Fluxes in Suspended Sediment Concentration and Total Dissolved Solids Upstream of the Galma Dam, Zaria, Nigeria

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1. Introduction

Soils are formed from the weathering of the earth's surface and it is loose thereby subject to washing away by various erosive agents including water. Earth materials can therefore be transported in water bodies as either sheet or channel erosion. Water is the transporting medium through which sediments entering the stream from the catchment area are carried down stream. As water moves, its potential energy is transformed into kinetic energy and part of the latter is consumed for transporting the sediments. Mineral materials of many different shapes and particles sizes erode and contribute to the overall stream load. Stream load is broken into three types: dissolved load, suspended load and bed load (Ritter, 2006).

Dissolved loads are materials carried by rivers in true chemical solution. Consist mainly of materials, organic or inorganic, carried in solution by moving water. This type of load can result from mineral alteration chemical erosion or may even be the result of ground water seepage into the stream. Materials comprising the dissolved load have the smallest particle size of the three load types. The quantity of the dissolved solids in the stream is referred to as the Total Dissolved Solids (TDS) and it is important in the assessment of water quality and pollution (Leopold *et al*, 1964; Smith and Stopp, 1978 and Degens *et.al.*, 1991).

Suspended load comprises of fine sediment particles suspended and are transported through the stream. They are transported with no direct contact with the channel floor. In other words, they are too large to be dissolved, but too small to lie on the stream bed; they are rather buoyed by the flow of the stream. They account for the largest majority of the stream load in many rivers and consist of materials such as clay and silt. Suspended Sediment Concentration (SSC) is the volume of suspended sediments at successive depths along the vertical profile of a river, from the water surface to close the river bed (Colby and Hubbell, 1961). Walling and Kleo (1979) added that information on the magnitude of the suspended loads of rivers has many practical applications ranging from geomorphologic studies of denudation rates and patterns of landform development to problem of upstream soil loss and downstream channel and reservoir sedimentation.

Bed load are materials that remain in contact with the bed of the stream and moves by a combination of rolling, sliding and skipping (Knighton, 1998).

The product of the SSC and TDS with the stream discharge gives the suspended sediment discharge (load) and the dissolved sediment discharge (load) respectively. The SSC and the load computed from it is said to increase downstream, while the TDS with the load computed from it is said to decrease downstream, all things being equal (the reverse should be true for an upstream consideration) (Leopold *et al*, 1964; Smith and Stopp, 1978 and Degens *et al*., 1991). However, since all things are not equal in nature, the study of SSC and TDS variations upstream of the Galma Dam is therefore necessary. Furthermore, an idea of the upstream fluxes of these parameters will help in the development and maintenance of the water infrastructure, which will be of great relevance to the inhabitants of Zaria and Kaduna State at large.

2. Study area

The Galma River is mainly situated in Zaria, with some portion of it extending to Kano and Katsina states. The Galma River originates from the Jos plateau in the South Western area of the Shetu hills, which is some 350km away from Zaria. The river then flows from there, Northwest towards longitude 8^0E and Southwest towards Zaria. It flows from Zaria to join the Kaduna River (Abdulrafiu, 1977). Galma dam is located on the Galma River, at a distance of about 10km Northeast of Zaria town (see fig.1a, 1b and 1c). The dam consists of a 550m long earthfill embankment with a maximum height of about 14 metres, and a spillway that is 91.5 metres. (NUWSRP, 2004)

The study area lies within the tropical wet and dry climatic zone, exhibiting a strong seasonality of rainfall. The area is characterized with 6 months of rain and 6 month of dryness, denoted as the Aw climatic type. The rainy season starts around May and terminates around October; on the other hand, the dry season lasts between November and April (Iguisi and Abubakar, 1998). The mean monthly temperature is about 27^0C, temperature varies and it is highest between the months of March and May, which represents the hot and dry period. It is lowest in December/January reaching about 22^0C.

The basement complex rocks primarily underlie the Zaria region. The region is an area within the Zaria plain, a dissected part of the Zaria-Kano portions, an extensive peneplain that had developed in crystalline metamorphic rock. The geology is constituted of three basic rock types: gneissic complex, metasediments and older granites. Younger granites can occur mostly as the ring complexes of Jurassic age. Alluvial deposits are quite extensive in Galma area, traversing wide open, shallow and gently sloping channels that had been cut mainly into the thick mantle of the overburden with some bedrock exposures. Shallowness of the stream channel enables the formation of extensive flood plain along the river and hence is often flooded during the rainy season (Nassef and Olugboye, 1979).

The vegetation type of the northern Guinea Savanna, which is mainly characterized by herbs and grasses, with few deciduous trees widely scattered, characterizes the area. The herbs and grasses grow very tall, in some places, along the perennial rivers and streams, riparian vegetation consisting of evergreen trees are found. The common grass and tree communities in the study area are mostly *Andropogon spp*, Mango trees, *Parkia clappertonia, Azfelia africana* and *Daniella oliveri* used for making mortar and *Acacia balanites* are found in the area.

The soil type in the area is highly leached ferruginous tropical soils that develop on weathered regolith overlain by a thin deposit of wind blown silt from the tropical continental air mass into the area (McCurry and Wright, 1970 and Torkarski, 1972). The physical conditions of the soils are generally poor. The soil aggregates are very small and unstable with tendency to compact under wet condition (Kowal and Kassam, 1978).

The rural inhabitants living around the river are mainly subsistent and peasant farmers, hence the land is subjected to intensive seasonal farming. In addition, along the Galma River and its tributaries, irrigation farming is being practised on a small scale, where farmers divert flowing water into their farmlands, or they can use machines or pumping device to supply water to their farmland. Rising population however, has led to massive deforestation in the area to create space enough for cultivation, thus posing a serious environmental threat, in terms of upstream soil loss and downstream sedimentation. The available grassland encourages grazing of cattle and other pasturing activities in the area, likewise, the river supports fishing activities, which also improves the economy of the area.

