STREAM PROCESSES AND DYNAMICS IN THE MORPHOLOGY OF THE DENSU RIVER CHANNEL IN GHANA.

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ABSTRACT:

The Densu River Basin has come under serious threat from a number of human activities such as farming, lumbering, sand winning, animal grazing, dam construction among others. These activities have significant implications on the fluvial processes of the river such as erosion, braiding and flooding. The study examined the current fluvial processes and landforms and the dynamics in the river morphology since the 1960s. This was done by analysing existing survey maps and air photographs. This involved air photo interpretation and digitizing of old topographic maps which were overlaid on each other to identify changes in the river's course. These analyses were backed by field studies to verify findings from these secondary data sources. Fluvial processes in the river channel include erosion and braiding which is hastening the siltation of the Weija Lake, a dam built at the river's mouth. The study revealed that the lower section of the river channel was characterised by ox-bow lakes, meanders and sand dunes. Channel morphology in the middle and upper courses was that of incised river valleys with rapids, water falls and pot-holes. It was also noticed that, the construction of the Weija Dam has led to the drying up of the Sakumo Lagoon below the dam as water flow into the lagoon is regulated. The reduction of fresh water flow into the lagoon has promoted salt mining in the delta declared as a RAMSAR Site. Another major change at the mouth of the river has been the sealing – off of one distributary of the river due to the accretion of a sand bar westwards from Grefi to Bortianor. This change in the river's course is due to the low flows at the mouth as a result of the dam hence the river lacks the requisite energy to carry away sand dunes deposited at its mouth.

1. INTRODUCTION

River morphology is the shape or form of a river along its length and across its width. Transported materials are used in eroding a riverbed (degradation) and thus shaping its morphology. The transported materials are deposited (aggradation) either temporally or permanently along the course of a river when they can no longer be transported. Throughout geological history, rivers have altered their channels through erosion and deposition or human intervention.

The Densu River system is one of the coastal drainage basins of Ghana. Its floodplain and river channel have been dramatically altered by building and construction, installation of a dam, salt mining, grazing, channel incision and other fluvial processes. The river lies between latitudes 5°30'N to 6°20'N and longitudes 0°10'W to 0°35'W. The basin area is about 2488.41km^2 with an average length of 225.6km. Its main tributaries are the Kuia, Adaiso, Nsaki and Aprapon (Fig.1). The Densu Basin passes through three regions in Ghana namely Eastern, Greater Accra and Central Regions and falls under ten district administrations. The basin plays a critical role in the socio-economic development of the many towns and satellites villages dotted within it. Most of the urban centers such as Koforidua, Nsawam, Suhum (Fig.1) among others get treated water from the Densu River. From its reservoir at Weija, 91,000m^3 of water a day is pumped to supply about 340,000 people in western Accra (Ghana Water Sewerage Company, 2003). Other small settlements also depend on untreated water from the Densu River and its tributaries.

The Densu Basin is also intensively used for the cultivation of both cash and food crops. Principal food crops cultivated within the basin are cassava, maize, yam, plantain, banana and cocoyam. Cash crops include cocoa, oil palm, papaya, pineapple, mangoes and citrus. Other land use activities include housing, sand winning, animal rearing, salt mining etc. These activities have seriously depleted the vegetative cover of the basin with hydrological and geomorphological implications such as flooding, soil erosion, siltation of the river channel and evaporation. In view of the above problems, the study investigated the hydrological and geomorphological processes within the river channel and how these processes are shaping the morphology of the river channel.

2. METHODOLOGY

The methodology took two forms. The first step involved a review of existing literature on fluvial geomorphology, hydrology, remote sensing and geographic information system. Secondary data such as topographical maps and air photos were sourced from appropriate agencies and institutions. Digitised drainage network, basin boundary and contours were obtained from the Centre for Remote Sensing and Geographic Information Services (CERSGIS) in the Department of Geography at the University of Ghana, Legon. Other data types such as roads, railway lines and settlements were on-screen digitized using ArcGIS 9.2 software. A digital elevation model or terrain of the catchment was produced using the contours sourced from CERSGIS.

