Evaluation of Bed Load Sediments in Srinagar Valley of Alaknanda River (Garhwal Himalaya) India

Sapna Semwal[1], D. D. Chauniyal[2]

Department of Geography, Dr. Nitya Nand Himalayan Institute of Research Center, Doon University Dehra Dun, India

Abstract: ***Sediment load is most important variable to determine the nature of channel pattern and hydraulic geometry. The bed load sediment that is carry by the specific amount of water supply. The present study evaluates the types of bed load sediments in the Srinagar Valley of Alaknanda River in Garhwal Himalaya within the context of mountain meandering river. The Krumbein (1937) standard scale has been adopted for the measurement of bed load sediments and classification of its size range. Results show that maximum 54% sediments material is boulder and cobbles. The second higher percentage of sediment is under different size of gravels i.e. 30%. The percentage of sand is 15.4 while the very fine material like silt/mud/clay is negligible e.i.0.94% in the study area. Gravel size clasts in the channel bed and river banks constitute 70% of the total Quaternary sediment. Most of the boulders pebbles and garbles in channel beds are crystalline and meta-sedimentary rocks which derived from the Higher Himalaya. Thus the final results show that it is a boulder and gravelly bed river in the Srinagar valley because 84% of sediment material belongs to the boulders and gravels.***

Keywords: Alaknanda, Sediments, Boulder, Gravel, Himalaya

1. Introduction

The scientific study of sediments and of the processes by which they were deposited is the description, classification, origin and interpretation of sediments (Glossary of Geology, AGI, 1974). Sedimentation is a process whereby rock and soil particles are eroded and transported by agents and deposited as layers in plain surface, channel bed, lake, reservoir and sea (Colleta et al 2018). Basically it is very complex process in which sediment yield, erosion, transportation and deposition work together (Ezugwu 2013). In geology or geomorphology, sedimentation is often used as the opposite of erosion, i.e., the terminal end of sediment transport. In that sense, it includes the termination of transport by saltation or true bed load transport. Settling is the falling of suspended particles through the liquid, whereas sedimentation is the termination of the settling process *(*Van Santen, et al, 2007). When the river loses energy, the eroded material is dropped down through the process of deposition. River can loses its energy when it reduces channel gradient, flood water, friction close to river bank and shallow area which leads to the speed of the river reducing. River is a highly competent agent which has capable to carry larger size of particles. Greater the volume flow of the river, the high amount of load in motion and as a result the greater its capacity. The turbulent flow fluid has a much erosion and deposition power. As velocity increases, the flow tends to become turbulent.

In the Himalayan region most of the sediment studies are rely on sediment discharge and suspended sediment load samples measured during the summer season for short time (Fort, 2016). The suspended sediment concentration (SSC) show spatial and temporal variations due to variation in water discharge (Ali & Boer 2007, Collns et al, 2013). Transportation of sediment load is varying from place to place according to a real expansion and seasonal changes in the Himalayan region. Production of sediment load in is controlled by spatial and temporal pattern of erosion, process of erosion, steepness of the river gradient, climatic changes and tectonic movements (Andermann et al, 2012). Out of these factors, rare sediment transport events also play a significant role (Wasson et al 2008, 2013). Recent catastrophic flood event caused by either by intensive rainfall, landslide outburst floods (Wulf et al, 2010) that have affected in the Himalayan region. Srinagar valley of Garhwal Himalaya is most affected by 1894, 1970 and 2013 flood events. In the Garhwal Himalaya, the parental rivers Bhagirathi and Alaknanda are rise from glaciers of the Higher Himalaya. Therefore, large amount of suspended and bed loads transported by these rivers and their tributaries. Hussain and Chauban (1993) estimated the ratio of suspended to traction loads (525gm/L) in the Alaknanda at Badrinath. Similarly, Bhagirathi River was transported 1.22mt/yr suspended load at Maneri station (Chakrapani and Saini (2009).

Sediment can be classified based on its grain size and/or its composition (Neuendorf, et al, 2005, Wilson & Moore, 2003). Mathur et al (2001) estimated the sediment load of Mississipi River in the United State. Dill, William (1990) also estimated the sediment amount of Po River in Italy annually. It has been estimated that the Yellow River annually carries 796 million tons of sediment to the sea (Dill, 1990). However, no work has been carried out on bed load sediment flux in the Himalayan Rivers so far. Therefore, present problem has been taken into consideration as a pilot project. Very little attention has been paid to the measurement of river sediments in the field of the geomorphology and geologyin India. The most frequent reasons for this are lack of awareness of current techniques in sedimentology and lack of funding equipments etc (Ongley, 1996). Direct and indirect methods are two ways in which bed material can be measured. No one method is entirely satisfactory and no any bed load measurements sampler has been extensively tested and calibrated over a wide range of hydraulic conditions.

