IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 12, Issue 9 Ver. II (September. 2018), PP 09-27
www.iosrjournals.org

Assessment of Channel Sedimentation of Selected Reach of River Benue In Yola

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Abstract: *When sedimentation occurs in excess, it directly affects the health of a waterway, decreasing its life-supporting capacity. River Benue seems to have experience some form of channel morphological change ranging from erosion in some areas to excessive deposition in some areas. Hence, the need for river sedimentation studies towards providing solution to aforementioned alterations of the fluvial many rivers in the world are no longer navigable. The research aimed at assessing the channel sedimentation of River Benue at Yola based on the nature of the sediment loading in the channel and the effects of sedimentation load characteristics on gauge height readings. Equipment required for field measurements of bedload include Helley-Smith bedload sampler, complete instrument for discharge measurement and complete set of sieve and other laboratory instrument, indirect vertical integration method was used for bedload sediment. Sieve method was adopted for bedload sediment analysis. Findings indicated that the cross-sectional measurement of river Benue at Jimeta Bridge experienced a lot of bedload sedimentation, the bedload sedimentation of river Benue at Jimeta Bridge were mainly fine grain size sediment with trace of coarse grain size and are uniformly graded because the particles were of equivalent size with volume of 10900483.2g of bedloard sediments per day. At present, measurement of bedload is time-consuming and expensive undertaking, so technology that could substitute the direct sampling of bedload is needed for development and encouragement. The zero level should be taken continually. The uprooted gauges should be reinstalled again since the sea level of the river is subjected to change through aggradation and degradation of the river bed. The stream flow of the river should be conducted time to time so as to obtain accurate bathymetry of the river, width of the river, bed level of the river, gauge height of the river and velocity of the river. Dredging of the river should be done so as to remove the accumulated bedload particles that are presently cemented in the river. This will result to smooth flow of the water in the channel.*

Keywords: *BedLoad, BedLoad Sampler, Bed Sediment Discharge, Degradation, Deposition, Sediment Concentration, Sediment Discharge, Sediment Load, Total Sediment Discharge.*

Date of Submission: 26-08-2018 Date of acceptance: 11-09-2018

I. Introduction

World's water bodies are generally dominated by Sediments, and are a global geomorphic phenomenon that threatens the morphological structure of the water bodies as important water resources. This directly affects the health of a water channel when it occurs in excess, decreasing its life-supporting capacity which needs to be nursed.

Sediments are particles that have been transported by water, air or glaciers from the sites of their origin in a terrestrial environment and have been deposited on the floor of a river, lake, or ocean. In addition to these particles, sediments contain materials precipitated from chemical and biological processes (Roger *et al* 200). Sedimentation is the tendency for particles in suspension to settle out of the fluid in which they are entrained and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them: these forces can be due to gravity, centrifugal acceleration, or electromagnetism. Furthermore, it is the collective name for particles that are transported by natural processes such as wind, water, glaciers and eventually deposited elsewhere (Joanne *et al* 2011).

When soils erode, sediments are washed into streams and rivers. Sediments in waterways are often high in areas where river banks are grazed by livestock, on farms with steep slopes cleared of trees, and where there is a lack of riparian vegetation. Grazing along river banks removes or damages existing vegetation, increases compaction of the soil, and damages the banks of a waterway. In time, the area around a stream will become unstable, prone to slips, and vulnerable to erosion, especially during floods. Animals can cause high sediment loads into waterways because they have a tendency to walk along fence lines. This activity causes soil compaction and erosion and may lead to the formation of drainage channels that then transport water and sediment to the nearest stream. The natural behaviour of animals (they like to wallow in wetlands and small streams), particularly in confined farming situations, makes it harder to manage water quality. Human activities, including urban development, agriculture and forestry, can accelerate the delivery of sediment to streams or disrupt their natural downstream progression. When this occurs, resource managers and stakeholders need to know to what degree this affects in-stream values and biota (Taihoro 2013). One cause of high sediment loads from slash and burn and shifting cultivation of tropical forests. When the ground surface is stripped of vegetation and then seared of all living organisms, the upper soils are vulnerable to both wind and water erosion. In a number of regions of the earth, entire sectors of a country have become erodible. Erosion is also an issue in areas of modern farming, where the removal of native vegetation for the cultivation and harvesting of a single type of crop has left the soil unsupported.

Sedimentation is very important, without it we wouldn't have any dinosaur fossils. It is the building up of layers of small particles like sand or mud. The easiest place to see this is the beach. A beach is made up of lots of sand which have been deposited, or left behind, by the sea. Sand and mud come from inland. Rivers erode them from the land and bring them towards the sea. As the water slows, it can't carry as much and so sand and mud are dropped. The bigger the grain of sand, the sooner it is dropped. If you look at a cliff, you will often see layers which make the cliff look like a layer cake. These layers are caused by sedimentation. Over a long period of time, the grains of sand and mud build up and up, forming the layers (Aaronfaunch2013). However excessive erosion, transport, and deposition of sediment in surface waters are major problem in the world (International Atomic Energy Agency 2003).

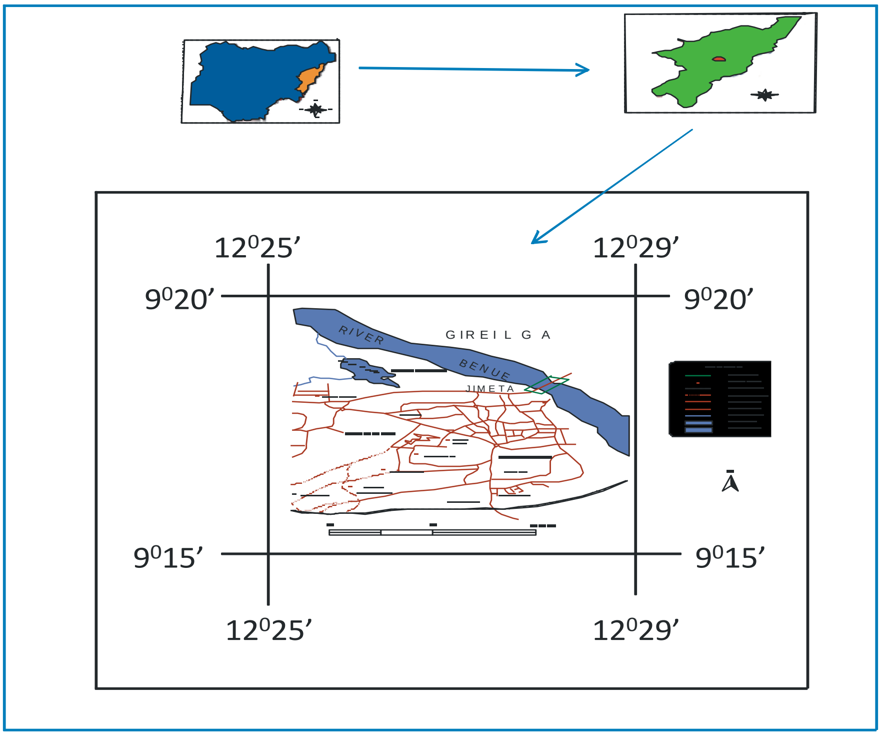
In the past, River Benue was Navigable from Cameroun Republic to Locoja where the river joins the Niger. This enhanced the transportation of goods and services at that period. People and goods from Cameroun and far places were Navigable through Jimeta Bridge to the southern part of Nigeria, trading, but no longer possible even in the rainy season in these days.