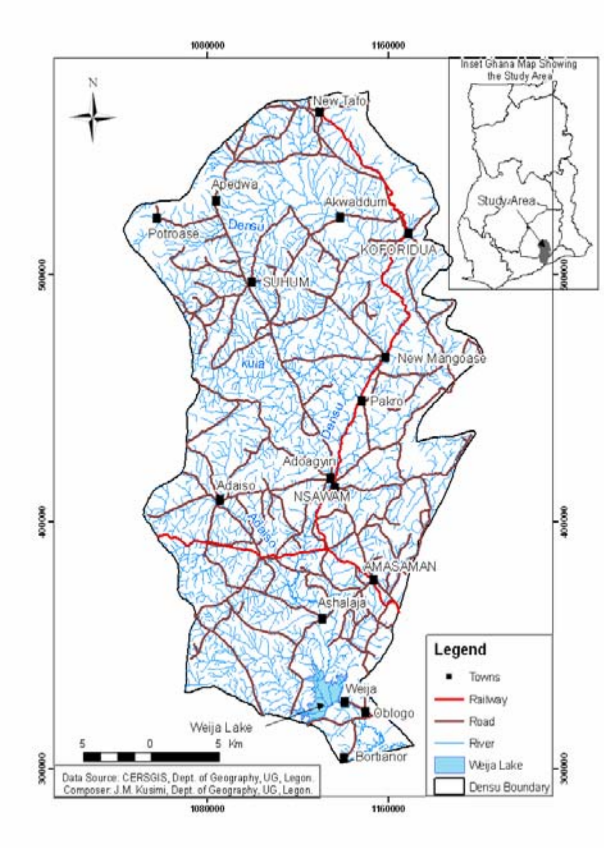

Figure.1: Map of the Densu Basin - Ghana

Topographical maps (1964, 1975, 1976 and 1996), and Aerial Photographs (1975) of the study area were acquired from Survey Department in Accra. These were analysed for morphological changes in the basin channel. Aerial photos were analysed using the mirror stereoscope (Curran, 1989, Barrett and Curtis, 1982). The longitudinal profile of the Densu was drawn from 1975 topographical map.

The catchment area of the Sakumo Lagoon was digitised from the topographical maps and the various layers overlaid on each other to determine the changing pattern of the lagoon from 1964 to 1996. Rainfall data from the 1960s to 2000 were also acquired from Meteorological Services Department, Accra to find out whether rainfall pattern over the years had any significant impact on the dwindling size of the lagoon.

The second step was primary data acquisition which included field survey and interviews to complement findings from maps and aerial photographs. An in-depth interview of the elderly of 70years and above was conducted to find out morphological changes that have occurred during their lifetime within Oblogo-Weija locality and other sections of the river. The interview also tried finding out the possible causes of such changes in the river channel. The sampling method was purposeful.

3. RESULTS AND DISCUSION

The study revealed that the profile of the Densu River has been undergoing degradation since the 1960s, degradational processes dominant in the upper and middle courses and aggradational processes in the lower course. Generally the longitudinal profile (Fig.2) can be termed graded, though not up to the ideal equilibrium parabolic profile concave to the sky, postulated by W.M. Davis (1902, in Geographical Essays) and other known geomorphologists. According to Davis, grade is a condition of balance between corrassion and deposition, between degradation and aggradation, which is brought about by the ability of the river to adjust its capacity. The stream is thus graded when these two forces are equal (Morisawa, 1968).