Direct measurement is done through use of a physical trap (Andrews, 1981). Box, basket or tray and pressure

ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

difference are described by Hubbell (1987). Indirect measurements can be performed by a tracer, repeated channel surveys, bed form velocimetry. Indirect channel surveys, provided they are detailed enough at the reach scale, can produce reliable results, and have the advantages of minimum disturbance to the flow and time-integrated sampling which averages out short-term fluctuations in the transport rate (Lane, et al 1995). Hubbel (1964) mentions various apparatus and techniques of bed load and bed material collection. An Indian method have been developed and tested by Irrigation and Power Research Institute, Punjab (Uppal and Gupta, 1958).

2. Study Area

Srinagar valley is formed by the river Alaknanda in Lesser Himalaya. The Alaknanda River rises from the snout of Satopant Glacier at the height of 3760m and after traveling 191 km distance it joins in the Bhagirathi River at Devprayag (442m). The average gradient of the river is about 17.3m/km from source to mouth (Nand and Kumar, 1989). After the distance of 161km downstream, it forms 11.5km long and 2.5 km wide sinuous meandering river valley of Srinagar (Fig. 1). Geographically the valley is bounded by 780 45' 16" E to 780 49' 43" E Long and 300 12' 36" N to 300 15' 47" N Lat. which covers 41.29 Km2 area. Out of the total area about 13.27km2 occupied Quaternary sediments. The average gradient of the river in the valley is very low (0.0054).

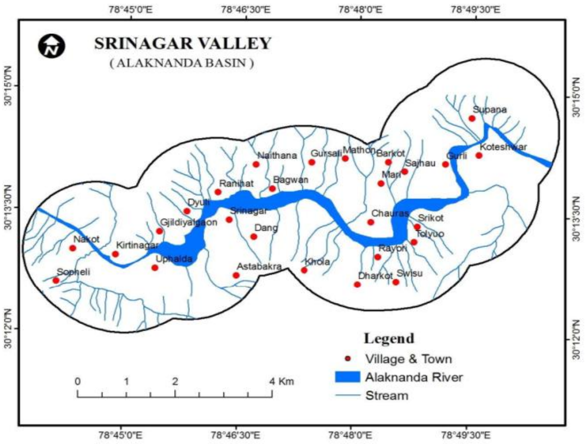

Figure 1: Location Map

3. Objectives

The main purpose of the present study is to evaluate the process, types and classification bed load in the Alaknanda River in Srinagar valley of Garhwal Himalaya.

4. Methodology

Based on the Indian method, a manual sampling method has been used to collect the sediment from 8 different segments of Alaknanda River in Srinagar valley. The sites have been randomly selected for the collection of sediment material. For this purpose 1m3 have been selected on the sub-surface of the channel bed. Due to the heavy load of the material, entire 1m3 materials was not possible to carry in the lab so that bed material collected from 30cm3 dimension area of the core of 1m3 from 8 different sites. It is therefore, the sampling has been done during the dry season (March) in 2016. All the samples were collected, measured and analyzed in the laboratory. For the classification of grain size, sieve method has been applied in the present study. The sediment size ranges are defined according to Wentworth scale (or Udden-Wentworth (1922) scale). It is a standard scale for measuring river sediments. The Krumbein *phi* (φ) scale, a modification of the Wentworth scale created by W. C. Krumbein in 1937, is a logarithmic scale.

The grain size data obtained from our own field data, but all data were collected using comparable field techniques. Surface and sub surface size grain size distributions were obtained through bulk sampling of the river substrata of middle and lateral bars, where the river deposited material in layers (Wolman, 1954, Church et al., 1987). Boulders, cobles, pebbles portion of the sediments (>0.26m) measured and analysed in the field and subset of the finer material (<0.26) was sieved and classified in the hydrological laboratory (Church, et al., 1987, King, et al., 2004). All bed load samples were dried up before the sieved in the lab. Methods may be simple shaking of the sample in sieves until the amount retained becomes more or less constant. This technique is well-adapted for bulk materials. A large amount of materials can be readily loaded into 32mm and <4mm diameter sieve trays. For this analysis, 8 bed material samples have been collected on in average 1.4km distance on the Alaknanda channel sub-surface bed. The results of the field data and sieve process are shown in Table 1.