Fishermen were boosted as a result of bumper harvest of different species of fishes, whereas, fishermen are becoming extinct in Yola metropolis due to lack of fishes and aquatic animals in the Benue River as before. This is possible because the physical habitat have been altered and the space used for refuge by benthic invertebrates and fish, the sites used for egg laying are also blocked. The cost of fresh fish today in Yola compared to the past say 20-30 years ago, tremendously have increased due to lack of fresh fish while there is a river channel across the metropolis. The amount of rice and maize produced in the deposited alluvial soil in the channel is increasing in arithmetic progression due to large deposition of sediments in the river channel. This can raise an alarming question like why such cultivation of such crops is possible in the semi-middle of a river channel like River Benue.

Expressly, land reclamation has become possible and frequent along the bank of the River Benue. Cases of flooding in the downstream of the channel have become inevitable. There is also a drastic in fishing activities at Yola in recent times compared to the past 30-40 years ago owing to large amount of money, food and employment. The river seems to have experience some form of channel morphology change ranging from erosion in some areas to excessive deposition in the areas. Because of the above problems, the following questions should be considered. Hence, the need for river sedimentation studies towards providing solution to aforementioned alterations of the fluvial many rivers in the world are no longer navigable. Because of the above problems, the research aimed at assessing the bed load transportation in middle reaches of river Benue, Adamawa state of Nigeria, based on the following objectives. To examine the stream flow characteristics of the river channel, to examine the nature of the sediment load transportation in the channel and to examine the effects of sediment load transportation on the channel morphology.

The Study Area

Yola, the headquarters of Adamawa state comprised of Yola North and South Local Government Areas. It is located between latitudes 09°15′ N and 09°20′ N and longitudes 12° 25′ E and 12°29′ E with an elevation of 135m above sea level. It covers a land area of about 2189km^2(Adebayo and Tukur 1999)



The towns Jimeta and Yola are gap towns which are situated at a point where the Benue River carves its valley through the eastern highlands. (Adamawa State Official Diary 1999). The study area falls within the Benue trough which is generally a low lying flat terrain of 183.3-200 meters above the sea level with gentle undulation and hill ranges punctuating the extensive flat flood plain at various locations notably across the river Benue (from Jimeta) eastward, the land rises steeply to attain a maximum height of 240 meter above mean sea level (Makpene, 2007). River Benue previously known as the Chadda River or Tchadda is the major tributary of the Niger River. The river is approximately 1,400km long and is almost entirely navigable during the summer months. As a result, it is an important transportation route in the region through which it flows.

II. Methodology

Materials/Equipment used

Equipment required for field measurements of suspended load sediment, bed load sediment and stream flow discharge included Helley-Smith bed load sampler, complete instrument for discharge measurement (SK 100 suspended Derrick, sinker weight, revolution counter, Bray Stock, fish tail and tools), Inventory checklist, Sample ID forms (sampling information and identification) and labels, G. P.S., Camera, Protective clothing, Tools (hammer, spanner, axe, knife, etc.), First aid kit, Grab sampler, Boat and Personnel.

Sampling Technique

The sampling procedure for bed load sediment was area sampling technique. The cross-section of River Benue was divided into five (5) sections (units) with equal increment of two hundred meters (200) with their distinct boundaries. After dividing the river into five (5) sections or units, the use of systematic sampling was adopted and drew two samples from each section so that the total sample was ten (10) for the whole cross-section.

Method of data collection

Indirect vertical integration method was used. During the process, the bed load sampler was tightened to the sinker weight mounted on cable, sank it in to the bed of the river and allowed it to settle for about twenty (20) seconds after the bed load sampler has been oriented to the flow of the river. Then the bed load materials entered the sampler through the inlet and the divergent flow within the sampler reduced the flow velocity allowing the sediment to accumulate. Affine mesh at the rear of the sampler allowed water to pass through, but not the bed load sediments. After the appropriate measured time-interval, the sampler was removed and the trapped sediment was removed for weighing.

Transportation and storage of sample

After collection of the sediment samples using the samplers at the field, the samples were transported to the laboratory under conditions that was not against the subsequent planned analysis. This was done by using vehicle as transportation means with the sampler under strict protection condition. Since the samples were mainly for physical analysis and concentration, plastic containers were used for transportation and storage. During the transportation, care was taken to minimize the interaction between samples and containers/implements minimized the interaction between sample and external environment treated the sample containers with the same precaution as that of samples, washed the containers and implement with appropriate cleaning agents and ran appropriate analytical blanks which was referred to every sample.

Analysis And Computation Procedure

Drying of Sediment Sample: -

The samples were placed in an open space where air dried them. Mortar and pestle were used gently to break up any big clumps of soil. Any individual pebbles or pieces of gravel were noted. The weights of each sieve as well as the bottom pan were written down for the analysis.

Source: Fieldwork 2017

***Weigh out the Sediment Sample**:*

The sample Weigh out to the nearest gram on an analytical balance. Ideally, the starting sample should contain approximately 25g and above of sediment that will pass through a number of sieves. The weight of the given dry sediment sample were recorded.

