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Analysis of Sediment Load and Riverbed Sedimentation in the Jiadhol River of the Brahmaputra Valley

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ABSTRACT

Most of the north bank tributaries of the Brahmaputra River brings heavy loads of sediments to the plains and heavy siltation of riverbed become a major problem in the region. Jiadhol River is one among those rivers. It is very notorious in causing frequent floods, siltation, and channel shifting in the region. This paper is an attempt to understand the pattern of change of sediment load in the river. A Sediment rating curve has also been derived to establish an empirical relationship between Discharge and Sediment load of the river. The channel cross-section has been observed over a period of two years to understand the pattern of siltation in different sections of the river. Field measurements and photography are used to understand the actual scenario. The study shows fast siltation occurs in the riverbed during the rainy season while the river is dry for half of the year.

KEYWORDS: Sedimentation, flow duration curve, sediment rating curve, Jiadhol River.

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INTRODUCTION

Riverbed sedimentation is a process of settling down of the load transported by a river on its own bed due to the loss of transport capacity. This is a very important and common process in all the fluvial systems. High rate of siltation has been considered as a major problem in many of the literature[1,2,3,4,5]. The problem of siltation becomes more severe when it occurs out of the river channel in the areas of human settlement and cultivation[6]. High sedimentation or siltation is the obviously related to high erosional rate in the upper catchment[2]. Whereas minimum accumulation sediment is found in high energy river environment[7]. In most of the studies it has been mentioned that the increase in the sediment flux is due to catchment disturbance by human activities[8, 9, 10, 11, 12]. Slope reduction due to lengthening of the river is another important cause of rapid aggradation of river[13]. Siltation of river bed causes reduction of the channel gradient and carrying capacity of the channel, hence reduction in the velocity and sediment transporting capacity of the stream, which further enhances the silting up of the channel and led to channel avulsion[14]. High sediment results to aggradation as point bar, mid-channel bars and increase the sinuosity of the river it also increases riverbed siltation and channel shifting and meander loop migration and result change in channel morphometry[15]. Das[16]in her thesis mentioned that one of the major causes of occurrence of flood is rapid siltation of the river bed and resultant frequent channel avulsion beside the rainfall events.

Sediment rating curve is very important in studying river sedimentation. It is defined as the statistical relationship between suspended sediment concentration or sediment load and stream discharge (Q) and this relationship generally takes the form of a power function[17]. Suspended solid discharge rating curve obtained for hydraulic stations can be used for estimation of suspended solid discharge [17]. A detail description on fitting and interpretation of sediment rating curve is given by Asselman[18]. He suggested that a steep curve indicated flushing of sediment even in low discharge condition where as lower steepness indicated occurrence of faster sediment deposition. Thickness of siltation deposition can be obtained by field survey, by measuring the recent bar height or depth of riverbed with reference to water surface using the steel rolling rule and comparing it with earlier available records[19]. The characteristics of the sediment carried and deposited by the river over time is very important in understanding the history of the river in terms of past climate and environment[20]. A detailed account of information on instruments and methods for sediment sampling are available in many literatures[21]. Ali and Shakir[22], used past hydraulic and sedimentation data for calibration of model to estimate the rate of deposition and study the sedimentation pattern in Chashma Reservoir and validated the results with real time bathymetry data.

The Jiadhol River is one of the north bank sub-tributaries of the Brahmaputra River that empties in Charikoria River. Charikoria is one of the anabranches of Brahmaputra like KherkutiaSuti. Basin of the Jiadhol River extends from 27˚15′ N to 27˚45′ N latitudes and 94˚15′ E to 94˚40′ E longitudes, covering an area of 1094.93 sq km, of which 38% (416.07 sqkm) lies in Arunachal Pradesh and 62% (677.86 sq km) in Assam (Figure1-Jiadhol River Basin). The Jiadhol River is one of the most notorious rivers in the north bank of the mighty Brahmaputra causing devastating floods almost every year during the peak monsoon season. Heavy siltation is cited as one of the most important cause of flood in the river beside rainfall[16]. So, it is very important to study the pattern of siltation within the river bed in various cross sections of the river brings. This paper is a sincere attempt to understand the pattern of change of sediment load and rate of sedimentation of the Jiadhol River with the help of field survey and measurements.

