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Spatial Variations in Meander Geometry of the Banar river

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Abstract: This study illustrates the spatial variations of meander geometry and changing trends of channel pattern of the Banar river. A time series satellite images of 1976 and 2016 have been used for thestudy. Remote Sensing and Geographical Information System (GIS) technique were used to measure and analyze the river geometry, and descriptive statistics used to represent the data in tabular form and graphs. The study reveals that the sinuosity ratio, river width, river meander wave length, and radius of meander curvature of the Banar river have variance in different reaches. In 1976 average width of river was 38.38 meter which was reduced to 35.79 meter in 2016. Average meander wave length and radius of meander curvature has increased 23.71 meter and 24.87 respectfully within the study period. Besides, the sinuosity ratio in 1976 and 2016 are 1.45 and 1.59 respectively. The study concludes that the study sections of the river Banar are reflecting a declining energy gradient. For further understanding of the relationships, it is essential to relate meander parameters with hydrologic and hydraulic parameters at the entire length of the Banar River.

Keywords: River width, Meander, Geometry, Sinuosity Ratio, Satellite Images, Banar River

Introduction

Meander geometry is simply a plan form of a watercourse/channel. It reflects the shape and size of the channel (Pierre, 2002). River channel morphology includes the consideration of channel geometry or channel cross-sectional characteristics e.g., channel length, channel width, channel depth, wetted perimeter, channel slope, channel bend etc. (Singh, 1998; Alam et al., 1998). An understanding of the channel geometry would enable us to relate it with the state of the valley in terms of energy gradient, cross and long profile characteristics and thus it can be related with different basin ecosystems developed along the channel. Besides, it would also help to generate ground data on meander reach specific bank line shifting tendency, stretches relatively vulnerable to erosion and valley sections to be restored thus help in basin management (Stewardson et al., 2021).

Interest on meandering river research had been shown initially by Davis 1899. From then on different techniques and approaches were followed by many researchers on this issue. Some of the pioneers were Leighly (1936), Leopold and Wolman (1960), Schumm (1967), Hickin (1974), Hooke (1984), and Hasfurther (1985) among them. In Bangladesh context, research on meandering river started back in 1959 (Chowdhury). Then interest on this issue continued with focus on understanding the hydraulic characteristics and sedimentation processes of the river channel in order to build infrastructures like embankment, bridge and river training(Thorn. et al. 1993 and Uddin et al.2010). Some of

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the later works have focused, on meandering river and their plan form geometry in Bangladesh (Islam et al. 2018, Biswas et al. 2018 and Mondal 2018). Apparently, specific works on central part particularly, Pleistocene terrace area-based research on meandering river channel are scanty. To fill this information gap, the present initiative attempted to follow an approach of graphical analysis along with techniques known as superposition or comparison of courses which reveals the results of spatial changes of pattern of the channel as proposed by Hooke (1984).

The Banar is one of the main rivers of the Madhupur Pleistocene Terrace. The Terrace itself has been subjected to tectonic upliftment and tilted towards northwest to southeastward (Morgan and McIntire 1959).Following the same slope direction, the Banar passes through Mymensingh district (Banglapedia, 2020). Consequent to the land upliftment, the rivers of the terraces have a general tendency to be entrenched. River bed and bank line of the Banar river have changed due to erosion, deposition and the volume of water flow decreased during the recent years. The river bank erosion and channel shifting are causing hindrance to the people's resources and livelihood. From this perspective, it was attempted to find out the spatial variations of meander geometry and changing trends of channel patterns of the Banar river.

Aim and Objectives

The main aim of this study was to find out the characteristics of meander geometry and their changing patterns over a period of forty years. In order to achieve the study aim, the objectives were as follows:

a) To measure the meander geometry of the Banar river; and

b) To analyze the channel shifting pattern of the study area between 1976 and 2016.