Source: Fieldwork 2017

Weigh each empty sieve and record the result

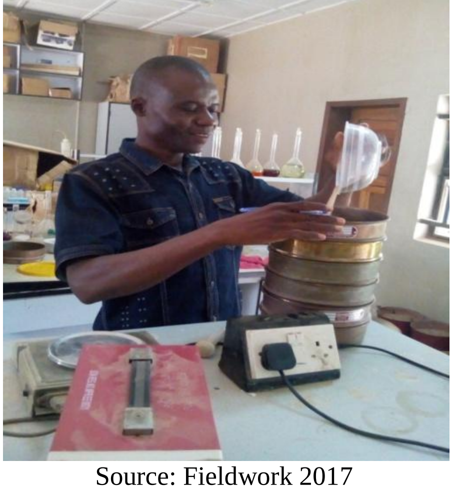
Source: Fieldwork 2017

Assemble all the sieves in the ascending order of sieve numbers:

Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (4 sieves at top and 200 sieves at bottom). Place the pan below 200 sieves. Carefully pour the soil sample into the top sieve and place the cap over it.

Source: Fieldwork 2017

Pour sediment sample into the sieve.



Source: Fieldwork 2017

Place the set of sieves with the sediment on the shaker to shake them very well.

Source: Fieldwork 2017

Weigh and record the weight of each sieve with its retained sediment*:*

Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained sediment. In addition, remember to weigh and record the weight of the bottom pan with its retained fine sediment.

Source: Fieldwork 2017

Determine the Amount Material Retained on the Sieve:

Obtain the mass of sediment retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of the soil sample. A loss of more than two percent is unsatisfactory.

Determine the Percentage Retained On Each Sieve*:*

Calculate the percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

Determine the Total Weight of each size Fraction Present in the sediment Sample:

Determine the total weight of each size fraction present in the sediment sample by subtracting each corrected sieve weight from the previous weight of container plus sediment.

Calculations:

Calculate the percent passing (or percent finer) by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure. Quantity passing = Total mass - Mass retained.
The percent retained is calculated as; % retained = Mass retained/Total mass. Quantity passing = Mass arriving - Mass retained.

Calculate coefficient of uniformity (C_u) and coefficient of curvature (C_c) using the following equations.

$$C_u = \frac{D_{60}}{D_{60}} \text{ While } C_c = \frac{D_{30}{}^2}{(D_{60} \times D_{10})}$$

Coefficient of uniformity here we said is C_u which is equal to D_{60} by D_{10} and Coefficient of curvature as (D_{30} square) by (D_{60} into D_{10}). Effective particle size is indicated as D_{10} which indicates that 10 percent of the particles are finer and 90 percent of the particles are coarser than this size. C_u shows whether the sediment is well graded or poorly graded. C_c complements C_u to evaluate whether the sediment is well graded or poorly graded, or gap graded. They are used for Unified sediment Classification System (USCS).

Plot a Curve or Histogram of the Size Distribution*:*

This information can then be used to plot a curve or histogram of the size distribution of the silt-clay, sand and gravel fraction of the sample as described previously, through that the grain distribution can be determined. Determine D_{10}, D_{30}, and D_{60} from the graph, which correspond to the particle size for 10% finer, 30% finer and 60% finer.

Bed load sediment analysis and discussion

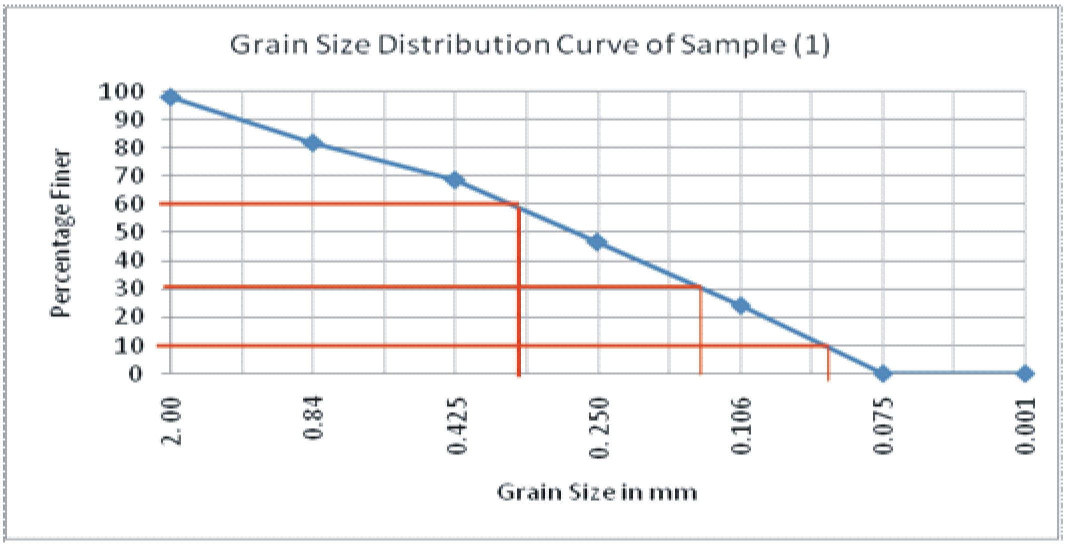
Cumulative percentage of sediment retained on successive sieve was determined. The graph grading curve between log sieve sizes versus % finer was drown, corresponding to 10%, 30% and 60% finer which obtain diameters from graph; these are D_{10}, D_{30}, and D_{60}. Typically D_{10}, D_{60} and D_{30} are used in arriving at measures of gradation. D_{10} is called effective size and is used to estimate coefficient of permeability. D_{50} is the average particle size, where D_{60} is the diameter corresponding to 60% finer in the particle-size distribution. C_c and C_u are also calculated. C_c complements C_u to evaluate whether the sediment is well graded or poorly graded, or gap graded. They are used for Unified Soil Classification System (USCS). C_u shows whether the soil is well graded or poorly graded. Sieve size number 4 is for retained coarse gravels, number 10 retained gravels, number 40 retained coarse sand, number 60 retained medium sand, number 140 retained finer sand, number 200 retained silts and pan retained fines (clay).

Grain Size Analysis (1) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 1 A, Visual Classification of Sediment: fine sand to trace of very fine gravel, Weight of Container: 15.52, Wt. Container + Dry Sediment: 294.93 gm, Wt. of Dry Sample: 279.44 gm.

