A Study on the Impact of Bridge Construction on Channel Dynamics of the River Jalangi, West Bengal, India

Balai Chandra Das

Department of Geography, Krishnagar Govt. College Nadia
West Bengal, India

ABSTRACT

River Jalangi is one of the three 'Nadia Rivers' of West Bengal, India on left bank of which Krishnagar, the head quarter of the district of Nadia, is located. Two bridges were constructed on the river Jalangi at Krishnagar to host the national highway 34 (NH-34) and the Sealdah-Lalgola railway. A third bridge, the New Railway Bridge (NRB) was constructed to host the second track of the Sealdah-Lalgola railway. But unlike Old Railway Bridge (ORB) and Dwijendra Lal Roy Road Bridge (DLRB), NRB was designed in such a way that it created a huge obstacle to the flow of the river and made a great change in the channel morphometry. To assess the impact of the bridge construction on river channel morphometry and hydraulics, first hand data were collected before and after the construction of the bridge. Velocity distributions across the channel were measured using submerged-float method and found a directional change as well as change in magnitude also. Channel and flow asymmetry were calculated. It was found that because of bridge construction bed asymmetry, Channel Asymmetry and Flow asymmetry has increased considerably. Due to construction of the NRB, mainly because of its mid-channel dais, left bank-line at downstream has retreated 7 meter, swallowing 1125 cubic meters of soil.

Key Words: Channel asymmetry, Dais, Flow asymmetry, Pier.

INTRODUCTION

The character and behavior of the fluvial system at any particular point reflect the integrated effects of a set of upstream controls (Knighton, 1984) notably natural variables and anthropogenic variables. Natural variables include independent controlling variables (time, initial relief, geology) and dependant variables e.g. soil, vegetation, sediment characteristics, (Schumm and Lichty, 1965) whereas anthropogenic variables include land and water uses which together determine the channel morphology and hydraulics of a river channel (Xu, 1997). Any stimulus in the form of change in external and controlling variables triggers remarkable response in adjustable variables of a river (Charlton, 2008). Under natural conditions, a river seeks to establish a morphometry, which is adjusted to its hydraulics i.e. a morphometry which will allow it to carry its load with least effort and maximum efficiency. However, man can easily upset the natural equilibrium of river by altering either the catchments surface or the river channel itself (Leopold *et al.*, 1964; Urban 2002). Local channelization (Brookes, 1985) or forcing (Przedwojski *et al.*, 1995) of rivers through bridging (Lane and Borland 1954, Laursen, 1960), embankment (Noble, 1976; Palmer, 1976), straightening, dredging, (Petersen, 1986) spurring, etc., are inseparable from the processes of advancement of modern civilization. But local channelization (Kondolf *et al.*, 2003) often ignores upstream and downstream links of a reach. Accelerated transmission of water and sediment through reaches artificially channelized (straightened, widened, steepened and deepened) causes increased flowing and aggradations downstream (Emerson, 1971) and may trigger incision of upstream.

River training in some cases goes against the purpose for which it was trained or may cause serious side effects. Sometimes it affects the river itself adversely. For example channel straightening lead to decreased length and increase slope, increase velocity, increase bed and bank scour. Increased bed and bank scour leads to decrease in slope and increase width, which in turn leads to braiding again. Pulsed-type external disturbances (Brunsden and Thornes, 1997) like improper designing of engineering works (Leopold and Bull, 1979; Galay, 1983; Van Haveren *et al.*, 1987) may leads bank-erosion, in-bed siltation or scouring, and downstream widening of channels (Williams and Wolman, 1984; Xu, 1990, 1996). Channel straightening (Winkley, 1982; Brookes, 1985, 1988; Chang, 1986;Yodis and Kesel, 1993), widening (Brookes, 1988), narrowing (Wyzga, 1993, 1996) also exerts considerable impact on both upstream and downstream morphometry of the channel.

Bridging two banks with rails or roads crossing interferes with the hydraulics of the river (Simon and Downs, 1995) leading remarkable change in water and sediment quality and ecological setup of the reach. Bridging banks exerts instantaneous and gradual impact on channel morphometric characteristics as well. Therefore it requires careful consideration of all possible consequences. A high turbidity value of 64 Nephelometric Turbidity Unit NTU due to construction processes was recorded in the Bridge Station and 8 – 18 NTU recorded at the downstream and upstream stations of the bridge on Nun River in Nigeria (Seiyaboh *et al.*, 2013a). Continuous upwelling of water and resuspension of sediment at construction site (Reid and Anderson, 1998) contaminate water with metals but claimed no considerable spatio-temporal significance (Richard, *et al.*, 1997). River water with turbulent flow and concentrated suspended sediment are harmful to gill of some aquatic life for which region fish population become rare at construction site (Seiyaboh *et al.*, 2013b). Along with all other human activities, construction in the river degrades biological environment locally (Karr *et al.*, 1985) as well as globally (Hughes and Noss 1992; Moyle and Leidy 1992; Williams and Neves 1992; Allan and Flecker 1993; Zakaria-Ismail 1994; McAllister *et. al.,* 1997). On site and downstream change of channel morphometry and flow regime is a direct response of bridging river banks. Bridge makes obstacles to flow regime (Musy and Higy, 2011), diverts flow directions (Keeley, 1971) and triggers bank erosion (Keeley, 1971) and onsite channel deepening (Inglis, 1949; Schumm, 2005). Constricted upstream channel increases turbulence and vortices at bridge piers leading scour (Neill, 1965) to undermine piers (Richards, 1982). Bridges that are built too low, or whose piers and footings constrict the channel, can affect hydrological flows and aquatic habitat conditions (NSW Department of Primary Industries, 2006). Poorly designed bridges disrupt natural hydraulics of streams and cause problem of increased erosion (SEPA, 2008; Cocchiglia *et al.,* 2012) or even structural failure (Chiew, 1992; Bradley *et al.*, 2005). Road crossing on channel morphology and hydraulics of Kunur river was studied and found prominent impact on channel depth, cross-section area, flow velocity, entrenchment ratio, channel bed gradient, water level and depth, braided index (BI), pool-riffle sequence, area and shape of bars (Roy, 2013). Roy and Sahu (2016) studied road crossings of Ajay river over a period of 40 years (1970-2010) and noted significant changes in bar dynamics, thalweg wandering.

In 2012, within a reach of a length of 155 meter of the river Jalangi at Krishnagar, New Railway Bridge (NRB), the third bridge, was completed (Fig. 1). During 1905, the year when Bengal was partitioned, a railway bridge was constructed across the river Jalangi on Ranaghat –Lalgola railway track (Pringle and Kemm, 1928; Mukherjee, 1932). There is also a road bridge, D. L. Roy Bridge (DLRB), for NH-34 on the river only 155 meter upstream of the old railway bridge (ORB). To keep pace with the fast growing demand of speedier transport for the rapidly multiplying population, double railway track was laid from Ranaghat to Baharampore which was bridged across the river Jalangi in 2012. This New Railway Bridge *(NRB)* aggravated the processes of bank erosion engulfing thousands of cubic feet of bank materials by a single flood of 2012. Present paper is worried about this third nail on the cross and to assess the effect of the engineering work of the NRB on channel morphology, bank erosion and hydraulics of the river Jalangi at local scale.