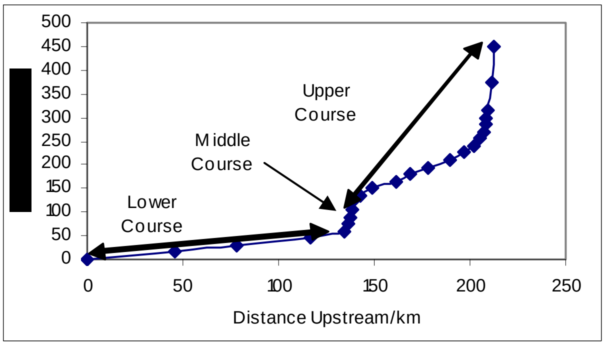

Figure.2: Long Profile of Densu River
Source: 1975 Topographical Map

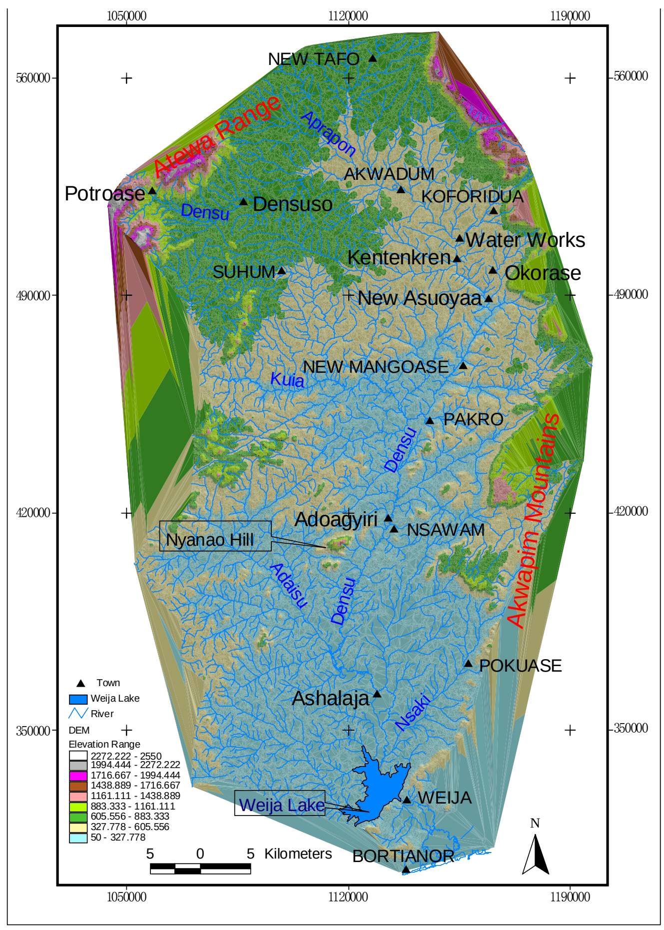

Figure.3: Digital Elevation Model of the Densu Basin

The profile of the River Densu is mainly of the lower course (mouth to New Asuoyaa) and upper course (Waterworks in Koforidua to the source) linked by a gorge from New Asuoyaa to Waterworks formed by the Akwapim Ranges (Fig.2 and 3). The middle section is primarily of irregular rapids. These rapids are outcrops of granites resisting the abrasional forces of the river. As a result of degradational processes, the riverbed at the mid-section has been degraded into two terraces of 2.35 and 1.05km of 42m high within the gorge. The gorge is characterised by three knickpoints of heights 12km at Okorase and 15km at Kentenkren giving rise to a Waterfall (Fig.2 and 3). Vertical erosion is dominant at this section due to granitic rocks embanking the valley, steep gradient (1 in 56.25) and increase in discharge

Characteristics of the upper course, the river channel is narrow but steep-walled, (Fig.3). This shape in the river channel is due to the relatively low gradient of 1 in 99.43 and low flows as compared to the middle course hence downcutting of the river valley will be lesser. Characteristic of the upper course (Potroase), potholes are found within the riverbed. These potholes are formed by the hydraulic force of running water and abrasion by bed load within weak structures (fractures, cracks, softer rocks etc) within the river bed. These potholes vary in sizes and depth. Average depth and width of samples measured in the field is about 30.9cm by 40cm.

At the lower course (Nsawam) the river channel is broad and nearly U-shape. The broad and flat bottomed nature of the river valley is due to a low gradient of about 1 in 1080.34, and coupled with sparse vegetative cover, high discharge and sediment load there is active lateral bank erosion during floods by hydraulic action, abrasion and mass wasting increasing siltation of the river bed), thus widening and flattening the river valley. From Nsawam to the mouth, Densu channel is characterised by meanders with well-defined channels and broad floodplains flowing over a relatively flat terrain except Nyanao Hill at Adoagyiri (Fig.3). The meanders are generally tortuous, incised and sinuous in form with sharp bends at certain sections. The outer edges of the meanders are abraded whiles the inner bends undergo deposition (lateral accretion) forming point bars and alluvial deposits especially at Nsawam. These bars are composed of a mixture of bed and suspended materials (force deposition hence ungraded/unsorted), which are vegetated on exposure. The primary activity of the river is bank erosion and deposition. A number of these meanders have been beheaded between Oblogo and the mouth, forming ox-bow lakes within the flood plain. Interview with people at Oblogo revealed that some of the ox-bow lakes were initially used as a fishpond when it contained enough water. It was also indicated that, these changes in the river system occurred in the mid 20th century affirming Hayward's (1967) findings that the changes in course at this section occurred between 1940s and 1950s.

