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MITIGATION STRATEGY, PREVENTIVE
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Degeneration of Jalangi River: An Investigation Based on Maps and Satellite Images

Sayantan Das* & Sunando Bandyopadhyay**

Abstract

Jalangi is a distributary of the Padma River which has opened up within the last few hundred years to flow actively in the southern and south-western direction through the districts of Murshidabad and Nadia in West Bengal. Initially, its source was the original Jalangi offtake located near Jalangi village, Murshidabad district. Earlier, it used to meet Bhairab River at two different points 5 km apart. But due to irregular flow of water, this part of the Jalangi River has become a palaeochannel and the discharge through Jalangi River is now maintained by Bhairab River. So, the lower part of the Bhairab River is actually the present Jalangi River. It flows into the Bhagirathi-Hugli River near Mayapur in Nadia district. The part of Jalangi River in Nadia district is considered for this study which is representing the

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lower course of the river. Jalangi is active during the monsoon season and Nadia district is quite susceptible to the flooding of Jalangi and Bhagirathi-Hugli rivers. Jalangi River is otherwise suffering from lack of supply of water to maintain its flow during the drier part of the year. This study is an endeavor to map the behavior of the Jalangi River in the past two hundred years.

The database for detecting the changes in the Jalangi river course consists of J. Rennell’s *Bengal Atlas* (1780), *Atlas of India* maps (1855-56), and topographical maps of 1: 63,360 scale (1914-18); satellite database includes Landsat (MSS, TM, ETM+) images (1973-2010) and LISS IV Mono images (2007). Discharge data of different periods have been used for identifying the variation of water flow through the main channel. The main channel of Jalangi is characterized by intense meandering and the channel has shifted a few times in the recent past. This fact is confirmed by the presence of ox-bow lakes, meander scars etc. near the main channel. It can also be found from the old maps of the 18th and 19th century that width of the Jalangi river channel—which was at a par with the Bhagirathi-Hugli river until a couple of centuries back—has been decreasing.

The main reason behind decreasing water flow in the Jalangi River is the shifting of the main channel of Ganga coupled with rapid siltation occurring at the off-take of Jalangi River. This prevents the discharge to enter through the course of Jalangi except during the monsoons. The other factors disturbing the main channel are sediment quarrying from the river bank and dry river bed, land-use changes, contamination of river water through the release of effluents into the river, garbage dumping etc. The presence of water hyacinth is a common phenomenon in the lower course of the river indicating eutrophication. The anthropogenic impact is mostly visible in the areas near Krishnanagar city. In spite of bankful and sometimes overbank discharge during the monsoon season, there is a possibility that the river could turn into an abandoned one in near future. Mitigation measures with proper planning should be implemented to regenerate the river environment.

**Key words:** Distributary, Offtake, Flooding, Palaeochannel, Meandering, Abandoned, Regenerate.
Introduction

The river Jalongi is a vital part of the Ganga-Brahmaputra Delta (GBD) system. The original offtake of the river is located near a village called Jalongi in the eastern part of the Murshidabad district, West Bengal. The river owes its name to the village Jalongi (Rennell, 1781). The initiation of the Jalongi river could be sourced to the course of presently non-active Bhairab river, which once flowed from the Padma river (main distributary of Ganga) across the present beds of Jalongi and Mathabhanga rivers in the south-easterly directions, and further eastwards towards Faridpur district of Bangladesh (Hirst, 1915). Since the main channel of Padma is shifting continuously, it might have affected the offtake of Bhairab in an adverse manner. Jalongi opened up long after the Bhairab ran as a strong stream. It is assumed that the Jalongi River opened up at about the end of 17th century, flowing south-west into the Bhagirathi-Hugli river and cutting across the Bhairab river flowing south-east (Reaks, 1919), although there is no direct evidence of this. During the greater part of 19th century, the discharge in this river has considerably diminished due to siltation of its offtake (Garrett, 1910).

The original offtake of Jalongi, though presently non-functional, is found to be at the north of the Jalongi village (24°11′01″N, 88°43′15″E), where Padma river takes a perpendicular bend towards east to enter Bangladesh. After initiation, the course of the river followed south-westerly direction and formed the boundary between Murshidabad and Nadia districts. On the way, Jalongi converges with Sialmari and Bhairab (opened up during early 20th century by capturing the upper course of the Kalkali river) rivers. The discharge through the Bhairab course is continuous and therefore it maintains the flow of the Jalongi River after the confluence. Jalongi, after meeting Bhairab, flows southward to enter Nadia district. It trailed in a tortuous manner towards south within Nadia until it reaches Ghurni near Krishnanagar town. From Ghurni, it proceeds due west up to Mayapur where it falls into the Bhagirathi-Hugli river (23°24′55″N, 88°23′48″E).

Previous Works

Although the decay of Jalongi River is appeared to be a major
issue, it is surprising to note that documented research works
highlighting the decay of Jalangi River are few. Initial works on
Jalangi River include the reports prepared by Fergusson (1863),
Garrett (1910), Hirst (1915), Addams-Williams (1919), Reaks (1919),
and Stevenson, Moor et al. (1919). Those reports mainly
emphasized on how Jalangi River was opened up during the
course of the time. Even though there were a few mentions about
how the general health of the river is deteriorating, a
comprehensive account of the decaying river system is lacking.
Moreover, the reports were compiled about a century ago.
Therefore, the present condition of Jalangi River could not be
successfully gauged by these reports.

Significant works related to the degeneration of GBD rivers
progressed only after the independence of India. Initially, Basu
and Chakraborty (1972) started the proceedings with the decaying
Bhagirathi drainage system. Later, Sen and Basu (1974) mentioned
that the bed of the offtake of Jalangi, like Bhagirathi is considerably
higher than the low water level of the surface of Ganga (Sherwill,
1858). Therefore, the offtake could be left dry if the water level
of Ganga (or Padma) recedes further. They highlighted that the
angle (> 90°) at which Jalangi takes off from Padma river is
awkward as it could prevent the required discharge of Padma to
enter Jalangi. They had also pointed out the disproportion between
the supply of water from Padma to the Jalangi river during the
monsoon as well as in the ‘dry season in this regard.

Standing on these premises, this paper endeavors to
underscore the behavior of Jalangi River for the last couple of
centuries using chronological maps and satellite images. It also
aims at emphasizing the interference by the human agencies on
the river.