Factors Controlling Bed Load Sediment

Charlton (2008) and Wohl (2014) explained that erosion, deposition, motion of sediment and nature of river bed are included in fluvial process. In the mountain river velocity of water plays a significant role in the process of bed load sediment deposition. On a specific velocity at which the grains start to move, called entrainment velocity. If the specific velocity will falls below the entertainment velocity the grains or sediment are to be deposited (Garcia and Parker 1991). There are numerous factors are affect and control the bed load sediment flux in the river channel. Among them nature of bed, composition of sediments, grain size and catchment lithology are prominent factors. As a general rule, the bed is the part of the channel up to the normal water line, and the banks are that part above the normal water line (Jerolmack and Mohrig, 2007). Sediments are transported, eroded and deposited on the river bed (Garcia & Parker, 1991).

The Alaknanda River bed is very complex in terms of erosion and deposition. Although the river bed of Alaknanda River is well defined but some time it change due to increased flood magnitude and frequency. It was observed that river bed changed at SSB, Diuli village and Chauras localities by the mega flood of 2013. The sediment that has been deposited during earlier flood needs a higher flood to become wash again. Most of the sediments washed out during higher flood and rock bed exposed on the surface. Some time fine material washes out and only course sediment like boulders cobbles and grabble remains behind. The prominent example of it has been reported at SSB and Diuli village in 2013 event.

Since from the source the catchment of the river lies in the Tethys Himalaya, the Higher Himalaya and part of the Lesser Himalaya, which are separated from each other by major tectonic units (Chaudhary, et al, 2015). After traveling a distance of 172 km it passes through the different litohological units. The major rock types of the catchment area are shale, sandstone, fossiliferous limestone of Tethys Himalaya; granite, gneiss schist and quartzite of the of the Higher Himalaya and quartzite, meta-sedimentary, phyllite and meta-basics rock fragments of Lesser Himalaya (Valdiya 1980). Gravel size clasts in the channel bed and river banks constitute 70% of the total Quaternary sediment in the Srinagar valley (Chaudhatry, 2015). Sediment can be classified based on its grain size and/or its composition. Granular material can range from very small colloidal particles, through clay, silt, sand, gravel, and cobbles, to boulders. Sediment size is measured on a log base 2 scale, called the "Phi" scale which classifies particles by size from colloid to boulder.

Types of Sediment Load

The sediment load of a river is transported in various ways although these distinctions are to some extent arbitrary and not always very practical in the sense that not all of the components can be separated in practice. Dissolved load, suspended load and bed load are the major three loads transported by the river or stream. Dissolved load is material, especially ions from chemical weathering, these are carried in solution by a stream. The dissolved load contributes to the total amount of material removed from a catchment. The suspended load of a flow of fluid, such as a river, is the portion of its sediment uplifted by the fluid's flow in the process of sediment transportation. It is kept suspended by the fluid's turbulence. The suspended load generally consists of smaller particles, like mud, clay, silt, and fine sands. Here the main focus is given on bed load.

Bed load is generally thought to constitute 5-10% of the total sediment load in a stream which moves by rolling, sliding, and hopping over the bed, and moves at a small fraction of the fluid flow velocity. Bed load is an important component of that it plays a major role in controlling the morphology of the channel. The nature of river bed material has significance on the morphological and hydrodynamic characteristics of the river. The amount and size of sediment moving through a river channel are determined by gradient, width, peak discharge, source of sediment and process of sediment supply. Low gradient successively increased the incompetency to transport sediment size. The channel width affects the competency and capacity of size and amount. Discharge refers to maximum amount of sediment that river can transport in traction as bed load. Sediment supply refers to the amount and size of sediment available for sediment transport. Roughness of the river channel determines frictional resistance. This resistance of the bed affects the average flow velocity of discharge and energy of the river to sediment transport (Lin, et al, 2014). Bed material determined the nature and type of the river bed and nature of roughness.

In a mountain river Alaknanda, carried large amount of boulders, cobbles, grabbles and sand in time to time depends upon the flow discharge. Gravel bed consists of a wide range of courser sediments to gravels or boulders. Sand beds are comprised of sand and smaller sized particles. Bed material grain sizes vary along the direction of the river flow, along the bars and vertically on the bed. This variability occurs at various spatial scales. Larger floods can carry boulders and cobbles in the high gradient river. These fluvial sediments are deposited on the widespread low lying areas in the formation of bars in fractal-shaped pattern. The grain size analysis of 8 bed material sample (Table 1) of the river give a basic understanding about the nature of sedimentary river bed.