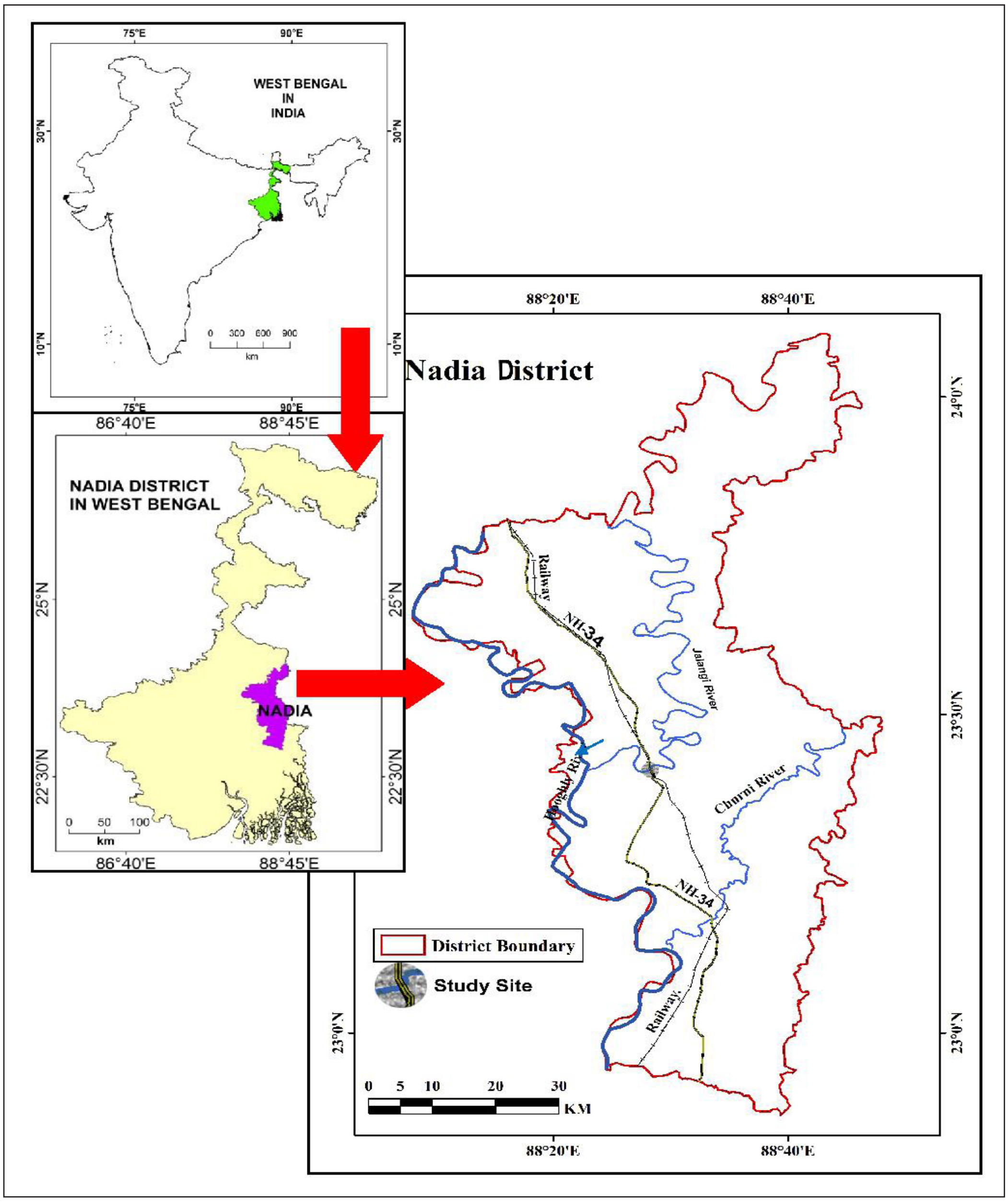

Figure (1): Location of the bridge and study site on the River Jalangi is shown by a shaded circle. Flow direction of the river is shown by blue arrow.

1. **The study area**

1.1.**The Jalangi River**

The name 'Jalangi' has been derived from that very settlement 'Jalangi' in C. D. Block Jalangi of Murshidabad district, at which, the river would take-off its supply from river Padma (Majumder, 1941, 1978, and 1995) during 18th century. Meaning of the word 'Jalangi' is 'the body is made of water'. The river runs for 220.5 km from its off-take to the confluence, out of which 48 km (from off-take at Char Madhubona near Jalangi to Bhairab confluence at Moktarpur) is dead at present and 172.5 km (from Bhairab confluence at Moktarpur to Bhagirathi confluence at Swarupganj) is being fed by the river Bhairab (Fig. 2). Up to late 19th or early 20th century the river was one of the three (Bhagirathi, Mathabhanga, and Jalangi – three *Nadia Rivers*) main waterways of south Bengal. Sometimes the river was more suitable as a navigation route than that of Bhagirathi and Mathabhanga. The first steamer record to pass through the river Jalangi dates back to 21st October, 1830 and mentioned as "….we left Calcutta on the

14th October 1830 in the steamer 'Hooghly' towing the 'Soonamokee' with Lord William Bentinck and suite; the steamer drew 4 feet 6 inches. On the 21st October we passed through the Jellinghy into the Ganges with nothing less than 6 feet" (Reaks, 1919). Since then the river Jalangi allowed hundreds of steamers and boats of considerable sizes to ply through it up to 1930, a time span of 100 years. But now the off-take of the river is completely closed to allow any boat to pass into the river Padma. At present, the river Jalangi above the village Madhubona in C. D. Block Kaqrimpur-I is untraceable in true sense. The river maintains its course, though during monsoon months only, being fed by the River Bhairab and some spills. River Bhairab is a distributary of the river Padma and at the same time a contributor to the river Jalangi. Bhairab takes off from the river Padma at *Ankhriganj*, about 5km. upstream from Hursi and falls into the river Jalangi at *Moktarpur* in C. D. Block Karimpur-II. At Krishnagar, 15.5 km upstream from Bhagirathi-Jalangi confluence, NH-34 and Sealdah-Lalgola railway line cross the river Jalangi. NRB was constructed there in 2012 to host the 2nd track of railway line.