Methodology

This study focused on the spatial variation of meander geometry of the Banar River and its shifting pattern based on the satellite images. To meet the study objectives both primary and secondary data have beenused. Landsat TM satellite image for 1976 was collected from the USGS website and Google Earth image for 2016 have been used to analyze the characteristics and spatial variations of meander geometry of the lower Banar Riverfrom 1976 to 2016. The study years were chosen on the basis of availability of imagery as well as for better understanding of the characteristics of meander geometry and spatial shifting pattern. In this research work, to create precise and comparable maps of river channel features Geographic Information systems (GIS) and Remote Sensing (RS) were used for image processing and interpretation. In data encoding and analyzing purposes, ArcGIS 10.2 and ERDAS Imagine 10.2 version software and human interpretation have been used.Then, data were tabulated, analyzed and presented by MS excel, and MS word.The following formula given by Schumm (1963) is applied in this study to compute the sinuosity ratio (SR):

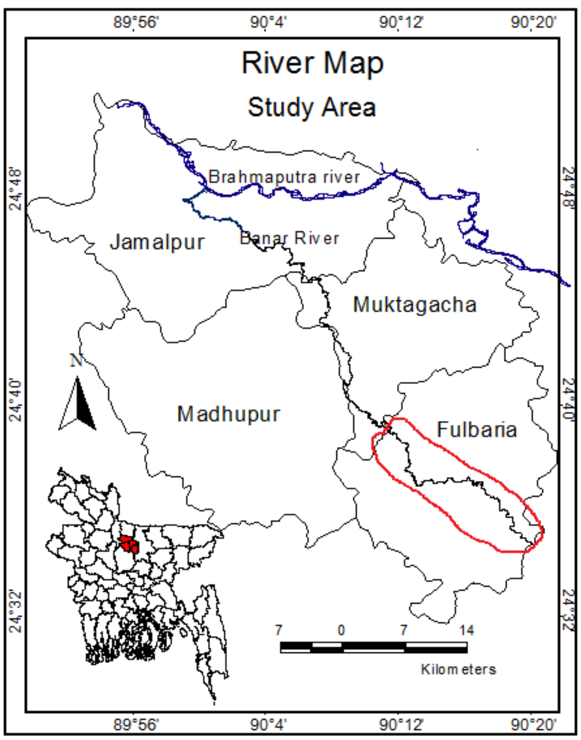
$$SR = \frac{Sl}{CI}$$

Where, SR is the sinuosity ratio, Sl is the stream length (m) and Cl is the channel length (m)

Initially, the river has been divided into three major sections according to its alignment, then it was divided into16 reaches according to the major bends for analyzing the sinuosity ratio and other meander characteristics. This study has some limitations which are the Banar river is a small river, average width of this river is about 40 meters. To analyze of this type of small river needs high resolution images which are not available. There are very few hydrological gauge stations available for the Banar River. Moreover, hydrological and hydraulic data are scanty and insufficient. Hence, this study merely focused on the meander characteristics of the Banar River.

Study area

The lower part of the Banar river of Fulbaria upazila in Mymensingh district is selected as the study area. The absolute location of the study area is 23°56´26.04´´ N to 23°55´45.85´´ N latitude and 90° 9´55.64´´E to 90° 9´0.81´´ E longitude (Map 1). This river enters into Fulbarianear Shibganga Bazar and flow north to south toward kasergang bazar than it turns into west to east, then the river again turns into southeastern direction and move in Trishalupazila. Flowing south, the river bifurcates into two, the eastern arm flows into the Old Brahmaputra and the southeastern arm falls into the Shitalakshya. The eastern arm which meets the Old Brahmaputra flows further ahead and ultimately joins with the Shitalakshya. Finally, the Banar becomes a tributary of Shitalakshya (Banglapedia, 2020).It is one of the key river of Fulbariaupazila. The total length of this river in the part flowing over Fulbaria upazila is about 12 km.