**Degeneration Scenario**

Jalangi flows through the moribund portion of the southwestern
GBD as found from the three-part division of southwestern GBD
made by Bagchi (1944). Jalangi, along with Mathabhanga and
Bhagirathi formed a network of moribund rivers in the concerned
region for study, and are still collectively known as the ‘Nadia
Rivers’ (Hirst, 1915). These rivers were the most important means
of communication until the advent of railways and were open
for navigation throughout the year. It was first revealed by Rennell (1781) that these rivers were not usually navigable in the dry season. He stated that the Bhagirathi River was almost dry except monsoon months and Jalangi was non-navigable in some years during two or three months of the dry season, though a stream flowed through it perennially. He also showed that Jalangi was the only navigable river of the region. Later Colebrook (1801) revealed that Jalangi was not navigable during the dry season, though previously it used to be navigable during the whole or greater part of the year. For purely navigational purpose, the ruling British Government initiated some measures like dredging to resurge the moribund rivers in the early 19th century with only Jalangi responding positively. It was in favourable condition during late 1820's and was navigable for the medium sized boats throughout the year. In 1831, a devastating flood occurred in the Bhagirathi basin which opened up the Bhagirathi River for navigation. The flood water inundated a major portion of the moribund region and caused a northward shifting of the Jalangi offtake (Garrett, 1910). The upper course of the Jalangi River became sluggish after that and it failed to transport the silt which it received from Padma River. The shoaling behind the offtake continued for a long period and as a result the river remained unfavourable during the middle part of the 19th century. Lang (1851) monitored the entrance of the Jalangi from 1821 to 1847 and showed that it had shifted five times during this period in accordance with the shifting of Padma in order to keep itself active. Therefore, since the midway of the 19th century, upper part of the Jalangi is gradually transforming into a palaeochannel. The situation is different in the lower course after the confluence point of Bhairab and Jalangi Rivers. The Bhairab River started to open up in 1874 and during 1880's, it developed into the main entrance channel of Jalangi (Reaks, 1919). Since that time, the flow of Jalangi is maintained by Bhairab River and the river till now is navigable for the small and mid-sized boats throughout the year. After the meeting point, Jalangi follows a winding path to course through the Nadia district up to its confluence with Bhagirathi near Nabadwip town. The most remarkable feature of this lower course is that the meandering curves are well preserved and their variability in different times seems to be minimal. This section gives an appearance of a river with well
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established banks in most places, probably made up of stiffer materials and therefore less subject to erosion (Reaks, 1919).

Methodology

Details of the maps and satellite images studied for the current paper are presented in Table 1. The graticules and reasonably stable cultural features like road junctions, bridges, embankments etc. were used as the references for matching the maps and satellite images with one another. The distortions in the final output are likely to be insignificant here as the maps and satellite images were reduced, rather than enlarged, in scale. The results are supported by the Ground Truth Verifications done on the field by taking some strategic Ground Control Points (GCP’s) using Global Positioning System (GPS).

Findings

The obtained results are the outcomes of the comparative study of the maps and satellite images of the moribund delta. They are recapitulated in Fig. 2-6 and in Table 2. They reveal the changes in the Jalangi river course for the last two centuries with some evident development.

- The offtake of the Jalangi River has shifted over different periods with the shifting thalweg of Padma. The original offtake is non-functional now. It is a real challenge to locate the original offtake in the field as well as in the contemporary satellite images.

- Significant changes in the general health of the channel occurred in the upper course of Jalangi and that part has become a palaeochannel during the course of time.

- The discharge of Bhairab River helps the flow of Jalangi River to continue up to its convergence with Bhagirathi-Hugli River. Otherwise the entire course of Jalangi would have become a palaeochannel.

- During the last century or so, major changes in the morphological character of the lower course of Jalangi could not be traced.

- The channel width of Jalangi River is decreasing continuously.
• Flood appears to be a major threat for the region during the monsoon season and a substantial proportion of land remains inundated for a long time if a major flood occurs. But even a high intensity extreme flood event may not bring about long term changes in the channel morphology of Jalangi.

• Location and arrangement of the brick fields, occurrence of water hyacinth, usage of river water for sanitation purpose etc. further degrade the health of Jalangi River.

Discussion

Shifting Offtake of Jalangi River

As a part of the active GBD system, opening of Jalangi River from Padma could be traced on the evolution of the distributaries of the GBD throughout the geological History. In this regard, Oldham (1870) and Bagchi (1944) considered that switchover from one distributary to another is a normal part of the delta building process. Therefore, it indicates that the opening up and shifting of the offtakes is a common phenomenon in a dynamic delta like GBD. Later Mukerjee (1938) mentioned about rising as well as subsidence of land in some parts of the delta which affected the opening or choking up of the main distributary sources. But Stevenson-Moor et al. (1919) reported earlier that there is no evidence to justify the elevation and subsidence of the delta though they admit that those processes are determining forces behind the drainage development of the delta. Afterwards, Morgan and McIntire (1959), Basu and Chakraborty (1972), Khandelkar (1984), Khan (1991) and more recently Goodbred et al. (2003) held faulting as the responsible factor for the shifting of Ganga distributaries.

According to Banerjee and Saha (1972), the gradual decay of the Jalangi source region could be attributed to a negative change in the base level for the Ganga distributaries in recent times. Sengupta (1966) stated that due to the mobility of the basement complex of the Bengal basin the sea-face has receded towards south-eastern part and expectedly this movement is widest in the eastern part of the GBD. As a result, knick points produced in the western distributaries of Ganga-Padma would be located further from their offtake points as compared to the eastern
distributaries. This theory is applicable to the parent river also. Since headwater migration of the knick point is proportional to the volume of discharge through the channel, Padma River, which carries the lion’s share of discharge, experience the most frequent migration of its own knick point resulting into regular shifting of its thalweg. Consequently, it beheads the offtakes of the distributaries and therefore the bed of the offtakes lies higher than the water level of the parent river Padma, forming a hanging valley relationship. The status of the offtake of Jalangi signifies the same scenario. The theory of the mobility of the basement complex of the Bengal basin to the eastern and south-eastern direction is actually substantiated by many workers viz. Oldham (1870), Reaks (1919), Fox (1938), Bagchi (1944), Bakr (1971), Basu and Chakraborty (1972), Niyogi (1975, 1989), Bagchi and Mukherjee (1978), Choudhury (1978), Chattopadhyay (1985), Rudra (1987). They suggested that the delta building procedure occurs to be in the east or south-east direction by throwing successive overlapping deltaic lobes relating to the different distributaries which came into prominence and lost importance one after another (Bandyopadhyay, 2007).

Sen and Basu (1974) forwarded that Jalangi, with its decaying head, would be in an awkward position to receive the incoming discharge from the Padma river. The variability in the discharge of Padma in different seasons played an important role here. During monsoon, offtake of Jalangi used to become active with greater amount of discharge. But as soon as the discharge used to make an entry into the Jalangi course, the flow would become sluggish since by then it would lose its kinetic energy so much so that the sediment it carried along would settle down at the bed of Jalangi. Therefore in the drier times and even in the wet season afterwards, it was practically impossible for Jalangi offtake to receive a substantial amount of water to maintain its flow. As a result, it became abandoned about a century ago and the stream behind it transformed into a palaeochannel. In this context, they put forward the noble concept of obtuse angular offtake of Jalangi which might have formed in order to cope up with the continuously shifting Padma thalweg.

