GEOINFORMATICS CHARACTERISATION OF DRAINAGE SYSTEMS WITHIN MUYA WATERSHED IN THE UPPER NIGER DRAINAGE BASIN, NIGERIA

Innocent E. BELLO1 Ayila ADZANDEH2 Momoh, L. RILWANI3

1 Mission Planning, IT & Data Management Department, National Space Research and Development Agency (NASRDA), Obasanjo Space Centre, Airport Road, PMB 437, Garki 2, Abuja, Nigeria. innobello@gmail.com, iebello@nasrda.net
2. Regional Centre for Training in Aerospace Surveys (RECTAS), United Nations ECA, Off Road 1, Obafemi Awolowo University Campus, Ile-Ife, Osun, Nigeria. ayila@rectas.org
3. Geography & Regional Planning Department, Ambrose Alli University, Ekpoma, Edo State, Nigeria. mrlrilwani@yahoo.com

ABSTRACT

This paper presents a geoinformatics-based modelling of Muya watershed drainage characteristics in the Upper Niger drainage basin in Nigeria. DEM was generated from topographic map, while the network of streams was generated from combined topographic map and Landsat image. Analysis was undertaken in ArcGIS/Arcview environment. Basic drainage parameters measured and analysed included stream order, stream length, stream pattern, flow direction, bifurcation ratio, drainage density, stream frequency and flow accumulation. The results show that the watershed drains an area of about 97.23km², and 468km of stream length of all segments with a mean length of 1.32km. 3D elevation model indicates a range of 198.12m-320.04m above sea level. The study also reveals that the streams generally flows in east-west direction with a total of 355 number of stream segments. The modelled drainage system in the watershed are categorised as ‘streams’ and not ‘rivers’ because the highest order observed was the 4th order. The percentage composition of each stream order are 1st order (186, 50.7%), 2nd order (75, 21.1%), 3rd order (59, 16.6%) and 4th order (41, 11.6%) respectively with 1st order streams accounting for more than half of all stream segments studied. Bifurcation ratio analysis shows that 1st order streams are approximately twice and half as those of the 2nd order; the ratio of streams of 2nd order to those of 3rd order are approximately one and one fourth; while the ratio of 3rd order to 4th order is approximately one and half. The watershed has a low drainage density of 4.81km of coarse texture, stream frequency of 3.65km and drainage intensity of 17.56km respectively. Analysis of flow accumulation using the Hydrology Modeller tool in ArcGIS/ArcView environment reveals that flow accumulation is more within the East-West stretch of the watershed and decreases in the North and South direction from the mid latitude. The implication of the results for water resources and environmental management in the basin were highlighted.

KEYWORD: Drainage Basin, Watershed, Geoinformatics, Watershed, Drainage Pattern, Drainage Analysis

1. INTRODUCTION

Information on water quality and their variation is urgently needed for national and local policies and management strategies, as well as for United Nations (UN) conventions on climate and sustainable development, and the achievements of the Millennium Development Goals -MDGs- (ITC, 2010). The study of watersheds, therefore, becomes very significant. The United States Geological Survey (USGS) in (Perlman, 2013) defines a watershed ‘as an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. Ridges and hills that separate two watersheds are called the drainage divide. The watershed consists of surface water: lakes, streams, reservoirs, and wetlands - and all the underlying ground water. Larger watersheds contain many smaller watersheds. A drainage basin
Drainage systems and the hydrologic morphometry of any nation is a veritable resource among the core dataset usually captured when producing a topographic map of a country. Nigeria like many other coastal countries of the world is blessed with a plethora of drainage systems of varied river morphometry. The flood events in Sokoto in 2010, Ibadan in 2011, Lagos in 2011, Jimeta in 2012, Niger-Benue floods of September-October in 2012 which affected over 13 states: Niger, Benue, Kogi, Edo, Ondo, Anambra, Ebonyi, Imo, Delta, Bayelsa, Rivers States, etc, have caused huge socio-economic loss to Nigeria (Ojigi, 2012). This is due largely to the impact it has on the natural and built environment. Unlike flooding in Nigeria, drainage system and watershed studies have not received much attention as expected. The available drainage basins in the country are limited to the main eight catchments and their sub-basins. The local people within such watershed often suffer from various environmental problems associated with watershed mismanagement unknowingly. Just like other basins, the Upper Niger catchments streams are not captured in detail hence there is limited information about the various smaller rivers and their watershed. However, sufficient knowledge of the spatial pattern and distribution of these watersheds are inevitable if proper planning of water resources are to be undertaken.