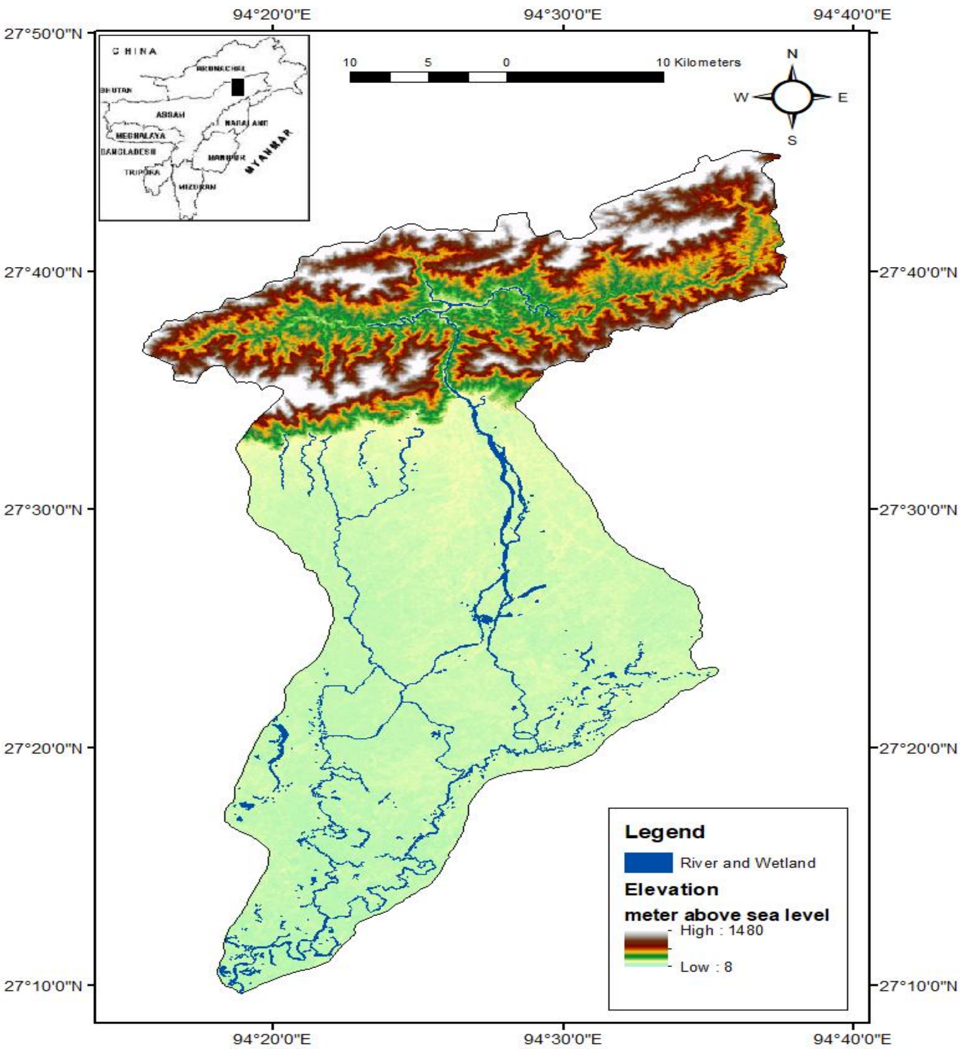

Figure 1- Map of Jiadhol River Basin

METHOD

Data on daily total sediment load Data, stage and discharge are collected for the station Jiyadholmukh and the data on daily rainfall are collected for rain gauge Panbari and Tinimukh for a period of ten years from 2003 to 2015 from Brahmaputra Board, Lakhimpur District. Tinimukh is located in mountains at the upper catchment of the basin where as Panbari is located near Jiyadholmukh in the lower reaches of the river. An analysis of correlation of rainfall with stage and discharge is done to understand their exact relationship in the studied basin. For analyzing the trends and estimating the relationship between these two parameters are plotted on a graph. Sediment rating curve fitting is done for the river for the year 2014.

Detailed field survey is done to understand the rate of sedimentation in Jiadhol riverbed. The data on channel width and depth has been manually measured in 15 sites along the main channel and the tributaries in the year 2013. The depth is collected in an interval of 1 meter along the smaller cross-section whereas at larger cross-section (more than 40 m), the depth is measured in 2 m intervals. To understand the change in riverbed, survey has been conducted again on the year 2015 for four sites, two sites are in the foothills and other two in the lower reaches. The Google maps are also used to understand the river sedimentation in the form of bars. The present ground clearance of the bridges over the river is measured during field survey 2015, to find out the rate of siltation under the bridges since its construction. The original ground clearance of the bridge, in 2007, has been collected and verified from Public Work Department and Border Road Organization Offices, in Dhemaji District.

RESULT

Rainfall

The average annual rainfall of the basin is 2390.67 mm. The maximum average annual rainfall is recorded along the foothills as compared to any other parts of the basin. July is the rainiest month throughout the basin with an average monthly rainfall of 573.33 mm. December is the driest month with most of the years without rainfall throughout the basin. Pre-monsoonal rainfall starts by the beginning of March continues through April and May. It is generally associated with thunder storms. Monsoon starts with the first week of June and last till the end of September but the rainfall continues even in the months of October and November whereas the intensity decreases. There is occasional rainfall even in the winter months of December, January and February. 77% of the annual rainfall is received in the monsoon season and 17 % in the pre-monsoonal season.The Pearson correlation coefficients between rainfall, discharge and sediment load are calculated in SPSS-17 software. These three shows positive correlation between each other the correlation matrix is shown in Table 1. Discharge and Sediment load has a very high correlation of 0.91 and rainfall and sediment load has a correlation of 0.74 at 99% confidence level.

Table 1 Pearson Correlation between Rainfall, Discharge and Total Sediment Load

	Rainfall in mm	Discharge in cumecs	Total Sediment Load in Tons
Rainfall in mm	1	.685**	.742**
Discharge in cumecs	.685**	1	.919**
Total Sediment Load in Tons	.742**	.919**	1

