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Sand Dredging in Anyang River and its Implication on Morphological Structure in Edebom II, Nsit Ibom, Akwa Ibom State, Nigeria

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Abstract

This study focused on sand dredging in Anyang Nsit River and its implication on morphological structure in Edebom II, Nsit Ibom, Akwa Ibom State, Nigeria, a third order tributary of Kwa Iboe river basin, which entails the morphometric parameters, dredging induced hazards, measurement and calculation of hydraulic parameters at two high dredging sites, are related to the dynamic nature of the river channel. Digital Elevation Model (DEM) of the study area with resolution 30x30m was obtained from United States Geological Survey (USGS) and the river channel was delineated. With the aid of Arc GIS 10.3 software package and Erdas Imagine 9.2 software reprojection and the map was produced in the layout view on a scale of 1:187500. The linear, areal and relief aspects of the sub-catchment were derived using strings and constructed grid lines placed on the map, while morphometric parameters of the river channel were calculated using relevant statistical package. The hydraulic parameters (bank full width, mean depth, velocity) of the two dredging sites were measured in a period of four months (March-June). The results showed that hydraulic parameters of these dredging points have changed significantly within this period. The calculated channel discharge had increased by 10m3/s and 7.42m3/s respectively at the two dredging sites. A total of 26,804 tonnes of dry weight sand is dredged both manually and mechanically (hydraulically) between March-June, 2021 which is consistent with the assertion that sand dredging is responsible for the change in the channel morphology especially in depth and deformation of channel configuration parameters. It was recommended that sand dredging in Akwa Ibom should be monitored by the Ministry of Environment as a statutory responsibility to maintain morphometric parameters in Akwa Ibom State, Nigeria.

Keywords: Digital Elevation Model; United States Geological Survey; Hydraulically; Morphometric Parameters; Morphological Structure

Introduction

Sand is an aggregation of rock particles that is dredged for diverse uses globally [1]. Sand is unconsolidated sedimentary mineral material with a particle size between 1/16mm and 2mm. Silt and clay are progressively finer materials. Granules, pebbles, and boulders are progressively coarser particles that make up sediments called gravel [2]. Carbonate sand and mixed sand are deposits found in Kwa Ibeo River, Ikpa River and Cross River Basins and also in the various coastal valleys throughout the tropical region [3-8]. Over the years, sand is a pivotal geomorphological asset that is dredged in the coastal region of Kwa Iboe and Ikpa River Basin. The dredging processes seldom provoke geomorphic instability causing morphological deformation. Sand dredging is the removal of sand coastal basin and is used for all kinds of projects like land reclamations, the construction of artificial islands and coastline stabilization. The rapid rise in urbanization and construction of large-scale infrastructure projects are driving increasing demands for construction materials globally. It is estimated that between 32 and 50 billion tonnes of sand and gravel are extracted globally each year with demand increasing, especially in developing countries [9].

Nurhasan and Saputra [9] described dredging as a process of extraction of valuable minerals or other geological materials from the earth, usually from an ore body, lode, vein, seam, and reef or placer deposit. Generally, the Environmental Conservation Department identified three methods of extraction in relation to sand mining. Mechanical method which normally involves the use of construction machinery such as excavator, backhoe, bulldozer, etc. This method is commonly used in shallow rivers and for larger size deposits Hydraulic dredging which involves specially built equipment to dredge sand, either by excavation, dragging or suction. Normally used for large-scale and complex operations. Manual method that involves the use of manpower with hand shovel, scoop, etc. Normally used for small-scale operations or in conjunction with the mechanical method.

Rivers are a major source of sand and gravel; and the material produced by rivers tends to consist of resilient minerals of angular shape that are preferred for construction and allied uses. Sand dredging processes tend to affect coastal ecosystem with support that help in socioeconomic development. Increasingly, the negative environmental and social impacts of sand mining, calls for stronger regulation of dredging laws/edit [9]. To this end, there is a need to understand the level of morphological distortion occasioned by Sand dredging.

Generally, rivers are agents that configure earth surface through balanced processes of erosion and deposition. Every depositional action is a result of erosion somewhere; and every erosional action is because something was deposited before that time. A clue about dredging reveals that it is an activity that monitors and follows the flow regime and sediment yield of rivers over time following the demand for sand which is very expedient for different construction works. The river system is an open system; because it adjusts to carry the appropriate load of sediments in relation to discharge (its volume of flow) and velocity. The removal of material from a river channel can alter river hydraulics due to changes in the depth, width or slope of a river, which in turn can alter ecosystem processes [10].

This gives an explanation as to why a small channel, when opened up will adjust to carry more sediment leading to changes in its morphometric; and a drainage system exhibits a constant struggle toward an equilibrium among interacting variables of discharge (velocity, width and depth) transported load, channel shape and channel slope. Therefore, the resulting physical appearance and character of the river is a product of its boundaries to current stream flow and sediment regime [11]. Observations from previous studies show that river channel and floodplain dynamics and morphology affected by interaction between flows and sediments [12].

The morphology of a river channel is a function of the composition and erodibility of the bed and banks, vegetation, the availability of sediment, the size and composition of the sediment transported the rate of sediment transport, its deposition and regional aggradation or degradation due to subsidence or uplift. Excessive removal of sand may significantly distort the natural equilibrium of a stream channel. By removing sediment from the active channel bed, in-stream mines interrupt the continuity of sediment transport through the river system, disrupting the sediment mass balance in the river downstream and inducing channel adjustments like incision extending beyond the extraction site itself. The magnitude of the impact basically depends on the magnitudes of the extraction relative to bed load sediment supply and transport through the reach [13].