The abnormal supply of discharge from Padma to Jalangi was also mentioned by Lang (1854). He calculated that the discharge of Padma stood at 118,304 cusecs in January 1853 and
13,55,707 cusecs during flood season of 1853 at Sarda (located in Bangladesh, about 18 km. north of the original offtake of Jalangi). Though the amount of discharge received by the Jalangi offtake was not mentioned, he observed that the least depth of the water column at the entrance of Jalangi in dry season was 0 ft. and greatest depth in flood season was 22 ft. It was further stated by him that Jalangi was non-navigable in the month of February. The records between 1840 and 1853 showed that the greatest depth of water column at the entrance of Jalangi during floods was usually more than 20 ft., but the least depth in dry season rarely crossed 1 ft. indicating variability of water supply in Jalangi river. The discharge records of Jalangi at Punditpur, Nadia for 1915 confirmed the same situation as the discharge recorded for September was 75,000 cusec (using Kutter's formula) and for February it was only 2,780 cusec. The records of 1914, 1916 and 1917 marked the same degree of variability in the discharge amount of Jalangi in flood and dry seasons (Stevenson, Moor et al., 1919).

In the current study, the 1780 Map of Cossimbazar Island revealed that the original offtake of Jalangi was adjacent to the Jalangi village, Murshidabad. But 1855 Atlas of India map indicated that afterwards it shifted by 3 km. to the north of Jalangi village. The offtake existed even in the first half of the 20th century. But in the recent maps and images, the absence of the Jalangi offtake is noticeable, although the parent river Padma have shifted quite a few times.

Shifting Offtake of Bhairab River

Rennell (1780), in his map of Cossimbazar Island, pointed out Bhairab as a small stream drained out of the Kalkali River towards south near Akheriganj and followed the course of Suti Nadi (Reaks, 1919). But in the latter half of the 19th century, it opened up only to capture the upper course of the Kalkali River. Reaks (1919) also stated that in 1914, Bhairab had completely appropriated the upper course of Kalkali and took off the Ganga about 15 km. west of Akheriganj. It then took a perpendicular bend towards south near Akheriganj to follow the course mentioned by Rennell up to Banti where it started to follow a new course leaving old Bhairab. As a result the connection between Kalkali and Sialmari was lost and subsequently at the start of 20th century, the offtake of Sialmari shifted 5 km. north of
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Akheriganj. From the image of 1973, it is very clear that the Padma channel is working southward near Akheriganj and eventually after 1978 flood it swallowed the entire upper course of Bhairab. Therefore, the presently the offtake of Bhairab river can be seen near Akheriganj. This entire sequence of events has badly affected the Salmari River as its offtake was wiped out and ultimately in due course of time, it has become a palaeo-distributary. Since opening up, Bhairab River acts as the main entrance of Jalangi River as the older upper course of Jalangi has silted up and only operates as a flood spill channel.

Confluence of Jalangi and Bhairab

With the emergence of Bhairab as a strong stream in 19th century, Jalangi River had revived in the downstream portion after confluence with Bhairab near Madhupur in Nadia. Until the first half of the 20th century, the confluence was quite active as Bhairab used to flow effortlessly and Jalangi used to receive a substantial amount of discharge from Salmari to maintain its upper course. The scenario changed afterwards as the Jalangi channel has silted up due to the sluggish flow caused by the degeneration of Salmari. After 1978 flood, Jalangi re-energized temporarily due to the surfacing of a new spill channel which left the older channel near Garibpur in Nadia to converge with the Bhairab River at about 5 km. north of the older confluence. But it also degenerated within a few years in the same manner of the older course. The beds of both channels of Jalangi are positioned at the confluences in such a way that the concept of hanging valley at the offtakes put forward by Sengupta (1966) could again be evoked.

Changing Width of Jalangi

It is very obvious from the maps and satellite images that the width of the channel of Jalangi has been decreasing with time. The changing dimension of thalweg is basically caused by the variability of discharge in different years as well as different seasons. In the upper course, the effect is severe as in some parts, the channel discontinued leaving no mark of the once existing thalweg. Even in the lower reaches, decreasing width of the river is quite evident. Therefore, it could be asserted that the regime of the Bhairab River which contributes to the lower course of
Jalangi is becoming lethargic day by day and in the coming years, both the rivers would be converted into abandoned streams like the upper course of Jalangi. In Table 2, it is shown how the width of the Jalangi River has been altering in the last two centuries. To estimate the earlier condition of Jalangi, a couple of abandoned cut-offs have also been referred. It is found that the width of the current Jalangi channel is about one third of those cut-offs indicating that in earlier times, Jalangi was indeed a healthy distributary of GBD system. However the age of those cut-offs is unknown as it is not very clear from the available maps and images.

Absence of Significant Morphological Alterations in Jalangi Watershed

Except one or two cut-offs, major morphological changes could not be detected in the entire Bhairab-Jalangi tract. Bagchi (1944), in his evaluation of the geomorphic division of the GBD, classified this area as a part of ineffectual moribund delta. However, Bandyopadhyay (2007) countered Bagchi’s view by stating that the area gets flooded at regular intervals and as a result vertical accretion occurs regularly by depositing silt layers. The channel pursues a meandering path all along and the direction of movement is mainly southward and south-westward. Though such a course is common in GBD, alteration in the channel orientation of Jalangi is a rare thing which is not expected for a river flowing in the supposedly active delta region. This indicates that the materials of the river bank are so rigid that the bank has become less susceptible to erosion. Therefore, it could further suggest the geomorphological stability of the region. In Table 2, it is shown that the sinuosity index of the river has not changed significantly in the last century. The features like natural levee, backswamp, floodplain and oxbow lakes are well established here. Almost all these features came into existence long ago and from the available data source, it is impossible to even guess their actual age. But it is evident that the river was quite active in the initial years. However, the channel takes an unusual westward turn near a place called Ghurni which may be doctored by the subsidence of Nadia region mentioned by Hirst (1915).
Degeneration of Jalangi River

Flooding in the Jalangi Basin

This portion of GBD gets flooded at regular intervals. The terrain is almost flat and general topography is only characterized by natural levee systems and earthen embankments alongside the river channel. In the present form, Jalangi has not been unable to contain the monsoon discharge within its banks and therefore the region becomes susceptible to floods almost every year. The last of the major floods occurred here in 2000 and that was the worst in living memory (The gauge height reading of Swarupganj station near Bhagirathi confluence on 24th September, 2000 was 11.92 m. while the extreme danger level of water is still marked at 9.05 m. Data Source: West Bengal Irrigation and Waterways Department). In some parts, the levees and dykes often act as barriers and prevent the water from getting back into the main channel causing stagnation of floodwater till it is percolated down or drained out using some palaeochannels. Moreover, it is important to know whether the morphological features of the region would withstand a given level of flood. But the threshold flood magnitude (discharge and stage) required for bringing about a detectable change in the morphology of the area is not very certain. Significant alterations are hardly there in the channel orientations. Features associated with the floodplain morphology haven’t changed too much either. Therefore, it can be understood that flood appears to be a major problem during the monsoon season and a substantial proportion of land remains inundated for a long time. But a high intensity flood event may not bring about long term changes in the fluvial morphology. The existing morphological characteristics might be the outcomes of relatively slower and less devastating ongoing fluvial processes.