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	0000	0000	0000
10	2. 0	356.56	362.40	05.84	2.10	97.90
20	0.84	340.74	393.95	53.21	19.00	81.90
40	0.425	347.29	376.10	28.81	10.30	68.60
60	0. 25	89.63	150.83	61.40	22.00	46.60
140	0.106	331.99	456.59	63.20	22.60	24.00
200	0.075	247.36	314.30	66.94	24.00	00.00
Pan	-------	281.38	281.38	00.00	00.00	00.00
Total Weight=				279.40		

Source: Fieldwork, 20167

From Grain Size Distribution: % Gravel= 2.10, % Sand= 73.90 and % Fine sand= 24.0



Grain size distribution curve of sample 1
Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 2.10_ D_{10}= 0.021 mm, % Sand= 73.90_ D_{30}= 0.171 mm, % Fine sand= 24.00_ D_{60}= 0.373 mm

$$C_u = \frac{0.373}{0.021} \; C_C = \frac{(0.171)^2}{(0.373 \times 0.021)} = 17.761 = \frac{0.029}{0.0078} = 3.718$$

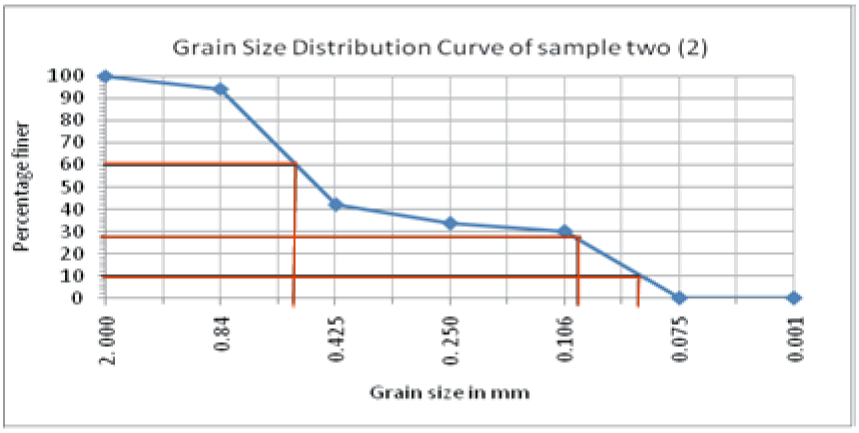
Since the C_u =17.761which is greater than four (4) to six (6), C_c = 3.718 which is above the range 1-3 with some fraction, then the sediment sizes are well graded. Uniformly graded looks like the particles are of equivalent size and you can see that this curve is a steeper curve that represents uniformly graded or a uniform fully graded soil. This represents a well-graded soil because the finer particles are filling the voids within the large particle sizes. So this is a well-graded purely sorted soil tank.

Grain Size Analysis (2) (Sieve Analysis), Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya and Mr. Oliver, Project Name: Assessment of Channel Sedimentation of selected Reach Of River Benue in Yola Adamawa State, Nigeria, Sample Number: 2 A, Visual Classification of Sediment: fine sand to trace of very fine gravel, Weight of Container: 15.52 gm, Wt. Container + Dry Sediment: 229.23 gm, Wt. of Dry Sample: 213.77gm.

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	0000	0000	0000	0000
10	2.00	356.55	356.61	00.06	00.03	99.97
20	0.84	340.74	352.76	12.02	05.62	94.35
40	0.425	247.29	358.79	111.5	52.16	42.19
60	0. 25	89.63	107.74	18.11	8.47	33.72
140	0.106	331.99	340.16	8.17	3.82	29.90
200	0.075	247.36	311.27	63.91	29.90	0000
Pan	------	281.38	281.38	0000	0000	0000
Total Weight=				213.77		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 0.03, % Sand= 70.17 and % Fine sand= 29.00



Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 0.03_ D_{10}= 0.083 mm, % Sand= 70.17_ D_{30}= 0.178 mm, % Fine sand= 29.00_ D_{60}= 0.530 mm

$$C_u = \frac{0.530}{0.983} \; C_c = \left(\frac{(0.178)^2}{0.530 \times 0.083)} \right) = 6.386 = \frac{0.032}{0.0499} = 0.641$$

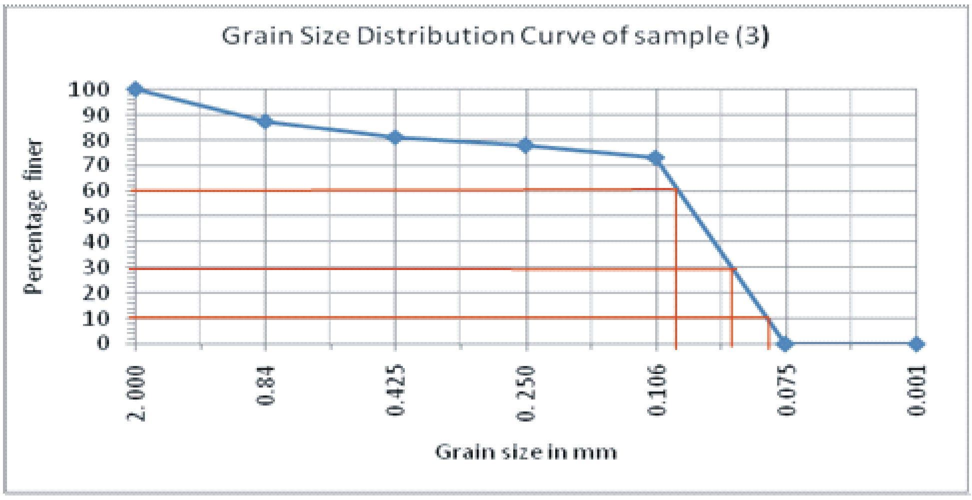
Since the C_u =6.386 which is greater than from four (4) to six (6) with some fractions, C_c = 0.641 which is not within the range 1-3, then the sediment sizes are graded. That means unified classification of sediment grain size.

Grain Size Analysis (3) Sieve Analysis, Date Tested: 7 June, 2017 Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 3 A,Visual Classification of Sediment: fine sand to trace of very fine gravel, Weight of Container: 15.52 gm, Weight of Container + Dry Sediment: 182.10 gm, Weight of Dry Sample: 166.63 gm.