River engineering should be based on a prior knowledge of river science for building harmonious human-river relationships; and this is what is lacking in most developing areas of the world due to the absence or paucity of "river data" that would have assisted in regional development planning rive management processes [14]. Whereas, the goal of studying dredging and its consequents impacts on the basin parameters which determine the state of the river system in its quest to achieve dynamic equilibrium.

Therefore, Effective River management planning is governed by an understanding of river morphology and channel processes. Knowledge of the interrelationships between channel form and hydraulic variables are of great practical value in flood management, water resources planning, prediction of channel deformation, design of stable canals and intakes, irrigation and river improvement work [15]. Detailed morphological assessment also enhances the understanding of channel processes, its natural capability to adjust and depicts the inherent character of the river and possible response to human impact and it's provide the provides the basis to develop ecosystem-based management for the river [16].

From a hydrological and geographical point of view, the extent of anthropogenic activities within the area is very expedient. The findings of this study will address several issues within this spatio-temporal entity of dynamism within the ecosystem sustaining several natural and human activities within Anyang River a 3rd order tributary of Kwa Iboe River Basin.

Statement of the Problem

River morphology has been a subject of great challenge to fluvial geomorphologist mostly because the morphology of any river shows great variability and dynamic behavior [17]. Although rivers already exhibit dynamic behavior, this dynamism can be accelerated by human induced factors. Knowledge of river science for building harmonious human-river relationships; and this is what is lacking in most developing areas of the world. In developed countries, such as the United States of America, Britain and Europe, large scale river studies are conducted; spatio-temporal data and information for decades are made available for study and management strategies.

Sand dredging, which is described as the removal of sand from where they are deposited naturally, is needed in every aspect of construction, be it road or land restoration. Upon its enormous usefulness, it causes some environmental problems and morphological changes to the river when it is over-dredged and when dredging practices are unregulated.

However, not much systematic research has been carried out to unravel the intricate nature of dredging activity in Anyang River. Therefore, an in-depth quantitative approach towards dredging activity in the river and knowledge of how this human influence is acting within channel bed and boundaries shape the channel form.

Aim of the Study

The aim of this study is to evaluate the dredging of sand in Anyang River and its implication on morphological structure of the river over time with a view to;

- Examining morphometric properties of the river.
- Assess the amount of sand dredged within the period of study.
- Measure changes in discharge or stream flow of the river.
- Measure the hydraulic parameters to quantify the impact of dredging on river morphology.

Review of Related Literature

Rationalizing Sand Dredging

Riverbeds are major sources of clean sand. Sand and gravel deposited by fluvial processes are essential components of construction materials and are in almost all construction projects, including buildings, roads and highways, pipeline beddings, bridges, and airports. The importance of these materials has resulted in aggressive dredging to meet needs of new construction as well as rehabilitation of aging infrastructures [18].

For inland waterways transportation of dredged sand from shipping channels is necessary to facilitate navigation. Sand is also dredged from rivers to replenish sand beaches or make sand bypassing projects in order to preserve structures and protect recreation industries. Underwater sand dredging is common on coasts throughout the world and some mining companies find that sand is noticeably replenished by natural sand movement sometimes in periods as short as a year or two. Excessive sand deposition can eventually lead to reduction in conveyance capacity of river leading to flood. Proper dredging of sand keeps the bed at the desired level. Thus, if dredging is not done, due to continuous deposition of sand, the depth of river may get reduced. This will result in flooding of water and loss of properties. Dredging sand from rivers and its distribution has become an industry giving job opportunities for thousands across the globe. According to an estimate, sand mining provides direct employment opportunities to over 60,000 registered laborers in the Kerala state of Kenya [19].

Sand Dredging and Variants

Dredging is the removal of material (sand, gravel, fine sand) from seabed/riverbed (river or sea) using a dredge (floating equipment) [20]. According to Udosen [21], dredging is the action of dragging a dredge or similar device to pick up or clean the bottom of a body of water. It consists of the excavation of soil or alluvium under water (lakes, rivers, streams, canals, estuaries, marine channels, etc.) As sand is loose detrital sediment whose grains are mostly composed of quartz between 1/16 mm and 2 mm, sand dredging is an activity that consists of extracting loose detrital sediment whose grains are mostly composed of quartz between 1/16 mm and 2 mm from the bottom of a body of water. Depending on the tools or equipment used in sand mining, there are several variants Adjagbo [22], namely:

- Artisanal sand extraction: a dredging technique that is done by hand from the time the sand is removed to loading. It is practiced in bodies of water,
- Semi-artisanal sand extraction: the sand is taken with a shovel and is directly loaded into the vehicles engaged in the trenches. It is the form of sand exploitation observed in open quarries on the continent; and
- Industrial or modern sand extraction: a form of industrial sand dredging where the operation consists of picking up the bottom of a watercourse and removing the sand with specialized machinery.

Impacts of Sand Dredging

Conceptually, there can be direct and indirect impacts of sand dredging both on and off river ecosystems. Direct impacts are those in which the extraction of material is directly responsible for the impact to the ecosystem, such as due to the loss of floodplain areas or removal of gravel, cobble or other habitat that is recognized as underpinning a specific ecosystem processes. Indirect impacts are related to ecosystem changes that are promoted due to physical changes in the river system resulting from sand extraction.