Anthropogenic Interferences

Interference of human agencies should be mentioned in the context of the degenerating Jalangi River. Activities like brick making, sediment quarrying from the river bank and dry river bed, release of industrial and household effluents into the river, garbage dumping etc. have caused the degradation of Jalangi River in the recent past.

The unwanted consequences of the brick making industry positioned near the river were first mentioned by Hirst (1915).
In order to make bricks, the brick field authorities cut pits across the bank up to the brick-field so that during monsoon, the sediment-filled water could passage into the brick-field. This water then evaporates and percolates down in due course of time so that during the dry season, only the silt is left to be used in the brick-making process. As these brick-fields are located very close to the main channel, the normal flow of the river gets disturbed which deteriorate the health of the river. According to West Bengal Irrigation Department officials, every brick-field should be located at least 100 m. away from the Jalangi channel. However, in reality, most of them violate the government order and some of those brick-manufacturing units don’t even possess any kind of permit.

A few industries are located near populous Krishnanagar town which is the district headquarter of Nadia. Waste matters released from those industries and other sources drain out of the city environment to the Jalangi River. Also, the river water is used for sanitation purposes. These, altogether degrades the condition of Jalangi.

The presence of water hyacinth is a common phenomenon in the lower course of the river indicating eutrophication. Impacted by human activities (both agricultural and industrial), the nutrient supply have been increasing in the Jalangi river and as a result water hyacinth invades the Jalangi course especially during monsoons, resulting into a choked up channel in few parts. These plants, known locally as Kochuripana, can unbalance natural lifecycles in a river like Jalangi which generally receives large amounts of nutrients.

Conclusion

Jalangi River still acts as a necessary component for the people of Nadia district. Human beings carry out different activities depending solely upon this river. From this study, it is revealed that the alterations in the physical landscape are very few in the areas through which the river continues to flow, further evoking the notion of moribund region suggested by Bagchi (1944). However, gradually the channel is shrinking and the water is getting polluted by different agents.

So, even though the discharge through Jalangi is satisfactory during the monsoon season, there is every chance that the river
Degeneration of Jalangi River

could turn into an abandoned one in the near future. The consequences could be really hazardous and could severely disrupt the eco-systems in the region. The curative measures with proper planning and management could be suggested to regenerate the river environment.

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<th>Year of survey/ Date of pass</th>
<th>Scale/Spatial Resolution</th>
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<td>J. Rennell’s 1780 Cossimbuzar</td>
<td>circa 1770’s</td>
<td>1: 760 320</td>
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<tr>
<td>SoI</td>
<td>Island Map</td>
<td></td>
<td></td>
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<tr>
<td>SoI</td>
<td>Map no. 120 of Atlas of India</td>
<td>1851-55</td>
<td>1: 253,440</td>
</tr>
<tr>
<td>SoI</td>
<td>Map no. 121 of Atlas of India</td>
<td>1851-55</td>
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<tr>
<td>SoI</td>
<td>Map no. 78 D</td>
<td>1847-68</td>
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<tr>
<td>SoI</td>
<td>Map no. 78 D/8</td>
<td>1914-16</td>
<td>1: 63,360</td>
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<td>SoI</td>
<td>Map no. 78 A/7</td>
<td>1916-18</td>
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<td>22/02/1973</td>
<td>60 m.</td>
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<td>Landsat ETM, P138R043</td>
<td>30/09/2000</td>
<td>30m.</td>
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</tbody>
</table>
Coping with Disasters

| USGS   | Landsat ETM, P138R044 | 30/09/2000 | 30m. |
| USGS   | Landsat ETM, P138R043 | 21/01/2010 | 30m. |
| USGS   | Landsat ETM, P138R044 | 21/01/2010 | 30m. |
| NRSC   | IRS P-6 LISS 4 Mono P108R055Q-A26/12/2007 | 5.8m. |
| NRSC   | IRS P-6 LISS 4 Mono P108R055Q-C26/12/2007 | 5.8m. |

SoI: Survey of India
USGS: United States Geological Survey
NRSC: National Remote Sensing Centre

Table 2. Channel Pattern Observations of Jalangi River

<table>
<thead>
<tr>
<th>Year</th>
<th>Length* of the channel (in km.)</th>
<th>Sinuosity Index</th>
<th>Area covered by the river width (in sq. km.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1780</td>
<td>155.25</td>
<td>2.39</td>
<td>52.45</td>
</tr>
<tr>
<td>1855</td>
<td>170.05</td>
<td>2.62</td>
<td>28.16</td>
</tr>
<tr>
<td>1916</td>
<td>177.78</td>
<td>2.74</td>
<td>21.84</td>
</tr>
<tr>
<td>1973</td>
<td>185.50</td>
<td>2.86</td>
<td>17.77</td>
</tr>
<tr>
<td>1989</td>
<td>183.21</td>
<td>2.82</td>
<td>17.51</td>
</tr>
<tr>
<td>2007</td>
<td>183.57</td>
<td>2.83</td>
<td>14.74</td>
</tr>
</tbody>
</table>

*Lengths were calculated from the confluence of Bhairab-Jalangi up to the confluence of Jalangi-Bhagirathi.

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1. Introduction

Works that holistically and specifically deal with the changes in river courses of the Ganga–Brahmaputra delta (GBD), India and Bangladesh, are rare. The approach toward this has mostly been made in a piecemeal manner, concentrating on a river or its portion. Therefore, any contribution on regional transformations of the GBD rivers should be considered as valuable. We went through the paper of Rudra (2014) with keen interest, expecting it to bridge a long-time gap in the literature. However, we found that the article not only contained many inaccuracies and contradictions but also often lacked scientific logic in arriving at a conclusion and its presentation. Instances of overlooking major previous works also occurred. In this communication, we bring out the major inconsistencies presented in Rudra’s (2014) article. To facilitate comparison, discussions are made in the same order in which the subsections of the original article were arranged.

