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HYDRAULIC CHARACTERISTICS AND RELATIONSHIP OF THE OROMINEKE CATCHMENT IN DIOBU, PORT HARCOURT, RIVERS STATE, NIGERIA.

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ABSTRACT: *This work is focused on the hydraulic characteristics and relationship of Oromineke catchment with a view to determining the intra and inter-process relationships and process-form of the river catchment. To achieve the objectives of the study, data were collected from field work survey, laboratory analysis and topo map analysis. Field data included those of stream velocity, channel width, channel depth, and water discharge while laboratory analysis entails the determination of the amount of suspended sediment yield. Map analysis entailed the determination, delineation and calculation of the river catchment characteristics. The data so collected were subjected to the Pearson's Product Moment Correlation Coefficient technique and the step wise regression analysis. This was achieved by regressing channel Cross-sectional area (A), the dependent variable, on water discharge (Q), Suspended Sediment Yield (SY), and distance from the river source (D), the independent variables. The study reveals that a strong (positive) relationship exists between channel cross-sectional area and water discharge within Oromineke channel, the latter predicting as much as about 80.34% of the variations in the former. This is in agreement with deduced theoretical postulations contained in the work. Furthermore, the result depicts a strong association of (0.9186) between suspended sediment yield and water discharge. Recommendation has been advanced accordingly.*

KEYWORDS: Oromineke catchment, Channel cross-sectional area, Water discharge, Channel width-depth ratio, Suspended sediment yield.

INTRODUCTION

Water, the most abundant compound on the earth's surface, exists in three phases viz; solid, liquid, and gaseous states of matter moves in a cyclical and dynamic system called the hydrological (water) cycle (Enete,2007). Water which exists in the solid state (glacier-ice) melts to liquid to form surface run-off or percolates to recharge ground water and soil moisture. Water eventually evaporates into the atmosphere in the form of water vapour and thereafter, condenses into a liquid form as precipitation (rain) among others. Falling rain infiltrates into soil and subsequently becomes run-off when the infiltration capacity of the soil is reached. Run-off which starts as overland flow excavates a channel of its own after exceeding a critical length of over land flow. (Bloom, 1969).

The channel created is delicately adjusted for the transportation of water and evacuation of materials eroded by the stream itself and those brought into the channel by rill wash as river load. Hence, there exists a relationship among the various components of a river channel: the velocity of flow, channel width and depth, and river load vary with the amount of water in the channel (water discharge), "that is, as discharge increases so also the channel morphology. This is because certain inter related variables governed the dynamics of fluvial system which adjusts its channel to accommodate its discharge" (Bloom, 1978); Graf, 1985;Kirbi, 1993; Butter, 2004). Hence, a structured examination of the relationships between stream channel and flow characteristics of a river channel is helpful. The study of the fluvial system or aspect is an age-long phenomenon dating back to the Egyptian civilization and even beyond. A fluvial study which is an aspect of geomorphology has been undertaken by geographers and geomorphologists in particular over the years. This is due to the importance of the fluvial system as a distinct geomorphic unit, and from the curiosity of researchers to juxtapose the pioneer work of the Davisian slope-velocity stage in stream velocity with the contemporary scheme of a general down stream increase in stream velocity in a bid to answering some questions about the hydraulic characteristics of stream channel catchment. Hence, the basis upon which this study has been contemplated.

Objectives of the Study

1. To examine the morphological characteristics of Orominere catchment.
2. To establish the intra and inter relationships of process form from river source for variations in channel cross-sectional area.
3. To determine the water discharge, suspended sediment yield and distance from river source of the channel cross-sectional area of Oromineke catchment.
4. To assess the relationship between suspended sediment yield and channel width-depth ratio of the study channel.

CONCEPTUAL FRAME WORK AND LITERATURE REVIEW

The conceptual framework for this study is the drainage basin. The drainage basin is a composite whole within which certain aspects of fluvial systems are related: suspended sediment load is related to both water discharge and channel morphology, channel morphology is related to water discharge, as is channel morphology (channel width-depth ratio) related to suspended sediment load.