Studying the spatial concentration of rock minerals mining on the Lower Silesia region in Poland, Abraham and Nyetiobong [23] concluded that in the context of regional spatial policy of the study area, increase of rock minerals mining results in growth of regional economy but also leads to intensification of environmental and social problems. The first are associated with pressures to increase production which is often in conflict with the requirements of nature protection and wellbeing of local populations. The second with growth of road transport of rock minerals and their products, which in turn results in deterioration of roads due to large volumes of rock minerals transport, decrease of road transport safety and discomfort of citizens.

Geomorphological and Hydrological Impact

One of the principal causes of environmental impacts from in-stream dredging is the removal of more sediment than the system can replenish [13]. Even without morphological study of the impacts of instream sand and soil mining has on riverbank erosion, it is now established Udosen and Etok [24] that when the rate of sand extraction exceeds the replenishment rate, significant and potentially irreversible changes occur in the hydraulic conditions and channel stability. The removal of material from a river channel can alter river hydraulics due to changes in the depth, width or slope of a river, which in turn can alter ecosystem processes [24].

Head cutting mobilizes substantial quantities of streambed sediments which are then transported downstream to deposit in the excavated area and locations further downstream. In gravel-rich streams, effects downstream of mining sites may be short-lived when mining ends, because the balance between sediment input and transport at a site can re-establish itself relatively quickly.

Effects in gravel-poor streams may develop rapidly and persist for many years after mining has finished. Regardless of downstream effects, head cutting in both gravel-rich and gravel-poor streams remains a major concern. Head cuts often move long distances upstream and into tributaries, in some watersheds moving as far as the headwaters or until halted by geologic controls or man-made structures.

Bio-ecological Impact

Dredging which leads to the removal of channel substrate, resuspension of streambed sediment, clearance of vegetation, and stockpiling on the streambed, will have ecological impacts. Impacts to the biological resources include removal of infauna, epifauna, and some benthic fishes and alteration of the available substrate [25]. This process can also destroy riverine vegetation, cause erosion, pollute water sources and reduce the diversity of animals supported by these aquatic habitats. Fish in the dredging area can accumulate with higher concentration of trace metals in their tissues. Byrnes and Hiland [26] the residue of the radioactive mineral such as monazite and zircon can be detrimental to local biota.

These impacts may have an effect on the direct loss of stream reserve habitat, disturbances of species attached to streambed deposits, reduced light penetration, reduced primary production, and reduced feeding opportunities [27]. People interviewed in mining area of East Konga of Iceland indicated loss or reduction of farmlands as a major impact of gravel mining. Other significant impacts of gravel dredging in the area obtained as views include pits serving as breeding grounds for mosquitoes and spread of other diseases, erosion and loss of vegetation, loss of economically important trees, as well as roots of conflicts [28].

Environmental and socio-economic impacts of sand dredging

The available information on the different bio ecological and socio-economic impacts of sand dredging covers more than 98% of the studies carried out in the marine environment. The remaining 2% mostly concern information on the lagoon environment [29,30], even if this information is very superficial and deserves to be deepened. The ecological impacts of sand dredging are multiple. They are interconnected and often result from the first physical modifications of the environment [31]. Many authors around the world have addressed the issue. Indeed, Maya [32] and Saviour [33] have pointed out that mining and dredging regulations in developing countries are often established without scientific understanding of the consequences, and projects are carried out without environmental impact assessments. The lack of appropriate scientific methodology for sand extraction is said to be one of the causes [10,33-35]. Accordingly, this has led to indiscriminate sand extraction, while weak governance and corruption have led to widespread illegal mining. The sand trade is a lucrative business, and there is evidence of illegal trade as in the case of the influential mafias in India. Several other authors Velegrakis, Ballay, et al. [19] have gone in the same direction, emphasizing the lack of adequate information on sand extraction or dredging activity, which limits its regulation in many developing countries. Similarly, access to data is difficult and data are not standardized. Collaboration or coordination between marine scientific research institutions and the marine aggregates industry is limited.

Sand Dredging and Watershed Responses

The dynamics of possible responses in a fluvial system to disturbances are often complex and unpredictable [36]; this according to Schumm [37] termed complexity or complex response. Additional traits of the complexity of fluvial systems important to establishing and understanding cause-effect relationships are singularity, divergence, and convergence [37]. Singularity acknowledges that well-established generalizations may not be applicable for site-specific predictions because of unexplained (or unknown) variations at a site [38]. Convergence is the condition where different processes (causes or stressors) can result in the same response (effect). Divergence is the condition where the same stressor (cause) can yield different responses (effects). In this case, two watersheds may respond differently (divergently) to a similar problem [39]. There are many individual natural and anthropogenic stressors that can affect fluvial systems. The source of many stresses is within the watershed, but others, such as climatic change, are due to outside factors. Changes in some situations are local in nature and subtle [40]. At the most basic level, the altered hydrology category includes any individual stressor that may affect pathway, rates, frequency, or location of water movement in a watershed [41]. This change in hydrology may be due to specific stressors such as forestry practices, withdrawal wash water discharge, storm runoff, and dredging activities from improper sand and gravel operations which can increase the turbidity of streams. Any stressor that may affect the availability and transport of sediment falls in the altered sediment budget category. While basin-scale stressors are limited to the two general categories above, an additional category of stressor is included for channel-scale stressors-altered channel [42]. This category includes individual stressors that directly affect the stream channel, such as dredging, trail crossings, channelization, and trampling of banks by grazing animals [43].