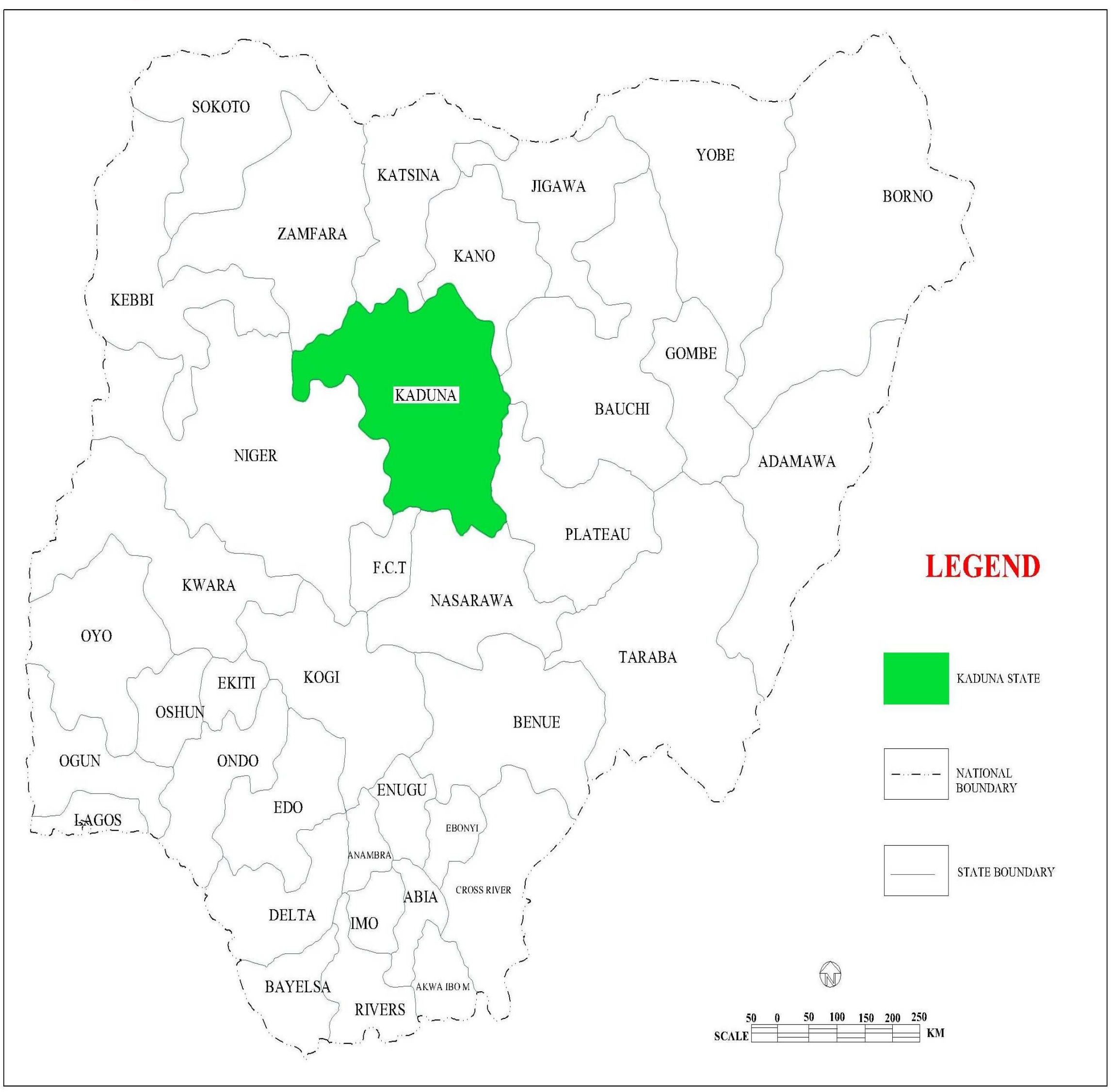

Fig. 1a. Map of Nigeria showing Kaduna State

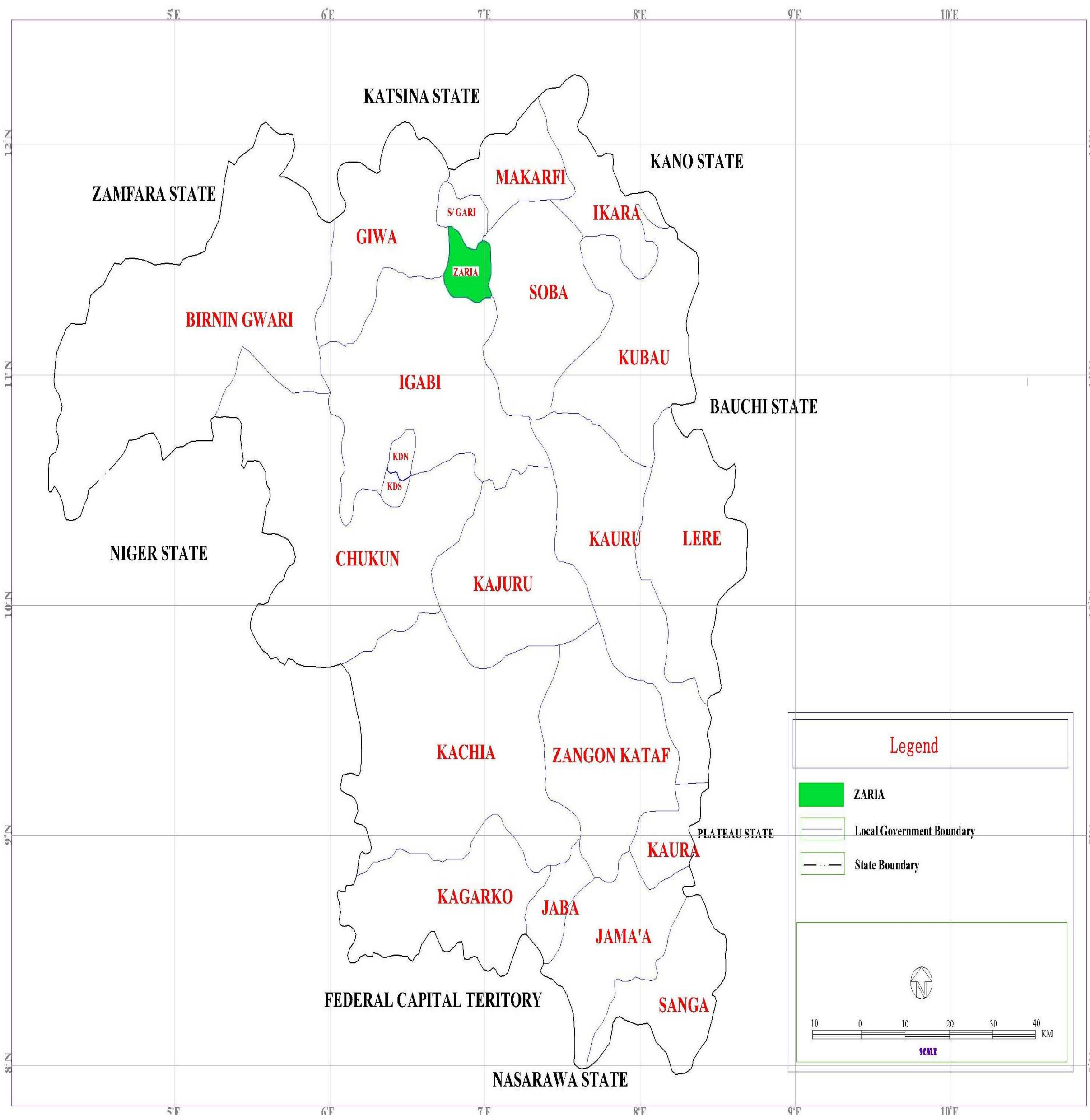

Fig. 1b. Kaduna State map showing Zaria local government

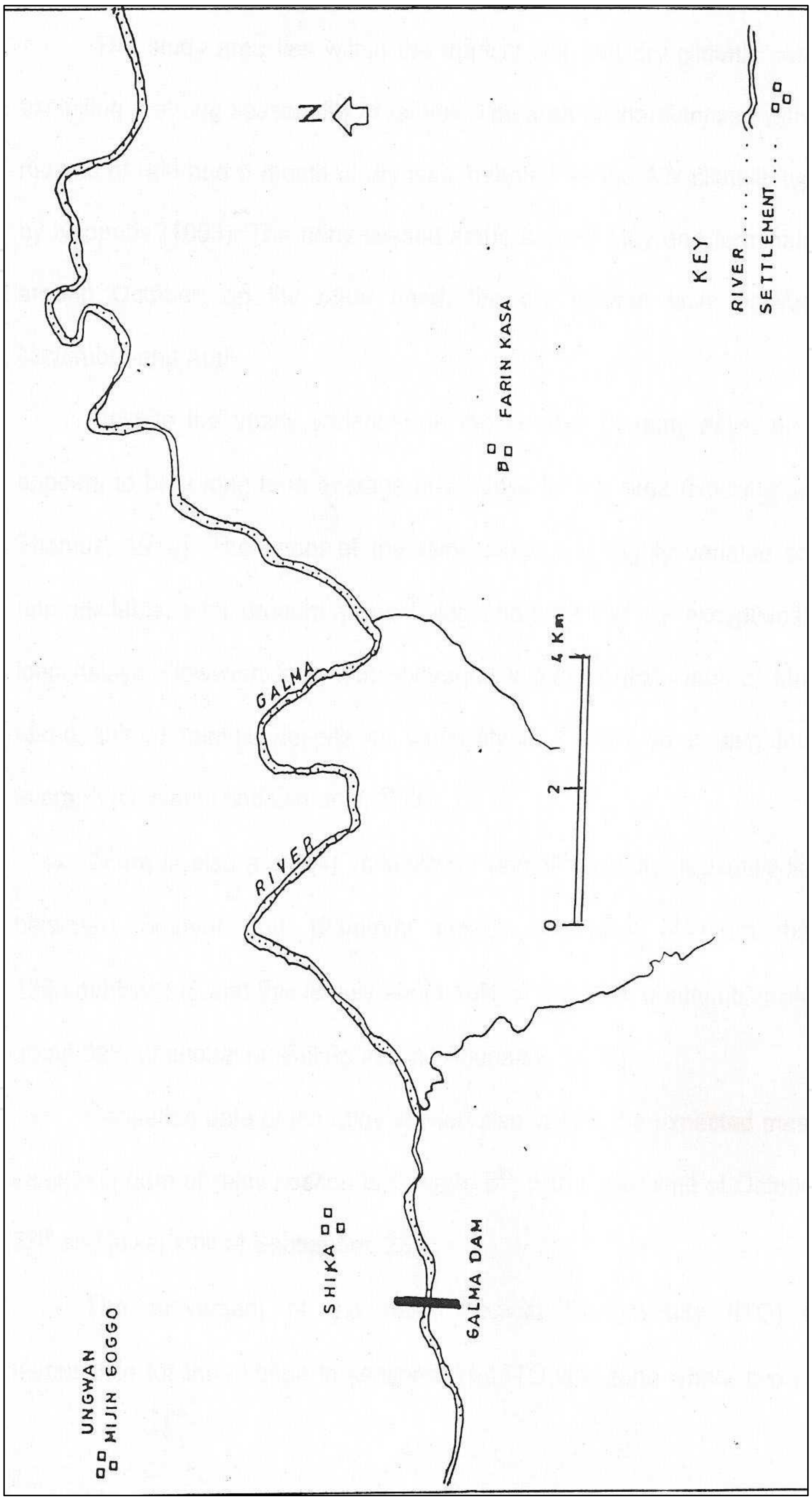

Fig. 1c. The Galma basin: Upstream of the Galma Dam

2. Methodology

2.1 Techniques of data collection

Data were collected using a systematic sampling approach, from the upstream section of the Galma dam. Starting point for the sampling was determined by moving 2km upstream away from the dam's embankment. From this starting point, 2km away from the dam's embankment, data on SSC, TDS and the stream discharge were obtained at 20 sampling points, over a distance of 100 metres each.