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	0000	0000	0000
10	2. 0	356.55	356.57	00.02	00.01	99.99
20	0.84	340.74	361.53	20.79	12.48	87.51
40	0.425	347.29	357.60	10.31	06.19	81.32
60	0. 25	89.63	95.23	5.60	3.36	77.96
140	0.106	331.99	339.76	7.77	4.66	73.30
200	0.075	241.36	363.50	122.14	73.30	00.00
Pan	-------	281.38	281.38	00.00	00.00	00.00
Total Weight=				166.63		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 0.01,% Sand= 26.6, % Fine sand= 73.30



From Grain Size Distribution Curve: % Gravel= 0.01_ D_{10}= 0.0789 mm, % Sand= 26.69_ D_{30}= 0.0866 mm, % Fine sand= 73.30_ D_{60}= 0.0982 mm

$$C_u = \frac{0.0982}{0.0789} \; C_C = \frac{(0.0866)^2}{(0.0982 \times 0.0789)} = 1.245 = \frac{0.0075}{0.007} = 0.974$$

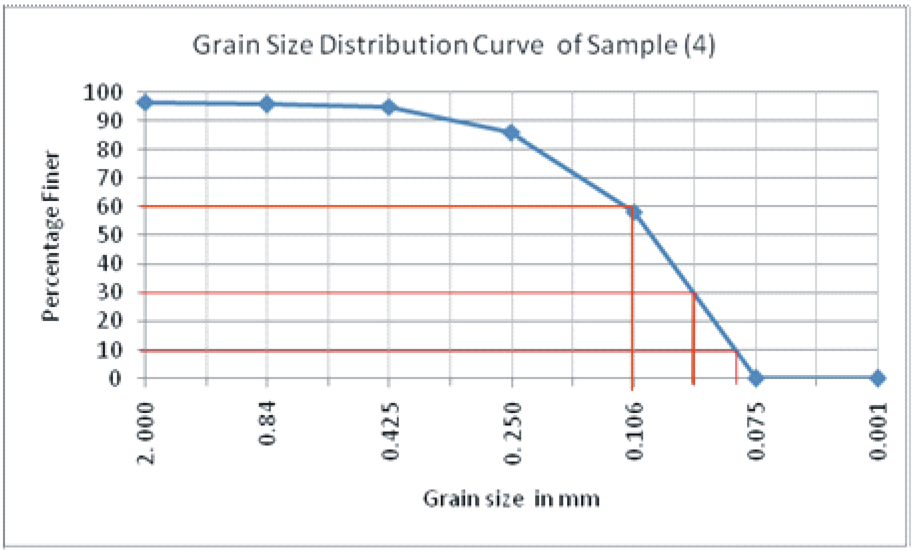
Since the C_u = 1.245 which is less than from four (4) to six (6), C_c = 0.974 which is not within the range 1-3, then the sediment sizes are poorly graded. That means unified classification of sediment grain size.

Grain Size Analysis (4) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of select Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 4A, Visual Classification of Sediment: Silty sand to trace of coarse sand, Weight of Container: 15.52 gm, Wt. Container + Dry Sediment: 297.63 gm, Wt. of Dry Sample: 282.11 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	0000	0000	0000
10	2. 0	356.55	365.55	09.00	03.19	96.81
20	0.84	340.74	343.22	02.48	00.88	95.93
40	0.425	347.29	349.36	02.07	00.73	95.20
60	0. 25	89.63	115.05	25.42	9.01	86.19
140	0.106	331.99	410.03	78.04	27.66	58.53
200	0.075	241.36	406.43	165.07	58.51	00.02
Pan	-------	281.38	281.39	00.01	00.02	00.00
Total Weight=				282.11		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel=3.19, % Sand= 38.28, % Fine sand=58.53



Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 3.19_ D_{10}= 0.079 mm, % Sand= 38.28_ D_{30}= 0.091 mm, % Fine sand= 58.53_ D_{60}= 0.106 mm

$$C_u = \frac{0.106}{0.079} \quad C_c = \frac{(9.091)^2}{(0.106 \times 0.079)} = 1.342 \qquad = \frac{0.0083}{0.0084} = 0.988$$

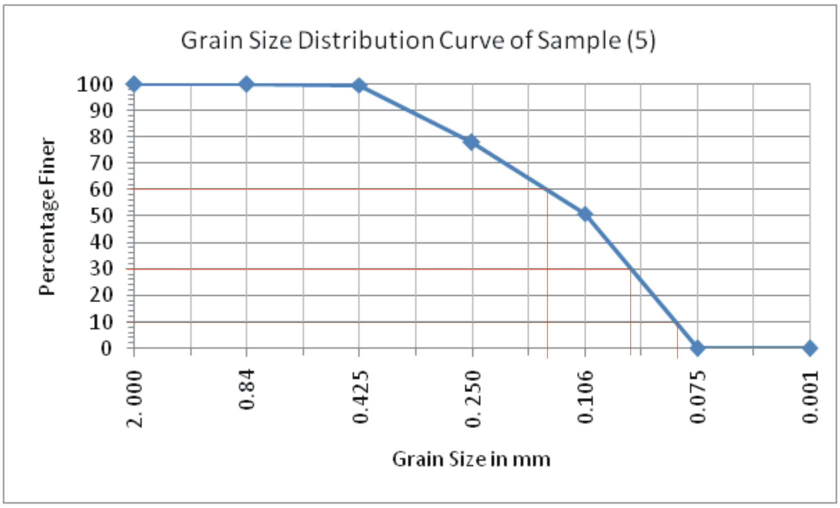
Since the C_u = 1.342 which is less than from four (4) to six (6), C_c = 0.988 which is not within the range 1-3, then the sediment sizes are poorly graded. That means unified classification of sediment grain size.

Grain Size Analysis (5) Sieve Analysis, Date Tested: June 7 June, 2017Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach Of River Benue in Yola Adamawa State, Nigeria, Sample Number: 5 A Visual Classification of Sediment: Silty sand to trace of coarse sand, Weight of Container: 15.52 gm, Weight of Container + Dry Sediment: 271.06 gm, Weight of Dry Sample: 255.55 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	0000	0000	000
10	2. 0	356.55	356.55	00.00	00.00	100
20	0.84	340.74	340.76	00.02	00.03	99.97
40	0.425	347.29	347.62	00.33	00.13	99.84
60	0. 25	89.63	145.52	55.89	21.87	77.97
140	0.106	331.99	399.96	68.60	26.84	51.13
200	0.075	241.36	371.96	130.6	51.11	00.02
Pan	--------	281.38	281.48	00.01	00.02	00.00
Total Weight=				255.55		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 00.0, % Sand= 48.87, % Fine sand= 51.1



Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 00.00_ D_{10}= 0.079 mm,% Sand= 48.87_ D_{30}= 0.094 mm, % Fine sand= 51.13_ D_{60}= 0.180 mm

$$C_u = \frac{0.180}{0.079} \quad C_c = \frac{(0.094)^2}{(0.094 \times 0.079)} = 2.278 \qquad = \frac{0.0088}{0.0142} = 0.620$$