Sand Budget

In general, sediment budget is defined as the material transport volume balance for a selected segment of the coast or river. The elements of the budget are processes that increase (sources) or decrease (sinks) the quantity of sand in a defined control volume [44,45]. Determining the sand budget for a particular stream or catchment requires site-specific topographic, hydrologic, and hydraulic information. This information is used to determine the amount of sand that can be removed or mined from the area or environment without causing undue erosion or degradation, either at the site or at a nearby location, upstream or downstream [46]. In-channel or near-channel sand-and-gravel mining changes the sediment budget and may result in substantial temporal and spatial changes in the channel hydraulics [47]. Minimization of the negative effects of sand-and-gravel mining requires a detailed understanding of the response of the channel to mining disturbances. Decisions on where to mine, how much and how often require the definition of a reference state, i.e., a minimally acceptable or agreed-upon physical and biological condition of the channel as well as the sand budget [48]. Determining the sand budget for a particular stream reach requires site-specific topographic, hydrologic, and hydraulic information. This information is used to determine the amount of sand that can be removed from the area without causing undue erosion or degradation, either at the site or at a nearby location, upstream or downstream.

In-channel or near-channel sand-and-gravel mining changes the sediment budget and may result in substantial changes in the channel hydraulics. These interventions can have variable effects on aquatic habitat, depending on the magnitude and frequency of the disturbance, mining methods, particle-size characteristics of the sediment, the characteristics of riparian vegetation, and the magnitude and frequency of hydrologic events following the disturbance.

Temporal and spatial responses of alluvial river systems are a function of geomorphic thresholds, feedbacks, lags, upstream or downstream transmission of disturbances, and geologic/physiographic controls. Minimization of the negative effects of sand-and-gravel mining requires a detailed understanding of the response of the channel to mining disturbances.

Dredging – River Flow Nexus

Hydraulic digging makes use of the erosive working os water flow. For instance, a water flow generated by a dredge pump is lead via suction mouth over a sand bed [49]. The flow will erode the sand bed and form a water mixture before its enters the suction pipe. Hydraulic digging is mostly done with special water jets. Hydraulic digging is mostly done in cohesion-less soils (sediments) such as silt, sand and gravel. Mechanical digging by cutting edges of dredging equipment is applied to cohesive soils. This entails that before any dredging activity is done. There should be a proper study into the nature of the river to ascertain the right dredge equipment to be used. This is to be done if there must be sustainable river ecosystems before and after every dredging activity. Hydraulic dredgers are best adapted to lift sediments from the river bed with a strong suction strength to gather sediments mixed with water for easy transport; therefore. It is easy to say that hydraulic dredgers are the most adapted dredgers for the dredging process.

The transport of the dredged sediment can be done hydraulically or mechanically. Either continuously or discontinuously (Table 1).

	Hydraulically	Mechanically
Continuously	Transport via pipeline	Transport Via conveyor
Discontinuously		Transport via grab, ship, car

Source: Vlasborn [49]
Table 1: Showing how dredgers transport sediments

The deposition can be done in the simple ways by opening the grab, turning the bucket or opening the bottom doors in a ship. Hydraulic deposition happens when the mixture is flowing over the reclamation are or dump site. The sand will settle while the water flows back to the river through a run way designed properly and embanked with bags of sand to stop fine sand in solution from flowing back with the water. Dredging can have these functions integrated or separated. The choice of the dredger for executing a dredging operation depend not only on the above-mentioned functions but also on the conditions such as accessibility to the site, weather and wave conditions, required accuracy and so on. There are mechanical and hydraulic dredgers and they include (Table 2).

Mechanical	Hydraulic
Bucket ladder dredger	Plain Suction dredger
Grab or clamp shell dredger	Barge unloading dredger
Hydraulic cranes (back hoe and front shovel)	Cutter suction Dredger
	Bucket wheel Dredger
	Trailing suction hopper dredger

Table 2: Types of Mechanical and Hydraulic Dredgers
Source: Vlasborn [49]

The Concept of Hydraulic Geometry

The concept of Hydraulic geometry was formed by Leopold and Maddock [50] as a remodeling of the Regime theory of Lancey. Hydraulic geometry involves the quantitative description of the channel cross section size and shape, fluid flow properties and sediment transport characteristics in relation to the discharge being conveyed by the channel [51].

The adjustment of channel morphology and hydraulics in response to change in discharge has been considered in two different contexts namely; at-a hydraulic geometry and downstream hydraulic geometry.

At-a-station hydraulic geometry describes hoe channel geometry and floe hydraulics change as discharge increases at an individual cross section over time. In other words, at-a-station hydraulic geometry describes how the increase in discharge is accommodated and depends on the channel shape and the resistance to flow. Thus, dynamics of river (erosion, transport and deposition) are assumed to be static.

Downstream hydraulic geometry describes how spatially increasing discharge enlarges and shapes the channel and alter stream flow properties in the downstream direction of the river. The downstream hydraulic geometry is determined by the way in which self -forming (alluvial) river systems are established and maintained via erosion, transport and deposition of sediments by the water flowing through the system. In downstream hydraulic geometry, channel geometry is assumed to be the result of the dynamic equilibrium established between the channel morphology and the formative discharge (a single discharge that over a long period of time would theoretically produce the same channel geometry as the natural long-term hydrograph). Leopold and Maddock [50] represented the hydraulic geometry relation as a power function equation.
The equations are as follows:

$W = aQb$ (1)
$D = cQf$ (2)
$V = kQm$ (3)

The variables w, d, and v are the parameters width, mean depth and mean velocity, respectively. The coefficients or intercepts are represented by a, c and k. The exponents or slopes are represented by b, f and m.