In the last five years, there has been increase in the reported and examined cases of flooding as a result of perceived climate change resulting in excessive rainfall and river bank overflow. For instance, it is reported that flood disasters account for about a third of all natural disasters; by number and economic losses (Nwilo, et al., 2012). Thus, Nigeria is no exception to countries that experienced flooding in recent time. Issues often appraised centers on vulnerability, risk and impact(s) of flooding without attendant evaluation of the drainage pattern of the affected area. Most often, emergency response in terms of the distribution of relief materials ensued in the event of flood hazard without examining the population at risk, terrain characteristics, and stream order vis-a-vis flow pattern, flow accumulation and river discharge in making informed decision in resettlement and resource allocation. Whenever such is ever done, it is haphazardly executed with myopic view of the main 8 drainage catchments without recourse to other smaller ones that may have a contributing role in the main watershed. An effective and more reliable method to achieve the above is to map other smaller watersheds by developing and implementing a digital database of the hydrological resources based on geoinformatics approach (GIS, Database and Remote Sensing) in addition to fieldwork data to account for the anthropogenic aspect of the use of the various drainage systems or watershed. Geographic Information Systems (GIS) are well-structured databases for handling large quantities of spatially varied data within a watershed (see Luzio, et al., 2004; Xu, 2001; and Tsirihrntzis, et al., 1996) because it provides a digital representation of watershed characteristics used in hydrologic modeling (DeVantier and Feldman, 1993). Complementarily, the application of Remote Sensing has also brought about rapid mapping of watershed from satellite images from both active (e.g. Rader) and Passive (e.g. multispectral) sensors, hence the application of both approaches in this study.

In this study, therefore, we examined one of the sub-watersheds within the main Upper Niger catchment area as a proof of concept in the understanding of the drainage pattern of most Nigeria Rivers. In scope, we limit our study essentially to examining the terrain (elevation) characteristics of the studied watershed, the area covered, drainage composition and the distribution of streams (including stream order, length, bifurcation ratio, drainage density, stream flow, drainage intensity, flow direction and accumulation) based on Strahler principle. The specific objectives are to: (i) examine the terrain characteristics and extent of the watershed; (ii) analyse the drainage system composition of the identified watershed; and (iii) carryout stream flow analyses (flow direction and accumulation).

1.1 Study Area

The Nigeria drainage system or basins are divided into eight (8) catchments and the two major rivers in the country are the Benue and Niger rivers respectively (Nwilo, et al., 2012). Muya Watershed is located within the Upper Niger drainage basin between latitudes 9° 46'59.94" N and 9° 52'45.73"N above the equator and Longitudes 6° 30’0.02”E and 6° 39’52.5”E of the Greenwich meridian respectively. Figure 1a shows the location of the study area in the Upper Niger catchment as
part of the eight (8) river catchments or watersheds of Nigeria. 1b shows the delineation and streams with the Upper Niger catchments produced on Risk and Vulnerability Studies and Mapping in Nigeria sponsored by FMEnv and (UNDP) while figure 1c shows the detailed map of the study area showing all the stream network within the watershed.