Bloom, (1978:197), observed that "when observing rivers, you probably have noticed that velocity, width and depth of a channel varies with the amount of water flowing in it, that is, as discharge increases so also the channel morphology". This is because certain inter related variables governing the dynamics of a fluvial system which adjusts its channel to accommodate its discharge. This work, therefore, intends to explore the intra and inter-process relationships and process-form with a view to determining the hydraulic characteristics and relationships of the Oromineke catchment.

Running water flows down slope under the force of gravity which is calculated to be 9.8 Newton at sea level at the equator (World Meteorological Organization, 1970). This in effect means that gradient, or slope, of the surface over which the river flow plays an important role in conditioning the velocity of the river. (Mejabi,2008)

Smith and Stopp (1979:63), observed that:

The steeper the angle of any channel, the faster the water that flows down it, since gravity has a more direct effect· on river channel. This is true other things being equal. However, the angle of slope of the channel is usually so small that it is measured more easily as gradient than in degrees. Researcher have observed that velocity (v) actually varies in proportion to the square root of the gradient(s) .

Smith and Stopp (1979:63), further claimed that "as the gradient increases, other things being equal, the velocity also increases at a proportional rate to the square root of the gradient".

While some scholars see the phenomenon of increasing velocity of flow as being explainable by increasing mean channel depth, others see it as increasing discharge downstream. However, with increasing discharge, a river demands relatively gentle slope for erosion and transportation. This relationship between water slope, or simply gradient, and water discharge is well explained by Bloom (1978:208) as:

As the quantity of water in a stream increases, the downstream slope of the water decreases. As an empirical rule, slope is inverse of discharge (……). Apparently, water flows more efficiently in larger channels and therefore, requires less slope to maintain its velocity.

King (1966, p. 786) expressed the relationship between longitudinal slope (S) and mean annual discharge (Q) as lying within the range of two power functions. $S \alpha Q^{-0.5}$ $S \alpha Q^{-1.0}$ *(. ….) ………… equ (1) That is, loop varies in a range between the reciprocal of discharge and the reciprocal of the square-root of discharge. For effluent rivers in which discharge increases downstream, the long profile should be concave to the sky as a parabolic curve.*

Rivers transport not only internally generated (endogenous) materials through the processes of corrosion, corrasion, abrasion, and attrition, and cavitation, but also externally derived (exogenous) materials which are the products of weathering, mass wasting and erosion by other agents brought to the river by rill wash load. (Soeter, 1994).

Like the channel geometry parameters, suspended sediment yield has been known to be related to water discharge. On this relationship, Smith and Stopp (1979: 92), asserted that suspended sediment yield has been known to vary directly with stream discharge downstream. For example, the result of a number of sample collected from river Avon at melksham as contained in Smith and Stopp (1979, fig. 77, pp. 92) reveals that:

For a discharge of 4 causes, the suspended sediment concentration is 1000mg/1. However, because flow has increased by twenty-five times, the quantity of materials carried as suspended sediment load at bankfull conditions (corresponding to approximately 100 cumeces) is over six thousand times greater than at low flow. Observations on other river(s) show that a similar relationship always exists between suspended sediment and discharge, although the slope of the line will vary.

Suspended sediment yield has been known to be related to channel width-depth ratio, but unlike hydraulic geometry properties of a positive association, suspended sediment yield is inversely related to channel width-depth ratio Bloom (1978).

MATERIALS AND METHODS

Study Area

The study area, Oromineke stream is located within Port Harcourt Local Government Area of Rivers State; Nigeria (fig. 1). The Oromineke is a second order channel (fig. ll) flowing from some. 76^0 South, 13° west of the Nursing school, Port Harcourt, into Diobu Creek some few metres north of Hotel Olympia and the Gulf Course, Port Harcourt. Oromineke stream has a channel length of about 2.7kms, a basin area of approximately 8.06sq.kms, and a basin perimeter of 10.3kms approximately.