The velocity-area technique of discharge measurement was employed for this study, because it's relatively easier, accurate and less costly; here discharge is by definition the product of velocity and Cross Sectional Area (CSA) of flow, and this procedures evaluate these two terms for a stream section at a particular point in time. The width of the river and its depth was measured at each sampling point, the product of which gives the Cross Sectional Area. The velocity of flow of each sampling point was also read on a current metre, which is a digital equipment consisting of a graduated rod and a valeport, a propeller and the digital machine attached to it. The discharge therefore is calculated as the product of its flow velocity and Cross Sectional Area.

Sediment samples were collected at each sampling point using the USDH 48 sediment sampler, which is a depth-integrated sediment sampler. It was used because concentrations vary in a stream's cross-section and therefore, a sampling device is required to provide a representative sample of the concentration at a particular point within the channel. The sediment sample collected was then transferred into a plastic container and tightly corked. The samples were taken to the laboratory for onward analysis to determine the SSC and TDS values of the various samples.

The analysis of the sediment samples to determine their SSC and TDS values was carried out in the laboratory. The SSC was obtained by fetching 250ml of the sediment samples, which had been vigorously shaked to resuspend some of the settled particles. A membrane filter, which had been weighed, was attached to the filtration apparatus, which is equipped with a vacuum pump to make the filtration faster. The filter paper and the residue on it are reweighed. The difference between the initial weight and the new weight gives the SSC.

In getting the TDS, the aliquot from the filtration process for each sample is poured into a weighed crucible and oven-dried. On complete drying, the crucible is reweighed with the dissolved sediments that did not evaporate. The difference in the initial weight of the crucible and the weight after oven-drying gives us the TDS. However, for both the SSC and the TDS, the values gotten was multiplied by four (4), this is done to make the values up to mg/litre, since the sample taken is just 250ml.

The values of the SSC and that of the TDS multiplied by the stream discharge gives the Qs (suspended sediment discharge) and Qd (dissolved sediment discharge) respectively.

2.2 Techniques of data analysis

All generated data were logarithmically transformed. The log-transformed data were plotted against distance upstream on a line graph to reveal their upstream trends. Data on Suspended Sediment Concentration and Total Dissolved Solids were separately correlated with distance upstream to show their correlations. Also data on suspended and dissolved solids discharge were separately correlated with distance upstream to observe their correlations.

Student's t was also used to test the significance of the correlation co-efficient at the 95% significance level (α= 0.05). Mean, standard deviation, co-efficient of variation and ranges for each variable were also calculated. All analyses were carried out by the use of Microsoft excel and SPSS statistical Package.

3. Results and discussions

Table1 shows summary of the descriptive statistics data on sediment concentration (suspended sediments and dissolved solids) and discharge of the upstream section of the Galma Dam.

	N	Range	Minimum	Maximum	Sum	Mean	Standard error	Standard dev	Coefficient of variation
SSC	20	72.00	180.00	252.00	4416.00	220.80	5.09	22.76	8%
TDS	20	1280.00	120.00	1400.00	10160.00	508.00	86.48	386.75	76%
Qs	20	3.03	0.65	3.68	39.83	1.99	0.16	7.16	36%
Qd	20	15.15	0.42	15.57	88.15	4.41	0.81	3.62	82%

Table 1. Table showing Summary of Descriptive Statistics for SSC, TDS, Qs and Qd

The results from the summary statistics show that Suspended Sediment Concentration (SSC) and Suspended Discharge are moderately variable while the Total Dissolved Solids (TDS) and dissolved discharge have higher variability. SSC varied from a concentration of 180mg/l to a maximum concentration of 252 mg/l, giving a range of 72 mg/l with a standard deviation of 19.04 mg/l and a very low co-efficient of variation of 8.65%. Suspended discharge varies between 0.65g/s to 3.8g/s, with a range of 3.03g/s, mean of 1.99g/s standard deviation of 0.72g/s and co-efficient of variation of about 36%.

Total Dissolved Solids varies between 120 mg/l and 1400 mg/l, with a wide range of 1280 mg/l. TDS has a mean of 508 mg/l, standard deviation of 386.75 mg/l and co-efficient of variation of 76%. Solute discharge on the other hand ranges between 0.42g/s and 15.57g/s, giving a range of 15.15g/s mean solute discharge is 4.41g/s with a standard deviation of 3.62g/s and co-efficient of variation of 82%.

The higher mean values of TDS (and solute discharge) above SSC (and suspended discharge) indicates the dominance of chemical denudation within the basin. This confirms findings elsewhere (Dole and Stabler, 1909; Morisawa, 1968; Smith and Stopp, 1978 and Bowale, 2007)

Table 2 below shows that the correlation co-efficient of SSC with distance upstream is -0.16, while those of TDS, Qs and Qd are 0.330, -0.32 and 0.346 respectively. All the correlation coefficients are not significant at 95% significance level (α = 0.05), because the r – values are all greater than 0.05. This means that the relationship of SSC and TDS (with their respective sediment loads) with distance upstream is not well defined as to say that an increase in distance upstream will connote an increase in TDS and decrease in SSC. This is largely attributed to the fluxes experienced in the SSC and TDS as one move upstream, giving an irregular, haphazard and indiscernible pattern relating to the findings of Bowale, 2007.