Figure 1a: Nigeria Drainage Map Showing study area as part of Upper Niger River Basin. (Source: Modified from NIWA, 2001).
Figure 1b: Major drainages within Upper Niger River Basin, Niger State, Nigeria
(Source: Risk and Vulnerability Studies and Mapping in Nigeria Sponsored by FMEnv and UNDP. Downloaded from http://nigeriafews.net)
2. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Studies on watershed and stream ordering systems abound all over the world as a result of the relevance of water to the sustenance of life. Depending on the outflow point; all of the land that drains water to the outflow point is the watershed for that outflow location and watersheds are important because the stream flow, and the water quality of a river are affected by things, human-induced or not, happening in the land area ‘above’ the river-outflow” (Perlma, 2013). In this subsection, we present a succinct conceptual overview of a watershed and stream order pattern in addition to some relevant studies that had been carried out in the subject area.

An understanding of the concept of a “stream”, “river”, “stream order” and “stream segment”, its delineation, classification and quantification, functionality and usages is a fundamental requirement in appraising drainage system and the water resources of an area. Ogunkoya (2013) remarked that “there is some ambiguity concerning the terms ‘stream’ and ‘river’. It is however generally accepted that all natural flowing water channel segments of ‘order 1’ to ‘order 4’ should be designated as streams while channel segments of higher orders are rivers.” This principle hold true in this study. Thus, the method of classifying stream size (including length and order) is important to geographers, geologists, hydrologists and other scientists because it gives them an idea of the size and strength of specific waterways within stream networks- an important component to water management (Briney, 2013). For example, “As water travels from headwater streams toward the mouths of mighty rivers, the width, depth, and velocity of the waterways gradually increase. The amount of water they discharge also increases. These physical characteristics dictate the types of aquatic organisms that can inhabit a stream” (Kreger, 2004).

Geomorphologists rank the relative importance of stream segments in the network by assigning a numerical order value to each segment using one of four ordering systems (Strahler, Horton, Shreve, and Scheidegger) (MicroImages, 2007). Stream order, that is, a measure of the relative size of streams and the smallest tributaries, usually perennial are referred to as first-order (1st) streams, followed by a second order beginning where two 1st orders meet to form the second order, in that...
progression until the water empties into another major river (see figure 2).

![Figure 2: Strahler’s Stream Ordering System](image)

Similarly, a “stream order” according to McGraw (2013) is defined as “the designation by a dimensionless integer series (1, 2, 3 ...) of the relative position of stream segments in the network of a watershed. The stream order hierarchy was officially proposed in 1952 by Arthur Newell Strahler, a geoscience professor at Columbia University in New York City, in his article “Hypsometric (Area Altitude) Analysis of Erosional Topology”. The article, which appeared in the Geological Society of America Bulletin outlined the order of streams as a way to define the size of perennial (a stream with water in its bed continuously throughout the year) and recurring (a stream with water in its bed only part of the year) streams” (Briney, 2013).

When using stream order to classify a stream, the sizes range from a 1st order stream all the way to the largest, a 12th order stream (Briney, 2013). A first order stream is the smallest of the world's streams and consists of small tributaries (See Ogunkoya, 2013; Olomo, 1997, p45). These are the streams that flow into and "feed" larger streams but do not normally have any water flowing into them. In addition, first and second order streams generally form on steep slopes and flow quickly until they slow down and meet the next order waterway. Often, small drainage basins or watersheds combine with one another, creating larger and larger networks of drainage basins. All of these combined drainage basins are together referred to as a watershed, while area between two drainage basins is known as drainage divide (kidsgeo.com, na).