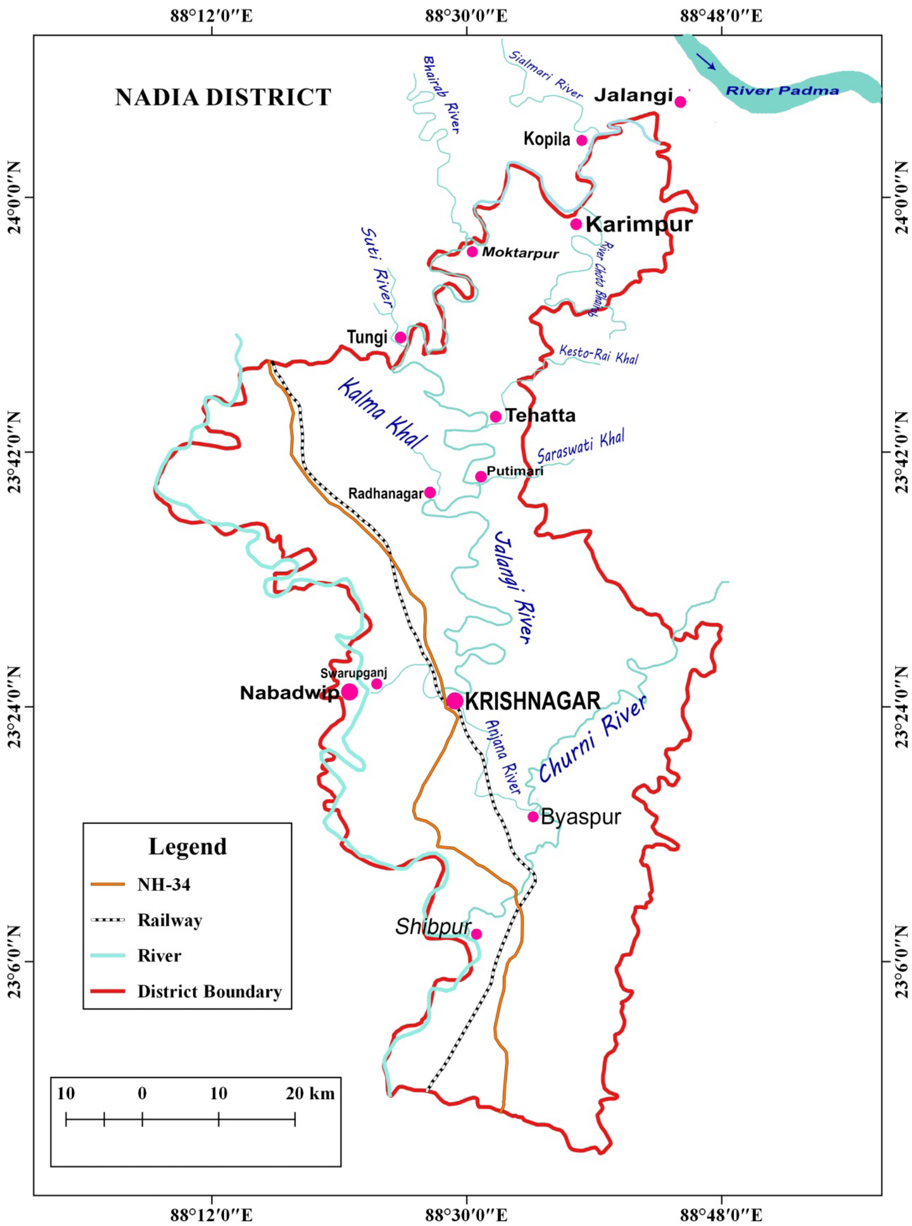

Figure (2): Course of the river Jalangi with its four left bank spills and four right bank spills

1.2. The Bridges

There are three bridges across the river Jalangi at Krishnagar within a reach of only 155 meter length. The first one was the Old Railway Bridge (ORB) constructed in 1905 (Pringle and Kemm, 1928; Mukherjee, 1932) on Ranaghat – Lalgola railway track. Second one is the 'D. L. Roy Bridge' (DLRB) on NH-34, at 155 meter upstream of old railway bridge (ORB).

The new railway bridge (NRB) has been completed in 2012 and sited between ORB and DLRB with a gap from ORB is only 11.40 meters (Fig. 3).

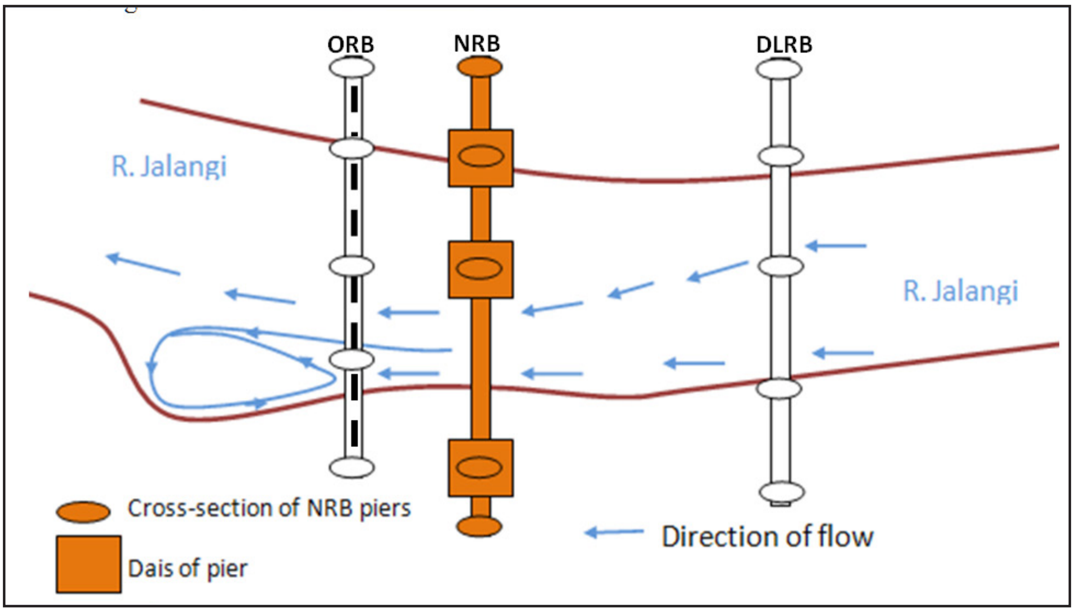

Figure (3): Sketched plan of NRB on the River Jalangi

After a single flood of 2012, the engineering work had tolled a lot of land on left bank creating a remarkable change in the morphometry of the reach which has been discussed under head *Adjustment of Channel Morphology*. Dimensions of the NRB are given in the Table 1.

Table (1): Dimensions of old and New Railway Bridge

Item	Old Railway Bridge (ORB)	New Railway Bridge (NRB)
Number of piers	5	5
Number of piers within river channel	3	2
Width of piers	3.95 meters	2 meters
Length of piers (horizontal)	9.30 meters	9.15 meters
Cross sectional area of piers	37.2 square meters	18.3 square meters
Length of dais (platform on which pier is based)	No dais	15.25 meters
Width of dais	No dais	10.65 meters
Height of daises above mean sea level (MSL)	No dais	Variable (5.55 meter for mid-channel dais)
Lowest bed level of the river		3.87 meters below mean sea level

Source: Field survey on 24.08.2013

MATERIALS AND METHODS

Materials for the present study are the reach of the river Jalangi where construction of the 3rd bridge (NRB) has been completed in 2012 and over which a prolonged survey has been carried out during the period 2010 to 2014. To assess the effect of bridge construction on river, measurement of pre-construction channel morphometry was mandatory. So a cross-section on the river Jalangi was drawn at the NRB site during March, 2010 when preliminary process of NRB construction was going on. Another cross-section on the NRB site was drawn again in March, 2013 when the NRB was already inaugurated and the flood of 2012 was over leaving its impact on channel form. As bridge piers and daises on river-bed alter the natural flow pattern, there must have some impact on channel form. To assess that impact, two cross-sections of river Jalangi at NRB site, before and after construction were compared in terms of change in channel asymmetry, shifting of thalweg point and bed asymmetry.