**. Correlation is significant at the 0.01 level (1-tailed).

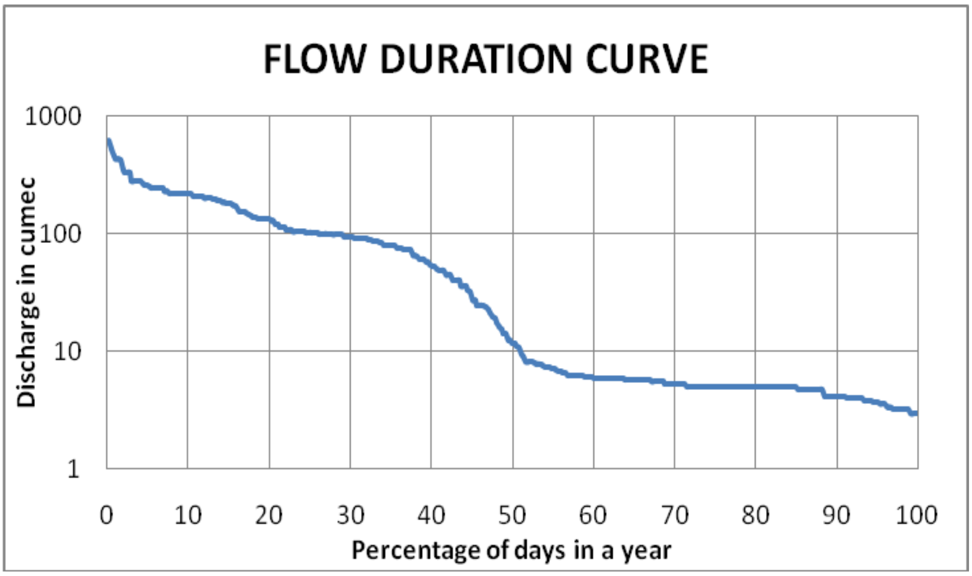

Figure 2 Flow Duration curve

Flow-duration curve

The best representation of the flow frequency is given by the flow duration curve. It is a curve showing the percentage of days from the total days a particular discharge has occurred and exceeded of. The area under the curve is a measure of the total volume of water that has flowed past the gauging station in the total time considered. The shape of the flow-duration curve gives a good indication of flow pattern in the catchment. An initially steeply sloped curve results from highly variable discharge, usually from small catchments with little storage where the stream flow reflects directly the rainfall pattern

A flow duration curve is prepared for with the help of average daily data for the period of 10 years and shown in Fig. 4. The flow duration curve shows that the low flow regime covers one half (50%) of the year. The high flow days are also less in number in the basin and fluvial activities are dominant for a very short period of time in a year.

Sediment Rating Curve for Jiadhol River

For a better understanding of the relationship between discharge and sediment load in the river a scattered diagram has been prepared and shown in Figure 3. The diagram shows very high positive correlation between discharge and sediment load. Thus, larger volume of water will bring large volume of sediment. Larger volume of sediment will subsequently led to more siltation of river bed and this will further reduce the carrying capacity of the river by reducing the gradient and all this will provide more suitable environment for the occurrence of flood. Due to the strong relationship between the discharge and sediment load, both can be used to estimate the other. Thus, a sediment rating curve has been proposed to estimate sedimentation when the data on discharge is available.

Sediment rating curve represent the relationship between suspended sediment concentration and the water discharge at a stream measurement station[23]. The coefficient correlation between Sediment load and Discharge is approximately equal to unity (0.9). So, there is one to one correlation between discharge and corresponding sediment load.

The equation for the line of best fit power function is

$$Y = 14.87\ X^{1.282}$$

$$\Rightarrow\ S = 14.87\ Q^{1.282}$$

The above equation gives the relation between Sediment load and discharge in the studied river. With the help of the equation we can estimate the sediment load of the river once we had the data of discharge. This relationship is significant at 95% confidence level. A comparison of observed Sediment Load and estimated sediment load done with the help of above equation for the year 2014 is given in Figure 4.