The area is composed of recent sedimentary rocks of marine origin which have been overlaid on the Precambrian basement complex rocks. The marines sedimentaries which are composed mainly of sands of the cretaceous, tertiary and quaternary epochs have been relatively undisturbed and from an almost flat lowland surface. Hence, have been referred to as, and form part of the coastal plain sands (Pitchard 1979; Barbour et al., 1982); Duze and Ojo 1982; Oguntoyinbo, et al, (1982). Barbour et al. (1982:12); noted that "the tertiary marine deposits consist of coastal plain sands of recent thickness resulting from continued subsidence during their period of deposition and have remained relatively undisturbed since their formations. On the coastal plain sands, there exist with a super-imposed alluvial deposit of terrigenous origin distributary's network of the Niger basin to form the Niger Delta.

The relief of the study area is an almost lowland plain common with most parts of southern Nigeria, within which the study area falls, "constituting near- level plains rising gradually from the coast to the interior" with a mean elevation of about 20m (Barbour, et al,., 1982, pp. 8-12).

The study area is drained by two main rivers, the Oromineke and its longest tributary with arivulet which joins the Oromineke stream, all forming a dendritic-like drainage pattern. On the whole, there are three rivers which forms the drainage network of dissect of the study area (figures. ii and iii).

It falls within the rain forest belt, a glimpse of which can be seen in fig iii. The vegetation is composed of secondary vegetation with trees of great vertical' extent and of various strata. The highest stratum consists of the tallest trees which assume great heights while the lowest stratum is made up, primarily, of hydromorphic, halophotic shrubs which have become adapted to an environment of abundant water supply. Also amongst the floral cover of the study area is a swamp vegetation of mainly shrubs and ferns which have become delicately adapted to a swampy (waterlogged) environment.

In pursuance of the objectives of this study, data on channel width and depth, stream velocity, suspended sediment concentration, channel cross-sectional area, channel width-depth cross-sectional area, channel width depth ratio, water discharge and suspended sediment yield were derived from three major sources viz: from field work and survey; from laboratory analysis, and from map work analysis. While the first two sources data were primary in nature, the last source is secondary.

Field data include those of stream velocity, channel width, channel depth, from which data on channel cross-sectional area, water discharge and channel width-depth ratio were measured. These field data were obtained from careful and precise measurement of the relevant parameters in the field.

Data emanating from laboratory analysis have to do with the determination of the amount of suspended sediment in a given volume of river water. From this, suspended sediment yield data were derived.

Map work analysis entailed the determination, delineation and calculation of the river catchment characteristics set out in tables i and ii. Map work data also covers those of distance from river source. Accordingly, the study area, was delimited using maps of scales 1:20,000; and 1:2,500. In delimiting the catchment basin, figs. iii and i were used. This is because the former has no contours impressed on it, though the position of the stream is well preserved. The topographic map was used for catchment basin delimitation, and location of certain features. Calculating the ground equivalence of the channel length from fig iii, the channel was then interpolated into fig. iii using the denominator of map scale, length of channel and orientation of the contours as guides. Having interpolated the channel onto fig i, the contours along the ridge crest down to the river mouth were bisected perpendicularly by line segments which were joined together to form catchment basin boundary. The area of the catchment basin was thereafter calculated to be 8.06q.kms. The first delimitation with an area of 8.06sq.km is used as the catchment basin and to define the study area (fig i).

The data so collected were subjected to statistical analysis.

In doing this, the variables of study have been differentiated into three broad categories viz: the independent variables, semi- dependent variables, and; dependent variable (Bloom, 1969:64) as set out in table ii below.

Table 1: Some Drainage Basin Characteristics of Oromineke Catchment

Drainage Basin Characteristics	Numerical Values
Drainage density (Dd)	0.61km/km^2
Constancy of channel maintenance (C)	1.638
Stream Frequency (Fs)	0.372
Stream Intensity	0.227
Mean bifurcation ration (Rb)	3.000
Form factor (ff)	0.076
Basin Circularity (Rc)	9.835
Basin Elongation (Rc)	0.311
Basin Compactness ratio	7.213
Lemniscates ratio	3.291

Source: Researchers' Fieldwork, 2006.