2. The Bengal basin and the delta

Rudra (2014, p. 87) stated that the ‘Bengal basin’ is a ‘distinct geomorphic unit’ and used the term interchangeably with the GBD. On the contrary, the Bengal basin is a structural unit, the western and northern parts of which were formed in Early Cretaceous as a continental shelf of the Indian craton. During this time, India broke loose from the eastern Gondwanaland and started drifting northward (Lawver et al., 1985). Deltas formed on the shelf by east flowing rivers went on to prograde into the sea until the formation of the GBD much later (Niyogi, 1975; Agarwal and Mitra, 1991). Currently, these streams are represented by five major western tributaries of the Bhagirathi–Hugli river: the Mayurakshi, the Ajoy, the Damodar, the Shilabati–Rupnarayan, and the Kangsabati–Haldi. Their coalescing palaeodeltas, resembling a fan system, is known by the name of ‘Rarh plains’ in its lateritic west. India’s hard collision with Tibet prompted the rise of the Himalaya in mid-Eocene (Curry et al., 1982; Chen et al., 1993). Contemporary to this, the Bengal basin acquired its eastern boundary in the form of the Indo-Burman ranges. Three tectonic provinces are differentiated in the basin (Alam et al., 2003): the shelf region, underlain by continental crust; the deeper basin region, underlain by oceanic crust; and the folded flysch sediments of the arc–trench accretionary prism — the Chittagong–Tripura fold belt (CTFB). The Bengal basin is the cradle of the GBD that essentially rests on the first two of the basin’s three tectonic provinces. In a larger perspective, the basin and the delta can be visualised as components of the Bengal depositional system that extends from south of the Himalaya to the distal edge of the Bay of Bengal (Curry, 2014).

The western and northern boundaries of the GBD are broadly delineated by the fan system of the rivers emanating from the crystallines of the Chhotanagpur plateau, the Rajmahal hills, and the Meghalaya plateau — all of which were parts of the Gondwanaland. Its
The GBD is a composite entity, contributed by a number of rivers of which the Ganga and the Brahmaputra are the largest. Oldham (1870, p. 47) stated that “the whole of the country, including the Sundarban proper, lying between the Hughly [sic] on the west, and the Megna [sic] on the east, is only the delta caused by the deposition of the debris carried down by the rivers Ganges and Brahmaputra, and their tributaries.” He was probably the first worker to explain the eastward younging sequences of the GBD distributaries but made no attempt to demarcate the Ganga delta as Rudra (2014) mentioned. While describing which part of the GBD was primarily contributed by the Ganga, Rudra (2014) overlooked the contribution of Allison et al. (2003) who delineated the deltaic lobes deposited by the Ganga, the Brahmaputra, and both of the rivers in a temporal sequence. Allison et al.’s (2003) work showed that the entire area south of an imaginary line drawn through the Ganga–Padma and the Garai–Madhumati rivers was accreted exclusively by the Ganga, with the Brahmaputra contributing the central and northeastern parts of the delta, including the area between the Ganga–Padma–Meghna and the Garai–Madhumati. Despite this, Fig. 1 of Rudra (2014) delineated the entire region south of the Ganga–Padma–Meghna as the ‘G–B delta’, leaving the rest of the delta composite simply as ‘plains’.

In subsequent discussions, Rudra (2014) designated the Chhotanagpur highlands as part of the northeastern Deccan. While the Chhotanagpur forms one of the cratonic blocks of the peninsular India, it cannot be cited as a part of Deccan, the country south of the Satpura ranges (Valdiya, 2010, p. 10).

Rudra (2014) discussed Bagchi’s, 1944 classification of the southeastern part of the GBD into moribund, mature, and active parts but did not fully elaborate that this model is not tenable in the light of the present state of knowledge and that alternative classifications are available (Niyogi et al., 1970; Chattopadhyay, 1985; Bandyopadhyay, 2006; Bandyopadhyay et al., 2014). Bagchi himself suggested certain alterations in his classical scheme in a later work (Bagchi and Mukherjee, 1978, p. 15). Importantly, the delineation of Bagchi’s deltaic regions shown in Fig. 1 of Rudra (2014) is the author’s own interpretation and has little resemblance to Bagchi’s (1944) original demarcations.

Rudra (2014) stated that in Bangladesh, a feeble connection with the Ganga–Padma is maintained by its distributaries even during the lean

levels above and below the barrage to be 5 m. It also indicates that the water surface gradient along the widest braid of the river in the immediate upstream and downstream sections of the barrage were 1:39,300 and 1:41,000 respectively. This somewhat negates the idea of any major ponding by the barrage, in which case the upstream gradient would have been much lower.

The Survey of India (SoI) topographical map (#72P13, 1970–71) shows the area adjacent to the barrage to be ~24 m high. A water surface elevation of 23.77 m constitutes the extreme danger level for floods at Farakka (http://wbiwd.gov.in/application/index.php). The lowest and highest water levels recorded at Farakka prior to the construction of the barrage were 17.59 and 25.36 m respectively (Mazumdar, 1953). The structure was planned to raise the dry season level of water in its upstream so that discharge can be poured into the Bhagirathi–Hugli through a feeder canal. The designed crest and pond levels of the barrage were 14.3 and 21.9 m, respectively (Basu, 1982). The difference between these works out to be 7.6 m, instead of 6.7 m as given by Rudra (2014). Obviously, the difference between the water levels on the upstream and downstream sides of the barrage becomes less during the wet season (July–October) when the discharge of the Ganga increases about eight times of its dry season (January–June) flow. Notably, the average of the ratio between dry and wet season flows of the river remained the same at 1.79 in the pre-barrage years between 1949 and 1973 (ftp://daac.ornl.gov/data/ridvs/STATIONS/TEXT/INDIA/863/SUMMARY.HTML) as well as in the post-barrage years from 1975 to 2011 (SCoWR-LSS, 2014).

2.1. The western delta

The GBD is a composite entity, contributed by a number of rivers of which the Ganga and the Brahmaputra are the largest. Oldham (1870, p. 111; Valdiya, 2010, p. 26), and both were shown as ‘Tertiary highlands’ (Rudra, 2014, Fig. 1).

Rudra (2014) stated that the northern portion of the submarine part of the GBD measures 25,000 km² and that this was determined from satellite images. Firstly, isobaths can only be measured from depth soundings and satellite altimetry (http://topex.ucsd.edumarine_grav/ explore_grav.html). Secondly, as indicated by the map provided by Michels et al. (2003), the subaqueous GBD actually measures 55,000 km² up to the shelf break at 100-m isobath. However, its extension up to 10-m isobath is 24,500 km², and this area closely corresponds to the extension of turbid estuarine waters apparent from dry season (December–March) satellite images as well as Rudra’s (2014) estimation. In the same section, the Bay of Bengal was described to have subsided by 120 m since Early Pleistocene, but the statement was not supported by any reference. Rudra (2014) also mentioned the distance between the Indus delta and the Himalaya as more than 3000 km which is incorrect as the total length of the Indus is 3200 km and its reach between the Himalaya and the sea is about 1300 km long.