5. Results and Discussion

The bed load sedimentation of Alknanda River is assessed after the mega flood of 2013. The bed load sediments are generally divided into five major type i.e. giant boulder, boulder, coble, gravel and sand. The giant boulder, coble and pebble are measured by tape/scale in the field however; the gravel and sand are assessed and classified by sieve. In the mountains, rivers are transported large size of rock resistant pieces in the narrow v shaped walleyes. High channel gradient and very high amount of water discharge jointly along with high velocity help to push the giant rock boulders in the channel bed and as the channel gradient and velocity decreases it started to deposit on the bed of the channel. The sources of giant boulders on the channel bed are either from land slide or rock fall or erratic boulders of past glaciers which derived by the river from higher Himalayan slopes. Earlier giant boulders would be transported by glaciers and deposited as till. Later on the finer grains like gravels and sand may be entirely washed away by water action, leaving a deposit of only boulder and cobbles. Glacially transported boulders tend to share several shapes and downward diagonal striation on lateral facets (Pettijohn, 1975). Some of the giant boulders are also derived by the Alaknanda River through a narrow shaped valley and dropped them when the river course becomes wide at Srikot. Most of the granite and gneissic boulders are derived from Higher Himalayan crystalline rocks while quartzite boulders are derived either from Higher Himalaya or Laser Himalaya. Some of the elongated and sub rounded boulders are derived from Garhwal group of rocks which are derived from short distance in the Srinagar valley. These giant boulders are further classified in the Table 2. The density of the different size of boulder is varying from place to place as the downward distance increases. Most of the giant quartzite boulders (>4m) are found where the valley becomes wide at Srikot. After that the river bed is covered by more than 2m size boulders (Fig. 4). The average density of these boulders is 18 per 10 m2. However, the density of the 1m size boulders increases (Fig. 3 & 4). After downward from the Srikot meander bend the size of boulders are reducing in to cobbles and further cobbles are changes in to gravel as the downward distance increases.

Table 1: Results of the Bed Load Sediment Samples

Sediment Type	Sieve Size	Percentage of different size material in different distance locations									Result
		Surasu	Srikot1	Srikot 2	Bridge site	Kikileswar	Ranihat	SSB	Sriyantra Tapu	Average %	
		3km	4.3km	2.15km	6.5km	7.5km	9.7km	10.5km	11.2km	1.4km	%
Boulder	256-600 mm	32.5	38	37.5	33	32.2	30.5	23	17.3	30.5	53.98
Cobble	64-256 mm	24.2	17.9	17.1	20.4	25.3	26.2	27.5	29.2	23.48	
Pebble	32-64 mm	12.9	11.8	9.1	12	7.9	15.2	15.6	16.1	12.58	12.58
Course Gravel	16-32 mm	9.2	9.3	8.8	5.8	4.9	4	7.4	9.7	7.39	
Medium Gravel	8-16 mm	6.3	8.4	11.3	2.4	4.1	2.4	3.2	4.3	4.77	
Fine Gravel	4 - 8 mm	3.5	11.8	0.4	2.4	2.3	0.8	1.2	1	3.21	
V. Fine Gravel	2 - 4 mm	1.9	0.7	5	0.3	3.5	2	2.5	3.7	2.45	17.82
V. Course Sand	1 - 2 mm	0.4	2.5	0.4	0.4	0.6	0.4	1.8	2	1.06	
Course Sand	0.5 - 1 mm	0.4	0.6	1.2	0.7	1.2	0.8	0.9	0.7	0.81	
Medium Sand	.25 - .5 mm	2.9	2.9	8.9	17	6.9	12.5	12.3	11.5	9.36	15.44
Fine Sand	125- 250 um	3.7	5.8	0.2	3.1	9.4	2	2.2	2.5	3.36	
V. Fine Sand	62-125 um	1.2	0.2	0.1	1.1	0.5	0.8	1.3	1.6	0.85	
Silt/Mud	4-62um	0.9	0.1	0	1.4	1.2	2.4	1.1	0.3	0.93	0.94
Clay	<4 um	0	0	0	0	0	0	0	0.1	0.01	
	Total	100	100	100	100	100	100	100	100	100.76	100.76

Table 1 reveals that maximum 54% sediments material consists of boulder and cobbles. The second higher percentage of sediment is under different size of pebbles and gravels i.e. 30%. The percentage of sand is 15.4 while the very fine material like silt/mud/clay is 0.94% in the study area.