Table 2: Differentiation of Variable of study

Independent variable	Semi-dependent variables	Dependent variables
Distance from river source (D).	Water discharge (Q); suspended sediment yield (SY).	Channel cross-sectional area (A) ; channel width-depth ratio ($^w/_d$) ; stream velocity (V).

Source: Researchers' Fieldwork, 2008.

The sampling frame of this study consists of the whole of the 2.7km channel length of Oromineke stream from which 30 sample points were selected. The 30 sampling points were chosen by dividing the main channel into 30 roughly equal segments of about 90 metres apart. The line demarcating each of the 90m segments, excluding river source, constitutes a sample point from river source also, constituting a sample point from which measurements have been made (fig. iii).

Table 3: Summary of Statistics of Channel Characteristics of Oromineke Catchment

Variables	Number of observations (n)	Mean (x)	Variance (S^2)	Standard Deviation (S^2)	Best estimate of standard Deviation (S)
Channel cross-sectional area (A)	30	1.6694	1.8635	1.3651	1.3884
Water Discharge (Q)	30	0.2817	0.1043	0.3230	0.3285
Suspended sediment yield (SY)	30	885.185	3518278.3	1875.7074	1907.773
Stream Velocity (V)	30	0.1426	0.0022	0.0465	0.0473
Distance from river source (D)	30	1395.00	606825.42	778.900	792.37
Channel width-depth Ratio ($^w/_d$)	30	9.9336	55.6173	7.4577	7.5851

Sources: Researcher's Fieldwork, 2008.

Where:

ryx= Pearson's Correlation co-efficient between variables

y = Mean value of variables y,

x = mean value of variables x,

n = number of paired observations (paired sample points)

Sy = best estimate of the standard deviation Y,

Sx = best estimate of the standard deviation of variable x,

Σ = Greek sigma for summation.

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The formula for the Pearson's Product moment correlation co-efficient used in this study is:

ryx = (n) $^{-10}$ Σ {(y – y) (x – x)} { (sy) (sy) }$^{-10}$…………………………………… equ. (ii)

The Co-efficient of Determination, R^2 was used to determine and predict the degree of explanation provide by the independent variable for variations in the dependent variable. Simply, the co-efficient of Determination index shows the degree to which the dependent variable depends on the independent variable for it variation.

Equationally, as used in this study,

R = 100 {(n) $^{-10}$ Σ (y-y) (x-x)} {(sy) (sx)} $^{-10}$ ……………………………………… equ. (iii)

Where R = Coefficient of determination, and other symbols are as in equation ii above.

The test was used for the significance of the calculated Pearson's test of association. The calculated 't' value is compared with the critical (table) 't' value at the 95.45 percent significance level and appropriate degrees of freedom. The formula for the test used here is:

t = (r) – (n-2) $^{0.5}$ 1-(r) 2^{-10}……………………………………………… Equ. (iv)

while the formula for the degree of freedom, which is the number of paired items (that is, number of paired sample points) less two, as used in this study is:

v = d.f. = n-2 ……………………………………………………………………………… equ. (v)

where:

't' = 't' test

r = Pearson's product moment correlation co-efficient,

n = number of paired items,

v and d.f. degree of freedom

Accordingly, stepwise regression analysis was carried out using the Spss/Pc computer programme. This was achieved by regressing channel cross-sectional area (A), the dependent variable, on water discharge (Q), suspended sediment yield (SY), and, distance from river source (D), the independent variables in a bid to developing the model:

A = a + b1Q + b2 SY + b3 D + e ……………………………………………………………(vi)

Where

A = channel cross-sectional area

a = numerical value of the constant of the regression model,

bi = numerical value of the beta,

2 = the numerical value of the beta index of water discharge,

Q = water discharge of suspended sediment yield,

SY = suspended sediment yield,

b3 = the numerical value of the beta of distance from river source,

d = distance from river source,

e = error term.

The numerical values of the relationship of the four variables that cannot be explain by the model.