Map 1: Study Area- the Banar River

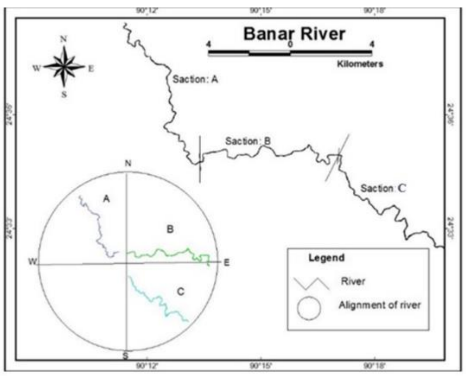
Source: USGS; analyses by authors, 2020

Results and Discussion

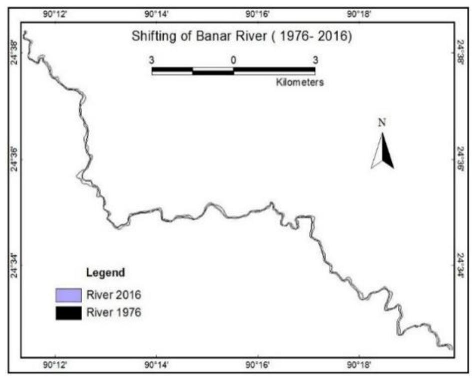
This study explainsthe spatial variations of meander features like meander wave length, river width, sinuosity ratio, radius of curvature, meander amplitude and other characteristics of meander and changing trends of channel pattern of the lower Banar River.

Alignment of the Banar River

The Banar River mainly flows into the south-east direction. The part of this river that flows on Fulbaria Upazila has been divided into three sections according to its alignment. The first section named Section-A is flowing from the north to south direction. The second section of the study river named Section-B flows from west to east direction. The last section named Section-C flows into the south-east direction (Map 2).



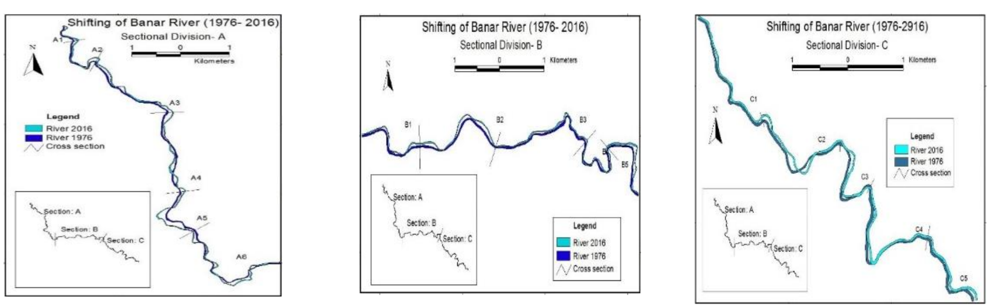
Map 2: Alignment of the Banar river study sections.
Source: USGS; analyses by authors, 2020



Map 3: Channel shifting trends of the Banar river.
Source: USGS; analyses by authors, 2020