Classification of Giant Boulders: On the basis of size, the giant boulders are classified into following three types (Table 2)-

Table 2: Classification of Giant Rock Boulder

Size in m	Shape	Rock type	Example
0.60 - 1m	Sub Rounded	Granite/Gneisses/ Quartzite/Meta basic	Fig.2 a, b, c & d
1 – 2m	Rounded to Sub rounded	Quartzite/Meta basic rock	Fig. 3 a, b & c
>2m	Sub-rounded to elongated	Quartzite rock	Fig.4 a, b, & c

Figure 2: a & b are Quartzite giant boulders and 2 c & d are meta-basic rock's giant boulders on the channel bed near Srikot. Pot holes are also developed on boulders

Figure 3: a, b & c: 1m to 2m size granite and quartzite boulders

Figure 4: a, b & c: 0.6m to 1m Size Boulders

Classification of Cobbles

A cobble is a clast of rock with an average size of 64-256mm as defined on Krumbein Phi Scale (Table 1). According to their size they are further classified in to course (64-128mm), medium (128 – 190mm) and fine classes (190 - 256mm) (Fig. 5a, b, & c). These are consisting of granite, quartzite and meta-basic rocks which shape has varying from sub-rounded to round. Out of the total sample sediments, average 23.48% is estimated cobbles in the study area (Table 1). Recently deposited cobbles are shown in figure 6 by the mega flood 2013.

Figure 5: a, b, & c: Course cobbles, medium cobbles and fine cobbles

Figure 6: Boulders, cobbles and recently deposited gravels bed

Pebbles

Large size of gravels is also called pebbles. A pebble is a clast of rock with an average particle size of 32 to 64mm based on the Krumbein Phi Scale (Fig.7 a, b, & c). Pebbles are generally considered smaller than cobbles and larger than gravels in size (Table 1). Generally pebbles left above the high water marks and comes in various rocks and texture. Table 1 reveals that about 12.58% contains under pebbles in the Alaknanda channel bed.

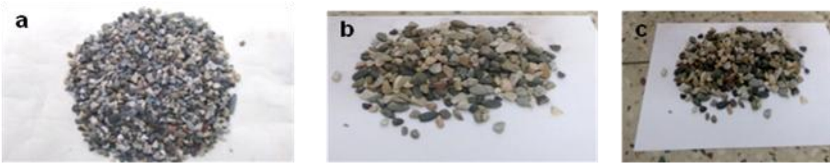

Figure 7: a, b, & c Pebbles of different sizes (or very course gravels)

Classification of Gravels

Gravels are composed of unconsolidated rock fragments that have a general particle size range 2 to 64mm and include size classes from granular to pebble sized fragments (fig. 8 a, b, c, d & e). International Organization for Standardization 14688 grades gravel as fine, medium and course. Gravels are classified by the Udden-Wentworth scale (1922) into course (16-32mm), medium (8-16mm), fine (4-8mm) and very fine (2-4mm). One cubic meter of gravel typically weight about 1,800 kg. Table 1 reveals that out of the total sediment about 17.8% is under gravel bed. Out of which 7.23% amount is course grabble followed by medium grabble (4.77%). Very little percentage of area is under fine and very fine e i. 3.21 and 2.45% respectively. It shows that the gravel size decreases from course to fine. Table 1 also reveals that as the downward distance gradient increases the size of gravels are also decreases in the study area. Gravels are an important commercial product with a number of applications. Most of the matteled roads are surfaced with gravels.

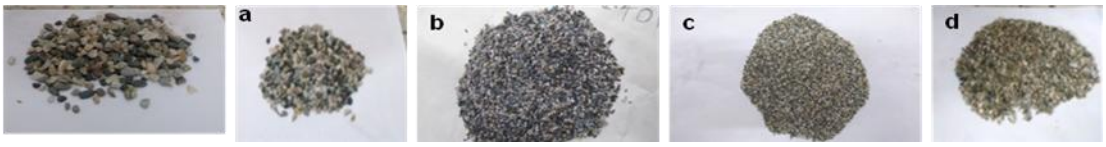

Figure 8: (a) Very Course gravels, (b) Course gravels, (c) Medium gravels (d) Fine gravels and (d) Very fine gravels

Classification of Sand

Sand is a distinguishable piece of material composed of rock and mineral particles. Sand is generally considered finer than gravels and courser than silt in size (Table 1). On the basis of particle size sand can classified from very fine sand to gravelly send. The size of grains between 0.075 to 0.425mm is known as fine sand (Fig. 9d) which is mainly used for plastering jobs. The sand grains size between 0.425 to 2mm is known as medium sand (Fig. 9c). Beside these 2.0 to 4.75mm grain size sand is known as the coarse sand (Fig. 9b). It is generally used for brick masonry work. The sand passing through the size of 4.75 to 7.62 mm is known as the gravelly sand (Fig. 9a). It is generally used for concrete work.

