

Channel Form Prediction of Chinda Creek: A Critical Factor to Sustainable Management of Flood Disaster in Port Harcourt, Niger Delta Nigeria



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Abstract

Flooding have been identified by different scholars as a major challenge facing communities, hence this study examines the role of water bodies in the control and management of flood. The study was conducted in Chinda Creek in Ogbogoro section of the New Calabar River, Niger Delta Nigeria. Measurement of study variables was done, this was to identify the influence of velocity, sediment yield, depth and discharge on channel morphology. The channel length measured 643.275m and was divided into 30 sample points where measurement of the study variables were taken. The result from the correlation revealed that channel morphology of Chinda Creek is significantly correlated with discharge and depth. Nevertheless, it has positive correlation with velocity, bed load and suspended sediment load but their correlation were not significant. Multiple regression analysis was used and the result showed that only two variables, discharge and velocity provided 94.8% explanation for the variation in channel morphology. Hence the study recommended planned sand mining of the creek to increase its capacity for discharge as well as serve as a flood control mechanism in the study area.

Keywords: Flood; Disaster; Management; Sustainability; Channel; Prediction

Introduction

Stream channels have similar forms and processes throughout the world. Water and sediment discharge create channels as they flow through drainage networks. Obstructions and bends formed from resistant material can locally control channel form by influencing flow and sediment deposition [1]. In forest streams where structural elements such as woody debris, bedrock, and boulders are commonly abundant, these effects are particularly important. Sediment load, water discharge, and structural elements, the controlling independent variables of channel morphology determine the shape of the channel along the stream network. The form of any channel cross section reflects a balance between the channel's capacity to carry sediment away from that point and the influx of sediment to that point. A stable channel is one whose morphology, roughness, and gradient have adjusted to allow passage of the sediment load contributed from upstream [2]. Characteristics of the banks also influence the cross-sectional shape of the channel and help to regulate channel width at any point in the stream.

Chinda Creek which is a tributary of the New Calabar River is an alluvial river, in that it flows through sands, silts, or clays deposited by flowing water [1]. Natural alluvial rivers are usually wide with an aspect ratio (width to depth) of 10 meters or greater [3] and the boundary can be moulded into various configurations as was demonstrated in the seminal work of Gilbert in Roberts [4]. With alluvial rivers, the channel geometry is influenced not only by the flow of water but by the sediment transported by the water. When the flow discharge changes, the sediment transport changes and, in turn, the channel geometry usually changes. Morphological change in stream channels may be a result of stream side forest harvesting. Millar [5] developed a model to predict stream channel morphology based on the condition of riparian vegetation. This model was tested on a portion of Slesse Creek (a tributary to the Chilliwack River) downstream of an old-growth area in the headwaters. The riparian area was extensively logged in the 1950s and 1960s, and has subsequently become parkland. The model predicted that in the presence of dense riparian vegetation, Slesse Creek

would form meandering channel morphology, and that in the absence of dense riparian vegetation it would form a braided channel. These predictions were then confirmed using pre- and post-logging air photos.

However, corresponding changes in stream morphology may change stage discharge relationships and thereby increase or decrease peak flood stages [6]. Thus, predicting changes in base level and channel morphologies are important steps toward understanding future stream behaviors and risks.

A few key relationships describe the physics governing channel processes and illustrate controls on channel response. Conservation of energy and mass describe sediment transport and the flow of water through both the channel network and any point along a channel. Other relationships describe energy dissipation by channel roughness elements, the influence of boundary shear stress on sediment transport and the geometry of the active transport zone.

A common problem faced by geomorphologists is the identification of the dominant process responsible for creation of a particular form. Arising from this, it is the interest of the study to examine the influence of hydraulic parameters such as depth, discharge, velocity; bed load and suspended sediment load on channel morphology and also identify the major factors controlling morphological change in the area. The study therefore intends to develop a model which predicts channel morphology from hydraulic parameters with the intent to identify its role in sustainable flood disaster management.