Channel asymmetry in fluvial geomorphology is very important because it not only gives shape of a channel but also indicates efficiency and flow type and pattern. Channel asymmetry (A*) were computed using the equation

$$A^{*} = \frac{A_r - A_l}{A} \quad \text{(Knighton, 1981)} \qquad (1)$$

Maximum depth (thalweg or d_{max}) of a cross-section of a channel reach and its position determines channel asymmatry (Knighton, 1981) to a large extent. Amount of shift of thalweg point was calculated from cross-sections.

Hydraulic radius of a channel is inversely proportional to the length of wetted perimeter. Therefore, length of wetted perimeter (bed length) along with its roughness and symmetry determines not only hydraulic radius but also flow resistance (Leopold *et al.*, 1964; Chanson, 2004). Bed asymmetry can recognize differences in channel efficiency and resistance between two halves of a cross-section. Bed asymmetry was calculated using formula

$$A_b = \frac{\mathrm{A_r} \times \mathrm{B_r} - \mathrm{A_l} \times \mathrm{B_l}}{\mathrm{A} \times \mathrm{B}} \quad \text{(Das and Islam, 2015)} \qquad (2)$$

Here, A_r and A_l are cross-sectional area of right and left part from center line (red vertical line in Figs. 4) of the channel; B_r and B_l are bed length of right and left part from center line of the channel; A and B are total cross-sectional area and total bed-length respectively. Bed length was measured as hypotenuse from cross-sectional trapeziums using the Pythagorean Theorem as shown in Fig.4.

$$a = \sqrt{b^2 + c^2} \qquad (3)$$

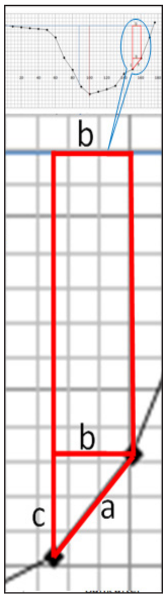

Figure (4): calculation of bed length (a) from channel cross-sections using Pythagoras Theorem

Bridge piers make obstacles to flow regime (Musy and Higy, 2011) and divert flow directions creating change in hydraulics which is one of the prime concern of river channel management. In this study, data on variation in river velocities across the channel were collected using submerged-float method. Submerged – float minimizes the effect of winds on river velocity. Using cross-sectional area method (Charlton, 2008), total discharge and discharge of both right and left haves of the channel were calculated. Then flow asymmetry was calculated using the formulae

$$A_Q = \frac{Q_r - Q_l}{Q} \qquad (4)$$

Where are discharges through right and left haves of the channel cross-section respectively. Q is the total discharge through wetted cross-section of the channel.

Poorly designed bridges disrupt natural flow pattern of streams and cause problem of increased erosion (Inglis, 1949; Keeley, 1971; Schumm, 2005; SEPA, 2008; Cocchiglia *et al.*, 2012) or even structural failure (Chiew, 1992; Bradley *et al.*, 2005). A pier with broad dais at base of NRB was constructed in mid channel. As a consequent, flow of the river concentrated towards left bank and a considerable portion of the river bank was engulfed.

Amount of bank erosion was estimated by simple trigonometric method adding volume of several blocks of eroded bank $(a_1 \times b_1 \times c_1) + (a_2 \times b_2 \times c_2) + \ldots\ldots\ldots\ldots (a_n \times b_n \times c_n)$. As the eroded volume was tapering towards both ends, it was taken into consideration and eroded section of the bank was divided into a number of blocks to make the estimation easier (Fig.5).

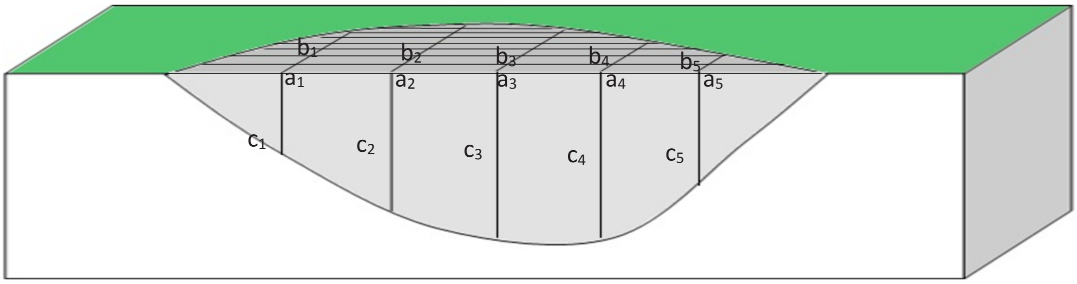

Figure (5): Scheme of measurement of eroded volume of bank

Then the length (a), breadth (b) and depth (c) of eroded bank were measured to get the volume of erosion.

A pier with broad dais at base of NRB was constructed in mid-channel. It makes considerable obstruction to the river flow. To estimate percentage of obstruction to total flow, dimension of submerged part of different parameters of pier and dais (like width, breadth, thickness and height above mean sea level) were measured using measuring tape and dumpy level. Then total area of the surface of submerged part of pier and dais perpendicular to flow direction (Os) (that makes obstruction) was calculated. It was then divided by total cross-sectional area of the channel (A) and multiplied by 100.

$$\text{Percentage of obstruction to total flow} = \frac{\text{Total area of the surface of submerged part of pier and dais perpendicular to flow direction } (O_s)}{\text{Total wetted cross-sectional area of the channel } (A)} \times 100$$

Or

$$\text{Percentage of obstruction to total flow} = \frac{O_s}{A} \times 100 \quad (5)$$

RESULTS AND DISCUSSION

Channel forms and processes operating within channel through moving water feedback each other to set equilibrium between processes (hydraulics) and response (forms) (Knighton, 1984; Charlton, 2008; Hugget, 2011). Construction of a pier (and a dais of significant dimensions at its base) within mid-channel had greatly changed the processes of flow-dynamics (adjustment in hydraulics) of the reach of the channel. This change in processes in turn shaped the channel forms (adjustment in channel morphometry) to set equilibrium between forms and processes.

4.1. Adjustment in Hydraulics

Impulsive construction of NRB made the main current of the river to flow along the left bank at the reach bringing a significant change in flow asymmetry. This finding confirms observation of Keeley (1971). Flow asymmetry at NRB station was calculated before and after construction. It was -0.03 and -0.65 respectively, a change of 23.89 times. This is because

1. In between piers of DLRB and NRB, the

velocity after construction along left bank was 35.9 m / minute (as on 24.08.2013), the mid-channel-velocity was 29.05 m / minute and along the right bank velocity was 21.67 m / minute. Average velocity of the reach was 28.87 m / minute.