The importance of classifying stream order allows scientists to more easily study the amount of sediment in an area and more effectively use waterways as natural resources. Stream order also helps Geomorphologists, Biogeographers, Ecologist and Biologists in determining the morphometry and the types of life that might be present in the waterway. This is the idea behind the River Continuum Concept (Kreger, 2004); a model used to determine the number and types of organisms present in a stream of a given size. Different types of plants for example can live in sediment filled slower flowing rivers like the lower Mississippi than can live in a fast flowing tributary of the same river (Briney, 2013). As previously argued, Frissel, et al., (1986) opined that the
classification of streams and stream habitats is useful for research involving establishment of monitoring stations, determination of local impacts of land-use practices, generalization from site-specific data, and assessment of basin-wide, cumulative impacts of human activities on streams and their biota. For example, in comparison, there is the possibility of non-conformity of two basins, especially when Horton’s law of stream order is applied as in the case of the drainage network characteristics in Luleha-Ikin in Bendel State (now Edo/Delta) as observed by Imoroa, (1989).

The nature of a given watershed is vital to the interaction of man-environment and the ecological balance of the ecosystem. Consequently, reiterating the rationale behind drainage analysis in watershed studies, Olomo (1997) argued that “drainage analysis is concerned with water and the effect on landforms and before 1945 drainage analysis was based on qualitative and descriptive tradition of W.M. Davies. He further asserted that channel configuration (of stream order) which made up the shape, size and internal composition of a drainage basin was the focus of R.E. Horton’s work of 1945. Furthermore, literature reveals that drainage patterns are classified on the basis of their form and texture while the shape or pattern develops in response to the local topography and subsurface geology properties (WCVA, 2013). To Olomo (1997), the most important of these properties which can be studied from topographical maps are stream order, stream length, bifurcation ratio (linear properties), drainage density, stream frequency and drainage intensity (areal properties). One can then argue, in principle, that drainage channels develop where surface runoff is enhanced and earth materials provide the least resistance to erosion. Similarly, the texture is governed by soil infiltration, and the volume of water available in a given period of time to enter the surface (WCVA, 2013). Figure 3 shows the major drainage pattern a given stream could assumed depending on the above characteristics and the general geomorphic formations of a watershed.

![Figure 3: Model of Common Drainage Pattern](http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/fluvial_systems/drainage_patterns.html)
GIS which entails the capture, storage, retrieval, manipulation, analysis and presentation of georeferenced spatial information and its application in watershed mapping or automatic catchment delineation (see ITC, 2010), has brought about some added advantage especially in data management and analysis of drainage systems. Similarly, GIS and Remote Sensing applications in Hydrologic Modeling is drastically improving the way and manner in which researches on watershed are conducted (see for example, DeVantier and Feldman, 1993). Some specific applications include: the definition and connection of hydrologic elements (Hellweger and Maidment, 1999); hydrologic as well as river water quality modelling (Tsihrintzis, et al., 1996: Xu, et al., 2001); integrated hydrologic modelling and water resources management (Wang et al., 2005; Savabi, et al., 1995: Warwick and Haness 1994). For example, in the work of Warwick and Haness (1994), a hypothetical watershed was constructed to test the efficacy of using the ARC/INFO geographic information system to provide spatially related input for the U.S. Army Corps of Engineers HEC-1 hydrologic model. The ARC/INFO system performed the tedious and time-consuming tasks of spatial averaging (basin areas, average runoff, curve numbers, etc.) quite well. Difficulties, however, were encountered in using the TIN (triangulated irregular network) module to accurately assess average rainfall intensities. The inaccuracies associated with the computation of average basin rainfall intensities were quantified by using a defined rainfall pattern imposed upon a simple geometric shape (equilateral triangle) and were found to be directly related to the number of prescribed contouring intervals. The highest density of contouring intervals (0.010 nm) resulted in only a 0.55% over-estimation. The number and location of rain gages relative to watershed boundaries imparted a significant error (approximately ± 10%) to average rainfall estimation.