Evidence of land subsidence is not uncommon in Indian Sundarban and, as discussed by Rudra (2014), has been reported for a long time (Blanford, 1864; Gastrell, 1868, pp. 26–28). But it needs to be pointed out that on a regional scale, general dominance of sands and silts over clays in the GBD sediments prevents autocomposition. Therefore, the chief cause of the 2–4 mm y⁻¹ subsidence rate estimated for the central and coastal GBD is ascribed to tectonic reasons (Goodbred and Kuehl, 2000) apart from sediment compaction solely, as envisaged by Rudra (2014).

While describing the 1975 Farakka barrage project (FBP) that diverts a certain amount of water from the Ganga into the Bhagirathi–Hugli, Rudra (2014) stated that the project impounded some 83 M m³ of water by raising the level of the river by 6.7 m. The structure at Farakka is not associated with any reservoir, therefore formation of such a large pool of water becomes difficult to comprehend, especially because in this case it would have inundated large overbank areas upstream of the barrage, which did not happen. The lean season Shuttle Radar Topography Mission (SRTM) elevation data of February 2000 (tile 54-08, http://earthexplorer.usgs.gov) shows the difference between water
months. In reality, among the three streams that currently branch off from the Ganga–Padma above its confluence with the Meghna, the Mathabhanga, on the India–Bangladesh border, gets routinely disconnected from the Padma in the driest part of the year between January and March. Further east, the Garai–Madhumati off-take first dried-up in the lean season of 1988 and continued to do so until dredging operations started in 1998. Since 2006, the perennial flow of the river again started to get disrupted (Hore et al., 2013). The Arial Khan is also degenerating, and its February discharge became almost non-existent around 1975 but picked up subsequently (Akter et al., 2013). The flow into these rivers was found to be closely linked to planform changes in the braidedbelt of the Ganga–Padma, which, in turn, follows a self-organising cyclic behaviour (Gupta et al., 2013). Some other distributaries like the Chandana and the Kumar, discussed prominently in the early accounts of the delta (Fergusson, 1863; Hunter, 1875b, p. 262; La Touche, 1910, pp. 17–21; Hirst, 1915; Addams Williams, 1919), have long been silted up and largely have become part of the delta’s accretion topography.

3. Bhagirathi–Hugli river system

As apparent from Rudra’s (2014, p. 90) own statements and figures besides several other writings, maps and satellite images, Ganga does not really ‘bifurcate into two major branches’ of the Bhagirathi and the Padma as he stated. The Bhagirathi–Hugli is a greatly degenerated offshoot of the Ganga–Padma for the past few centuries. On the other hand, it is not clear why the Bhairab and the Mathabhanga–Churni were designated as ‘beheaded off-shoots of the Ganga’ in spite of the fact that they receive some amount of discharge from the Ganga–Padma during the monsoons. In the subsequent section Rudra (2014) even mentioned that the Mathabhanga–Churni got disconnected from the Ganga–Padma in the early twentieth century.

The mean monthly ‘freshwater’ flow through the Bhagirathi–Hugli was estimated by Rudra (2014) at Nabdwip and Gangasagar. At its narrowest reach, the river is 290 m wide at Nabdwip, with its swale at 10.5 m (Sen, 1998) lower than the ground level of 11.1 m (Sol map #79A07, 1968–69). The place marks the landward limit of tide propagation through the channel. Conversely, Gangasagar is situated on the sea-face, 289 km downstream of Nabdwip and marks the locality where the river empties into the sea. The estuary mouth is 51.6 km wide and is up to 11 m deep from mean sea level (National Hydrographic Office Chart #3011, 1992–2002). Tidal range reaches a maximum of 5.0 m in the Hugli estuary and generates flood-dominated tidal currents at 2–3 m s⁻¹ toward the north for 3 h and south-directed ebbs currents at <1 m s⁻¹ for the rest of the 12.4-h tidal cycle (Sanyal and Chatterjee, 1995).

Typical spring flood and ebb peak discharges at the 27-km-wide mouth of the main (western) branch of the estuary amount to 260,000 and 109,000 cumecs , respectively (McDowell and O’Connor, 1977, p. 10). This makes the Hugli a well-mixed estuary with its 2007 average salinity value varying between 3 psu in monsoon and 11 psu in premonsoon seasons (Mitra et al., 2009). All these connotes that channel morphology and hydrology of Nabdwip and Gangasagar are quite dissimilar. While it might be possible to estimate freshwater discharge into the Hugli estuary, freshwater discharge through the mouth of the estuary at Gangasagar makes little sense as there is no freshwater in this locality at all.

Moreover, the discharge data set provided by Rudra (2014; Table 1 and Fig. 3) reveals some facts that are hard to explain. For example, it states that in November and December, monthly freshwater discharge of the Bhagirathi–Hugli at Nabdwip gets augmented by just 25 and 7 cumecs (65 and 19 M m⁻³) at Gangasagar despite outfall of four sizeable streams into it downstream of Nabdwip: the Mathabhanga–Churni, the Domadar, the Shilabati–Rupnarayan and the Kangsabati–Haldi. Previously, Rao (1979, p. 74) made a widely quoted and accepted estimation of the annual discharge of the Bhagirathi–Hugli downstream of the Haldia at 15,646 cumecs (493,400 M m⁻³). Rudra’s (2014) figure of 2870 cumecs (90,507 M m⁻³) is just 18% of this.

Rudra (2014, p. 93) elaborated that according to measurements by the Government of West Bengal’s Irrigation and Waterways Department (IWD), a discharge of ‘less than’ 3000 cumecs constitutes bankful capacity of the Bhagirathi–Hugli at Nabdwip. Flood occurs in the river whenever this ‘threshold’ limit is exceeded and the marginal dykes are forced to give way. Between 1971 and 1985, the peak discharge of the Bhagirathi–Hugli averaged 2789 cumecs with a maximum value of 4057 cumecs (during 1984 floods) at Purbasthali, about 5 km north of Nabdwip (Parua, 2010, p. 32). However, the data provided in Rudra’s (2014) Table 1 show that during the monsoon months of July, August, and September, average discharges of the Bhagirathi–Hugli at Nabdwip stay at 3573, 4258 and 4451 cumecs (9569, 11,405 and 11,538 M m⁻³) respectively, indicating some flaw in his or IWD’s and Parua’s (2010) data as the river does not remain perpetually in the flood for two to three months every year.