Based on the continuity equation where Q=(w)(d)(V), the product of the respective coefficients (a)(c)(k) equals one, and the sum of the exponents (b + f + m) equals one Udosen [52].

Apart from its importance to hydrology and fluvial geomorphology, hydraulic geometry as a concept has been utilized in the researches of different fields and have been shown to have practical values in area of canal design, layout of river draining works irrigation, hydro power production, river improvements work, impact assessment and planning resources etc. [15].

The Theory of Equilibrium Channel Morphology

In its simplest and most general form, it states that, if left undisturbed, rivers will establish some stable combination of morphological elements for a given discharge of water and sediment. Any disturbance to this equilibrium channel morphology will set in motion processes that will return the channel to its stable form and pattern. Any change in the character of fluid discharge will set in motion changes to establish a new state of channel equilibrium in a manner dependent on the degrees of freedom of channel adjustment and on the nature of the adjustment processes.

A river conveying a given discharge possesses the potential of at least eight significant degrees of freedom for change (A.S.C.E. Task Force report, 197lc): width, depth, sediment caliber, sediment discharge, velocity, slope, boundary roughness and platform. It follows that it is necessary to specify as many processes linking these variables to fully characterize this fluvial system. The search to identify these process equations has constituted a major effort by river scientists during this century.

Three particular processes are thought to provide obvious candidate equations: flow continuity, flow resistance, and sediment transport. The exact nature of the corresponding process equations is the subject of much debate. The general character of the remaining five processes is even less well understood.

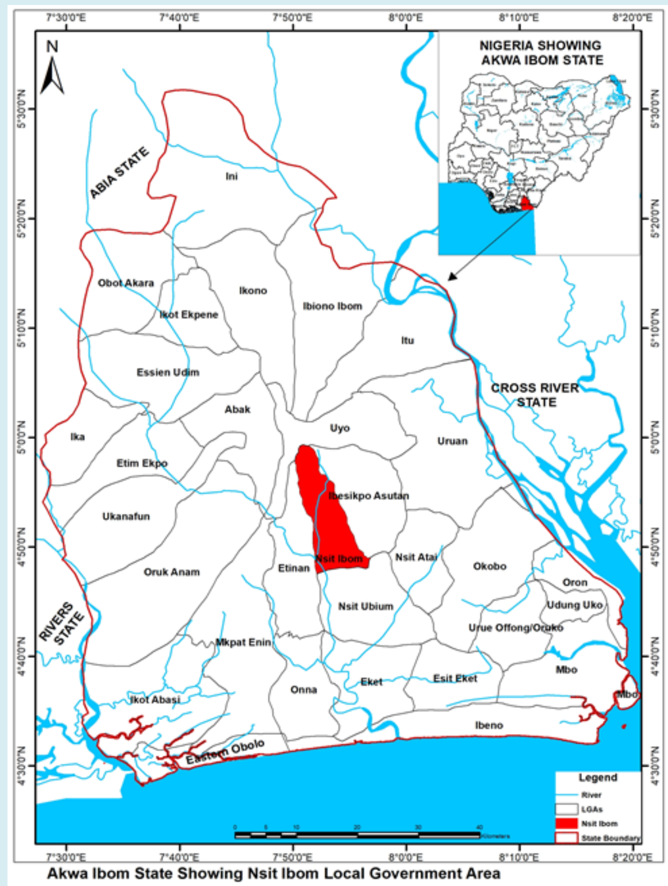
Perhaps one of the best-known attempts at closure of a somewhat simpler set is that of Leopold [53]. They postulated two further "processes" (actually probable conditions) to the three listed above: a tendency for a river to expend equal power per unit bed area and another tendency towards equal power expenditure per unit channel length (minimum work rate). Although these two conditions allow closure and yield a supposed average hydraulic geometry, they are nevertheless; probability statements rather than process equations unique solution simply are not possible. Indeed, the two conditions are mutually exclusive.

Materials and Methods

Study Area

Nsit Ibom share boundaries with Ibesikpo/Asutan, Etinan, Nsit Ubium, and Uyo local government areas, the people of Nsit Ibom are of the Ibibio ethnic extraction. Its geographical location is 4°53′0″N 7°54′0″E.

Nsit Ibom comprises the following important communities: Afaha Offiong, Edeobom, Oboyo Ikot Ita, Oboetim Ikot Ekong, Obio Okpok, Obo Ntong, Ikot Obok, Obo Etuk, Ikot Enwene, Asang and Okukok. It has two sub clans which are Asang and Mbiaso (Figure 1).