Studies on Channel Form Prediction

Changes in channel morphology following large sediment inputs have been demonstrated in several regions. Lisle [7] showed a decrease in pool depths following a large flood and associated channel aggradation. Madej & Ozaki [8] quantified the decreases in both pool depth and frequency associated with a sediment pulse. The model for predicting morphologic change developed by Millar [5] indicated that Narrowlake Creek is a transitional watershed, but it was not sensitive enough to accurately predict the apparent shift from a meandering to a braided morphology. This reinforces the notion that stream side forest harvesting does affect stream channels in the Central Interior, though not necessarily in a way that can be readily predicted from hydrology models or empirical analysis. While it is impossible to quantify the exact amount of channel widening in Narrowlake Creek directly associated with forest harvesting, the cumulative effects of logging and natural disturbance have led to channel change throughout the logged portions of the watershed. The predictive model Millar [5] developed a tool for Slesse Creek, Canada and will be important for future prescription development in watersheds. However, for transitional systems like Narrowlake Creek in Vancouver, model predictions indicate

that cautionary measures for either floodplain protection or restoration must be undertaken.

The linkages between logging activity and channel morphology are complicated. Predictive models have great value as tools that can be used to assist in successful watershed protection and restoration, but it will be important that they are not been used without watershed analyses, particularly in the case of transitional systems. The biological implications of the Millar (2000) model, as indicated by the Narrow lake Creek and Slesse Creek case studies in Canada, are profound and worth the effort of further analyses and adjustment to provide a useful tool for both watershed protection and restoration.

Similarly, Oyegun [9] in his study on channel morphology prediction using urbanization index, discharge and sediment yield of the upper Ogunpa River discovered that discharge was a major determinant of channel form and therefore was able to develop a model for channel morphology prediction using the above variables. This was also the same in the case of Oku [10] whose study revealed a significant correlation between discharge and channel shape and size of Ntawogba creek in Port Harcourt where discharge was the main determinant of channel morphology amidst several other variables.

As cited by Oku [10], Faniran & Jeje stated that the geology of a basin is a determining factor of channel shape and size characteristics, his work of the Rima basin revealed that despite discharge and other basin shape and size predicting and determining variables that channel geological characteristics determines the level of carving and enlargement of a channel.

Various studies carried out by several geomorphologist from both local and international have an agreement that channel form prediction as well as determinant variables seem to follow a trend irrespective of climatic conditions.

Method of Study

The study was conducted in Chinda Creek in Ogbogoro town in Obio/Akpor Local Government area of Rivers State, which is located at latitude 4° 50'42.00"N and longitude 6° 55'44.10". The community is about 1.37 kilometres away from the creek which lies at latitude 4° 50'2.43"N and longitude 6° 56'6.26"E. The total length of the creek to an adjoining creek called Okolo-Nbelekwuru is 1.93 kilometres, connecting to the New Calabar River, the total length is 3.04 kilometres.

Field studies and river measurement of Chinda Creek in Ogbogoro section of the New Calabar River was done. This was to enable the examination of the influence of velocity, sediment yield, depth and discharge on channel morphology. To do this, measurement of velocity, depth, discharge and sediment yield of the channel were taken. The length of the channel was determined with the aid of a measuring tape, and the channel

measured 643 meters. This was divided 30 sample points as data collection points for the entire channel at an interval of 21.4m each.

Velocity determination

To determine the velocity of flow in the channel, according to the International Irrigation Management Institute report no T-7, several methods of velocity measurement were identified, but in the case of this study the two point method was used. This implies that instead of taking measurements on the water surface alone, velocity measurements was taken both on the surface and beneath, precisely at 0.2m and 0.8m respectively. This is because the flow depth of the river exceeds 0.76m [11].

Therefore velocity meter measurements were taken at 0.2 and 0.8m of the flow depth, d. This was done with the use of a digital water velocity metre. The mean velocity was obtained by averaging the velocities measured at 0.2 and 0.8m of the flow depth. Thus, the mean velocity V, in the reach would be:

$$V = \frac{(V_{0.2} + V_{0.8})}{2} \quad (1)$$

Determination of depth

To determine the depth, measurements were taken at each sample point in the channel. This was done with the aid of a calibrated leveling staff.

Discharge determination

To determine discharge, the principle to obtain the discharge per unit width (m²/sec) is to determine the product of mean velocity in the vertical per unit area. This method remains the same whether the measurements are carried out under permanent or non-permanent flow conditions. The total discharge of the channel was calculated from the measurement of velocity in the channel, noting that discharge per unit width q (m²/sec) which is the product of mean velocity in the vertical (m/sec) and the water depth (d) at the vertical at the moment of measurement.

$$\text{Therefore discharge } Q = VA \quad (2)$$

Where V =mean velocity, A = cross sectional area.