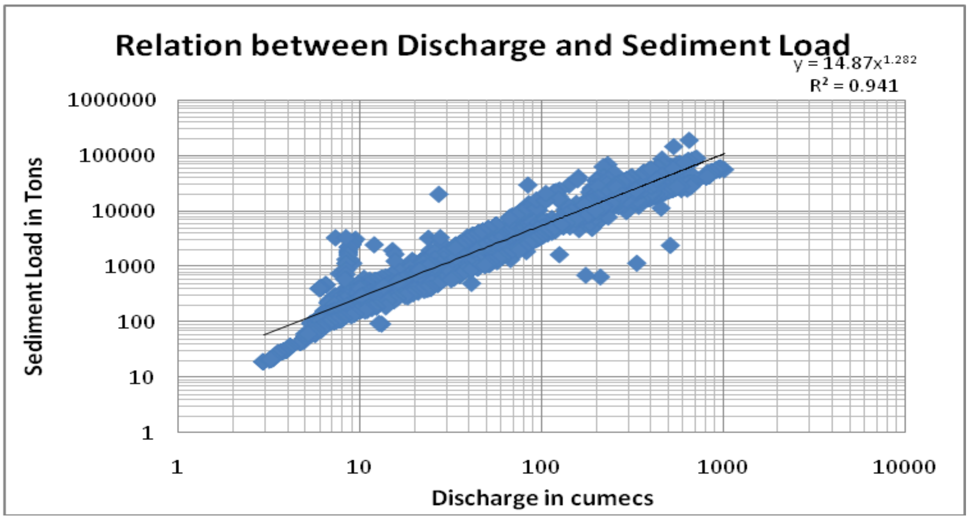

Figure 3 Relationship between Discharge and Sediment Load

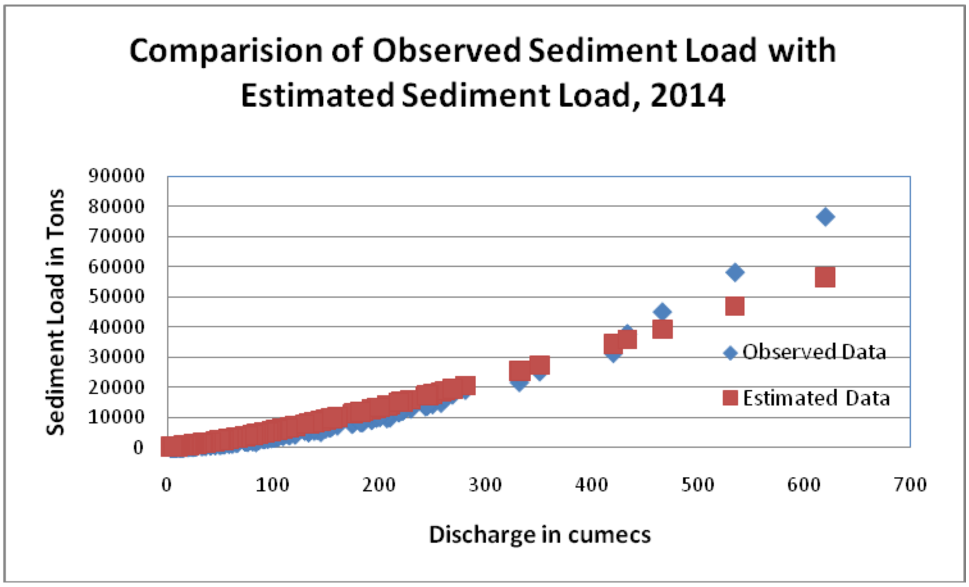

Figure 4 Comparision of observed daily sediment load and estimated data for 2014

Channel Morphometry

Channel morphometry include the study of the shape and forms of the channels and its changes over time. The rivers and the streams continuously shape and reform their channels through erosion of the channel boundary both the bed and the bank material and the reworking and deposition of the sediments[24]. The width-depth ratio is a good representation of the representation of the erosive as well as dispositive potential of the river. The sediment transported is determined by the size and composition of the river bed. The depositional characteristics of the river are analysis with the help of associated channel geomorphic units.

Channel width-depth ratio

The width, depth, and width/depth ratio at bank-full height are frequently used to characterize channel dimensions. Channel width and depth has been manually measured in 15 sites along the main channel and the tributaries with the help of measuring tape, leveling stuff and dumpy level (Figure 5 Location of 15 survey sites). The rough terrine and inaccessibility of the upstream mountainous region the site selected for the measurement are limited to the plains. At few places the river does not have any permanent channel but have multiple courses this also possess serious troubles in collecting the measurements. The depth is collected in an interval of 1 meter along smaller cross section where as at larger cross section (more than 40 m), the depth is measured in larger intervals. The average depth is used for calculating width-depth ratio. The measurements are shown below in Table. 2. Cross sections with larger values of width-depth ratio imply very low energy and are suitable location for sedimentation. According to Rosgen[25], a value greater than 12 is considered as high value and ratios higher than 60 are representative of anabranching channel. All of the sites surveyed have higher values of width/depth ratio thus confirms the depositional nature of the river. The ratio is greater than 60 at three sites, two of the sites are located north of NH-52 and one is on Samarajan branch of Jiadhol, south of NH-52. The widest cross section of the river has the lowest depth even during peak flow season. The low value of average depth near Jiyadholmukh is an evidence of lower carrying capacity of the river during the high flow season, hence, added to the occurrence of floods in the piedmont zone.

Type of bedload

Bedload samples were collected from all 15 sites as shown in Table 2. The collected bedload samples are dried and shorted with hand and with the help of sieves of different size. The river bed materials are divides into boulders (>256 mm), cobble (64mm-256 mm), gravel (2mm-64 mm), sand (0.063 mm - 2 mm), silt (0.062mm-0.004m) and clay (< 0.004 m) based on its size. The presence of each of these categories in all 15 site is marked in the table. Boulders are found to have accumulated in the banks of the river in the A,B,C, and D sites. Site D is located 2 km downstream of the Arunachal Assam Border. The availably of these boulders suggests that these have been transported from the upstream areas during the high flow periods. It also indicates the huge amount of energy with which the flood water of Jiadhol River debouches to the plains of Assam. Thus, the river had tremendous capacity to cause severe erosion along the banks and to transport heavy loads.

Changes in channel cross section

The study of changes in channel cross sections of Jiadhol River is conducted by comparing the channel cross section of the river in four sites. The first site D, is at the foot hills, here the river debouches to the plains of Assam. The second site is I, this is the location that shows rapid channel avulsion. The third and the fourth sites are M and O, located along the lower course of the river. The cross-sections at these four sites are measured during two time period to analyses the temporal change and shown in Figure 6, Figure 7 Figure 8 and Figure 9. The first field survey was conducted on December 2013 and the second on December 2015. Out of these four cross-sections, the first two sites D and I, shows rise in the bed level during the studied period, where as other two sites, M and O do not show any significant changes.