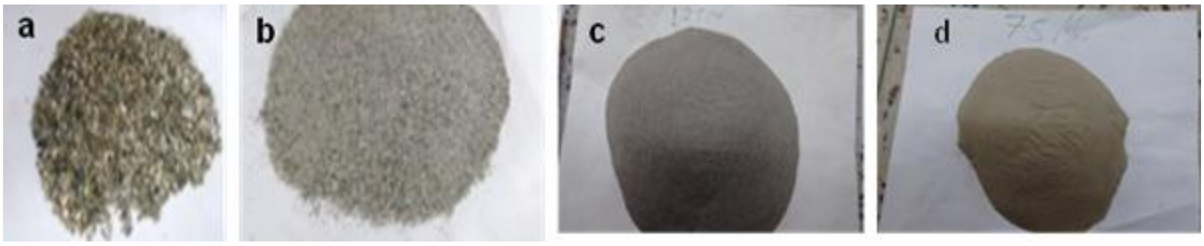

Figure 9: (a) Very coarse sand; (b) Coarse sand; (c) Medium sand and (d) Fine sand

Sand is generally deposited on the point bars and lateral bars of the channel. The major areas of the sand deposition are at the lower end of Srikot, near Ranihat and Sriyantra Tapu. Course and very course sand lenses are generally deposited between fine and very fine gravel layers by the current bedding. There are few pockets where the silts and clay deposited in the study area. Suspended load is only deposited on those places where the eddy motions of river water taken place during high flood.

Most of the silt and clay particles are flow through very high velocity of water discharge.

Silt and Clay

Silt is an inherently occurring material composed of quartz and feldspar minerals. Silt is also a clast of rock with an average particle size of 0.0039 and 0.0625 mm, based on the Krumbein Phi Scale. Silt is generally considered smaller than very fine sand (>.62um) and larger than clay (>.4um) in size (Table 1). Clay is a fine grained inherent occurring rock material that combine one or more clay minerals mainly quartz, metal oxide and organic matter (Guggenheim1995). Mineral particles are so small less than 2 micron. Silt and clay may occur as a soil or sediment mixed in suspension with river water. Silt and clay contain is found 0.94% in the study area. Due to the turbulent flow and very high amount of discharge the silt and clay are transported as a suspended load. Therefore, very little amount of fine material deposited in channel banks and bars by the river.

The distribution trend of grain size is very from place to place as downward distance increases. As the distance and width of the river is increases from Supana to Kirtinagar the gradient is decreases. As a result most of the boulders and cobbles are short out behind at Srikot, pebbles and gravels are up to SSB and fine gravels and sand are found up to Sriyntra Tapu. Thus the final results show that it is a boulder and gravelly bed river in the Srinagar valley because of the highest percentage (84%) of sediment material is belonging to the boulders and gravels.

6. Application of the Study

River sedimentation study is applied to solve many environmental, geomorphological, geological, engineering and geotechnical problems of any region. Measuring or quantifying sediment transport or erosion is therefore, important for mountain regions. Erosion, flash flood, siltation, etc are the very serious problems of the Himalayan mountain region. Rate of erosion can be asses by measurement of sediment deposits. Flow and transportation of sediments in the rivers is very important in providing habitat for fish and other organisms. River sediments supply soils and nutrients to repairman vegetation. Knowledge of sediment transport can be used to plan and extend the life of a dam. Size and types of sediments on the river bed can assess the nature, velocity and recurrence of water discharge of past and present. Estimation of flood can be asses by the nature and extension of past sediments in the river. Beside this Geologist can use inverse solution of transport relationship to understand flow depth, velocity and direction from sedimentary rocks and recent deposited sediments.

During flash flood huge amount of sediments are transported by the river which erode the river banks and spared over the flood plains, inhabited area and damage the manmade structures. Erosion can damage the adjoining environment and exposed the foundation of culverts, dam, and bridge and unsettled the foundation of the structures. Therefore, good knowledge of the mechanics of sediment transport is very useful for the civil and hydraulic engineers. Alaknanda flood of 26 August 1894, 20 July 1970 (Wassan, et al. 2013) and Kedarnath flash flood 17June 2013 are well documented. On 6 Sept. 1883, Birahi Ganga (a tributary of Alaknand) was blocked Alaknanda at Belakuchi by 5000 tonnes of rock mass (Holland 1984). The flood was damage to the property around Srinagar town. 20 July 1970, Alaknanda flood was transported about 15.9 x 10^6 tonnes of sediments within a day (Rana et al, 2013). About 13 bridges were washed out in the event. Beside this 10km stretch of Ganga canal in Haridwar was clogged with sediments.

