream number against Stream order.

of the number of stream segments of different orders generally lie on a straight line <sup>[12]</sup>. In a first-order stream, the overall length of stream segments is greatest, and it decreases as stream order increases. The 1st and 2nd order streams in the study region are longer than the 3rd, 4th, and 5th order streams, respectively (Table 1). The stream length evaluation in Table 1 reveals that stream length reduced as stream order increased.

$$Rb = Nu/Nu+1 \quad (1) \quad [13]$$

Nu = Total no. of stream , u is the segments of order

Nu +1 = No. of segments of the next higher order

$$Rb=5432/742=7.32$$

$$Rb=742/232=3.20$$

$$Rb=232/87=2.67$$

$$Rb=82/28=2.93$$

$$\text{Mean Bifurcation ratio} = 16.12/4= 4.03$$

### 3.2 Areal Morphometric Parameters

The length of a basin outline, which can be plotted and approximated using GIS software, is known as its perimeter. The basin area and characteristics were determined to be 625.61 km<sup>2</sup> and 307.98 km, respectively.

#### 3.2.1 Drainage density (Dd)

Drainage density (Dd) is defined as the length of streams per unit area divided by the size of drainage basins by Horton <sup>[14]</sup>. It is written as:

$$Dd = Lu/A \quad (2) \quad [12]$$

Where, Dd= Drainage Density, Lu=Total stream length of all orders, A= Area of the basin

A low drainage density implies porous subsurface strata and is a defining property of coarse drainage, which often exhibits values less than 5.0. <sup>[8]</sup> observed that when basin relief is low, low drainage density is preferred, and vice versa. The lower Orashi River basin has a Dd of 2.00 km/km<sup>2</sup>,

indicating that the studied region has a porous or permeable underlying material with moderate drainage and low relief.

#### 3.2.2 Drainage Texture (Tx)

Climate, lithology, vegetation, rainfall, soil type etc. all influence drainage texture, which is a measure of relative channel spacing in a fluvial-dissected landscape <sup>[14]</sup>. Drainage density in the studied area is 20.84 km/km<sup>2</sup> (Table 2), indicate very fine texture.

$$Tx = Nu/P \quad (3) \quad [12]$$

#### 3.2.3 Stream Frequency (Fs)

The total number of stream segments per unit area within a basin is referred as the stream frequency (Fs) <sup>[12]</sup>. The frequency of streams in the watershed has a positive connection with drainage density, meaning that as drainage density rises, stream population rises as well. Climate, vegetation covering, rock, run off intensity, rainfall, infiltration topography and soil types, and slope all influence drainage frequency and density. The Fs of the basin is 10.44 (Table 2) indicate surface runoff leading to flooding.

$$Fs = \sum Nu/A \quad (4) \quad [12]$$

$\sum Nu$  = Total No. of stream segments of all order and A = Area (km<sup>2</sup>)

#### 3.2.4 Form Factor (Rf)

This component indicates the magnitude of a basin's flow in a particular region <sup>[14]</sup>. The form factor is always smaller than 0.754. (This number indicates a completely circular watershed.) A lower form factor results in a longer basin, while a higher value results in a circular basin. Larger peak flows with a shorter duration occur in basin with high form factors, while in extended watersheds with low form factors, flatter peak flows with a longer duration

occur. The Rf value for the study region is 0.24, which is more in line with the basin circular form than with its elongated shape. Where Rf is the Form factor, A is the area of basin (km<sup>2</sup>) and Lb<sup>2</sup> is the square of basin length.

$$Rf = A/Lb^2 \quad (5)^{[14]}$$

A = Area (km<sup>2</sup>) and Lb<sup>2</sup> = Square of Basin Length

### 3.2.5 Elongation Ratio (Re)

The ratio of the diameter of a circle of the same size as the drainage basin to the greatest length of the basin is known as the elongation ratio (Re) <sup>[13]</sup>. The elongation ratio is found in a wide range of climatic and geologic types, with values ranging from 0.6 to 1.0. (0.9-0.10), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (0.5-0.7). (0.5-0.7). A circular basin discharges runoff more efficiently than an elongated basin <sup>[15]</sup>. The value varies from 0.6 to 0.8 for high relief areas, and values near to 1.0 indicate areas with very little relief and a circular form <sup>[8]</sup>. Table 2 shows that the research area Re is 0.15, indicate very low sloped, little relief and Circular shape.