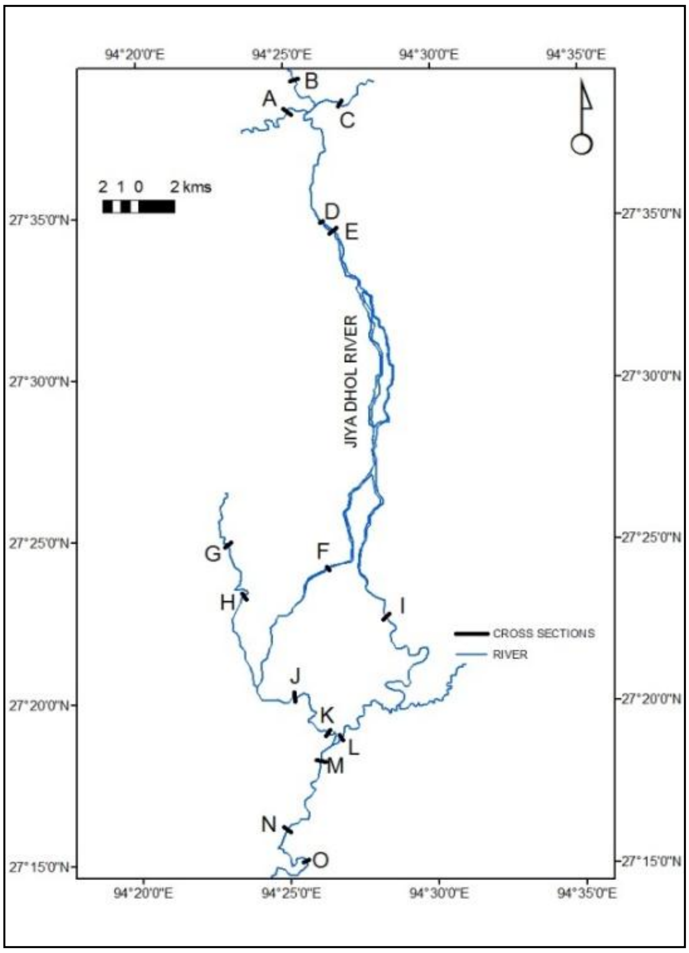

Figure 5 Location of 15 field survey sites

Table 2 Channel width, depths and type of bed material of the Jiadhol River and its tributaries

Survey Sites	Width in m	Depth in m	Width-Depth Ratio	Type of Bed load
A	22	0.5	44	Boulder, gravel and sand
B	25	0.6	41.66	Boulder, gravel and sand
C	24	0.7	34.3	Boulder, gravel and sand
D	150	1.6	**93.75**	Boulder, gravel, cobble and sand
E	270	1.5	**180**	gravel, cobble and sand
F	45	2.4	18.75	gravel, cobble and sand
G	66	2.3	28.69	silt and clay
H	15	0.7	21.42	Sand
I	75	1.1	**68.19**	Sand
J	69	2.3	30	silt and clay
K	51	2.1	24.28	silt and clay
L	54	2.7	20	silt and clay
M	57	2.5	22.8	silt and clay
N	72	2.5	28.8	silt and clay
O	67	2.6	25.7	silt and clay

Source: Field Survey, 2013.