Variables	Correlation with Distance (r)	t – values	Significance at 0.05 level
SSC (mg/l)	- 0.016	0.948	Insignificant
TDS (mg/l)	0.330	0.155	Insignificant
Qs (g/s)	- 0.320	0.893	Insignificant
Qd	0.346	0.135	Insignificant

Table 2. Correlation of SSC, TDS, Qs and Qd with distance upstream

4. Upstream fluxes of sediments

A more detailed and careful examination of the upstream patterns of SSC, TDS, Qs and Qd as shown in fig. 2-5 reveals that they show some pulses upstream; the pulsations are similar to waves having an amplitude and a pulse-length. SSC has four (4) pulses (fig. 2.); this is same for TDS, Qs and Qd (fig. 3-5). Nonetheless, despite showing some pulsations, the logarithmic line in figures 2-5, show that the variables increases generally upstream, except for the suspended discharge, Qs (fig. 4). The patterns exhibited by the four variables as revealed by the graphs are summarized in tables 3-6.

4.1 Fluxes of suspended sediment concentration

From fig. 2 and the summary in table 4, the first pulse of SSC started from 100m, which is the first point of measurement as well as the minimum SSC of 180mg/l, it peaked at a concentration of 232mg/l at a distance of 400m from starting point of measurement. The first pulse of SSC therefore has amplitude (range) of 52mg/l, representing 22.4% of maximum concentration, over a pulse length (distance) of 400m. The second pulse started immediately at the end of the first at 501m, got to a peak at a distance of 1000m and then declined to another minimum at a distance of 1200m from starting point. Pulse 2 had SSC amplitude of 56 mg/l, representing about 22.2% of maximum concentration and a pulse length of 700m. Pulse 3 starting from 1201m got to a maximum at 1400m and then declined to another low at 1700m, giving amplitude of 40mg/l, representing just 16.1% of maximum concentration, over a pulse length of 500m. Pulse 4 of SSC starting from 1701m reached a maximum at 2000m, the last point of measurement to give amplitude of 68mg/l, representing 27% of maximum concentration and a pulse length of 300m.

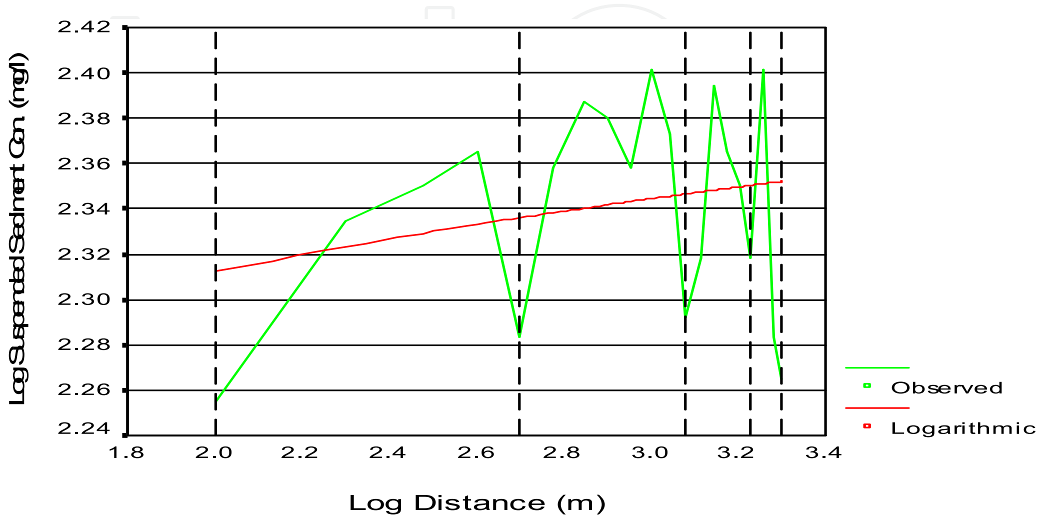

Fig. 2. Upstream Fluxes of Suspended Sediment Concentration

Pulse Parameter	Pulses			
	1	2	3	4
Distance of peak pulse concentration (m)	400	1000	1400	1800
Beginning of pulse (distance (m)	100	501	1201	1701
End of pulse (distance) (m)	500	1200	1700	2000
Pulse length (m)	400	700	500	300
Maximum concentration, (mg/l)	232	252	248	252
Minimum concentration (mg/l)	180	196	208	184
Amplitude (range) of concentration (mg/l)	52	56	40	68
Amplitude as % of maximum concentration (%)	22.4	22.2	16.1	27.0

Table 3. Upstream Fluxes (Pulses) of SSC, produced from fig. 2

4.2 Fluxes of total dissolved solids

Total Dissolved Solids, similar to the SSC also has four pulses (fig.3 and Table 4). Beginning from 100m, the first pulse of solute concentration peaked at a concentration of 200mg/l at the 100m point of measurement and thereafter declined to a minimum at 300m to give solute concentration amplitude of 80mg/l, representing about 40% of maximum concentration, over a pulse length of 300m. The 2nd pulse starting at 401m, got to a maximum concentration of 1000mg/l at 1100, thereafter, declining to a minimum about 100m from the point of maximum concentration, over a pulse length of 800m. Pulse 3 starting at 1201m, got to a maximum solute concentration at a distance of 1400m, and then declining to minimum solute concentration at 1600m. It has amplitude of 600mg/l, representing 75% of maximum solute concentration, over a pulse length of 400mg/l. The fourth pulse starting at 1601m got to a maximum solute concentration at 1800m and then declined to a minimum at a distance of 200m, the last point of measurement. Pulse 4 has an amplitude solute concentration of 1280mg/l, representing 91.4% of maximum solute concentration, over a pulse length of 400m.