2. About half of the wetted channel along the right bank was spurred by earth to facilitate the access to the mid-channel-pier for constructional work of the bridge. This was done by putting 130000 cubic feet of soils in the river bed which has not yet been removed even after completion of the construction. This earthen spur across the river has forced lion share of the flow towards the left bank. Moreover, the dais of the mid-channel-pier has shortened the width of the channel resulting higher velocity along left bank in between piers of ORB and NRB. After construction, velocity of current in between piers of ORB and NRB along left bank was 59.7 m / minute (as on 24.08.2013) which was 1.4 times higher than the mid-channel-velocity (42.5 m / minute) and 2.1times higher than velocity (28.4 m / minute) along the right bank (Fig. 6).

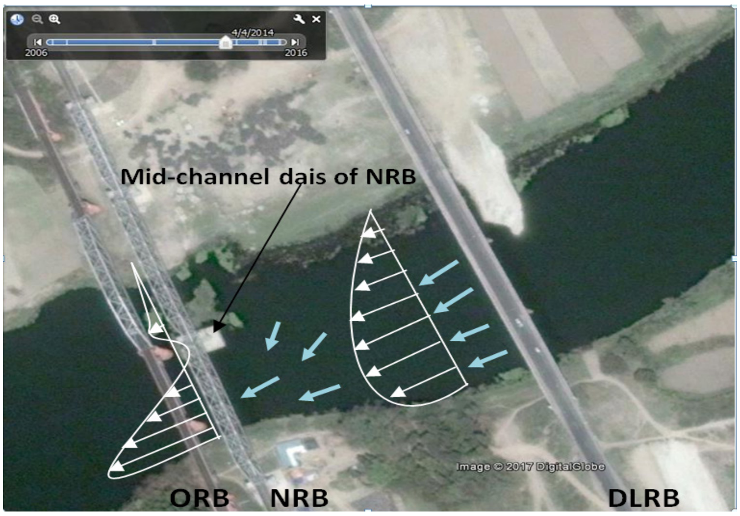

Figure (6): Flow direction (light blue arrows) immediate downstream of DLRB is slightly diverted towards left bank. But in between NRB and ORB it is highly diverted and concentrated towards left bank because of mid-channel dais (pointed by black arrow). Velocity distribution across the channel is proportional to white arrows.

3. The most decisive structure for the interference of the hydraulics of the river is the mid-channel dais of the pier. Its length, breadth and height (Fig. 7; Table 2) is so designed, that it obstacles about 4.95% of total flow (calculated in respect of mean water level, M.W.L., the average of highest flood level H.F.L. and lowest water level L.W. L.) of the river. Height of the dais corresponds to 97.30 % (Table 2) of the lowest water level (L.W. L.). This is very crucial so far as the lean season flow and self maintenance of bed is concerned. Above results also confirms observations of Simon and Downs (1995) and Musy and Higy (2011).

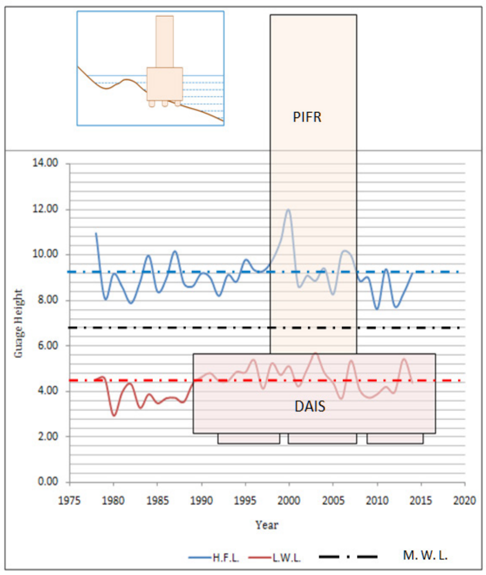

Figure (7): Mid-channel dais and pier made obstacle to the flow

Table (2): Cross-sectional area of pier and mid-channel dais making obstacles to river flow

Cross-sectional area of channel @ mean water level 6.77. m.	585.83 (sq. meter)
Cross-sectional area of dais	33.44 (sq. meter)
Cross-sectional area of piers making obstacle to flow regime	2.44 (sq. meter)
Cross-sectional area of base-piers making obstacle to flow regime	6.58 (sq. meter)
Total obstacle made to flow regime	42.46 (sq. meter)
% of obstacle made to flow regime	4.95

4.2. Adjustment of channel morphometry

Cross-section at NRB station before and after construction of bridge (Fig.7, Fig. 8) shows that there was a great change in the morphometry of the channel. Before construction of NRB, right bank (7.545m) was1.205m higher than after NRB (6.34 m). Soil cutting from right bank to facilitate the movement of Lorries carrying construction materials was responsible for that change in bank height.

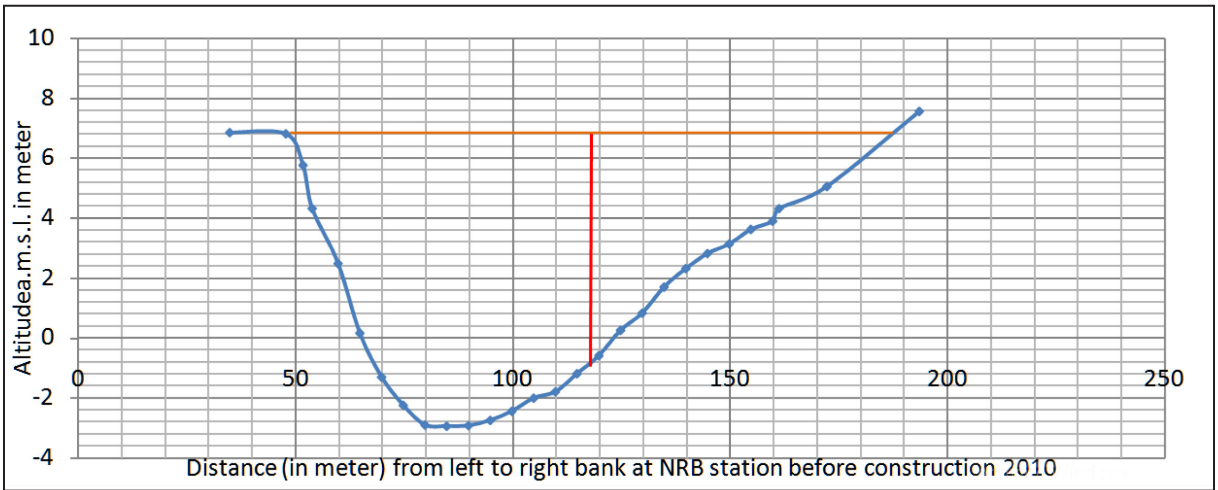

Figure (8): Cross-section at a station during 2010 before construction of NRB. Vertical red line is the centre line of cross section and horizontal yellow line represents bankfull width of the channel. Higher the difference between cross-sectional areas to the left and right of the centre line more is the channel asymmetry.