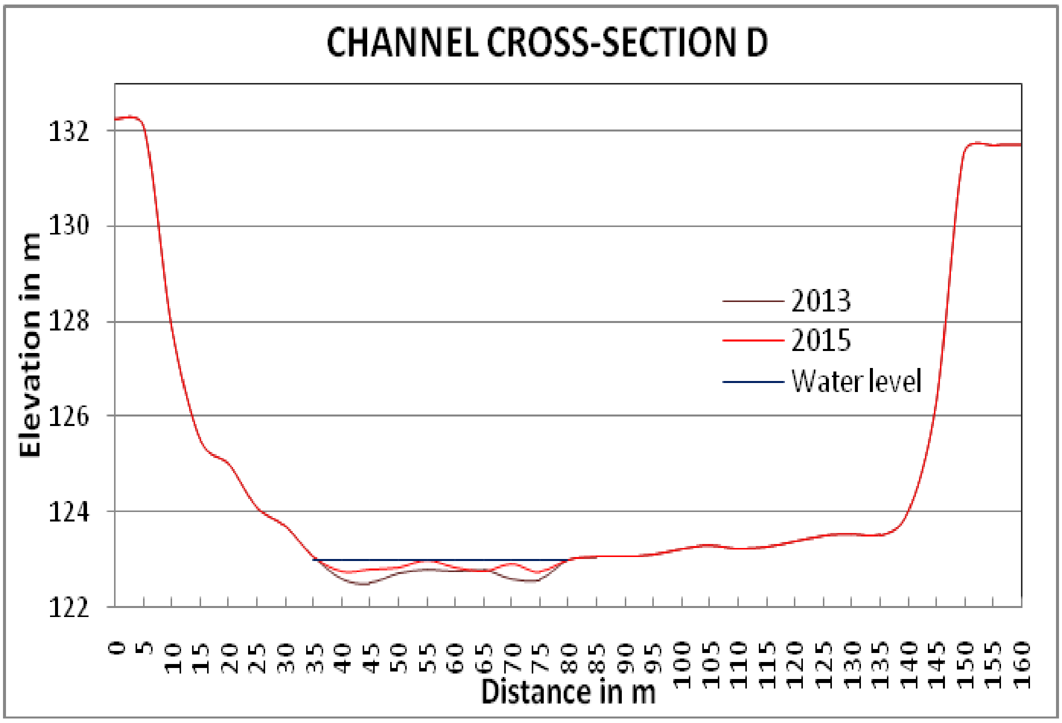

Figure 6 Channel Cross Section at D

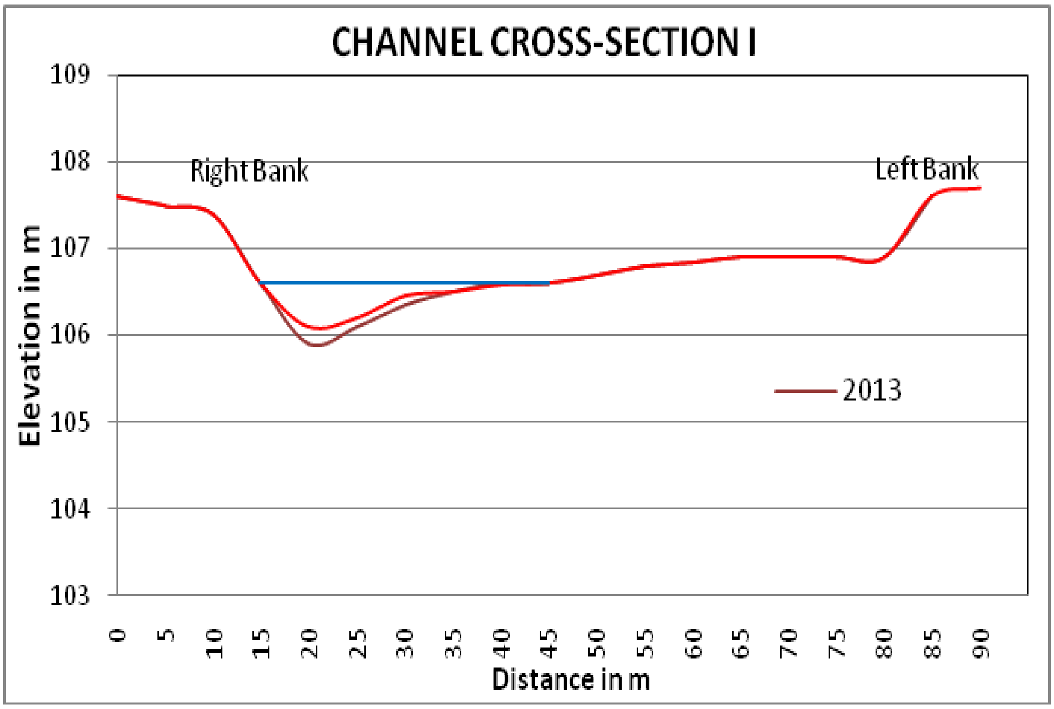

Figure 7 Channel Cross Section at I

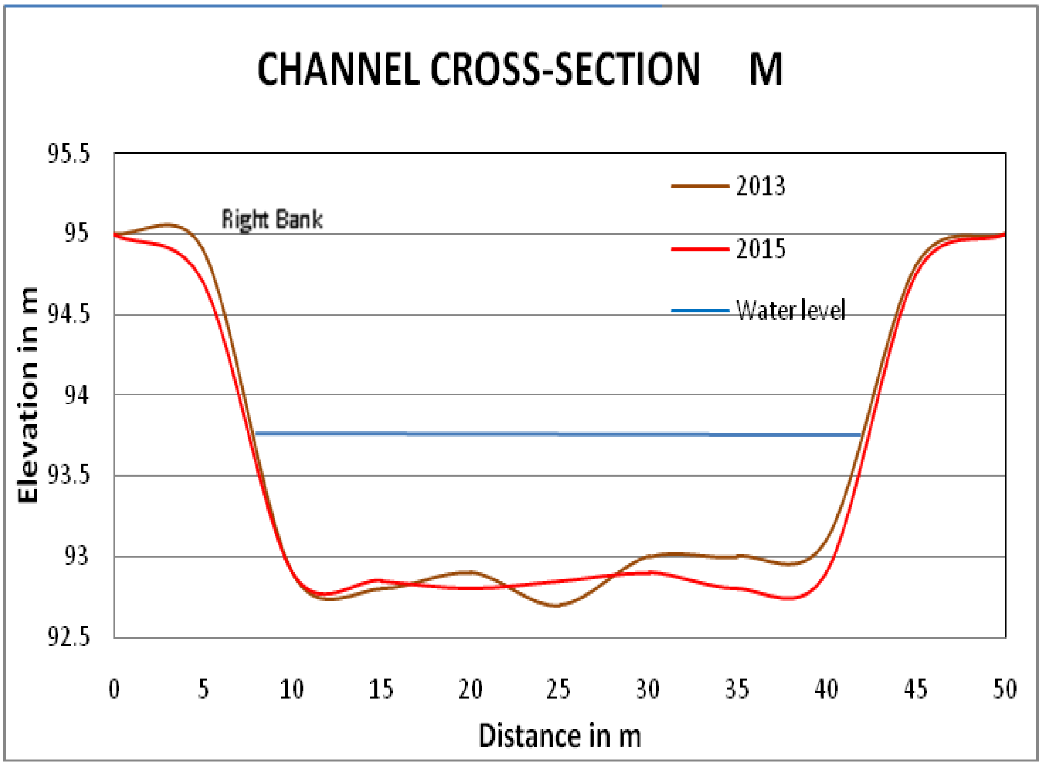

Figure 8 Channel Cross Section at M

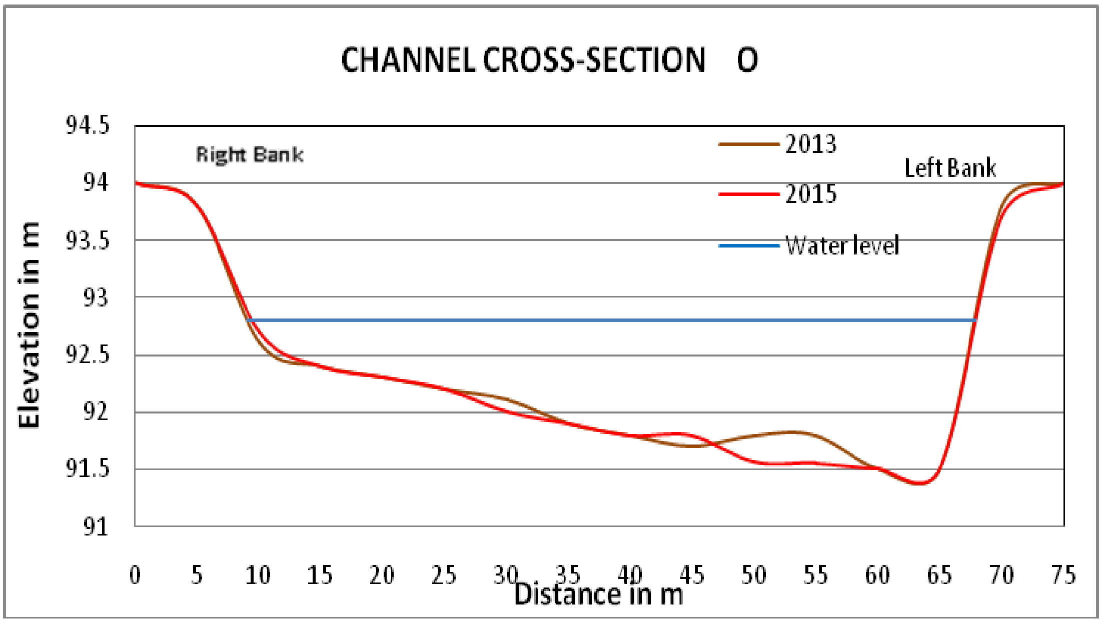

Figure 9 Channel Cross Section at O

Riverbed sedimentation in the form of bars

The channel bars are the most common features in the Jiadhol River. Bars are in-channel accumulations of sediment which may be formed from boulders, gravel, sand and silt[24]. The channel bars of Jiadhol River are made up of sand and silt. The different types of the bars that are easily visible in the basin are longitudinal bars, point bars, channel junction bars, diagonal bars and mid channel bars. Different types of bar appearing in Google earth image along Jiadhol River and its tributaries are shown in Figure 10, 11, 13, 14, 15 and 16.

Figure 10- Longitudinal Bar

Figure 11- Point Bar

Figure 12- Side Bar (with Chute)

Figure 13- Diagonal Bar (Disected)

Figure 14- Channel Junction Bar

Figure 15- Mid-Channel Bar

Siltation of river bed

The sediment load of Jiadhol River is showing an increasing trend as compared to the discharge as per analysis done in chapter three of this thesis. The sediment load brought by the river is either deposited in the bed of the river or in the adjoining areas of the flood plain. The field study reveals that a large volume of the sediment brought by the river is dumped in its own bed (Plate. 1).

According to the data collected from Water Resource Department, Dhemaji District, 2 to 2.5 meters thickness of silt was deposited during the period 2003 to 2011. According to the Data collected from Department of Agricultural, Dhemaji District, during the year 2014, on an average 300 mm thick siltation of recorded throughout the stretch between Jiyadholmukh to National Highway. The Jiadhol RCC Bridge on NH 52 (Plate 1) was completed in 2007 with vertical clearance of 3 m (10 feets). During the field survey in December 2015 the vertical clearance of the bridge is measured as 0.76 m. Thus, it can conclude that during the period 2007 to 2015, 2.24 m thick layer of silt deposited under the Jiadhol RCC Bridge.

Plate 1- Siltation below of Jiadhol RCC Bridge at N

DISCUSSION