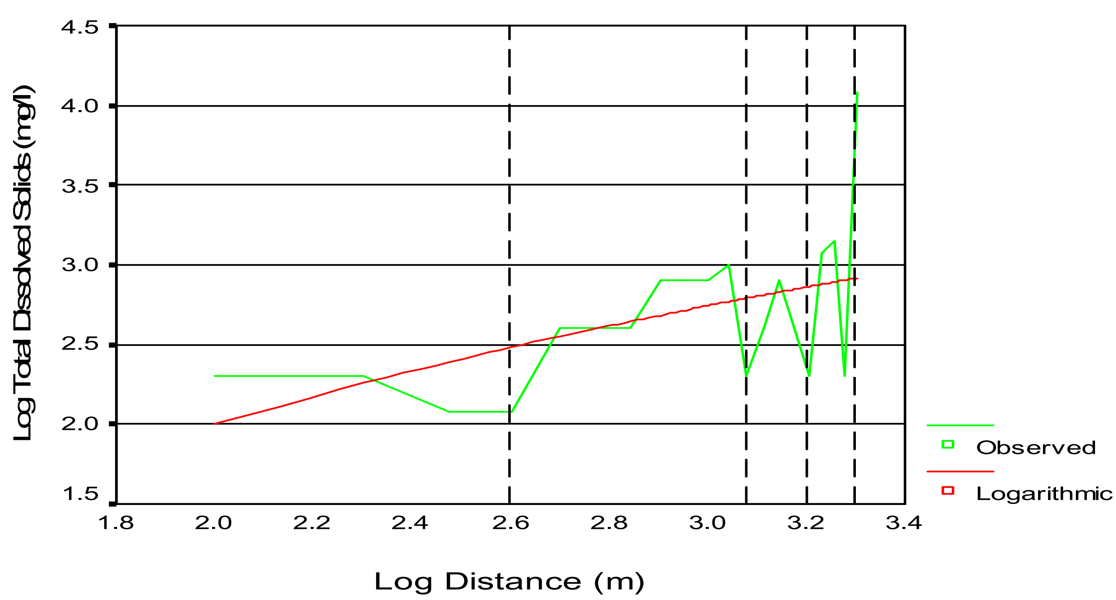

Fig. 3. Upstream Fluxes of Total Dissolved Solids

Pulse Parameter	Pulses			
	1	2	3	4
Distance of peak pulse concentration (m)	100	1100	1400	1800
Beginning of pulse (distance (m)	100	401	1201	1601
End of pulse (distance) (m)	400	1200	1600	2000
Pulse length (m)	300	800	400	400
Maximum concentration, (mg/l)	200	1000	800	1400
Minimum concentration (mg/l)	120	200	200	120
Amplitude (range) of concentration (mg/l)	80	800	600	1280
Amplitude as % of maximum concentration (%)	40	80	75	91.4

Table 4. Upstream Fluxes (Pulses) of TDS, produced from fig. 3

4.3 Fluxes of suspended sediment discharge

The suspended sediment discharge also has four pulses (fig.4 and table 5). The first pulse beginning from 100m reached the maximum suspended load of 2.39 g/s at a distance of 400m, after recording the minimum sediment discharge for the pulse at the first point of measurement of 100m, giving amplitude of 1.1g/s, representing 46% of the maximum sediment discharge over a pulse length of 400m. The second pulse beginning from 501m reached peak sediment discharge at 700m and declined to a minimum at 900m. It has an amplitude sediment discharge of 1.46, representing 50.3% of maximum sediment discharge over a pulse length of 400m. pulse 3, beginning at a distance of 901m peaked at 1000m and declining thereafter to a minimum at 1300m, with an amplitude of 1.33g/s, representing 51.8% of maximum sediment discharge, over a distance of 400m. Pulse 4, beginning from 1301m, reached peak sediment discharge at 1900m and declining to a minimum at 100m further upstream at 2000m, with amplitude of 3.03g/s, representing 82.3% of maximum sediment discharge over a pulse length of 700m.

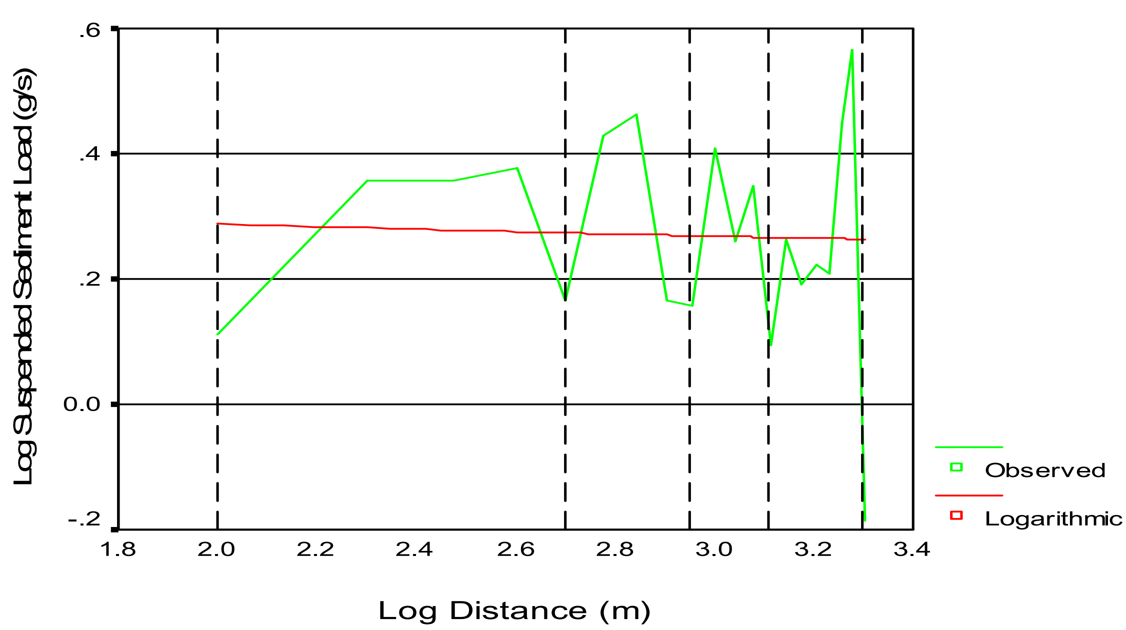

Fig. 4. Upstream Fluxes of Suspended Sediment Load

Pulse Parameter	Pulses			
	1	2	3	4
Distance of peak pulse concentration (m)	400	700	1400	1900
Beginning of pulse (distance (m)	100	501	901	1301
End of pulse (distance) (m)	500	900	1300	2000
Pulse length (m)	400	400	400	700
Maximum concentration, (mg/l)	2.39	2.90	2.57	3.68
Minimum concentration (mg/l)	1.29	1.44	1.24	0.65
Amplitude (range) of concentration (mg/l)	1.1	1.46	1.33	3.03
Amplitude as % of maximum concentration (%)	46.0	50.3	51.8	82.3