Shifting pattern of Different Reaches

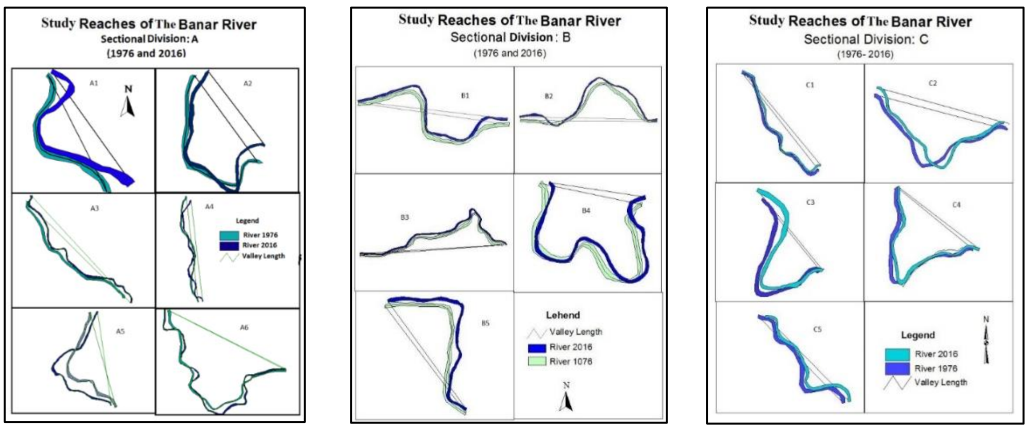
Overlapping2016 on 1976 study reaches of the river channels, it was apparent that channel has shifted over the years (Map 3). In the Map 4 and Map 5channel shifting patterns have been clearly reflected according to the study river length and occurred mostly along the river bend instead of straight part.



Map 4. Cross sectional shifting trends of the Banar river across the sectional divisions A, B and C (1976-2016).
Source: USGS; analyses by authors, 2020

Reaches of the Banar river

The sectional divisions of the Banar river A, B, and C have been further divided into six, five and five reaches respectively based on major bend of the river to analyze the sinuosity ratio. The Map 5showsthe shifting of reaches, their valley length and the sinuosity of sectional division of the Banar river from 1976 to 2016.



Map 5: Reaches of the Banar river sectional divisions.

Source: USGS; analyses by authors, 2020

River Width of the Reaches

Meandering rivers are characterized by a relatively uniform river width, which can be considered constant in the long-term (Brammer,1996). The width of the Banar river has decreased during the last forty years (Table 1). The Figure 1 shows the widths and its changing pattern of the Banar river sectional division. In 1976 average width of the river was 38.38 meter and it was reduced 35.79 meter in 2016 reflecting a declining energy gradient. In reaches A3, A4 A5, B5 and C3 the rate of reduction of river width is higher than other reaches. It is sharply clear that width of Banar river is reflecting a decreasing trend.

Table 1: Sinuosity Ratioof Different Reaches of the Banar River (1976-2016)

Reach	1976				2016			
	Width	Valley Length	Thalweg	Sinuosity	Width	Valley Length	Thalweg	Sinuosity
A1	25.34	467.1	558.4	1.26	23.04	443.7	676.8	1.45
A2	27.58	584.2	1152	1.71	24.71	675	1408	2.41
A3	37.16	2068	2053	1.08	31.51	1897	2429	1.17
A4	33.41	2040	2252	1.06	23.43	2124	2345	1.15
A5	35.87	1095	1511	1.33	27.05	1140	1793	1.64
A6	29.29	1794	2801	1.6	25.71	1748	3346	1.87
B1	26.43	1208	1538	1.26	24.34	1219	1619	1.34

Reach	1976				2016			
	Width	Valley Length	Thalweg	Sinuosity	Width	Valley Length	Thalweg	Sinuosity
B2	27.85	1658	2035	1.25	23.17	1624	2209	1.33
B3	32.16	1746	2105	1.24	35.14	1696	2223	1.27
B4	32.37	507.6	1472	2.72	26.43	540.3	1635	3.22
B5	37.41	967.4	1296	1.34	23.25	965	1405	1.45
C1	31.81	1723	1986	1.14	25.91	1746	2092	1.21
C2	33.24	1343	1839	1.36	27.38	1349	1933	1.44
C3	42.72	738.9	1328	1.88	34.81	705.5	1359	1.84
C4	42.67	1112	2045	1.92	39.75	1063	2187	1.97
C5	38.35	1198	1452	1.19	32.13	1217	1450	1.21