In drainage characterisation, Digital Terrain Models (DTM) has been employed for decades as a support in several analyses (Godone and Garnero, 2013): such as drainage parameters analysis (Olomo, 1997), morphometric parameters computing (Anselmo and Godone, 1976) and watershed analysis (Collins, 1973). DeVantier and Feldman (1993) paper summarized past efforts and current trends in using digital terrain models and GIS to perform hydrologic analyses. Three methods of geographic information storage were discussed: raster/grid; triangulated irregular network; and contour-based line networks (these analyses were also adopted in this study). The computational, geographic, and hydrologic aspects of each data storage method were analyzed. The use of remotely sensed data in GIS and hydrologic modeling was reviewed. Lumped parameter, physics-based, and hybrid approaches to hydrologic modeling were also discussed with respect to their geographic data inputs. Finally, several applications areas (e.g., floodplain hydrology, and erosion prediction) for GIS hydrology were described.

From the foregoing conceptual framework and review of related work, the inevitability of GIS and Remote Sensing application in watershed management are well document and thus exemplified in this study.

3. RESEARCH METHODOLOGY

Data Requirement: Topographic Map (Minna NW, sheet 164) and 2002 Landsat Satellite Image.

Data Processing

Data processing involved:
- Geometric Correction of Topographic map (figure 4) and overlay on satellite image
- Contour extraction and stream network update
- Database population – (contour number & stream order)

Data Analyses

Data analyses entailed:
- Use of 3D Analyst for terrain modeling
- Use of Spatial Analyst for Stream Order, Stream Length, Stream pattern, statistical Analysis: Bifurcation Ratio,
4. RESULTS AND DISCUSSION

4.1 Terrain Characteristics, Drainage Pattern and Watershed Delineation

The watershed was mapped by delineating the boundary of the entire area drained by all the streams within the watershed from source to mouth (Figure 5). The stream network shows that the watershed has a “dendritic drainage pattern” in nature. Dendritic drainage pattern is a “branching, treelike drainage pattern. In areas of uniform rock, with little distortion by folding or faulting, the rivers develop a random branching network similar to a tree (WCVA, 2013), hence the name dendritic.
Figure 5: Drainage Network overlay on Contour within Muya Watershed

Figure 6: Drainage overlay on DEM of Muya Watershed & Area Coverage (left) Vector, (right) Raster

The total landmass or area (figure 6) drained by the watershed is 97.23km$^2$ while the elevation range (Figure 7) is between 650ft and 1050ft above mean sea level. Results of figure 6 and 7 indicate that the highest region is to the Eastern part of the watershed while the lowest region is to the North-Western part of the watershed. The elevation differences show that all the streams contribute to the major stream flowing towards the Western part of the watershed. And this could also affect the degree of surface water accumulation of the receiving higher order streams down the valley.
4.2 Drainage Composition Analysis (DCA)

Drainage composition refers to the numbers and lengths of stream and tributaries of different sizes of orders regardless of their pattern (Olomo, 1997; Horton, 1945). Results of DCA are presented below.

4.2.1 Stream Order Analysis

Figure 8 shows the stream order system of Muya watershed based on the Strahler’s principle earlier examined in the introductory and literature review sections of this study. As also shown in Figure 9, in the application of the Strahler’s stream order principle to hydrology, each segment of a stream or river within a river network was treated as a node in a tree. Therefore, when two 1st order streams come together, they form a 2nd order stream. Similarly, when two 2nd order streams come together, they form a 3rd order stream. Streams of lower order joining a higher order stream do not change the order of the higher stream. Thus, if a 1st order stream joins a 2nd order stream, it remains a second-order stream. It is not until a 2nd order stream combines with another 2nd order stream that it becomes a 3rd order stream.
Figure 8: Muya watershed stream ordering system. Note the highest order is 4th.

Figure 9 shows that based on the origin (sources) of the 1st Order stream and the preceding flow pattern mainly in all direction toward the western part of the watershed, there is the likelihood of much water inflow and accumulation in the event of excessive rainfall due to overland flow from the higher regions of the study area. The major factor responsible for the nature of stream flow and drainage pattern is the geologic formation on one hand and the terrain (topography) characteristic on the other.