Table 5. Upstream fluxes (Pulses) of Qs produced from fig. 4

4.4 Fluxes of solute discharge (load)

The upstream fluxes of solute discharge (fig 5. and Table 6) closely replicate those of Total Dissolved Solids (fig. 3 and Table 5). Consequently, solute discharge has four pulses, same for TDS with the points of maximum discharge, discharge amplitude, pulse length and beginning and end of each pulse resembling those of TDS, except for the lower numerical values of minimum, maximum and amplitude of solute discharge.

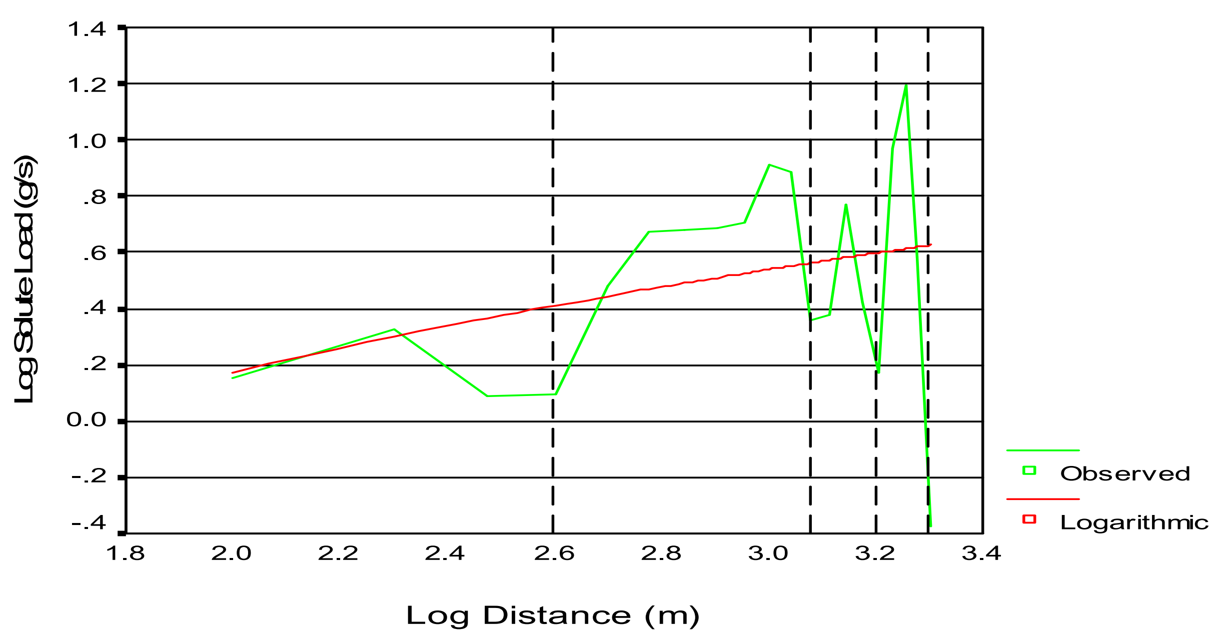

Fig. 5. Upstream Fluxes of Solute Load

Pulse Parameter	Pulses			
	1	2	3	4
Distance of peak pulse concentration (m)	200	1000	1400	1800
Beginning of pulse (distance (m)	100	401	1201	1601
End of pulse (distance) (m)	400	1200	1600	2000
Pulse length (m)	300	800	400	400
Maximum concentration, (mg/l)	2.11	8.15	5.90	15.57
Minimum concentration (mg/l)	1.22	2.28	1.48	0.42
Amplitude (range) of concentration (mg/l)	0.89	5.87	4.42	15.15
Amplitude as % of maximum concentration (%)	42.2	72	75	97.3

Table 6. Upstream Fluxes (Pulses) of Qd, produced from fig. 5

5. Comparison of sediment variables

5.1 Relationship between SSC and TDS

Suspended Sediment Concentration (SSC) in the Galma basin is lower than Total Dissolved Solids (TDS); the mean SSC is 220.8 mg/l, while mean TDS is 508 mg/l (table 2), a ratio of about 1:2.3. Looking at fig. 2 and fig. 3 in relation to each other, especially their logarithm lines, it can be observed that there is a general upstream increase in both variables, implying that a positive association exists between both variables. The test of association between both variables, shows a significant correlation between them, r=0.535, a moderately positive correlation (table 7). Therefore, generally on the average, despite the fluxes, as we move upstream, both the SSC and TDS tends to increase.

Compared Variables	Correlation values (r)	t– values	Significance at 0.05 level
SSC/ TDS	0.535	0.015	Significant
SSC/ Qs	0.321	0.168	Insignificant
TDS/ Qd	0.927	0.000	Significant
Qs/ Qd	0.317	0.174	Insignificant

Table 7. Correlations of SSC, TDS, Qs and Qd with each other

5.2 Relationship between SSC and Qs

In Table 7, the correlation between the SSC and sediment discharge (Qs) had an r-value of 0.321, which is poorly and insignificantly correlated. The correlation though positive is not strong, this can also be observed by viewing closely together the graphs of SSC and Qs (fig. 2 and 4), and they show a similar though not perfect trend upstream. Therefore, high levels of SSC correspond to high levels of suspended sediment discharge and vice versa.

However, when the logarithm line for both variables graph are viewed, there is a difference, which is reflected in the general upstream increase in concentration for the SSC, whereas there is a general upstream decrease for suspended sediment discharge, this could be a reason for the insignificant correlation between the two variables.