The Snedecor's 'F' test was also used to test for, and determine the level of significance of the multiple regression model in jointly explaining variations in channel cross-sectional area.

RESULTS AND DISCUSSION OF FINDINGS

The calculated Pearson's product moment Correlation of Determination has a value of 80.5 percent. The calculated 't' has a value of about 10.73 while the critical (table) 't' value is 2.0 05 at the 95.45 percent significance level. This reveals that a high positive relationship between channel cross-sectional area and water discharge within Oromineke channel with the latter predicting as much as about 80.43 of the variations in the former. This is in agreement with deduced theoretical postulate which sees channel width and channel depth (the product of which is channel cross-sectional area) as varying with changes in water discharge. Bloom (1978), among others expressed this relationship as "observing rivers a probably among others noticed that velocity, width depth of a channel varies with the amount of water flowing in it, that is, as discharge changes so also the channel morphology". Oyegun (1984:47), also reached the same conclusion in his study of upper Ogunpa River Basin.

Channel cross-sectional area and suspended sediment yield

Referring to table iv, the calculated Pearson's Correlation co-efficient and Co-efficient of Determination both yielded values of 0.74 and 55.36 percent respectively at the 28 degrees of freedom and at the 95.45 percent significance level. The calculated 't' value is approximately 6.00 while the critical (table) ‘t' has a value of 2.05. This result reveals that no statistically significant relationship exists between channel cross-sectional area and suspended sediment yield of Oromineke stream. Consequently, therefore, there is also a positive relationship between channel cross-sectional area and suspended sediment yield of Oromineke stream. With the latter providing an explanation for about 55.6 percent variation in the former. This is also in agreement with theoretical postulations of Twidale (1976:232), about analysis of landform.

Channel cross-sectional area and distance from river source

The calculated Pearson’s test of association and the co-efficient of determination both yielded values of 0.7838 and 61.44 percent respectively at the 28 degrees of freedom and 95.45 percent significance level. While the calculated ‘t' value is approximately 6.68, the critical (table) ‘t' has a value of 2.05. Hence, there is no statistically significant association between channel cross-sectional area and distance from river source of Oromineke stream (catchment). From this therefore, it is obvious that there is a high positive association between channel cross-sectional area and distance from river source of Oromineke stream (catchment) with the latter offering an explanation for about 61.44 percent of the variations in the former. This is also in agreement with established theoretical deductions that channel width and channel depth, and channel cross-sectional area, increase in a downstream direction as some power functions of water discharge.

Stream velocity and distance from river source

The calculated Pearson's product moment correlation co- efficient and the co-efficient of determination have values of 0.68 and 46.91 percent respectively at 28 degrees of freedom and 95.45% significance level. The calculated ‘t' has a value of 4.97 approximately while the critical ‘t' has a value of 2.05. With this result, there is no statistically significant association between stream velocity and distance from river source of Oromineke stream. Consequently, there exists a strong association between stream velocity and distance from river source of Oromineke catchment with the latter determining about 46.91 percent of the variations in the former.

Water discharge and distance from rivers source

The calculated Pearson's test of association and the co-efficient of determination having values of 0.73 and 52.76 percent respectively as well as degrees of freedom of 28. From the table, the calculated ‘t' value is approximately 5.59 while the critical ‘t' value is 2.05 at the 95.45 percent significance level. From this therefore, there is no statistically significant relationship between water discharge and distance from river source of Oromineke stream (See table iv).

Suspended sediment yield and distance from river source

The calculated Pearson's Product Moment Correlation Co-efficient and Co-efficient of Determination have values of approximately 0.60 and 35.44 percent respectively as well as a degree of freedom of 28. The calculated 't' however, is 6.29 while the critical 't' has value of 2.05 at 95.45 percent significance level. Consequent upon this, therefore, there is a direct association between water discharge and distance from river source of the study channel with the latter predicting about 35 percent of the variations in the former.