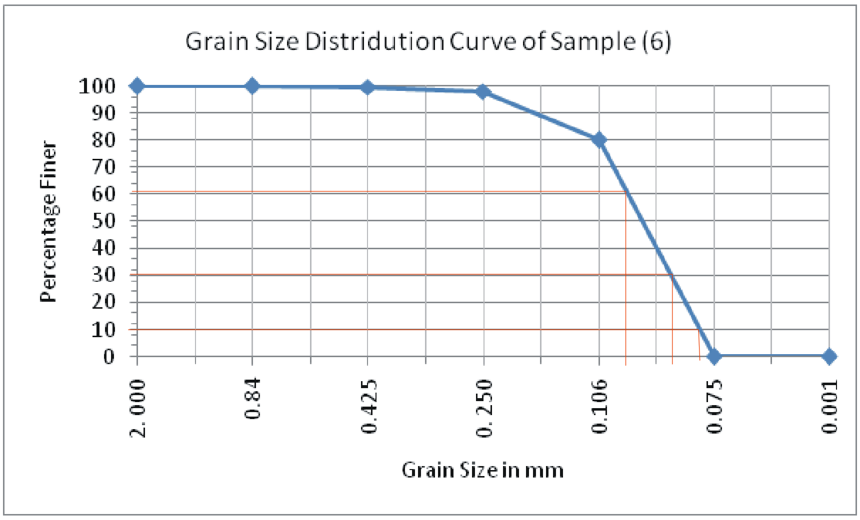
Since the C_u = 2.278 which is less than from four (4) to six (6), C_c = 0.620 which is not within the range 1-3, then the sediment sizes are poorly graded. That means unified classification of sediment grain size.

Grain Size Analysis (6) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach of River, Benue in Yola Adamawa State, Nigeria, Sample Number: 6a, Visual Classification of Sediment: Silty sand to trace of coarse sand, Weight of Container: 15.52 gm,Wt. Container + Dry Sediment: 184.12 gm,Wt. of Dry Sample: 168.60 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	0000	0000	0000
10	2. 0	356.55	356.55	00.00	00.00	100
20	0.84	340.74	340.82	00.08	00.04	99.96
40	0.425	347.29	347.51	00.22	00.13	99.83
60	0. 25	89.63	92.19	2.56	1.52	98.31
140	0.106	331.99	362.4	30.41	18.04	80.27
200	0.075	241.36	376.58	135.22	80.23	00.04
Pan	------	281.38	281.46	00.08	00.04	00.00
Total Weight=				168.57		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 00.0, % Sand= 19.73. % Fine sand= 80.27



Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 00.00_ D_{10}= 0.079 mm, % Sand= 19.73_ D_{30}= 0.087 mm. % Fine sand= 80.27_ D_{60}= 0.980 mm

$$C_u = \frac{0.980}{0.079} \; C_c = \frac{(0.087)^2}{(0.980 \times 0.079)} = 12.405 = \frac{0.0076}{0.774} = 0.098$$

Since the C_u = 12.405 which is greater than from four (4) to six (6), C_c = 0.098 which is not within the range 1-3, then the sediment sizes are well graded. That means the classifications of sediment grain sizes are not uniformly graded.

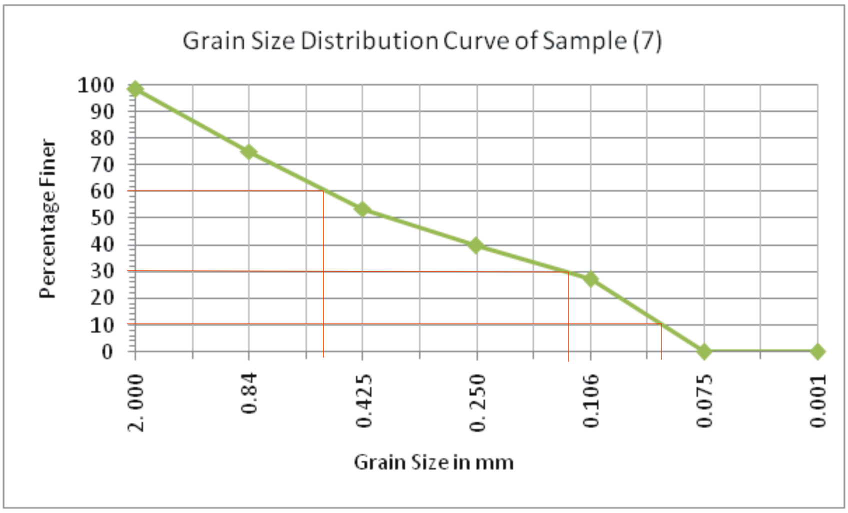
Grain Size Analysis (7) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected

Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 7 A, Visual Classification of Sediment: Silty sand to trace of fine gravel, Weight of Container: 15.52 gm. Wt. Container + Dry Sediment: 489.49 gm, Wt. of Dry Sample: 473.97 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	0000	0000	0000
10	2. 0	356.55	362.90	06.35	01.34	98.66
20	0.84	340.74	451.69	110.95	23.41	75.25
40	0.425	347.29	449.12	101.83	21.48	53.77
60	0. 25	89.63	155.99	66.36	14.00	39.72
140	0.106	331.99	391.36	59.37	12.53	27.24
200	0.075	241.36	370.47	129.11	27.24	00.00
Pan	-------	281.38	281.38	00.00	00.00	00.00
Total Weight=				473.97		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 1.34, % Sand= 71.42, % Fine sand=27.24



Source: Fieldwork, 20167.