5.3 Relationship between TDS and Qd

TDS and Qd show a very strong, positive and significant relationship, with an r-value of 0.927 (table 6). This correlation is strongly positive indicating a perfectly direct relationship between both variables i.e. as the TDS increases, so does the solute discharge and vice-versa. This relationship is also reflected in the similar pattern and pulsations, the graphs of both variables with distance upstream gives, and in the general upstream increase as depicted by the logarithm line of both variables (fig. 3 and 5).

A downstream study of both variables by Walling and Webb (1986), however, revealed that while solute discharge increased with increase in river discharge downstream, solute concentration decreased, it can therefore be said that for an upstream scenario, the relationship will be positive, all things being equal. The decrease in the downstream case of the solute discharge can be attributed to the dilution effects of solutes, which increases as river discharge increases downstream.

5.4 Relationship between Qs and Qd

Suspended Sediment Discharge and Solute Discharge showed a poor and insignificant correlation, with an r-value of 0.317 (refer to fig. 4 and 5). At the start of measurement, especially the first and second pulse for both variables, there was an increase in suspended discharge that was associated with a decrease in the solute discharge, however, pulses 3 and 4 for both variables show a great correspondence, in that as the suspended discharge increases, the solute discharge increases and vice-versa. This kind of association is found between suspended and solute discharges due to the moderating effect of river discharge.

6. Discussion

6.1 Fluxes of SSC and Qs

The fluxes in SSC and Qs can be attributed to sand mining at irregular points along the river channel, to animals grazing around the channel banks, and the effect of cultivation near the riverbanks. Sand mining within the channel, most especially for construction works, promotes turbulence, which entrains sediments already settled on the riverbed. These sediments go into suspension to become part of suspended sediment load thereby increasing SSC. In addition, the release of sediments into the channel during mining operations enhances the concentration of suspended sediments. The entrained or released suspended sediments travel from point of release for a short distance before they settle back on the riverbed; the distance travelled by these sediments before resettling depends on the nature (weight and shape) of sediments, degree of turbulence eddies generated at the point of entrainment or release, flow characteristics and channel configuration among others. As sand mining occurs in a few irregular spots along the channel, sediment concentration and discharge show fluxes in the form of irregular pulses along the river channel. Dearing (1992) and Bowale (2007) have observed similar effect of sand mining on SSC and load in Wales and Samaru respectively.

Grazing of animals around the riverbanks has caused bank collapse in many parts of the channel by their trampling effects. Some of the bank materials slumped into the channel go into suspension and are transported in suspension before settling down on the riverbed further downstream. Likewise, human activities such as cultivation practices close to the riverbanks can lead to the intermittent addition of soil particles to the river and forthwith carried in suspension. Cultivation of lands along the river channel generally increases the level of SSC in a water body, as the soil becomes more susceptible to erosion, because of tillage.

6.2 Fluxes of TDS and Qd

The cause of the fluxes of Total Dissolved Solids and solute discharge (Qd) in the river channel is uncertain. However, fertilizer application by farmers cultivating the land along the river channel may be thought of as a possible cause. Excess chemical fertilizer not used up by plants fined their way into the river through various routes to increase the solute load of the river.

7. Conclusion

This study shows that chemical denudation seems more dominant within the basin than mechanical denudation; this is reflected in the higher mean value of dissolved solids over the suspended loads. Furthermore, sediment concentrations and discharges show wave like fluxes upstream. Using the logarithm line, the suspended sediment concentration, total dissolved solids and discharges showed an increasing trend upstream except for the suspended sediment discharge. The fluxes were attributed to certain physical and anthropogenic factors, implying that certain elements capable of creating disturbances within the river channel can lead to a diversion from the ideal patterns.

8. Recommendation

The study of sediment concentration and discharge fluxes is very important and useful in municipal water supply. This study therefore is of great importance to the Federal Ministry of Health as well as the Kaduna State Water Authority (K.S.W.A). The study was carried out in the upstream section of the Galma dam, which serves as the major reservoir for municipal water supply in Zaria and environs. The study was necessitated considering the effects of suspended and dissolved sediments on water quality and quantity in the reservoir, it also provides information on the rate at which sediment are being deposited into the reservoir.

Institution of an effective watershed management policy is recommended to help curtail the general increase for sediment released into the reservoir. The watershed management authority should be mandated to moderate or stop practices of sand mining at irregular spots on the channel; cultivation practices in the river basin; and cultivation requiring use of inorganic fertilizer should be moderated in the river basin. This will reduce the dissolved sediment sources in the basin thereby increasing the quality of water going into the reservoir.

Grazing of cattle on the riverbank should also be discouraged, to reduce sediment generated because of loosening of the soil by trampling effect of the cattle. The authority should also embark on massive afforestation programmes to reduce the rate of erosion, consequently, reducing sediment generation in the basin. Planting trees and cover crops that will protect the soil from raindrop impact and erosive work of wind and water is important. The authority should also carry out regular studies on sediment concentration and discharges to obtain data that gives an idea of the reservoir's lifespan; it can also be used to determine the cost of water treatment. This information will help the Kaduna State Water Authority, Nigeria to effectively carry out their function of municipal water supply.

9. References

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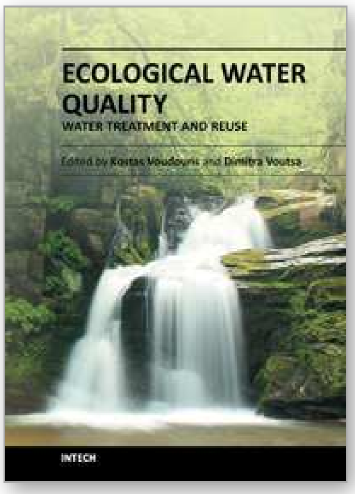

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This book attempts to cover various issues of water quality in the fields of Hydroecology and Hydrobiology and present various Water Treatment Technologies. Sustainable choices of water use that prevent water quality problems aiming at the protection of available water resources and the enhancement of the aquatic ecosystems should be our main target.