Based on the stream order principle earlier reiterated by Ogunkoya (2013, p4), since the highest stream order within Muya watershed is the 4th order, we can conclude that the watershed is made up of streams only. Thus, the entire watershed is made up of major contributing streams to another main river, meaning, there is no “RIVER” within the watershed but “STREAMS” because none met the criteria as only 5th order streams and above that qualifies as a “RIVER”.
4.2.2 Stream Number and Bifurcation Ratio Analysis

The stream number, that is, the Strahler number or Horton–Strahler number of a mathematical tree is a numerical measure of its branching complexity. From Table 1, we can conclude that the total stream number within the watershed is 355 (that is 180+75+59+41).

Bifurcation Ratio ($R_b$) is the ratio of the number of segments of a given order to that of the segments of the next higher order (Olomo, 1997).

\[
R_b = \frac{N_{u+1}}{N_u} + 1
\]

i.e, \( R_1 : R_2 : R_3 : R_4 : \ldots : R_n \) order

Where \( u \) is the order designation of a stream segment, where \( N \) is the number of segment of that particular order.

Based on the above formula, the bifurcation ratio of Muya Watershed is calculated as shown in Table 1.

<table>
<thead>
<tr>
<th>Stream order ((u))</th>
<th>Number of Stream Segment ((N_u))</th>
<th>Percentage Composition of stream Orders ((%N_u))</th>
<th>Bifurcation Ratio ((R_b))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>180</td>
<td>50.7</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>21.1</td>
<td>180/75 = 2.40</td>
</tr>
<tr>
<td>3</td>
<td>59</td>
<td>16.6</td>
<td>75/59 = 1.27</td>
</tr>
<tr>
<td>4</td>
<td>41</td>
<td>11.6</td>
<td>59/41 = 1.43</td>
</tr>
<tr>
<td>Total</td>
<td>355</td>
<td>100</td>
<td>-</td>
</tr>
</tbody>
</table>

(Source: Author, 2013)

The implication of Table 1 result is that the 1<sup>st</sup> order streams are approximately twice and half as those of the 2<sup>nd</sup> order while the ratio of streams of 2<sup>nd</sup> order to those of 3<sup>rd</sup> order are approximately one and one fourth. However the $R_b$ of order 3 and 4 is approximately one and half.

4.2.3 Percentage Compositions of Stream Order and Stream Length Analyses

In terms of percentage composition of each stream order within the watershed, Table 1 above shows that the 1<sup>st</sup> order streams are more than half (50.7%) of the total stream segments within the watershed while, as expected, the 4<sup>th</sup> order ranks the least (11.6%).
Consequently, the stream length is the distance from source to mouth of a given stream segment. Therefore, the total stream length is the sum of all segments of streams within a given watershed. As shown in figure 10, the total stream length within the watershed is 468km with a mean length (468/355) of 1.32km. The 1.32km stream length, usually among the shortest within the watershed, reaffirms the earlier findings that the watershed area is made up of mainly 1st order streams (see figure 8, 9 and Table 1 respectively).

**Drainage Density (Dd) Analysis**

The formula for calculating drainage density (Dd) is given as:

\[ Dd = \frac{\sum L}{A} \]

Where \(\sum L\) is the total length of all stream segments within an area and \(A\) is the Sample area.

*Therefore, \(Dd = \frac{468}{97.23} = 4.81\)*

The implication of the above result is that there are 4.81 kilometers of channel for every 1 kilometre of land surface. The drainage density of Muya is, therefore, said to be low thus having coarse texture based on the drainage density classification scheme provided by Olomo (1997, p49). The above result is a reflection of the rock type, relative ease of infiltration of precipitation into the ground and the nature of vegetal cover within the study area.

**Stream Frequency (Fs) Analysis**

The formula for calculating Stream Frequency (Fs) is given as:

\[ Fs = \frac{\sum N}{A} \]

Where \(\sum N\) is the total number of stream segments and \(A\) is the Sample area.