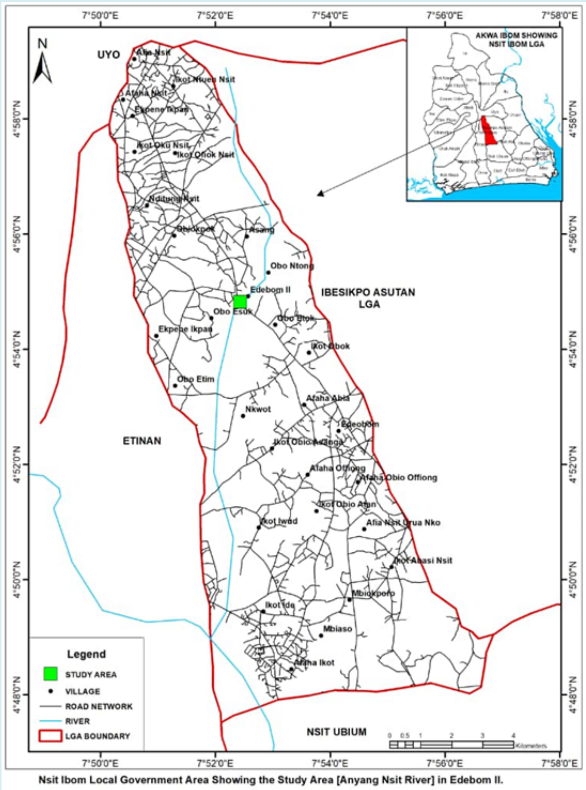


Source: State Survey

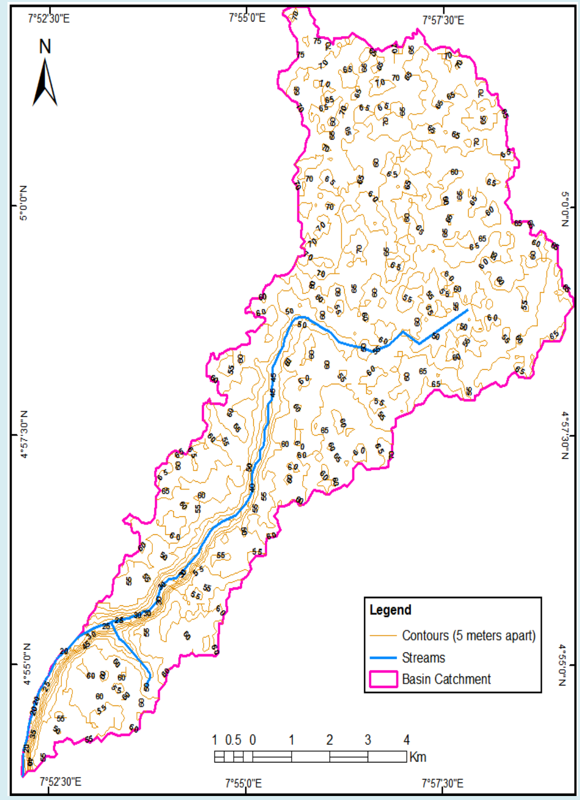
Figure 1: Akwa Ibom State showing Nsit Ibom Local Government Area.

Farming is a key economic activity in Nsit Ibom LGA with crops such as Oil palm, Cassava, yam, and cocoyam grown in the area. The area is also a hub for fishing with the LGA's rivers and streams being rich in seafood. Other important enterprises undertaken by the people of Nsit Ibom LGA include Trade and the making of canoes and fishing nets.

The physical relief of the Anyang Nsit Stream is basically flat. There are in some areas, valleys, creeks and swamps due to the influence of the Atlantic Ocean, the Qua Iboe and the Cross Rivers which traverse the length and breadth of the State. The community has basically two distinct seasons: The rainy season lasts from May to October, while the duration of the dry season is November to April. However, in the coastal areas, rain falls almost all year round. The harmattan, accompanied by the North-East Wind occurs in December and early January.



Source: State survey.
Figure 2: Map of Nsit Ibom L.G.A showing the Study Area.



Source: Analysed from USGS Satellite Image 30x30m.
Figure 3: Map of Anyang Sub-catchment

Research Design

Remote Sensing Data/ Data captured in GIS

Digital Elevation Model (DEM) of the study area with a resolution of 30 x 30 was obtained from the United States Geological Survey (USGS) and Base map of Akwa Ibom State was also acquired.

Having captured all the data into GIS environment, the data were edited georeferenced, followed by the creation of shape file. The River is digitized starting from the main trunk of the river to the fingertips followed by attribute table and layer extraction in Arc GIS 10.3 software package. Contour with specific interval of 5 meters was generated. Furthermore, Erdas Imagine 9.2 was used to re-project the digitized features to a common projection ad coordinates system. This was imperative to integrate data from various sources, scales and projections. In order to achieve this, the features were re-projected to World Geodetic System (WGS) 1984 Universal Transverse Mercator (UTM) zone 32. All the map components were added in the layout view and the map was printed on a scale of 1:187500. Global Positioning System (GPS), meter rule, stop watch, linen tape, float, digital camera, rope, to take field measurement for the study.

Methods of Data Analysis

Linear aspect

In this study, the manual and digital method of data analysis was used. The river area from the topographic map on a scale of 1:187500. The linear measurements of the basin were done with a strung and measured out with a ruler. With the derived data, some morphometric parameters were calculated. The map was printed on a large format paper and was covered with grid lines after the measurements of the length and width of the map.

Areal Aspect

The Area of the river was measured using the measure using the measure tool option of Arc GIS 10.3 software package. The morphometric parameters were calculated using relevant established equations and formulae.

Relief Aspect

The highest basin elevation (relief) and lowest basin elevations were read off from the topographic Map of the basin. The highest elevation was read off from the topographic map as the value of the highest contour elevation of the ridges forming the boundary of the river at Ikot Abasi LGA, while the lowest elevation was the elevation read from the topographic map at Obio Ntong.