Apparently, Rudra (2014, p. 90) used ‘mathematical modelling which takes into account rainfall, evapotranspiration, infiltration and storage in the basin’ to arrive at his estimations. Unfortunately, no explanation of this crucial model, used for discharge measurements at two widely dissimilar sections of the Bhagirathi–Hugli, was made in the paper and was ascribed to an unpublished and unobtainable report (Rudra, 2012a).

3.1. The Jalangi and the Mathabhanga–Churni

Rudra (2014), while discussing the southwestward flow of the lower parts of the Bhairab–Jalangi and the Mathabhanga–Churni in contrast to the south or southeastward orientation of other GBD distributaries, mentioned that Hirst (1915) ascribed this to a local subsidence. This requires some elaboration. Hirst (1915) pointed out that the Bhairab, currently occupying the lower course of the Jalangi, used to flow south-eastward following the regional fabric. This is indicated by the channels that still carry its name. The Mathabhanga also used to flow into a southeast-directed river — the currently degenerated Kumar. Hirst (1915) stated that the orientations of the Bhairab–Jalangi and the Mathabhanga–Churni changed to their present direction toward the Bhagirathi–Hugli sometime before the later part of the eighteenth century. He cited evidence from course changes in the Damodar, a major west bank tributary to the Bhagirathi–Hugli, and formation of marshes to suggest an area of local subsidence around the outfall of the Bhairab–Jalangi and the Mathabhanga–Churni that caused the alteration of their direction of flow.

The 1916–28 Sol maps 78D16 and 79A11–14 (2014 Landsat-8 OLI Images) denote that sinuosity indices of the Bhairab–Jalangi and the Mathabhanga–Churni rivers were 2.46 (2.61) and 2.15 (2.11), respectively, versus Bhagirathi–Hugli’s 1.98 (1.78), up to its confluence with the Mathabhanga–Churni. Rudra (2014, p. 92) held the reduced flow, fluctuating discharge and unconsolidated bank materials responsible for the development of meanders in the first two rivers, which he stated was considered as an ‘abnormality’ by Hirst (1915). While it is improper to comment on this without making any investigation of the variables involved, the factors mentioned by Rudra (2014) seem too generalised for the region to reach any conclusion. Hirst’s (1915) comment on ‘abnormality’ in meandering was strongly criticised later by Reaks (1919) citing sinuosity of the Mississippi and the Tigris.
Although Rudra (2014, p. 90) stated that the Mathabhanga–Churni ‘has been changing its course by meander migration, avulsion and a multiplication of distributaries’, a comparison between the SoI maps surveyed in 1916–28 (#78D16, 79A11–14, 1:63,360) and recent satellite images indicate that its planform has remained essentially the same for its entire 227-km course for the last 92 years barring one meander cutoff that was artificially made at Kalhikasundi (23.879°N, 88.864°E) between 1979 (Corona KH9–15 image) and 1989 (Landsat–5 TM image) in Bangladesh. This changed the length of the river by 6.7 km and reduced its sinuosity index from 2.15 to 2.11.

3.2. Closure of the off-take and decay of the channel

In the detailed discussion on the changes in the off-take of the Bhagirathi–Hugli from the Ganga–Padma, Rudra (2014) did not mention one of the most detailed studies on this aspect carried out by Reaks (1919), in which he made a comparison of eight maps between 1898 and 1905. Rudra’s (2014) later observations that the Ganga is shifting toward the east upstream of the Farakka barrage and is ‘posing a threat of avulsion’ is dated because the trend of eastward shifting of the river has largely stopped since 2007 and as a study of historical images in Google Earth (https://www.google.com/earth) would reveal, a reversal of this trend is now apparent.

3.3. Altered meander geometry

Rudra (2014) suggested that formations of cutoffs and oxbow lakes have increased in the Bhagirathi–Hugli after discharge through the channel started to get augmented from the 1975 FBP. He cited examples of three cutoff events near Bhanta, Nabadwip, and Santipur (Figs. 7, 9 of Rudra, 2014) and stated that these occurred in 1984, 1990, and 1994, respectively. Rudra (2014) did not mention any source of these dates. The cartographic materials and images available for the region show that among the two oxbow lakes close to Bhanta (Fig. 1, this paper), the eastern one, specifically annotated in Rudra’s (2014) Fig. 7 as detached in 1984, actually formed sometime between 1949–51 and 1967. It is the western lake that separated between 1979 and 1989. At Nabadwip, the cutoff initiated in 1989 and separation of the oxbow lake was complete by 1991. The Santipur oxbow, which is situated much closer to the Kalina town (2 km) than Santipur (7.5 km), formed between 1967 and 1972 (Fig. 2, this paper). Thus, only one of the three detachments described by Rudra (2014) can be arguably linked to the FBP.

Apart from this, it is important to note that the occurrence of cutoffs in Bhagirathi Hugli – confined to its upper 314 km (2014 length) – was prevalent in the pre-augmentation period also (Fig. 3, this paper). A comparison between maps and images of the river available from pre- and post-augmentation periods (Table 1) reveals that within the 39 years since commissioning of the FBP in 1975, four cutoffs were completed at an average rate of one in every 9.8 years. This is not overtly dissimilar to its preceding 53 years, during which five oxbow lakes formed at an average rate of one in every 10.6 years. Occurrences of the meander cutoffs, however, were notably lower than these between 1849–55 and 1916–28, when just three events were completed at the rate of one per 23.3 years. This indicates that the Bhagirathi–Hugli, notwithstanding its overall pre-1975 deterioration and fall in water level in drier parts of the year, was quite active during the monsoons. Its gradual degeneration is indicated by the increase in its sinuosity index from 1.73 in 1849–55 to 1.96 in 1967 (Table 1). After 1967, i.e., eight years prior to discharge augmentation from the FBP, the index started to decrease (albeit a slight rise between 1976 and 1989–90, immediately after the commissioning of the barrage). The river’s 2007 and 2014 sinuosity indices (1.75) were close to its 1849–55 value (1.73) and may reflect the effect of increased discharge from the FBP.

Rudra (2014) stated that on an average the west bank of the Bhagirathi–Hugli stands 2 m higher than its eastern bank. As indicated by Sol spot heights as well as SRTM elevation model (tile 54–08), there is no evidence of this in a 1-km buffer around the river. At one point Rudra (2014) concluded that the banks of the lower tidal reach of the Bhagirathi–Hugli are stable because they are composed of fine silt and clay. The many instances of bankshift of the Bhagirathi–Hugli in its lower reach between Kolkata and the sea, especially in its estuarine sector, disprove this hypothesis (Roy, 1969; Bandyopadhyay, 2000).