Source: USGS; analyses by authors, 2020

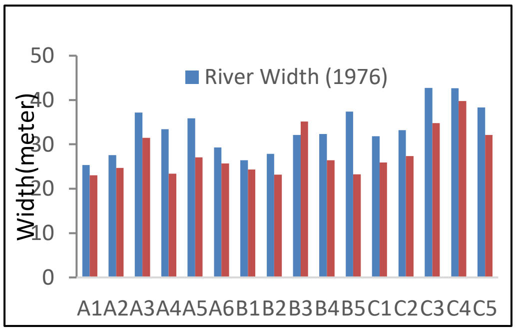


Figure 1: River width of different reaches of sectional divisions at the Banar river (1976-2016)

Source: USGS; analyses by authors, 2020

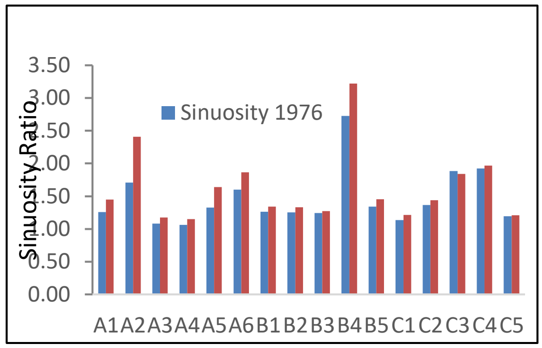


Figure 2: Sinuosity Ratio of different reaches of the Banar river (1976- 2016)

Source: USGS; analyses by authors, 2020

Sinuosity Ratio of the Reaches

Sinuosity ratio of a river depicts that the river is straight or sinuous (Leopold et al, 1963). The Figure 2 shows the sinuosity ratio of the reaches of the Banar river for the years 1976 and 2016.The sinuosity ratioof 2016 of all reaches of river has increased than 1976. In the reaches A2 and B4, the increasing rate appears higherand, in the reach, B3 and reach C5 the increasing rate appears lower than other reaches. The average sinuosity ratio of the river was1.42 in 1976 and 1.59 in 2016reflecting a declining energy gradient.

Meander Wave Length of the sectional Division

The distance of one meander along the down-valley axis is the meander length or wavelength(Hey, 1975). The following diagram 3 shows the meander wave length of 1976 and 2016 of three major Sections of the Banar river. The meander wave length of most of the reaches has increased in sectional division-A river band A6, A7, A8 and A9 it has decreased steadily within the study period. There are 11 meander bends in the sectional division B. Though in this section the meander wave length was almost same over the 40 years but it has increased at all bend. In the sectional division C, there are 11 meander bends. The river band C6 the meander wave length decreased and in C11 the increasing rate appears high. But meander wave length of all other bend was about same from 1976 to 2026.

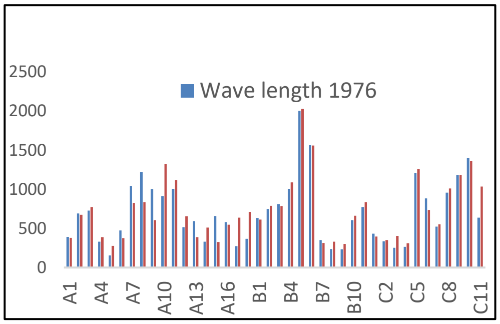


Figure 3: Meander Wave Length of the Banar river (1976- 2016).

Source: USGS; analyses by authors, 2020

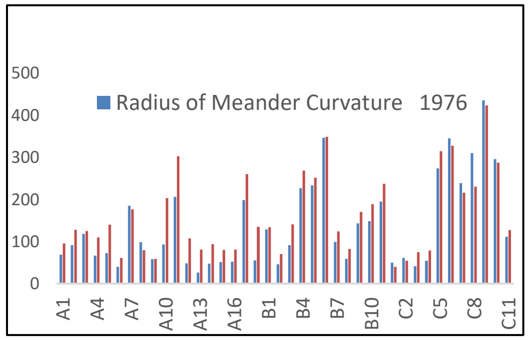


Figure 4: Radius of Meander Curvature of Banar River (1976 and 2016)