Morphometric measurements

In order to carry out the measurement of the channel parameters, two (2) impacted locations of coordinate 007º 52.435' (point A) and 007º 52.421' (point B) sampling (high dredging areas along the river) were selected along the reach of Anyang River in Nsit Ibom Local Government Area of Akwa Ibom State. At both sampling location, the measurements taken included bank full width, mean depth, measurement of velocity and the calculation of discharge for the section of the river. The values for the mean depth of each cross section was measured by taking five measurements across the width then divide the sum of the depths by five to derive the mean depth. Velocity was measured using the float method, whereby for a known length along the reach, the average time taken for the float to move to the end of the known point is divided by the distance covered to obtain the velocity. A correction factor of 0.85 was applied to results to correct for inadequacies [54-56].

The above hydraulic parameters are measured in four (4) months to depict the change in the hydraulic geometry of these high dredging sites. Cross section profiles of the two (2) sampling locations of months are shown.

Results and Discussion of Findings

Basin Morphometric Parameters

In River Channel Studies, the knowledge of the morphometric parameters of the river is very important to unravel the geo-hydrologic dynamic nature of the river. The data on sediment dredged also presents detailed information on the changes that will occur within the river along the river bed which affects depth. Discharge values indicate the intricate relationship that exists between the basin parameters (width, depth, velocity). The Details of the calculated morphometric parameters and interrelationships, Basin parameters, sediments dredged with time are shown below (Tables 3-7).

Morphometric Parameters	Values
Area	65.7km*2
Basin Relief	55meters
Drainage density	0.23km/km*2
Drainage Frequency	0.045
Form factor	0.185
Constant of Channel maintenance	4.34
Stream Order	2
Mean Stream length	18.8km
Number of order 1	2
Drainage Intensity	0.01
Relief Ratio	0.0293
Ruggedness number	0.0126

Source: Analysed from USGS Satellite Image 30x30m
Table 3: Morphometric Parameters of Anyang River.

Table 3 shows the calculated morphometric Parameters which show the areal aspects and relief aspects of the Anyang River.

Discharge Measurements and Sediment Dredged

Month	Width(m)	Mean depth(m)	Velocity(m/s)	Discharge(m^3s^1)
March	16.36	1.0	0.40	6.54
June	17.11	1.5	0.48	12.32

Source: Researcher's Field Work.
Table 4: Anyang River Channel Parameters in the month of April and June at Point A.

Month	Width(m)	Mean Depth(m)	Velocity (ms1)	Discharge (m^3s^1)
March	12.33	0.4	0.34	1.61
June	13.8	1.32	0.50	9.11

Source: Researcher's Field Work.
Table 5: Anyang River Chanel Parameters in the month of April and June at point B.

Sediment Dredged

No of dredged sites	Duration (months)	Duration (weeks)	Sales (daily)	Sales (weekly)	Tonnages (daily sales x)	Weekly tonnage	4 months Tonnage
6	March - June	16	21 trucks	147 trucks	882 tonnes	6200	24,800

Table 6: Hydraulically Dredged Sediment Tonnage at point A.

Date: April- June2021	Amount (₦)	Tonnage (Trip)
March	42	256
April	34	310
May	54	480
June	45	378
Total	147	1424

Source: Researcher's Calculations from hand-load record.
Table 7: Summary of Manually Dredged Sediment at Edeobom I.

Findings on Morphometric Properties of Anyang River

The Relief Morphometric Properties of the basin indicate the vertical dimension of a drainage basin; it indicates factors of gradient and elevation. These relief aspects of the basin include basin, relief ratio and ruggedness number. Rugged number is the product of maximum basin relief (H) and drainage density (Dd), where both parameters are in the same unit [57]. An extreme high value of ruggedness number occurs when both variables are large and slope is steep. The value of ruggedness number for the basin is 0.0126km. The basin relief is the difference between the highest and lowest values of the basin contour values; the basin relief of Anyang River is about 55m above sea level. This moderate relief value indicates that relief plays a meager role in the basin dynamics as the basin is nearly a floodplain with no part of the basin above 60m. Relief ratio is another important predictor of Relief Aspects of the river sub-catchment; it is derived by the ratio of the basin relief and Length of basin. The Relief Ratio of Anyang River is 0.0293.

The Areal Aspects of Anyang River are exemplified by Drainage Density (Dd). Stream Frequency (Sf), Form Factor (Rf) and the Constant of Channel maintenance (C). The fundamental unit of areal elements is the area contained within the basin of a given order (Ao). Schumm [58], demonstrated that basin areas are related to stream order in a geometric series. Studies have also been successful in formulating relationships between basin are and discharge.

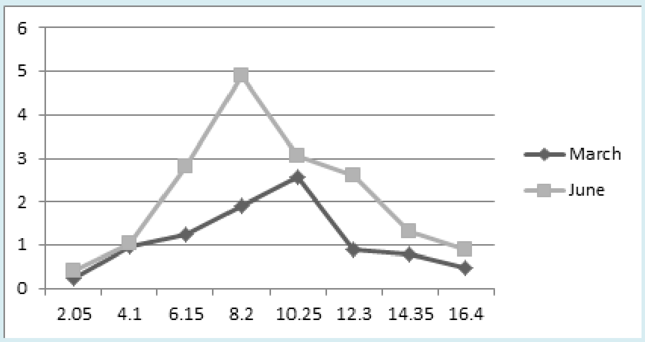
The Drainage Density is an important indicator of the linear scale of landform element in stream eroded topography and defined as the total length of erosion of all orders/ drainage area and may be an expression of the closeness of spacing of channels [59]. Sreedevi [60] posited that a strong relationship exists between various environmental variables and density. Udosen, Udoidiong, Eduok [52] showed that the greater drainage density is inversely related to hydraulic conductivity of underlying soil. The significance of the drainage density is recognized as a determining factor of the time travel by water [58]. The Drainage density value 0.23km/km^{2}which is low indicates that most rainfall infiltrates, rather than runoff. This finding is consistent with Eze and Effiong [61] and Udosen [21].