Suspended sediment yield and water discharge

The calculated Pearson's Correlation Co-efficient has a value of 0.92, and the Co-efficient of Determination has a value of approximately 84.38 percent, with a degrees of freedom of 28. The table shows the calculated 't' value and the critical 't' value at the 95.45 percent significance level as approximately 12.30 and 2.045 respectively. This shows a strong direct association between the two variables strongly agreeing with deduced theoretical postulations as expressed by Bloom (1966:59), among others that "in general, as the discharge increase at a gauging station, the suspended sediment load increases".

CHANNEL WIDTH-DEPTH RATIO AND SUSPENDED SEDIMENT YEILD

The calculated Pearson's Correlations have values of 0.275 and 10.73 percent respectively while the degree of freedom is 28. However, the calculated 't' value is approximately 1.83 while the critical 't' value is approximately 2.05 at 95.45 percent significant level. Hence, the findings of this study for the relationship between channel width-depth ratio and suspended sediment yield is that there is no association between channel width-depth ratio and suspended sediment of Oromineke stream.

TABLE IV: Summaries of Test Statistics of Channel Characteristics of Oromineke Catchment

Variables Pearson Product correlation co-efficient (R)	Co-efficient of determination (R)%	Calculated ‘t’ value	Critical ‘t’ value	Degrees of freedom (v)	Level of significant (%)	hypothesis
Channel cross-sectional area and water discharge + 0.8968	80.4290	10.7270	2.048	28	95.45	Rejected

Channel cross-sectional area and suspended sediment + 0.7440	55.3565	6.0000	2.048	28	95.45	Rejected
Channel cross-sectional area and distance from river source + 0.7838	61.4404	6.6794	2.048	28	95.45	Rejected
Stream velocity and distance from river source + 0.6849	46.9112	4.9741	2.048	28	95.45	Rejected
Water discharge and distance from river source + 0.7263	52.7563	6.2909	2.048	28	95.45	Rejected
Suspended sediment yield and distance from river source + 0.5952	35.7563	5.5914	2.048	28	95.45	Rejected
Water discharge and suspended sediment yield + 0.9186	84.3752	12.2964	2.048	28	95.45	Rejected
Channel width-depth ratio and suspended sediment yield + 0.3275	10.7252	1.8341	2.048	28	95.45	Rejelcted

Source: Researchers' Field work, 2008.

CONCLUSION

An analysis of the Hydraulic Characteristic and relationship of Oromineke Catchmen has been carried out. The essence is to examine the intra and inter-relationship between process and or within Oromineke stream catchment with a view to determining the relationship between:

1. Channel cross sectional area on the one hand, and each of water discharge, suspended sediment yield, and distance from river source of the study

catchment on the other hand;

2. Each of stream velocity, and water discharge from the river source of the study Catchmen;
3. Suspended sediment yield and water discharge of the study Catchmen;
4. Channel width-dept ratio and suspended sediment yield of the study catchment, and also to establish the level of joint explanation provided by water discharge, suspended sediment, and distance from river source for variations in channel cross-sectional area.

Results indicate that while channel cross-sectional area is directly related to both water discharge and distance from river source of Oromineke catchment, it is however, inversely related to suspended sediment yield. This is due to the fact that strong (positive) relationship exists between channel cross-sectional area and suspended sediment yield with the latter providing explanation for variation in the former. The result conforms with and strengthen established theoretical postulations of a general downstream increase with stream velocity, channel cross sectional area and suspended sediment yield in a direction as some power functions of water discharge (Bloom, 1978; Smith and Stopp, 1979).

It is obvious that the intensity of interaction amongst the Catchment attributes increases downstream while that of the slope elements decrease. The former is attributed to the variations in channel cross-sectional area and from constraints on stream network organization as a result of downstream increase in the width and dept of the channel, while the latter arises from the downstream weakening in the link between stream channel and valley-slides effected by the downstream increase in the extend of valley and alluvial deposition adjacent to the higher-order stream segments. By way of recommendation, a similar study can be carried out at flood tide with it findings correlated with these outcomes. This is with the view to establishing regularities, similarities, and or differences between both flow regimes of the study area.

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