Bed load measurement

To measure the bed load, the Handheld Bedload- US BLH-84 sediment sampler was used [12]. The reason for the choice is that it is mechanically simple, and can be used at depths up to 3m. To carry out the measurement, it was done at each sample point in the channel. To calculate this, the sediment transport formula been put forward by Chang et al [12] was used.

$$g_b = \frac{w_i}{T x h_s} X b \quad (3)$$

In which,

g_b = transport in kg/s

w_i = weight of bedload sample in kg.

T = sampling time in seconds.

h_s = width of sampler nozzle in meter

b = section width of the stream in meter.

Suspended sediment yield

To measure the suspended load as well, the Depth-Integrating Suspended-Sediment Wading Type Sampler Model DH 48 was used. The sampler container is held in place and sealed against a rubber gasket in the sampler head, by a hand-operated spring-tensioned clamp at the rear of the sampler. This when immersed into the channel was removed after every 5 minutes and emptied into separate clean used bottled water containers for the 30 sample points. The content was there after filtered to determine the weight of the clastic particles in the water sample. since the sampler have a volume of 470cc, the researcher ensured that the volume of water collected did not exceed 440cc but fell within the range of 375cc to 440cc. To achieve this, enough time was given during submergence of the sampler to ensure that the volume of the sampled water falls within the acceptable standard.

Channel morphology

The ultimate goal of the data collection process was basically to access the relationships between the various independent variables of discharge, velocity depth, bedload and suspended sediment yield on one hand and the channel morphology on the other hand. The data set of Chinda Creek was collected with the aid of a calibrated leveling staff and measuring tape. Within the context of the present study, channel morphology, which is the shape of the channel, refers to the cross sectional area of the channel at various sampled points of the basin. In order words, the average channel width and depths were measured and their products were stated in square metre. This was done using Cuencia [13] formula for estimating cross sectional area.

$$\text{Area} = \text{width} \times \text{depth} \quad (4)$$

The cross sectional area of the thirty (30) sample points was determined.

However, from the data generated the mean cross sectional area of the channel was 10.7223 with a standard deviation of 3.70872.

Data analysis

Tables and charts were used in the presentation of data while in the analysis bivariate and multivariate analytical techniques (Correlation matrix and multiple regression analysis) were used. The model equation of the stepwise multiple regression analysis

is as follows:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + e \dots\dots\dots (5)$$

Y = Channel Morphology

a = regression constant

b₁ - b₅ = regression co-efficient

X₁ = velocity

X₂ = Depth

X₃ = Discharge

X₄ = Suspended load

X₅ = Bed load

e = error term

Results and Discussion

Pair-wise correlation between hydraulic parameters of chinda creek

This section examined the predictive capacity of the hydrological parameters of discharge, velocity, depth, suspended sediment yield and bed load of channel morphology in Chinda creek using the SPSS multiple regression (R) statistical tool.

Below is a correlation matrix table which identifies the relationship between the dependent variable of channel morphology and the independent variables of velocity, depth, discharge, bed load and suspended sediment yield (Table 1).

Table 1: Correlation Matrix for Channel Morphology and Velocity, Depth, Discharge, Bed Load and Suspended Sediment Yield.

	Chan. Mor.	Vel.	Depth	Dis.	B. load	S.S Yield
Chan. Mor.	1.000*	0.074	0.536*	0.768*	0.33	0.33
Vel.		1.000*	0.19	0.672*	0.399*	0.400*
Depth			1.000*	0.407	-0.19	-0.18
Dis.				1.000*	0.471*	0.471*
B. load					1.000*	1.000*
S.S yield						1.000*

(*0.05 significant level).

The above shows the correlation matrix of five independent variables of velocity, depth, discharge, bed load and suspended load on the dependent variable of channel morphology of Chinda Creek in Ogbogoro. The testing of various relationships are shown in the summary on Table 1. With the student “t” statistic at 0.05 significant levels revealed that the channel morphology of Chinda Creek is significantly correlated with discharge and depth. Nevertheless, it has positive correlation with velocity, bed load and suspended sediment load but their correlation are not significant [14,15].

The finding of the study is of importance to geomorphological studies, such that even though velocity, bed load and suspended

sediment load does not significantly correlate with channel morphology of Chinda Creek, it indirectly contributes to the existing channel form. In other words, discharge is partly a function of velocity.

Table 2 above, shows that only two variables discharge and velocity entered the regression equation. Discharge alone provided 59% explanation for variation in channel Morphology for the study creek while velocity accounts for 35.8% of same. Hence the total explanation provided for the variation in channel morphology by the independent variables of discharge and velocity is 94.8%.