$$Re = (2A/\pi)/Lb^2 \quad (6)^{[13]}$$

A= Area (km<sup>2</sup>) and Lb = Basin length (km)

### 3.2.6 Circulatory Ratio (Rc)

The Circulatory Ratio is the relationship between the area of a basin and the area of a circle having the same diameter as the basin perimeter <sup>[16]</sup>. The Rc value of the basin is 0.08, indicating an elongated shape, low runoff flow, and high subsoil permeability. Rc is an integer with no dimensions. Its low, middle, and high levels correspond to the tributary basins' youth, maturity, and elderly stages of life <sup>[17]</sup>.

$$Rc = 4 * \pi * A / P^2 \quad (7)^{[19]}$$

Pi = 3.14, A = Area (km<sup>2</sup>) and P<sup>2</sup> = Square of the perimeter (km)

### 3.2.7 Length of Overland Flow (Lg)

This is length of water over the ground before it is concentrated into the mainstream, affecting the drainage basin hydrologic and physiographic dynamics <sup>[12]</sup>. Infiltration (exfiltration) and percolation through the soil, both of which fluctuate in time and area, have a substantial impact on Lg <sup>[18]</sup>. The high Lg value suggests that precipitation had to travel a considerable distance before concentrating in stream channels <sup>[19]</sup>. In this study, the length of overland flow is 1.00 km, indicating decreased distance runoff in the study area.

$$Lg = 1/2Dd \quad (8)^{[12]}$$

### 3.2.8 Basin Length (Lb)

The longest dimension of a basin to its main drainage channel is called basin length. When compared to a more compact basin, the greater the length of the basin, the lesser the likelihood of flooding. Varied workers have given different interpretations to basin length (Lb) by Schumm <sup>[13]</sup> and Cannon <sup>[20]</sup>. Lb is the longest length in the basin, measuring 50.84 kilometers from the catchment to the point of confluence.

### 3.2.9 Constant Channel Maintenance (C)

The 0.5 km long basin channel (Table 2) illustrates that structural factors have negligible impact on infiltration rates, surface runoff, less discharges, and watersheds.

$$C = 1/D \quad (9)^{[13]}$$

where D= Drainage Density

## 3.3 Relief Morphometric Parameters

These deal with the characteristics like as relief, relief ratio, ruggedness number, and so on. Relief Aspects is a subfield of geology.

### 3.3.1 Basin Relief (Bh)

The relief of a basin is determined by subtracting the height of the basin mouth from the elevation of the basin's highest point, and then multiplying the result by 100. Strahler <sup>[21]</sup> in order to understand the geomorphic qualities of the basin, as well as the development of landforms and drainage systems, the flow of surface and sub-surface water, the permeability of the terrain, and the erosional properties of the terrain, it is necessary to first understand the basin geomorphic qualities <sup>[8]</sup>. In the research, the value of Bh is assessed to be 31.00 meter (Table 2). Because of this, the low relief value of the basin indicates that infiltration is strong and runoff is little.

$$H = Z - z \quad (10)^{[21]}$$

### 3.3.2 Relief Ratio (Rh)

It's a ratio with no dimensions. Rh ratios above a certain threshold indicate a steep slope and high relief, and vice versa. In steeper basins, run-off is often faster, resulting in more peaked basin discharges and increased erosive power <sup>[22]</sup>. The Rh values is 0.0014 (Table 2), suggesting very low relief and a very low slope, implying that it is less susceptible to sudden erosion. Where Rh is the Relief ratio, H is total relief, Lb is Basin length .

$$Rh = H/Lb \quad (11)^{[13]}$$

### 3.3.3 Relative Relief

The relative relief of a basin is calculated by dividing the difference in height between the highest and lowest points in the basin (H) by the perimeter of the basin (P) [23,24]. As a consequence of relative relief being an essential morphometric measure employed in the overall evaluation of the morphological features of terrain in the research area, the result is 0.007 (Table 2) in the study region [23,24].

$$\text{Relative relief} = H/P \quad (12) \quad [24]$$

### 3.3.4 Ruggedness Number (Rn)

When the maximum basin relief (Bh) and drainage density (Dd) of a unit are multiplied together, the result is called Rn. It is a measure of the irregularity of the surface. Whenever the size of both variables and the slope are both big, the roughness number reaches an exceptionally high level of value [21]. In the current basin, the roughness number is 0.14, indicating that it has a very low slope and is less prone to severe erosion.