The Jiadhol River has a positive trend for both the discharge and sediment load for the period between 2003 and 2015. The rate of increase in sediment load is increasing more sharply compared to the discharge of the river. Thus, the river is carrying more volume of sediment at present. The relationship between sediment load (S) and discharge (Q) is derived from year 2014 using sediment rating curve method for river Jiadhol as, S = antilog (4.872 (log Q)1.4). The study of the change in channel cross-section suggests that the river bed siltation is rapid in the foot hill section of the river and this continues throughout the center of the basin but it is not very significant in the lower section of the river. Thus, the problem of heavy siltation in Jiadhol River is limited to the foothill section of the river. The field measurement along the RCC Bridge revels that the average rate of siltation under the Jiadhol RCC Bridge is 0.15 m per year between 2007 and 2015.

CONCLUSION

Jiadhol River has shown increase in volume of sediment load over time compared to that of the discharge of the river. This increase in sediment load has caused rapid siltation of river bed in the foot hill region and drastic reduction of the carrying capacity of the river. The depth of the river has been reduced overtime and this is sharply visible under the bridges and along the cross sections with high values of width-depth ratio. This is also confirmed by the study of change in channel cross section during the study period. The increase of siltation within the riverbed causes frequent overflow of the river during the monsoon season, so, annual floods and frequent breaching of bridges is a common fact in the foothills of Jiadhol River.

LIST OF ABBRIVIATIONS

S	=	Sediment load of the river,
Q	=	Discharge of the river,
RCC	=	Reinforced Cement Concrete,
NH-52	=	National Highway- 52,

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REFERANCEs

1. Dendy F E. Sedimentation in the Nations reservoirs. Journal of Soil and Water Conservation. 1968; 23: 135-137.
2. Mahmood K. Reservoir Sedimentation: Impact, Extent and Mitigation. World Bank Techinical Paper no.71. 1987. Available form http://documents.worldbank.org/curated/en/888541468762328736/Reservoir-sedimentation-impact-extent-and-mitigation
3. Lwenya C, Yongo E. Human aspects of siltation of Lake Baringo : Causes , impacts and interventions, Aquatic Ecosystem health and management. 2010; 13(4): 437–441.
4. KarnaN, Prasad K S H, Giri S, Lodhi AS. ISH Journal of Hydraulic Engineering Intrusion of fine sediments into river bed and its effect on river environment – a research review, 2014; 37–41.
5. Schweitzer M, Dieterich A, MorillasN C et al. The importance of sediments in ecological quality assessment of stream headwaters : embryotoxicity along the Nidda River and its tributaries in Central Hesse , Germany. Environmental Sciences Europe. 2018; 30:22.