Source: USGS; analyses by authors, 2020

Radius of Meander Curvature of Sectional Divisions

Radius of curvature is measured from the outside of the bankfull channel to the intersection point of two lines that perpendicularly bisect the tangent lines of each curve departure point. Radius of curvature is expressed as a ratio to the bankfull channel width (Rc /Wbkf)(Leopold et al., 1957; Rosgen, 1994;Reza, 2016).Radius of meander curvature of the Banar river sectional division presented in the Figure 4 appeared to have increased in the sectional division during the last 40 years. Changing pattern of section, A and B is almost matching. In reaches A10 and A11 of sectional division A, rate of increase appeared higher and only one reach like A8 decreased. In sectional division C, changing pattern is a bit changed from section A and B. Radius of meander curvature of eight reaches of this section have decreased except three reaches where it has increased. It is clear that radius of meander curvature has been on increasing trend during last forty years.

Comparison between Meander Wave Length and Radius of Curvature

The Figure 5 shows the relation of the meander wave length and the radius of meander curvature from 1976 to 2016. There is a positive relation between meander wave length and the radius of meander curvature. With the increase of meander wave length, the radius of meander curvature also increased.

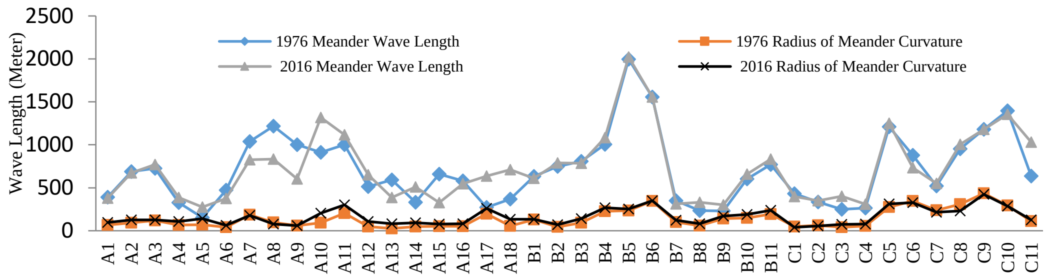


Figure 5: Comparison between meander wave length and radius of curvature of the Banar river sectional divisions (1976- 2016)

Source: USGS; analyses by authors, 2020

Conclusion

The study reveals that there has beena spatial variation in meander geometry of the Banar river. The sinuosity ratio, river width, river meander wave length and radius of meander curvature of the Banar river reflects variance in different reaches within the study period. Both average meander wave length, radius of meander curvature and sinuosity ratio has increased. The Banar River width reflecting a decreasing trend, indicating low energy availability and low water flow. The river channel shifted mainly along the meander bend. For further understanding of the relationships, it is essential to relate meander parameters with hydrologic and hydraulic parameters at the entire length of the Banar River. Given the locational orientation of the Banar river, it passes through northern edge of the Madhupur terrace maintaining several distributary channels which are dependent on this river for discharge. Unless the Banar river is restored, the drainage ecosystem will be impacted negatively. The study thus, recommends for initiating more scientific research on restoration of Banar river through systematic dredging of the river, particularly at the mouth of the Banar river at old Brahmaputra point.

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References

Alam, M.M. and Nazrul, M. 1998. Channel Pattern and Sedimentation Style in the Meghna River, Bangladesh:An example of a Large-Scale Anastomosing Fluvial System. Journal of Remote Sensing and Environment, Vol.2.

Banglapedia, 2020. National Encyclopedia of Bangladesh. In: Islam, s. (eds). Rivers ofBangladesh. Asiatic society of Bangladesh: Dhaka.

Biswas, R. N., Mia, M. J., & Islam, M. N. 2018. Predictive Dynamics of Channel Pattern Changing Trends at Arial Khan River (1977-2018), Bangladesh. Current Research in Geoscience, 8(1), 1–13. https://doi.org/10.3844/ajgsp.2018.1.13

Brammer, H. 1996, The Physical Geography of Bangladesh, University Press limited, Dhaka.