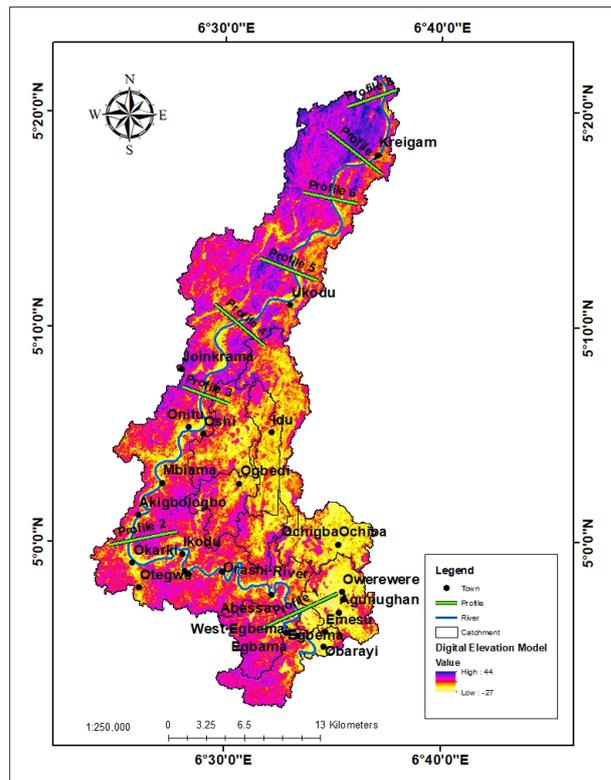
**Table 2.** Morphometric Characteristics of lower Orashi River Catchment (Areal Aspects and Relief)

S/N	NAMES	VALUES
1	Area (A)	625.61 km <sup>2</sup>
2	Perimeter (P)	307.98 km
3	Stream Order	5
4	Mean Stream Length	0.19 km
5	Mean Stream Length Ratio	1.4
6	Mean Bifurcation Ratio	4.03
7	Drainage Density (Dd)	2.00 km/km <sup>2</sup>
8	Stream Frequency (Fs)	10.44
9	Drainage Texture (T)	20.84 km/km
10	Basin Length (Lb)	50.84 km
11	Circulatory Ratio (Rc)	0.08
12	Elongation	0.15
13	Form Factor (Ff)	0.24 km/km
14	Constant channel maintenance(C)	0.5 km
15	Length of overland flow (Lg)	1.0km/km
16	Basin relief (Bh)	31.00 m
17	Relative relief (R)	0.07 km
18	Relief ratio (Rr)	0.0014
19	Ruggedness number (Rn)	0.14

### 3.4 Topographic Changes

The results of the analysis of the geomorphological sequence in the profiles established in Figure 5 show

that the terrain has a low elevation in Figure 6a at 6h, and the river shows that the width of the river decreases in various topographical changes like the shows Figure 6a, 6b, 6c and 6e due to accretion. Figures 6f, 6g and 6h show that the depth of the river is almost at the same elevation in the land area due to the deposition of sand due to lack of maintenance by dredging the river, resulting in flooding during the season. rains. According to Eteh and Okechukwu [3] proper planning and management of the flood situation is essential to avoid major effects on flooding during the rainy season in the Niger Delta. It is therefore important to study the terrain of the area by investigating the hydrological property and the depth of the river to monitor the statue of the area, especially in terms of the drainage system, making decisions for the construction of structures mainly along the riparian communities and including roads, agriculture, buildings construction, Because most of the topography has poor drainage system due to lack of planning, structures and roads are built on drainage canals, resulting in flooding during the rainy season. Therefore, government need to plan and manage the waterway because is critical as flood has come to stay. But we must manage our rivers and protect the safety of our citizens.