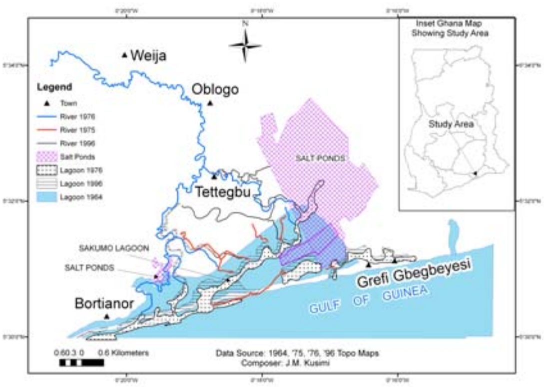

Figure.4: Overlays of the Sakumo Lagoon

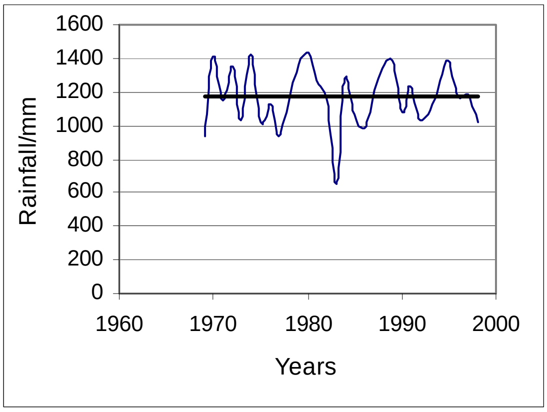

Figure.5: Annual Rainfall Distribution of Nsawam (1960-1998)

The river's delta has also been undergoing certain changes. The Sakumo Lagoon has been drying up since 1960s (Fig.4). It covered an average area of 10.16km^2 in 1964 reducing to 4km^2 (1975) and increased marginally to 5.66km^2 in 1976 and reduced again to 4.125km^2 in 1996 (*Topographical Maps*).

Rainfall amounts of four stations within the basin namely Nsawam, Koforidua, Kibi and Weija of years under review indicate a reduction in rainfall with a stable pattern over the periods in Nsawam and Koforidua and a falling and rising trend in Weija and Kibi respectively, (Fig.5 to 8).

Rainfalls have been reducing from 1974-'90s at all the stations indicated above. At Nsawam, it reduced from 1417.3mm (1974) to 1021.8mm (1975), increased marginally to 1122.9mm (1976) and farther reduced to 938.5mm (1977) with an average percentage reduction of about 33.78 over the period. Koforidua recorded 1439.7mm (1974), reduced by 19.70% and 33.73% to 1156.1mm and 954.1mm in 1975 and 1976 respectively. In general, average amount of rainfall reduction over the period is highest at Weija which is about 45.45%, very severe in 1976 about 47%. The only available data at Kibi in 1976 and 1977 showed a 15% reduction in rainfall. Also rainfall amounts in the second half of 1990s in all stations upstream Weija Lake has been dwindling particularly from 1995-1998. No data was available at Weija during this period. Specific percentage reductions in rainfall at the following stations were, 16% for Nsawam, 31.85% for Koforidua and 5.68% for Kibi between 1995 and 1996. Nsawam experienced a 26.39%, Kibi 27.16% fall in rainfall totals from 1996 to 1998. Koforidua was worst hit, 48% reduction during in the same period (Ghana Meteorological Services Department-Accra, 2003).

Though the construction of the Weija Dam has been the most significant cause of the reduction in size of the Sakumo Lagoon, the reduction in rainfall amounts over the period as explained above is a secondary factor, since before the rebuilding of the dam in 1976 the lagoon's size was less than half its original catchment. Other explanatory factors include indiscriminate farming and building along the river bank causing siltation and the encroachment on the Weija wetland for salt mining by Panbros Salt Mining Company. (Fig.4) Temperature rise due to climatic changes have also increase evaporation of the lagoon.
Evidence from the maps also shows that, Densu's mouth has been undergoing a westwards migration, contradicting