Other environmental problem by the sediment is siltation on agricultural land and upgrading the channel bed. Whereas siltation is dangerous on the mountains, in the other hand it is also useful in plains which bring new fertile soil and nutrition for agricultural land. In spite of number of disadvantages are of river transport sediments but some advantages can also be asses in the study area. Boulders, pebbles, gravels and sand deposited on the channel bed are utilised for construction in different infrastructure works. Alaknanda river channel bed of Srinagar valley is supplied sand and gravels to all over the hills of Garhwal region. Due to the wide channel bed and lateral and channel bars in Srinagar valley sand and gravel mining is accessible to transport.

7. Conclusion

Sediment transport rates are continuously increasing in the Himalayan Rivers in the last two or three decades which is an important issue for future researchers. In the present contrast it is experienced that most of the sediments deposited by the destructive events in the past. Recently Kedarnath disaster 2013 indicates that the siltation level in Srinagar valley is increased about 4.6m over the pre sediment (Semwal 2018; Chauniyal et al., 2018). Boulders, pebbles, gravel, and sand of different sizes deposited in the form of lateral and point bars. Garhwal Himalaya is a very vulnerable part of the Uttarakhnd region which affected in different ways because of the incidents of cloud burst, glacial lake burst, landslides and other impulsive events. They are first order of generation of fluvial sediment flux in the Himalayan region. However, such type of events to mobilized large amount of bed load in the rivers. Out of these natural factors some anthropogenic activities such as construction of dams and canals, roads, tunnels, houses, urban centers etc excavated dump and waste material are also generate bed load sediment flux in the tributaries of Ganga River in Garhwal Himalaya. This process will result in an increase of sediment fluxes downstream from the higher Himalaya. They may be clog dam reservoir located in the lesser Himalaya and affect the water recourse both in quantity and quality. Bed load sedimentation study is very essential for the assessment of channel morphology and nature of river dynamics.

References

[1] Neuendorf, K.K.E., et al (eds), 2005. Glossary of Geology. American Geological Institute, Alexandria, Virginia. Pp 800.

[2] Wilson W.E. & Moore, J.E., 2003. Glossary of Hydrology, American Geological Institute, Springer, Pp248.

[3] *Charlton R., 2008. Fundamentals of Fluvial Geomorphology. London: Rutledge. p. 234.*

[4] *Wohl, E., 2014. Rivers in the Landscape: Science and Management. Wiley-Blackwell. p. 330.*

[5] Mathur A. and Cunha D. D., 2001. Mississippi Floods: Designing a Shifting Landscape. New Haven, CT: Yale University Press.

[6] Dill, William A., 1990. Inland fisheries of Europe. Rome, Italy: UN Food and Agriculture Organization. http://www.fao.org/docrep/009/t0377e/t0377e00.htm Fluvial processes.

[7] *Van S. P. et al, 2007.* Sedimentation in an Estuarine Mangrove System. *Journal of Asian Earth Sciences. Morphodynamics of the Red River Delta, Vietnam.* ***29*** *(4): pp 566–575.*

[8] *Garcia, M. and Parker, G. 1991.* Entrainment of Bed Sediment into Suspension. *Journal of Hydraulic Engineering.* ***117*** *(4): 414–435.*

[9] *Phillips, C. B. and Jerolmack, D. J., 2016.* Self-organization of river channels as a critical filter on climate signals. *Science. 352: pp 694–697.*

[10] *Chaudhary, S. et al, 2015. Formation of Paleovalleys in the Central Himalaya during valley aggradations. Quaternary International Journal, 371. Pp254-267.*

[11] *Valdiya, K.S., 1980. Geology of the Kumaun Lasser Himalaya. Wadia Institute Himalayan Geology publication, p291.*

[12] *Lin, C. P., et al., 2014. The Variation of River bed Materials due to Tropical Storms in Shi-Wan River, Taiwan. The Scientific World Journal, Vol. pp 1-12.*

[13] *Andrews, E. D. 1981.* Measurement of Bedload Transport in Sand-Bed Rivers: A Look at Two Indirect Sampling Methods. *Webcache.googleusercontent.com. Archived from the original on 2015-10-21.* Retrieved 2015-12-17.

[14] *Hubbell, D.W., 1987. Bed load sampling and analysis. Chichestre: Wiley. pp. 89–10*

[15] *Lane, S.N, et al., 1995. Morphological estimation of the time-integrated bedload transport rate. Water Resource Research. Pp 761-72.*

[16] Wentworth, C.K., 1922. A scale of Grade and Class Terms for Clastic Sediments. The Journal of Geology, USA.