Onsite channel deepening due to constriction and consequent scouring of channel bed were also noted by onsite channel deepening Schumm (2005) and Inglis (1949). NRB made the channel constricted and flow concentration. Concentrated flow in constricted channel at NRB station stimulated bed scour as a result of which thalweg level (d_{max}) before NRB was -2.94m from mean sea level which was -3.87m after flood of 2012. To keep pace with the volume, the river scoured its bed 0.93 m deeper towards left bank. Due to earthen spur up to mid-channel from right bank and location of mid-channel dais, flow was diverted towards left bank. This diverted flow made thalweg point shifted 14 meters towards left bank (34m – 22m). After NRB, mid-channel dais reduced the width of the channel.

Table (3): Increased asymmetry in flow and morphometry of channel

Year	Channel Asymmetry		Bed Asymmetry		Flow Asymmetry		Average Velocity			
							In between DLRB and ORB (m/minute)		In between NRB and ORB (m/minute)	
	Bridge Site Station	Downstream Station	Bridge Site Station	Downstream Station	Bridge Site Station	Downstream Station	Left side of the mid channel pier	Right side of the mid channel pier	Left part of the channel	Right part of the channel
2010	-0.03	-0.15	-0.20	-0.20	-0.03	- 0.02	34.95	32.83	-	-
2013	-0.57	-0.36	- 0.55	-0.29	-0.65	- 0.053	35.9	29.05	59.7	28.4

Diverted and concentrated flow triggers bank erosion (Keeley, 1971) and onsite channel deepening (Inglis, 1949; Schumm, 2005). At NRB station channel asymmetry before and after NRB was -0.03 and -0.57 respectively with an increase of 21.05 times (Figs. 8 and 9; Table 3). Channel asymmetry at 107.5m downstream before NRB was -0.15 which became -0.36 after NRB, a 2.40 times increase in asymmetry (Fig. 10).

Bed asymmetry at NRB station before and after construction was -0.20 and -0.55 respectively indicating a change of 2.73 times. At 107.5m downstream, bed asymmetry before and after NRB were -0.20 and -0.29 respectively and change was 1.44 times. This bed asymmetry leads to unequal flow resistance and thereby scouring and deposition site of the channel.

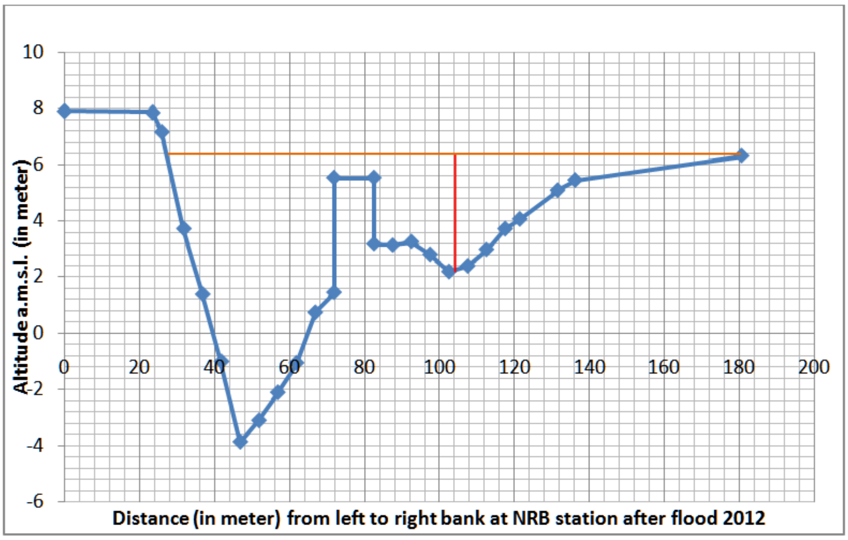

Figure (9): Cross-section at NRB station after flood of 2012

Dais at the base of the mid-channel pier created a considerable obstruction and diversion of flow. Flow was diverted and concentrated towards left bank. The mid-channel-dais of the pier was completed before the flood of 2012 and the single flood of 2012 engulfed about 500 m^2 of agricultural lands by the river. About 15 trees on bank have been swallowed by Jalangi. Here, the river has widened its width 5.93% cutting 7m of the left bank. The volume of bank materials eroded was estimated at least 1125 cubic meters. A whirl of back current of 72 meter long and 7 meter wide was developed which scoured the left bank immediate downstream of the construction work. A shoal along the right bank has been developed 250 meters downstream of the NRB site.

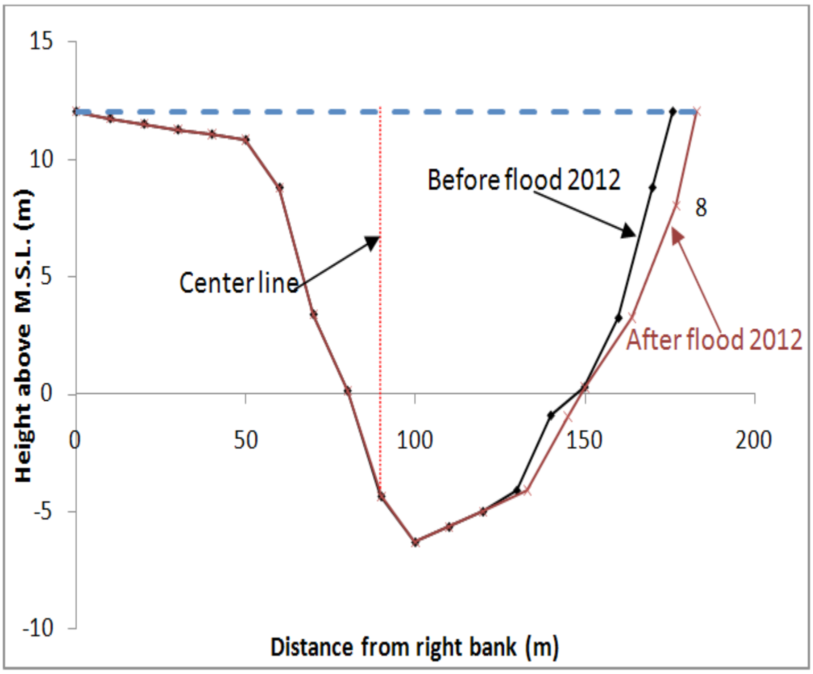

Figure (10): Superimposed cross-section at downstream of the bridge showing bank erosion before and after flood of 2012