Hayward's (1967) eastwards movement. The right distributary of the Densu from Tetegbu had its mouth at Grefi (1964 Topograhical Map). This has been sealed-off since the reconstruction of the dam and both distributaries now discharge into the sea (Gulf of Guinea) at Bortianor (Topographical Maps 1975 and 1996). Average migration of this distributary is 6.7km. The embankment (Weija Dam) and the reduction in rainfall amounts coupled with a low gradient (about 1 in 2458.33) from Weija to the coast has promoted the westward coastal accretion of a bar sealing Densu's mouth at Grefi. This activity is quiet unusual, as most dammed rivers erode their mouths because such currents are often under-saturated with sediments. There are two possible explanations to this situation, either enough sediments are discharged into the ocean or the waves at the mouth are mainly constructional. The discharge of enough sediment into the ocean is more plausible from renew erosion downstream the dam since such currents are deprived of sediments. The reduction in discharge has resulted in aggradational and degradational processes downstream Weija Dam, with erosion deepening the channel bed and depositing materials in the river channel creating sand bars forming braided channels especially at Oblogo. This implies that much sediment will be entrained to the mouth.

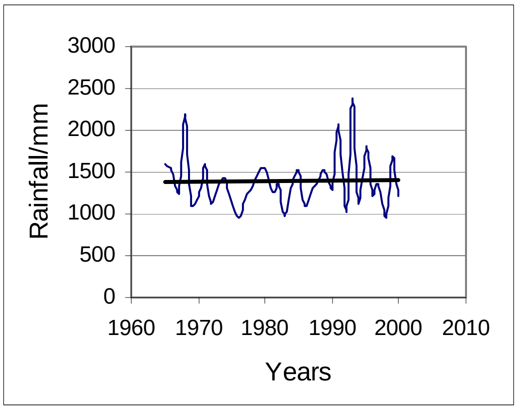

Figure.6: Annual Rainfall Distribution of Koforidua (1965-2000)

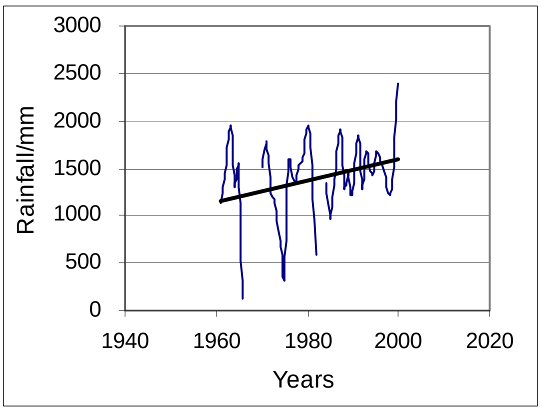

Figure.7: Annual Rainfall Distribution of Kibi (1961-2000)

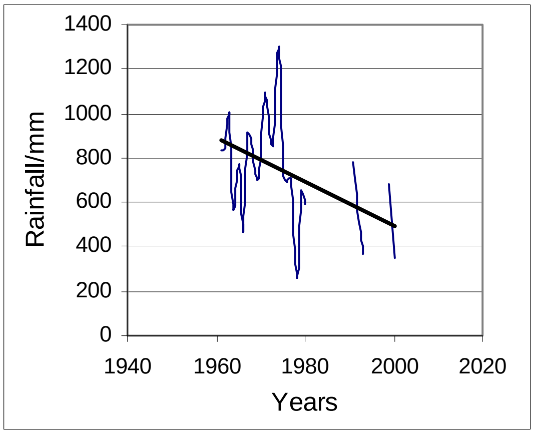

Figure.8: Annual Rainfall Distribution of Weija (1961-2000)

4. CONCLUSION

Like many other rivers, the Densu River channel is experiencing certain dynamics in its channel. The profile of the river is receding headward extending the lower section. In general the upper and middle sections are prone to degradational processes and the lower section by both aggradational and degradational processes. This has resulted in varied fluvial forms such as potholes, incised channels and irregular rapids in the upper and middle courses and meanders, ox-bow lakes and alluvial deposits in the lower section. The variation in channel morphology is attributed to the differences in gradient, fluvial processes (discharge) and physical elements such as vegetative cover and the underlying lithology of the river catchment.

Anthropogenic activities such as indiscriminate farming and salt mining at the Densu delta was found to be negatively impacting on the Sakumo Lagoon, causing it to disappear. The Weija Lake is also adversely affecting water discharge into the Sakumo Lagoon. The reservoir also accounts for the westward migration of the Densu mouth as discharge into the Gulf of Guinea is incapable of removing sand dunes deposited at its mouth by waves.

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