From Grain Size Distribution Curve: % Gravel= 1.34_ D_{10}= 0.083 mm, % Sand= 71.42_ D_{30}= 0.142 mm, % Fine sand= 27.24_ D_{60}= 0.529 mm

$$C_u = \frac{0.529}{0.083} \; C_c = \frac{(0.142)^2}{0.529 \times 0.083)} = 6.373 \quad = \frac{0.0202}{0.0439} = 0.461$$

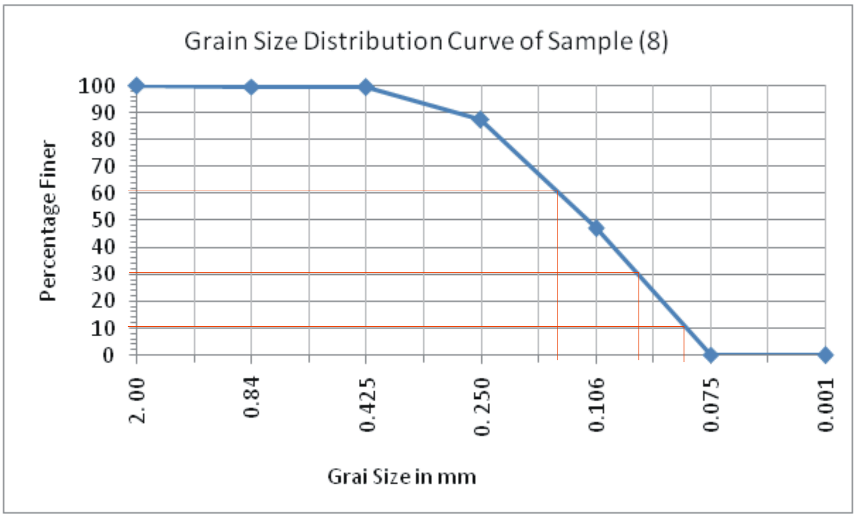
Since the C_u = 6.373 which is greater than from four (4) to six (6), C_c = 0.461 which is not within the range 1-3, then the sediment sizes are graded. That means the classifications of sediment grain sizes are uniformly graded. Uniformly graded looks like the particles are of equivalent size and you can see that this curve is a steeper curve that represents uniformly graded or a uniform fully graded soil. This represents a well-graded soil because the finer particles are filling the voids within the large particle sizes. So this is a well-graded purely sorted soil tank.

Grain Size Analysis (8) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 8 A, Visual Classification of Sediment l: Silty sand and medium sand, Weight of Container: 15.52 gm, Wt. Container + Dry Sediment: 426.27 gm, Wt. of Dry Sample: 410.75 gm.

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	00000	0000	000
10	2. 0	356.55	356.55	00.00	00.00	100
20	0.84	340.74	341.12	00.38	00.09	99.91
40	0.425	347.29	348.72	01.43	00.35	99.56
60	0. 25	89.63	138.93	49.33	12.01	87.55
140	0.106	331.99	498.42	166.42	40.52	47.03
200	0.075	241.36	433.14	191.78	46.70	00.33
Pan	-------	281.38	282.78	01.4	00.33	00.00
Total Weight=				410.70		

Source: Fieldwork, 201.

From Grain Size Distribution: % Gravel= 00.0, % Sand= 52.97, % Fine sand= 47.03



Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 00.00_ D_{10}= 0.083 mm, % Sand= 52.97_ D_{30}= 0.094 mm, % Fine sand= 47.03_ D_{60}= 0.152 mm

$$C_u = \frac{0.152}{0.083} \; C_c = \frac{(0.094)^2}{(0.152 \times 0.083)} = 6.25 = \frac{0.0088}{0.0126} = 0.698$$

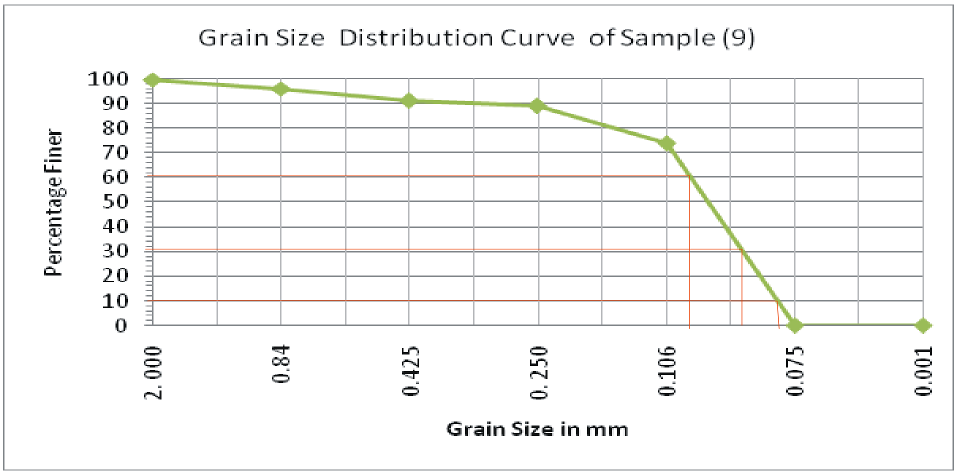
Since the C_u = 6.265 which is greater than from four (4) to six (6), C_c = 0.698 which is not within the range 1-3, then the sediment sizes are graded. That means the classifications of sediment grain sizes are uniformly graded. Uniformly graded looks like the particles are of equivalent size and you can see that this curve is a steeper curve that represents uniformly graded or a uniform fully graded soil. This represents a well-graded soil because the finer particles are filling the voids within the large particle sizes.

Grain Size Analysis (9) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 9A, Visual Classification of Sediment: Silty sand to trace of coarse sand, Weight of Container: 15.52 gm, Wt. Container + Dry Sediment: 152.30 gm, Wt. of Dry Sample: 136.78 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	0000	00000	00000	00000	0000
10	2. 0	356.55	356.74	00.19	00.14	99.86
20	0.84	340.74	345.66	04.92	30.60	96.26
40	0.425	347.29	353.97	06.68	04.88	91.38
60	0. 25	89.63	92.51	2.88	2.11	89.27
140	0.106	331.99	352.75	20.76	15.18	74.10
200	0.075	241.36	342.70	101.34	74.10	00.00
Pan	-------	281.38	281.38	00.00	00.00	00.00
Total Weight=				136.77		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 0.14, % Sand= 25.76, % Fine sand= 74.10



Source: Fieldwork, 2017.