6. KafleK R, Khanal S N, Dahal R K. Consequences of Koshi flood 2008 in terms of sedimentation characteristics and agricultural practices. Geomenvironmental Disasters. 2017; 4(4):1-13.
7. Dudley R W. Riverbed-Sediment Mapping in the Edwards Dam Impoundment on the Kennebec River, Maine, By Use of Geophysical Techniques, 1997; 1–7.
8. Meade R H. Sources, Sinks, and Storage of River Sediment in the Atlantic Drainage of the United States. The Journ of Geo. 1982; 90(3): 235-252.
9. WangS, HassanM A, Xie X. Relationship between suspended sediment load, channel geometry and land area increment in the Yellow River Delta. Catena. 2006; 65: 302–314.
10. GaoP, ZhangX, Mu X et al. Trend and change-point analyses of streamflow and sediment discharge in the Yellow River during 1950 – 2005 Trend and change-point analyses of streamflow and sediment discharge in the Yellow River during 1950 – 2005, Hydrological science Journal. 2010; 55(2): 275-285.
11. Hazarika L P. Siltation and Erosion in the Subansiri Downstream and its Impact on Social-economis Condition of Riparian People, Social ScienceResearch. 2013; 2(1):13-24. Available from :www.ssrnlc.org/issue/volTwo/2_1_2.pdf
12. WeiyiX, Xiaodong Z, Xinzhou Z et al. The analysis on the Water Sediment Characteristics and the Influences of Sluice construction in Jiaojiang River Estuary. The open Civil Engineering Journal.2015; 9: 705-713.
13. Shi C. Causes for continuous siltation of the lower Yellow River. Geomorphology. 2005; 68 (2005) 213– 223.
14. Mitra D, Tangri A K, Singh I B. Channel Avulsion of the Sharda River System, Ganga Plain. International Journal of Remote Sensing. 2005; 26(5): 929-936.
15. Guchhait S K, Islam A, Ghosh S, et al. Role of hydrological regime and floodplain sediments in channel instability of the Bhagirathi, Ganga-Brahmaputra Delta, India. Phy Geog. 2016; 1-35.
16. Das LM. Geomorphic study of the Jiadhol River Basin of the Brahmaputra Valley, Unpublished Thesis, North Eastern Hill University, Shillong.2016.
17. Latuf M, Amaral E. Assessment of suspended sediment discharge in the Purus River basin , Brazil.International Journal of River Basin Management. 2016; 0–17.
18. Asselman NEM. Fitting and interpretation of sediment rating curve. Jour of Hydo. 2000; 234: 228-248.
19. Yin H, Chen G, Li C, Wei Y.. On the siltation of the middle Yangtze River. Sci in China. 2004; 47(5) : 463-480.

20. Williams M. River Sediments. Phil. Trans. R. Soc.2012; 2093–2122.
21. Wildhaber Y S, Michel C, Alewell C. Measurement of spatial and temporal fine sediment dynamics in a small river. Hydro and Earth Sys Sci. 2012; 16: 1501–1515.
22. Ali M, Shakir A S. Sustainable sediment management options for reservoirs : a case study of Chashma Reservoir in Pakistan. App Water Sci. 2018; 8(4): 1–10.
23. Goudie AS. Encyclopedia of Geomorphology, Vol. I Routledge, New York. 2004.
24. Charlton R. Fundamental of Fluvial Geomorphology, Routledge, New York. 2000.
25. Rosgen D L. A classification of natural rivers, Catena. 1994; 22: 169-199.
26. Smith N D and Rogers J. Fluvial Sedimentology VI, Blackwell publishing Ltd. Oxford.1999.
27. Peter JJ, Sediment Sampling in Sand-Bed Rivers: Methods and Instruments, AGORA: Hydraulic Instrumentation 41-48. Available from www.vliz.be/imisdocs/publications/249798.pdf
28. Garde RJ. River Morphology, New Age International Publishers, New Delhi. 2006.
29. FanH, Huang H, Zeng T Q, Wang K. River mouth bar formation, riverbed aggradation and channel migration in the modern Huanghe (Yellow) River delta, China. Geomorphology. 2006; 74: 124–136.
30. Peng J, Chen S, Dong P. Temporal variation of sediment load in the Yellow River basin , China , and its impacts on the lower reaches and the river delta. Catena. 2010; 83(2–3): 135–147.
31. SoongT W, Zhao Y. The Flood and Sediment Characteristics of the Lower The Flood and Sediment Characteristics of the Lower Yellow River in China. Water International.1994; 37–41. Available from https://www.researchgate.net/publication/233007351_The_Flood_and_Sediment_Characteristics_of_the_Lower_Yellow_River_in_China
32. Srivastava P, Bhakuni S S, Luirei K, Misra D K. Morpho-sedimentary records at the Brahmaputra River exit, NE Himalaya: climate – tectonic interplay during the Late Pleistocene – Holocene, Journal of QuarternaryScience. 2009; 24(2): 175–188.