Stream frequency is referred to as the total number of segments of all order per unit area of the basin [59]. According to Waikar and Nilawar [57] stream frequency (Sf), is expressed as the total number of stream segments of all orders per unit area. The Stream frequency of the river is 0.045 which is low and in tandem with the drainage density. This is consistent with the position of Ashraf [10] that the greater the drainage density and stream frequency of a river, the faster the run off and vice versa.

Form factor (Rf) is defined as the ratio of the river area to the square of the basin length. This factor indicates the flow intensity of a basin of a defined area [62]. The Form factor should always be less than 0.7854 (the value corresponding to a perfectly circular river). The small the Form factor, the more elongated will the river be. Rivers with high form factors experience larger peak flows of shorter duration, whereas elongated watersheds with low Form factors experience lower peal flows of longer duration. The Form factor (Rf) value of Anyang River is 0.185, indicating an elongated basin with lower peak flows of longer duration than the average.

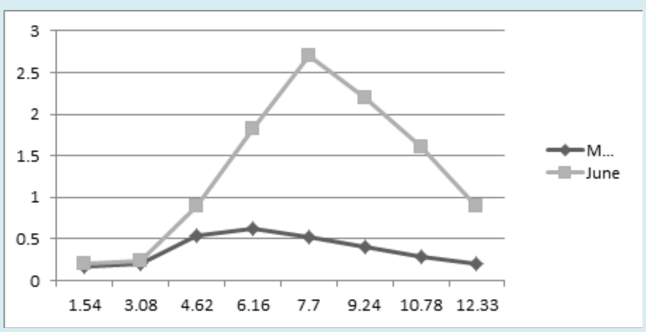
Constant of Channel Maintenance: Schumm [58] used the inverse of drainage density as a property termed constant of stream (channel) maintenance C. As Schumm [58] points out, relationship requires that drainage networks develop in an orderly way because the meter-by- meter growth of a drainage system is possible only if sufficient are is available to maintain the expanding channels. The value of C of the basin is 4.43, which indicates about 4. 34sq.ft is needed to maintain a unit linear foot of the channel [63].

Hydraulic parameters and sediments dredged (Figures 4 & 5)



Source: Researcher's field Work , 2021.

Figure 4: Anyang River Cross Section before and after dredging at point A.



Source: Researcher's field Work , 2021.

Figure 5: Anyang River Cross Section before and after dredging at point B.

Findings on Hydraulic Parameters and Sediment Dredged

Channel width

The measured width of point A and point B was 16.36m and 12.33m respectively in the month of March. The measured values in the month of June were 16.40m and 12.6m. These values (0.04m and 0.27m difference) show a very little change in the channel width from March to June. This goes to show that changes occurring in the river are not dependent on the width [64]. This also goes to explain that the channel erosion is mostly at the river bed with little bank erosion.

Channel Depth

The mean channel depth of point A and B was measured 1.0m and 0.4m respectively in the month of April. The measured values in the month of June were 1.5m and 1.32m. The difference of the values from March-June is 0.5m and 0.92m which show significant change in depth in just the space of 3 months [65]. This change account for the amount of sand dredged over the month of March- June.

Channel Discharge

Discharge is the product of channel width, depth and velocity. Channel discharge gives detailed information on the strength of a channel scour its bed and carries sediment effectively despite the amount of sediment concentration. The calculated discharge for the channel in March was $6.54m^3/s$ and $1.676m^3/s$ respectively. The calculated value for discharge derived in June was $17.24m^3/s$ and $9.1m^3/s$. The values yield a difference of $10m^3/s$ and $7.42m^3/s$ and these values is accounted for by the 0.5m and 0.92m change in depth respectively.

Recommendation and Conclusion

Based on the findings of the study, the following recommendations are made;

i. Regular studies of river characteristics should be made in order to allow for availability of river parameters data.
ii. The morphometric parameter from the study should be used as part of planning data for development plans within the watershed.
iii. There should be proper monitoring of dredging activities in the river catchment to ensure that the river does not lose its ecological significance.
iv. Modern techniques that are environmental friendly should be developed in order to localize river studies.

Dredging is a very important economic factor within the state as it ensures employment and construction materials which aid road and building construction following the need for more development in the state and high demand for sand to carry out road and building construction within the state [66]. The new development plan which now includes areas closer to the basin has called for a greater need for more sand within the state. However, it is expedient to study the impact of this high demand for sand to ensure that there is sustainable development within the river area. Although over the years, development plans at watershed level have ignored the need of the coastal communities.

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Photographs of Sand Dredged Sites in Anyam Nsit

Plate 1: Dredging Machine at work in Anyang Nsit River

Plate 2: Water Pollution in River due to Sand Dredging.

Plate 3: Use of Dredgers is detrimental to Coastal Morphology

Plate 4: Dredgers drilling Sand in Commercial Quantities to meet demand.

Plate 5: Keke Dredgers at work in Anyam.

Plate 6: Processed Aggregates in Anyam