**Figure 5.** Digital Elevation model showing Cross section profile



Figure 6a. Profile 1

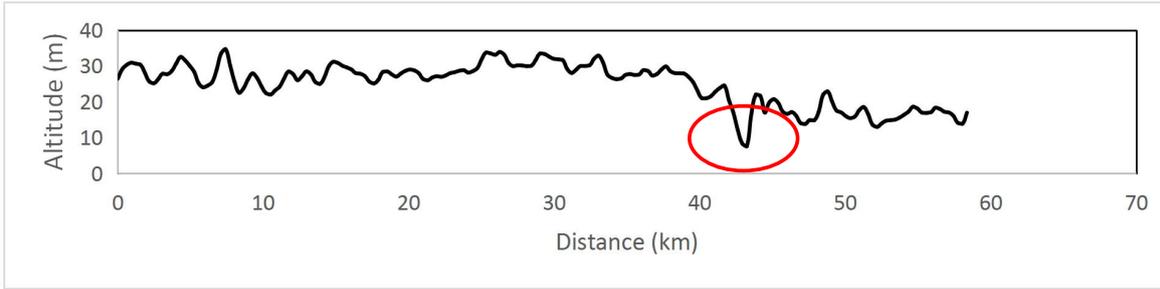


Figure 6b. Profile 2

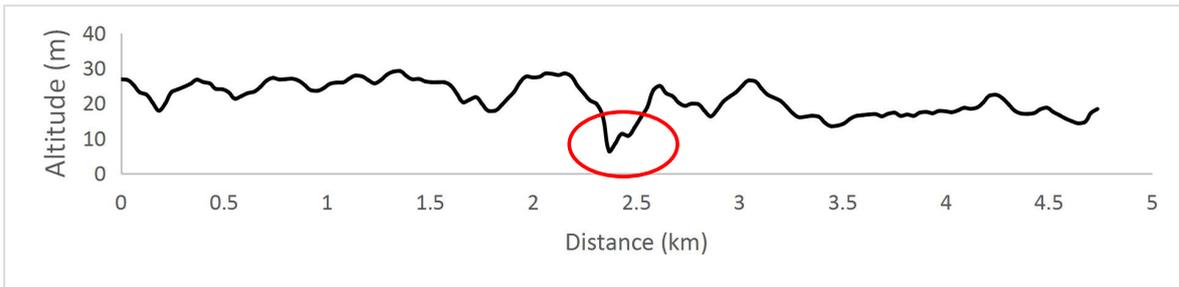


Figure 6c. Profile 2

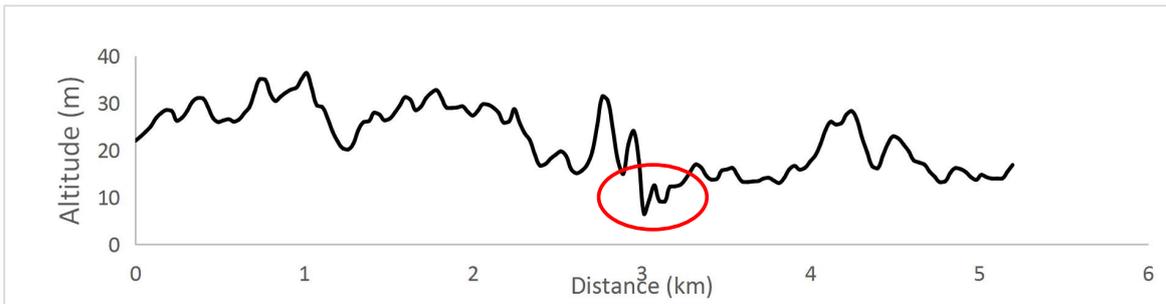


Figure 6d. Profile 3

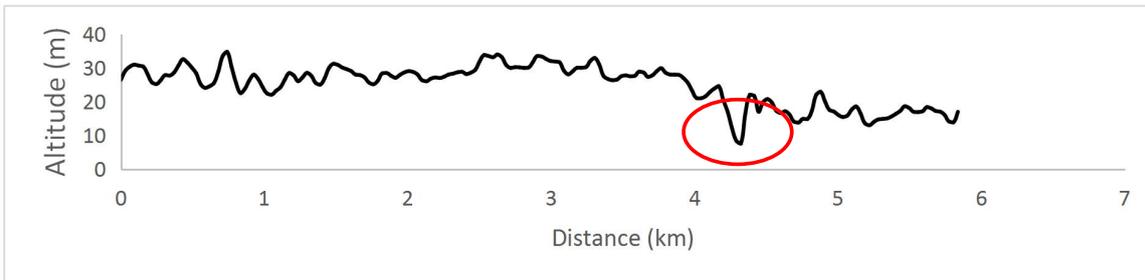
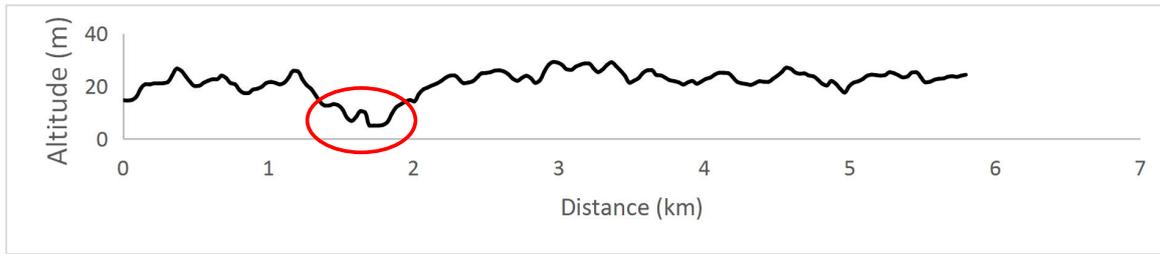
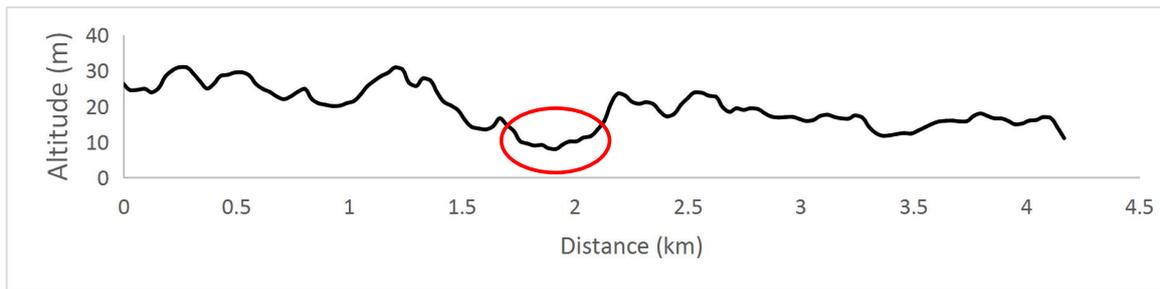


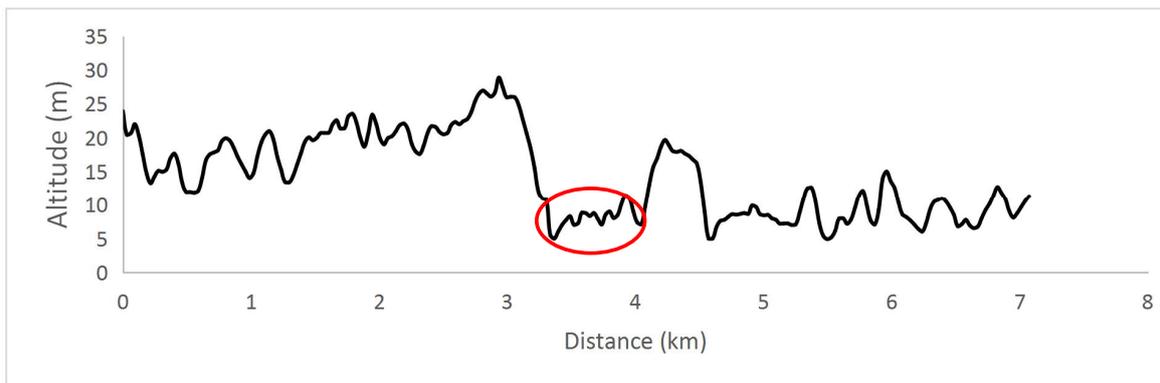
Figure 6e. Profile 4



**Figure 6f.** Profile 5



**Figure 6g.** Profile 6



**Figure 6h.** Profile 7

#### 4. Conclusions

The property of drainage basins contains the size, shape, geology are vital indices for predicting environmental hazards especially Flood and erosion. These indices are crucial for predicting environmental threats, particularly erosion and flooding. They reveal the rate at which rain reaches a major river, as well as the frequency and severity of flooding. This research demonstrates how drainage basin configuration has a major impact on the occurrence of environmental hazards in a given area. The narrow outlets of Orashi River elongated basins restrict runoff velocity and cause long-lasting flood peaks, yet their near circular form promotes rapid runoff circulation and the drainage system is dendric type with higher bifurcation ratio and low relief in lower Orashi River possess a great threat for erosion and flooding due to the topography has a poor drainage

system resulting from low altitude in river and land area as a result of sand deposited due to a lack of maintenance in low Orashi River.

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#### Conflicts of Interest

The authors declare that they have no conflict of interest.

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