From Grain Size Distribution Curve: % Gravel= 00.14_ D_{10}= 0.079 mm, % Sand= 25.76_ D_{30}= 0.087 mm, % Fine sand= 76.10_ D_{60}= 0.102 mm

$$C_u = \frac{0.102}{0.079} \quad C_c = \frac{(0.087)^2}{(0.102 \times 0.079)} = 1.291 = \frac{0.0088}{0.0126} = 0.698$$

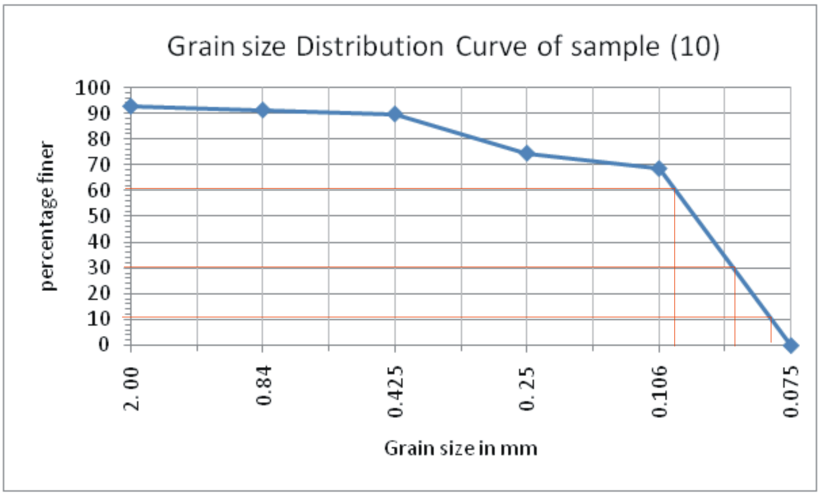
Since the C_u = 1.291. Which is less than from four (4) to six (6), C_c = 0.698 which is not within the range 1-3, then the sediment sizes are poorly graded. That means the classifications of sediment grain sizes are not uniformly graded.

Grain Size Analysis (10) Sieve Analysis, Date Tested: 7 June, 2017, Tested By: Mr. Hannaniya Musa and Mr. Oliver Kadmiel, Project Name: Assessment of Channel Sedimentation of selected Reach of River Benue in Yola Adamawa State, Nigeria, Sample Number: 10A, Visual Classification of Sediment: Trace of silt sand to trace of coarse Sand, Weight of Container: 15.52 gm, Wt. Container + Dry Sediment: 151.31 gm, Wt. of Dry Sample: 135.79 gm

Sieve Number	Diameter (mm)	Mass of Empty Sieve (g)	Mass of Sieve + Soil Retained (g)	Sediment Retained (g)	Percent Retained	Percent Passing
4	4.75	00000	00000	00000	00000	0000
10	2. 0	356.55	366.30	09.75	07.18	92.82
20	0.84	340.74	342.74	02.00	01.47	91.35
40	0.425	347.29	349.34	02.05	01.51	89.84
60	0. 25	89.63	110.34	20.71	15.25	74.59
140	0.106	331.99	340.04	8.05	5.93	68.66
200	0.075	241.36	334.59	93.23	68.66	00.00
Pan	-------	281.38	281.38	00.00	00.00	00.00
		Total Weight=		135.79		

Source: Fieldwork, 2017.

From Grain Size Distribution: % Gravel= 7.18, % Sand= 24.17, % Fine sand= 68.65



From Grain Size Distribution Curve: % Gravel= 7.18_ D_{10}=0.0206875mm, % Sand= 24.17_ D_{30}=0.086625mm, % Fine sand= 68.65_ D_{60}=0.102125mm.

$$C_u = \frac{0.102}{0.079} \; C_u = \frac{(0.087)^2}{(0.0102 \times 0.021)} = 4.9366 = \frac{0.0088}{0.00214} = 4.112$$

Since the C_u = 4.9366. Which is greater than from four (4) to six (6), C_c = 4.112 which is above the range 1-3, then the sediment sizes are not well graded. That means the classifications of sediment grain sizes are not uniformly graded. Uniformly graded looks like the particles are of equivalent size and you can see that this curve is a steeper curve that represents uniformly graded or a uniform fully graded soil. This represents well-graded sediment because the finer particles are filling the voids within the large particle sizes.

The total sediment load of the study area

sample	bed load sediment (g)
1	279.40
2	213.77
3	166.63
4	282.11
5	255.55
6	168.57
7	473.97
8	410.70
9	136.77
10	135.79
total	2523.36

Source: Fieldwork, 2017.

From the table above, the bed load sediment is 2523.26g. The river channel was able to transport 2523.26g of particles pre 20 seconds, this indicates that reasonable amount of particles are passing through the river channel of Benue. Therefore, 7569.78g of bedloard sediments are being transported per minutes, 454186.8g sediments per hour, 10900483.2g of bedloard per day. This amount of sediment will be deposited whenever the volume of stream flow reduces, eventually cause destruction in the river channel.

Based on the personal observation and oral interview conducted, sedimentation load characteristics have a lot of effects on gauge height readings. It was discovered that the river is filled with bed load sediments which consequently burry some plates of gauges. This affects the daily readings because you may not know the numbers of gauges buried. It was also discovered that when erosion take place, it uproots the installed gauges.

How bed load sediments buried some plates of gauges

Source: Fieldwork, 2017.

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III. Conclusion

Sedimentation is the tendency for particles to settle out of the fluid in which they are entrained and come to rest against a barrier. This is due to their motion through the fluid in response to the forces acting on them; these forces can be due to gravity, centrifugal acceleration, or electromagnetism. It is discovered that the sub-bank and edges of the river channel are aggradated with bed load sediment, while the deepest part of the channel is degraded due to high volume of stream flow. These resulted to the clogging of aquatic nest, inaccurate gauge heights, flooding, poor navigation and damage of morphology of the river. In the other hand, the deposited floodplain in the channel encourages irrigation.

IV. Recommendation

Some observed behavioral characteristics of stream flow suggested the relative greater importance of bed load at higher and low flows, that the transport process is characterized by spatial and temporal variability, neither of which can be ignored, and that adequate direct integrated sampling techniques exist to quantify characteristics of bed load in natural rivers.

At present, measurement of bed load is a time-consuming and expensive undertaking. Technology that will substitute direct sampling of bedload is needed to be both developing and encouraging; these indirect methods of measurement must provide information relevant to real-world needs. The ability of indirect methods to conform the observations from direct measurement should be useful in the continued development of substituted technology.

The zero level of the river at Jimeta Bridge should be taken continually so as to obtain the accurate depth of the river and water level. This will reduce the problem of inaccuracy in the maximum and minimum water level.

The installed gauges particularly those in the middle of the river should be reinstalled again, since the sea level of the river are subject to change through aggradation and degradation of the river bed.

The stream flow of the river should be conducted time to time so as to obtain accurate bathymetry of the river, width of the river, bed level of the river, gauge height of the river and velocity of the river.

Dredging of the river should be done so as to remove the accumulated bed load particles that are presently cemented in the river. This will result to smooth flow of the water in the river.

Planting of trees and cover crops should be adopted so as to reduce all forms of erosion.

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Hajjatu Tammi . " Assessment of Channel Sedimentation of Selected Reach of River Benue In Yola IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) 12.9 (2018): 09-27.