Table 2: Summary of multiple regression of channel morphology and hydraulic parameters.

Variable	Multiple R	R square	R Square Change	F Change	T-Value Variable	B Co-efficient
Discharge	0.768	0.59	0.59	40.308	22.149	5.572
Discharge & velocity	0.974	0.948	0.358	186.306	-13.649	-58.064

Source: SPSS Analysis result.

In conclusion, this study has revealed that discharge and velocity are the predictors of channel morphology in Chinda Creek. It should also be noted that suspended sediment yield, bed load and depth are indirect predictors of channel morphology in Chinda Creek. This is because they correlate positively with channel morphology and also have positive correlation with velocity and discharge which are the direct predictors, with net effect resulting in increased velocity and discharge.

More so, the five independent variables of the study directly or indirectly affect channel morphology of Chinda Creek. This shows that channel morphology of Chinda Creek correlates positively with discharge, velocity, depth, suspended sediment yield and bed load.

The stepwise multiple regression as shown in Table 3 above revealed that discharge and velocity explains the change in the channel morphology. This is because it accounted 94.8% change in the channel morphology.

Table 3: Step-wise Multiple Regression.

	Unstandardized Coefficient		Standardized Coefficient	T	sig.
	B	Std. Error	Beta		
(constant)	4.562	1.066		4.28	0
Discharge	3.263	0.514	0.768	6.349	0
(constant)	10.348	0.573		18.046	0
Discharge	5.572	0.252	1.312	22.149	0
Velocity	-58.064	4.244	-0.808	-13.649	0

Thus, the hypothesized model developed by this study is of the form,

$$Y = 10.348 + 1.312x_1 - 0.808x_2 \text{ ----- (6)}$$

Where,

Y = Channel morphology

X₁ = Discharge

X₂ = Velocity

In order to determine the significance of this relationship, Table 4 below was used.

From the Table 4 above, the analysis of variance chart above shows two independent variables that significantly explain variation in Chinda Creek morphology, jointly explained about 94.8% of the variation of channel morphology of Chinda Creek. Given an F calculated value of 246.68 which is greater than the table value of 3.35, reveals that discharge and velocity influence channel morphology of Chinda Creek. This therefore implies that channel morphology is influenced by hydraulic parameters.

Table 4: One way ANOVA for explanation of variation between hydraulic parameters and channel morphology.

Source of Variation	Sum of Squares	DF	Mean Square	F- Ratio	R2
Regression	328.188	2	189.094	246.688*	0.948
Residual	20.696	27	0.767		

(*0.05 significance level).

Conclusion and Recommendation

The analysis showed a positive correlation between discharge and channel morphology. The relationship was statistically significant at 95% level. The multivariate technique used in the SPSS computer programme of the step-wise multiple regression analysis revealed that discharge was the most single predictor of Chinda Creek morphology as it explains 59% of the variation in the existing channel morphology of Chinda Creek.

From the analysis of the study, the developed a model helped in predicting channel morphology using suspended sediment yield, bed load, velocity, discharge and depth, which is of the form:

$$Y = 10.348 + 1.312x_1 - 0.808x_2 \text{ ----- (7)}$$

Where,

Y = dependent variable (channel morphology)

X₁ = discharge (independent variable)

X₂ = velocity (independent variable)

One of the findings of the study is that the channel has high discharge. It also revealed that discharge and velocity are the major predictors of the channel form, with discharge providing 59% of the variation in channel morphology of Chinda Creek. The implication of this is that discharge has helped in the

clearing of the creek a tributary to a major river the New Calabar River. Velocity also provided 35.8% of the variation in channel morphology of Chinda Creek, this has contributed immensely to increasing the rate of flow in the channel and the amount of water the channel discharges.

The study therefore recommends that a planned sand mining of the creek should be done, to ensure that it has more capacity for discharge as well as serve as a flood control mechanism in Ogbogoro community noting its role in the control of flood within the rural catchment. This will also allow traffic flow for water transportation while generating revenue for the Government and the community through the sand mining process. With the growing demand for land space especially within rural catchments, exposure of the earth surface as well as concretization of the surfaces are possible, hence the the tendency to increase surface run off of the area. There is therefore need for annual and bi-annual study of the state of the streams, creeks and other water bodies within rural catchment to determine their role in flood control as a means to curb the menace of flooding which is a major environmental hazard in the Port Harcourt region.

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