For public awareness, Public Works Directorate (PWD) Roads & Mechanical Wing of Govt. of West Bengal, India, does not publish any report on impact assessment in terms of channel morphometry, ecosystem, bio-diversity, pollution etc for any construction within river. There is another state level authority 'Irrigation and Waterways Department (IWD), Govt. of West Bengal' to look after rivers and related affairs. But in their reports (Annual Administrative Report 2009-2010, IWD), no instances can be found where the health of the river is given any attention. It appears from the design of the NRB that engineering aspects, rather river health are their main concern. 'Engulfingof my banana garden could be avoided if the design of the NRB was as like as design of ORB. The left bank of the river came under severe attack of concentrated current diverted towards left. Only the mid-channel-dais is solely responsible for this bank erosion'- said Shyamal Sarkar, a peasant of Natun Shambhunagar. This was the learning from the nature by an illiterate village-peasant. He from his experience 'living with river' knew that major interference like construction of daises of such huge dimensions must take revenge by swallowing banks, what our learned engineers overlooked or simply ignored. To answer a question, Executive Engineer, Irrigation and Water Ways Department, Jalangi Bhawan, Krishnagar, said that Indian Railway Company did not take any consent regarding design of the NRB across the river Jalangi from his department. However, if the river was in its stage of vigor, it could take the revenge, even by endangering the very existence of the ORB and NRB. The earthen spur, one of the principal causes for leftward diversion and concentration of the current, was not removed from river bed. It has fasten the process of deterioration of the river by obstructing the flow and contributing huge silt (130000 cubic feet) to be deposited within channel. Some bamboo-porcupines with sand-bags, financed by Eastern Railway and executed by 'Irrigation and Water Ways Department', have been introduced to protect further erosion of the bank.

CONCLUSION

Although the river Jalangi is a moribund channel of West Bengal, yet its economic and social importance to the locality is beyond any question. It is the life-line of the region concerned. Therefore, any interference with its regime requires intensive study of the river as well as socio-economic scenario on banks. Otherwise construction like NRB on River Jalangi may cause bank erosion, change in channel morphology and hydraulics which in turn may disrupt fluvial ecosystem.

ACKNOWLEDGMENT

I acknowledge my students Biswajit Biswas, Biplab Sarkar, Subrata Sarkar and Suresh Paul especially Biswajit Biswas who made possible the herculean task of making cross-sections on the river and recording velocity and did much in processing of data collected from field study. Villagers, especially fishermen who provided boat and their physical labor during field study are also heartily acknowledged.

REFERENCES

Allan, J.D. and Flecker, A.S., 1993. Biodiversity conservation in running water. Biosciences. 43: 32 - 43.

Bradley, J. B., Richards, D. L., and Bahner, C. D. 2005. Debris Control Structures Evaluation and Countermeasures, Hydraulic Engineering Circular No. 9. Federal Highway Administration, Report No. FHWA-IF-04-016. Federal Highway Administration, Washington. 182 pp.

Brookes, A. 1985. River channelization: Traditional engineering methods, physical consequences, and alternative practices. Progress in Physical Geography. 9: 44–73.

Brooks, A. 1988. Channelized Rivers. Perspectives For Environmental Manegement. Wiley, Chichester.

Brunsden, D., and Thornes, J. B. 1997. Landscape sensitivity and change. Transaction of the Institute of British Geographer, NS4. 463-84.

Chang, H. H. 1986. River channel changes: Adjustments of equilibrium. Journal Of Hydraulic Engineering. 112: 43- 55.

Chanson, H. 2004. The Hydraulics of Open Channel Flow: An Introduction. Elsevier, Amsterdam.

Charlton, R. 2008. Fundamentals of Fluvial Geomorphology. Routledge, London, p-13.

Chiew, Y. M. 1992. Scour protection at bridge piers. Journal of Hydraulic Engineering. 118(9): 1260-1269.

Cocchiglia, L., Purcell, P. J., and Kelly-Quinn, M. 2012. A critical review of the effects of motorway river-crossing construction on the aquatic environment. Freshwater Reviews. 5: 141-168.

Emerson, J. W. 1971. Channelization: A case study. Science, 173: 325-326

Galay, V. J. 1983. Causes of riverbed degradation. Water Resources Research. 19: 1057-1090.

Hugget, R. J. 2011. Fundamentals of Geomorphology. Routledge, New York. P 209.

Inglis, C. C. 1949. The behavior and control of rivers and canals. Central Water Power Irrigation and Navigation Research Station, Poona. Research Publication 13.

Karr, J. R., Toth, L. A., and Dudley, D. R. 1985. Fish communities of midwestern rivers: A history of degradation. Biosciences. 35: 90 - 95.

Keeley, J. W. 1971. Bank protection and river control in Oklahama. Federal Highway Administration, Oklahama Division.

Knighton, A. D. 1981. A symmetry of river channel cross-sections: part 1. Quantitative indices. Earth Surf Process Landf. VI: 581–588.

Knighton, D. 1984. Fluvial Forms and Processes. Arnold, London, p- 1, 2,164.

Kondolf, G. M., Piegay, H., and Shear, D. 2003. Integrating geomorphological tools in ecological and management studies. *In*: Kondolf, G. M., and Piegay, H. (Eds.) Tools in Fluvial Geomorphology. John Wiley and Sons, Chichester, P- 633.

Lane, E. W., and Borland, W. M. 1954. River-bed scour during floods. Am. Soc. Civil Engrs. Trans. 119: 1069-1080.

Laursen, E. M. 1960. Scour at bridge crossings. Am. Soc. Civil Engrs. Proc. 86(2369): 39-53.

Leopold, L.B., and Bull, W.B. 1979. Base level, aggradation, and grade. Proceedings of the American Philosophical Society. 123 (3):168-202.

Leopold, L. B., Wolman, M.G., and Miller, J.R. 1964. Fluvial Processes in Geomorphology, Freeman, San Francisco.

Majumder, S. C. 1941. Rivers of the Bengal delta. *In:* Biswas, K.R. (Ed.) 2001, Rivers of Bengal, Department of Higher Education, Govt. of West Bengal. p-17,18,54.

Majumder, D. 1978. West Bengal District Gazetters Nadia. Govt. of W. B. p-5,7,16.

Majumder. S. 1995. Sri Chaitanya Janmas than Bitarka Tar Truti O Samadhan. Nabadwip, p-37.

McAllister, D. E., Hamilton, A. L., and Harvey, B. 1997. Global fish water biodiversity striving for the integrity of freshwater ecosystem. Sea Wind, 11(3): 1 – 140.

Moyle, P. B., and Leidy, R. A. 1992. Loss of aquatic ecosystems: Evidence from fish fauna. Pp 127 – 169. *In:* Fielder, P. L., and Jain, S.K. (Eds.) Conservative Biology. The Theory and Practice of Nature Conservation, Preservation and Management. Chapman and Hall, New York.

Mukherjee, B. B. 1932. Final Report on Survey and Settlement Operation In the District Of Murshidabad, Govt. of Bengal. P 3-8,74,75,76,96,125-127.

Musy, A., and Higy, C. 2011. Hydrologya Science of Nature. Science Publishers Enfield, New Hampshire. P- 265.

Neill, C. R. 1965. Measurement of bridge scour and bed changes in a flooding sand-bed river. Proceedings of the Institution of Civil Engineers. 30: 415-435.