Chowdhury, M.I.1959, Morphology of the Bengal Basin. Unpublished Master's thesis. University of Cambridge.

Davis W.M. 1899, The geographical cycle. *Geographical Journal* 14, 481-504.

Hasfurther V.R. 1985, The use of Meander Parameters in Restoring Hydrologic Balance to Reclaimed Stream Beds, Wyoming Water Research Center, University of Wyoming, Laramie, WY

Hey, R.D. 1975. Geometry of river meanders. Nature 262, 482 - 484 (05 August 1976); doi: 10.1038/262482a0.

Hickin, E. J.1974. The development of meanders in natural river channels. Journal of Science, Vol. 274, pp. 414-442.

Hooke, J. M.1984. Meander behavior in relation to slope characteristics.In River Meandering, Proceedings of the Conference Rivers '83, pp. 67-76.

Islam, M. K., Dushtagir, M., Rahman, M. M., & Rahman, M. 2018. Changes in Planform and Meander bends of Rivers in Southern Estuarine Region of Bangladesh and Its Implications on Development Project. Changes, 6(1).

Leighly, J. 1936. Meandering arroyos of the dry southwest. Geograph. Rev. 26:270-82.

Leopold L.B. and Wolman M.G. 1957. River Channel Patterns: Braided, Meandering and Straight Geological Survey Professional Paper. United states govi'rnm15n't printing office, Washington. 282, pp 1-84.

Leopold L. B. and Wolman M. G. 1960. River meanders. Bulletin of the Geological Society of America, Vol. 71, pp. 769-794.

Leopold L. B. and Wolman M. G. 1963. River Channel Patterns: Braided, Meandering and Straight. Geological Survey Professional Paper, 282-B, Washington, DC (USGS).

Stewardson J. M., Walker G., Coleman M. 2020. Hydrology of the Murray–Darling Basin, Chapter 3 Volume 1 in: Barry Hart Neil Byron Nick Bond Carmel Pollino Michael Stewardson (Ed.): Ecohydrology from Catchment to Coast, Elsevier, Pp 47-73

Mondal, C. 2018. 2D Morphological Modeling of Meandering River. *09*(2), 119–126.

Morgan J. P. and McIntire W. G. 1959. Quaternary Geologyof The Bengal Basin, East Pakistanand India, Bulletinof The Geological Societyof America, Vol. 70. Pp. 319-342

Pierre Y. 2002. River Mechanics. Cambridge University press. pp. 179–184.

Reza, M.A. and Islam, T. 2016. Assessment of Fluvial Channel Dynamics of Padma River in Northwestern Bangladesh. Universal Journal of Geoscience 4(2): 41-49

Rosgen, D.L. 1994. Classification of natural rivers. Catena, Vol.22, pp. 169-199.

Schumm, S.A. (1963) Sinuosity of Alluvial Rivers in the Great Plains. Bulletin of the Geological Society of America, 74, 1089-1100.

Schumm, S. A., 1967. Meander wavelength of alluvial rivers. Science, Vol. 157, No. 3796, September, pp. 1549-1550.

Singh, S. 1998. Geomorphology. Prayag Pustak Bhawan, Allahavad, India.Stream Geometry and Sketch Map, Copyright © 2013 Wildland Hydrology

Thorne, C. R., Russell, A. P. G., & Alam, M. K. 1993. Planform pattern and channel evolution of the Brahmaputra River, Bangladesh. Geological Society Special Publication, 75, 257–276. https://doi.org/10.1144/GSL.SP.1993.075.01.16

Uddin, M. N., Philosophy, D. O. F., & Management, F. 2010. Flow and Erosion Processes At Bends and Around River Training Works in a Sand Bed Braided River. December, 1–10