[17] Fort, M., 2016. Sediment fluxes in Himalaya. In Achim A.and et al (eds), Sink Fluxes in Undisturbed Cold Environments, Chapter: 23, Publisher: Cambridge University Press, pp.326-350.

[18] Ali, K. F., and De Boer, D. H., 2007. Spatial patterns and variation of suspended sediment yield in the upper Indus River basin, northern Pakistan. Journal of Hydrology, Vol. 334, Pp368–387.

[19] Collins, D. N., et al., 2013. Climatic variation and runoff from partially-glacierised Himalayan tributary basins of the Ganges. Science of the Total Environment, 468–469, Pp 548–559.

[20] Hasnain, S. I., and Chauhan, D. S., 1993. Sediment Transfer in the Glaciofluvial Environment -a Himalayan Perspective. Environmental Geology, 22, Pp 205–211.

[21] Chakrapany, G. J., and Saini, R. K, 2009. Temporal and spatial variations in water discharge and sediment load in the Alaknanda and Bhagirathi Rivers in Himalaya. India. Journal of Asian Earth Sciences, Vol. 35, Pp 545–553.

[22] Wasson, R. J., et al, 2008. The mountain-lowland debate: deforestation and sediment transport in the upper Ganga catchment. Journal of Environmental Management, 88, 53–61.

[23] Wasson, R. J., 2013. A 1000-year history of large floods in the Upper Ganga catchment, central Himalaya, India. Quaternary Science Reviews, 77, 156–166.

[24] Wulf, H., et al, 2010. Seasonal precipitation gradients and their impact on fluvial sediment flux in the Northwest Himalaya. Geomorphology, Vol. 118, Pp13–21.

[25] Wolman, M.G. 1954. A method for sampling coarse river-bed material. Trans. Am. Geophys. Union, 35, Pp 951–956

[26] Church, M. A., et al., 1987. Sediments transport in Gravel Bed Rivers, chap. River Bed Gravels : Sampling and Analysis. John Wiley and Sons, New York, 43–88, 1987.

[27] King, J., et al., 2004. Sediment Transport Data and Related Information for Selected Coarse-Bed Streams and Rivers in Idaho. USDA Forest Service - General Technical

[28] Guggenheim, Stephen; Martin, R. T., 1995, Definition of clay and clay mineral. Journal report of the AIPEA nomenclature and CMS nomenclature committees, Clays and Clay Minerals, **43** (2): 255–256.

[29] Holland, T. H., 1984. Report on the Gohna Landslip, Garhwal, Selections from the records of the Government of India in the Public Works Department: CCCXXIV(324), Office of the Superintendent of Government Printing, Calcutta, 1984.

[30] Rana N. et al., 2013. Recent and past floods in the Alaknanda valley: causes and consequences. Current Science, Vol. 105, No. 9, Pp 1209-1212.

[31] Pettijohn, F. J., 1975. *Sedimentary Rocks* (3rd ed.). New York City: Harper and Row.
[32] Hubbell, D. W., 1964. Apparatus and techniques for measuring bedload, U.S. Geol. Surv. Water Supply Pap., 1748.
[33] Nand N. and Kumar K. 1989. Holy Himalaya: A Geographical Interpretation of Garhwal. Daya Publisher, New Delhi.
[34] *Krumbein, W. C., 1934. Size frequency distributions of sediments. Journal of Sedimentary Petrology.* ***2*** *(4).* doi:10.1306/D4268EB9-2B26-11D7-8648000102C1865D.
[35] *Glossary of Geology, AGI, 1974.*
[36] Udden, J. A. (1914). "Mechanical composition of clastic sediments". *Geological Society of America Bulletin*. **25** (1): 655–744. Bibcode:1914GSAB...25..655U. doi:10.1130/GSAB-25-655.
[37] *Aberdeen, E., 1937.* The Sediments of Barataria Bay. *Journal of Sedimentary Petrology.* ***7*** *(1).* Retrieved 11 May 2014.
[38] *Folk, R. L., Ward, W. C. 1957.* Brazos River bar: a study in the significance of grain-size parameters *(PDF). Journal of Sedimentary Petrology.* ***27*** *(1): 3–26.*
[39] Chauniyal, D.D. et al, 2018. Channel morphology of Alaknanda River in Srinagar Valley. Journal of Indian Remote Sensing Society, Vol,
[40] Semwal S. and Chauniyal, D.D., 2018. River Meander Geometry of Alaknanda River in Srinagar Valley. Indian Journal of Geography and Environment. Vol. 15.