Noble, C. C. 1976. The Mississippi river flood of 1973. *In*: Coates, D. R. (Ed.) Geomorphology and Engineering. Hutchinson & Ross, Pennsylvania. Pp-79-98.

NSW Department of Primary Industries. 2006. Reducing the impact of road crossings on aquatic habitat in coastal waterways – Northern Rivers, NSW report.

Palmer, L. 1976. River management criteria for Oregon and Washington. *In:* Coates, D. R. (Ed.) Geomorphology and Engineering. Hutchinson & Ross, Pennsylvania. Pp-329-346.

Petersen, M.S. 1986. River Engineering, Prentice Hall, Englewood Cliffs, NJ.

Pringle, J. M., and Kemm, A. H. 1928. Final Report on Survey and Settlement Operation in the District of Nadia, 1918-1926. Govt. of Bengal, Calcutta.

Przedwojski, B., Blazejewski, R., and Pilarczyk, K.W. 1995. River Training Techniques: Fundamental Design and Applications. Rotterdam, Balkema.

Reaks, H. G. 1919. Report on the Physical and Hydraulic Characteristics of the Rivers of The Delta. *In*: Report on the Hooghly River and Its Head-Waters. Vol-I. The Bengal Secretariat Book Depot, Calcutta, 1919. *In*: Biswas, K. R. 2001. Rivers Of Bengal, Vol-II, Govt. Of West Bengal, P- 87,107.

Reid, S. M., and Anderson, P. G. 1998. Suspended sediment and turbidity restrictions associated with in stream construction activities in the United States: An assessment of biological relevance. Proceedings of the International Pipeline Conference- 1998. Calgary, Alberta.

Richard, S., Denise, W., Ian, W., and Jim, H. 1997. Environmental Study of Dredged Materials in Old River. Water and Sediment Quality Study for the Interim South Delta Program – Memo Report. Potential Environmental Impact.

Richards, K. 1982. Rivers Forms and Processes in Alluvial Channels. The Blackburn Press, New Jersey. P-301.

Roy, S., and Sahu, A.S. 2016. Effect of longitudinal disconnection on in-stream bar dynamics: A study at selected road–stream crossings of Ajay River. *In:* Das, B., Ghosh, S., Islam, A., and Ismail, M. (Eds.) Neo-Thinking on Ganges-Brahmaputra Basin Geomorphology. Springer Geography. Springer, Cham.

Roy, S. 2013. The effect of road crossing on river morphology and riverine aquatic life: A case study in Kunur river basin, West Bengal. Ethiopian Journal of Environmental Studies and Management. 6: 835-845.

Schumm, S. A. 2005. River Variability and Complexity. Cambridge University Press, New York. P-165.

Schumm, S. A., and Lichty, R. W. 1965. Time, space, and causality in geomorph1ology. American J. of Science. 263: 110-119.

Seiyaboh, E. I., Inyang I. R., and Gijo, A. H. 2013a. Environmental impact of Tombia bridge construction across Nun River in central Niger delta, Nigeria. The International Journal Of Engineering And Science (Ijes). 2(11): 32-40.

Seiyaboh, E. I., Ekweozor, I. K. E., Ogamba, E. N., and Alagha, W.E. 2013b. Effect of Tombia Bridge construction on the water quality of Nun River in central Niger delta, Nigeria. Journal of Applied Science. 10(3):7148-7156.

SEPA 2008. Engineering in the Water Environment Good Practice Guide: Construction of River Crossings. Scottish Environment Protection Agency. Report No. WAT-SG-25. Scottish Environment Protection Agency, Edinburgh. 33 pp.

Simon, A., and Downs, P. W. 1995. An interdisciplinary approach to evaluation of potential instability in alluvial channels. Geomorphology. 12: 215-232.

Urban, M. A. 2002. Conceptualizing anthropogenic change in fluvial systems drainage development on the upper Embarras River, Illinois. Professional Geographer. 54(2): 204–18.

Williams, G. P., and Wolman, M.G. 1984. Downstream effects of dams on alluvial rivers. United States Geological Survey Professional Paper no. 1286.

Williams, J. E., and Neves, R. J. 1992. Bioecological diversity in aquatic management. Trans. N. Am. Wldl. Nat. Resour. Conf. 57: 343 – 432.

Winkley, B. R. 1982. Response of The Lower Mississippi to River Training and Realignment. Wiley, Chichester.

Xu, J. 1990. An experimental study of complex response in river Channel adjustment downstream from a reservoir. Earth Surface Processes and Landforms. 21: 45-53.

Xu, J. 1996. Channel pattern change downstream from a reservoir: An example of wandering braided rivers. Geomorphology. 15: 147-158.

Xu, J. 1997. Evolution of mid-channel bars in a braided river and complex response to reservoir construction: An example from the middle Hanjiang River, China. Earth Surface Processes and landforms. 22: 953-965.

Yodis, E. G., and Kesel, R. H. 1993. The effdects and implications of base-level changes to Mississippi River tributaries. Zeitschrift Fur Geomorphologie. 37: 385-402.

Zakaria–Ismail, M. 1994. Zoogeography and biodiversity of the fish water. Fishes of Southeast Asia. Hydrobiologia. 285:41 – 48.

دراسة أثر إنشاء جسر على ديناميكية القناة على نهر جالانجي بالبنغال الغربية، الهند

بالاي شاندرا داس

قسم الجغرافيا، كلية كريشنجار الحكومية، ناديا
البنغال الغربية- الهند

الملخص

نهر جالانجي واحد من الأنهار الثلاثة المعروفة بـ «أنهار ناديا» في منطقة غرب البنغال بالهند ويقع على ضفته اليسرى مدينة كريشنجار، عاصمة مقاطعة ناديا. أنشئ سابقًا على النهر جسران يضمان الطريق الوطني السريع رقم 34 وخط قطار سلداه- لالجولا. وأنشئ جسر ثالث ليضم خطًا ثانيًا للقطار ذاته.

الآن -بخلاف الجسرين السابقين- فإن الجسر الجديد صمم بطريقة أدت إلى إعاقة كبيرة لسريان النهر، وأحدثت تغيرًا كبيرًا في الشكل الظاهري له.

ولدراسة أثر الجسر الجديد على شكل المجرى الظاهري وحركة الماء سجلت بيانات أولية لما قبل وما بعد إنشاء الجسر. توزيع سرعة التيار عبر المجرى قيست باستخدام طريقة عائمات مغمورة؛ حيث وجدت تغيرات في الاتجاه وفى شدة السريان أيضًا. قدر عدم انتظام المجرى والسريان، ووجد أنهما تزايدا بشدة بسبب عدم انتظام أرضية الأساس. وبسبب إنشاء الجسر الجديد -خاصة أعمدته الوسطى- فإن خط الضفة اليسرى قد تراجع بمسافة سبعة أمتار مبتلعًا 1125 مترًا مكعبًا من التربة.

الكلمات المفتاحية: انتظام السريان، انتظام المجرى، الجسور، المنصات.