*Therefore, \(Fs = \frac{180+75+59+41}{97.23} = \frac{355}{97.23} = 3.65\)*

**Drainage Intensity (Id) Analysis**

Drainage Intensity is computed as the product of drainage density and the stream frequency, as

\[ Id = \frac{\sum L \times \sum N}{A^2} \]

Where \(\sum L\) and \(\sum N\) are the total number of stream length and segments and \(A^2\) is the Sample Area.

*Therefore, \(Id = \frac{468 \times 355}{97.23^2} = \frac{166140}{9453.67} = (or 4.81 \times 3.65) = 17.56\)*

**4.3 Stream Flow Analyses**

**4.3.1 Flow Accumulation**

Flow accumulation in its simplest form is the number of upslope cells that flow into each cell and the Flow Accumulation tool calculates...
accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster (ESRI, 2010). The vector results are reiterated in this study based on the convincing visualization output. Figure 11 shows that most of the flow accumulation are within the central latitude of the watershed and thus decreases northwards and southward. This result is due to the geologic formation and the topography of the watershed which invariably determined the resulting drainage pattern observed in the study area.

4.3.2 Flow Direction

Based on ESRI (2010) definition and working algorithm, the direction of flow is determined by the direction of steepest descent, or maximum drop, from each cell.

Figure 11: Muya Watershed Flow Accumulation: (above) Vector, (below) Raster
The formula is given as: maximum drop = change in z-value / distance * 100

The distance is calculated between cell centers. If the maximum descent to several cells is the same, the neighbourhood is enlarged until the steepest descent is found. When a direction of steepest descent is found, the output cell is coded with the value representing that direction. Figure 12 (vector) shows that the streams flow toward the middle of the watershed in east-west direction. It can be argued that cells 64 and 4 have the highest contributing cells respectively to the watershed in terms of flow direction. Raster result (below) also shows the assignment of various cells based on flow direction resulting from the elevation model (DEM) of the watershed.
Similarly, Figure 13 shows the watershed flow accumulation within zones of filled flow direction. As observed, cells 64 and 4 have the highest flow accumulations within the various zones of flow direction.

5. SUMMARY AND CONCLUSION

In this study we examined the nature and characteristics of the drainage system: stream order, bifurcation ratio, stream number/segment composition, drainage density, stream frequency and drainage intensity; drainage pattern, flow direction and flow accumulation of Muya watershed within the Upper Niger Catchment of the Nigerian Basin. Using elevation information obtained from Topographic map covering the study area, the DEM was generated. The stream networks were likewise generated from combined topographic map and Landsat image of 2002 covering the same study area. The topographic map transparency was set at 40% to allow partial view of the area in satellite image. Since the topographic maps were produced in the late 1960s, the use of relatively current satellite data to update the stream network was inevitable. Stream ordering results shows that the 1st order streams are more than half (50.7%) of the entire streams. The bifurcation ratio result shows that the 1st order streams is twice and half more than the 2nd order stream while the 2nd order stream was about one and one quarter more than those of the 3rd order stream and the 4th order streams is about one and half ratio to those of the 3rd order. Since the entire streams are not up to the 5th order, we conclude that all the water bodies within Muya watershed are streams and could not be adjudged as rivers (see Ogunkoya, 2013, p4). The watershed has a low drainage density of 4.81km of coarse texture, stream frequency of 3.65km and drainage intensity of 17.56km respectively. Using the Hydrology Modeler tool within ArcGIS/ArcView, the general flow direction and flow accumulation of the watershed was analysed. It is concluded that the flow accumulation
is more within the East-West stretch of the watershed and decreases North and southward from the mid latitude. The entire stream could be said to flow westerly and the drainage pattern is dendritic in nature.

It is however recommended that for specific use of the watershed, detail study on the physico-chemical properties and the geotechnical parameters of the watershed be studied to provide additional baseline information necessary for effective utilization of the water resources.

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