Citing the reference of Chapman and Rudra (2007), Rudra (2014, p. 93) wrote that during the 2000 floods of southern West Bengal, the Bhagirathi ‘effectively avulsed into the Gobra river’. In 2000, the remnant of a cyclonic depression produced very high rainfall in the northwestern catchment of the Bhagirathi–Hugli and created a huge flood that simultaneously breached a dyke and a railway embankment at Kalukhali (24.289°N, 88.292°E) on 21 September, about 4.5 km northeast of the southern end of the channel depicted in Rudra’s (2014) Fig. 6. The floodwater surged southward apparently following a non-descript palaeodistributary of the Ganga called Gobra and inundated a large area (Landsat-7 ETM+ image: path 138 row 43, 30-Sep-2000). The distance between the breaching sites of the embankments and the 20–30-m-wide Gobra is about 1.5 km, and it is physically impossible for the 300-m-wide Bhagirathi–Hugli to get avulsed into its channel.

To illustrate the changes in the course of the Bhagirathi–Hugli, Rudra (2014: Figs. 6–10) presented five maps in which the last three used superimposed planform of the river from, as stated by him, the 1917 series of the SoI maps, the 1955 U.S. Army maps, and 2010 Landsat images. These materials represented survey/imaging intervals of 38 and 55 years respectively. No further details on the source materials or methodological aspects of their superposition were provided. Inspection of Rudra’s (2014) Figs. 8, 9, and 10 reveals that while there are marked changes between the 1955 and 2010 banklines at places, there is hardly any disparity between the 1917 and 1955 courses. This does not reflect the reality but occurred simply because the so-called U.S. Army map used by Rudra (2014) was published, not surveyed, in 1955. This inaccuracy is actually a replication of one of Rudra’s earlier works (Rudra, 2012b). The Army Map Service (AMS) sheet # NF 45–03 of series U502 (1:250 k) depicts the Bhagirathi–Hugli between 23°N and 24°N and must have been used in Rudra (2012b, 2014). Its annotation clearly states that the map is ‘compiled in 1954 from half-inch series 1:126,720, Survey of India, 1922–4’. The reliability diagram of the AMS map shows that it mostly used 1922–31 Sol maps of ‘good’ reliability (http://www.lib.utexas.edu/maps/ams/india/nf-45-03-jpg). The years referred to in the AMS map were again the publication years for the half-inch series maps of Sol that depicted the surveys made during 1916–28.

3.4. Decaying distributaries

Rudra (2014, p. 93) stated that the Adi Ganga, a palaeochannel representing the mediaeval outlet of the Bhagirathi–Hugli now carries wastewater of southern Kolkata and may be seen as a ‘classic example’ how human intervention had transformed a natural drainage line into a sewage. This requires some explanation. The ancient course of the Adi Ganga can be located with some certainty up to 80 km downstream of its off-take from the Bhagirathi–Hugli (Bandyopadhyay, 1996). Of this, the upper 13 km were excavated during 1775–77 to form a 27-km navigational canal from Kolkata port to the headwaters of the now-derelict Bidyadhari (see Section 3.4.2) that was directly linked to the Matla estuary and a major waterway to the eastern Bengal through Sundarban (Buckley, 1883). Called Tolly’s Nala, this canal fell into disuse as the Bidyadhari degenerated by the 1950s and largely turned into a wastewater outlet. The unexcavated portion of the palaeochannel was not involved in canalisation and is still not used as sewage per se as it does not have a flow. Considered sacred by the Hindus, the lower Adi
Ganga is currently represented by a number of elongated pools of stagnant water bodies for its northern 21 km. Farther south, the channel is mainly traceable from the disposition of levees.

3.4.1. The Saraswati

Like the Adi Ganga, Saraswati was another of the Bhagirathi–Hugli’s outlets in the mediaeval period. Although greatly degraded, its channel is still active for the greater part of its length barring the central section. Notwithstanding Rudra’s (2014, p. 94) observation that the river ‘remains dry during lean months’, tidewater enters and leaves both of its mouths throughout the year. Various authorities have put the operational span of Satgaon (22.960°N, 88.370°E), the principal port on Saraswati, from the fifteenth to the late sixteenth centuries (Hunter, 1876, p. 262; Crawford, 1903, p. 2; Mukerjee, 1938, p. 111). It is not

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clear, therefore, why Rudra (2014) put the active period of the Saraswati between the fourteenth and fifteenth centuries at one place.

Rudra (2014) used a quotation from Rennell’s Memoir of a Map of Hindoostan or the Mogul Empire to argue that the Bhagirathi–Hugli was directly connected with the Rupnarayan sometime in the past and that the Rupnarayan was used to be called ‘Old Ganges’ during Rennell’s time. Rennell’s book was actually published in 1788, not in 1793 as stated. In it, he noted: ‘Satgong [Satgaon]… was, in 1566 and probably later, a large trading city. … At that time Satgong [Saraswati] river was capable of bearing small vessels; and, I suspect, that its then course, after passing Satgong, was by way of Adaumpour [untraceable], Ompth [Amta], and Tamlook; and the river called Old Ganges, was a part of its course, and received that name, while the circumstance of the change was fresh in the memory of the people. The appearance of the country between Satgong and Tamlook, countenances such an opinion’ (p. 56). This indicates that a river called Old Ganges formed a part of Saraswati’s palaeocourse but does not establish the Rupnarayan to be that river per se, especially because Rennell himself used the name ‘Roopnaran’ in his maps, surveyed in 1767–74, to identify that river. In the earlier of these, entrance to the lower Rupnarayan was simply identified as the ‘Ganges’; while in the later chart it was marked: ‘… Roopnaran River, falsely called Old Ganges’. Nomenclature of these charts, besides the disposition of the Rupnarayan at its confluence with the Bhagirathi–Hugli that makes it more like a continuation of the latter rather than a branch channel, add credibility to the observation that the Saraswati was once connected with the Rupnarayan and was used to serve the Tamluk port (22.290°N, 87.930°E).

3.4.2. The Bidyadhari–Sunti–Noai system

The Bidyadhari was a tidal channel that connected the upper Raymangal estuary of the eastern Sunderban (Indian part) with the Matla estuary of the west through the east Kolkata wetlands. It used to receive discharges from minor streams like the Sunti, the Noai, and the Nona that drain the region enclosed by the Bhagirathi–Hugli, the Jamuna, and the Ichhamati (Hunter, 1875a, p. 25). Siltation of the Bidyadhari is now nearly complete, and at many places it is converted into farmland. Its up-country connection with any major GBD distributary remains untraceable; this has neither been mapped, nor reported. Rudra’s (2014) conclusions that the non-descript channel of the Nona was the former Bidyadhari and that the Nona was once connected to an oxbow lake of the Bhagirathi–Hugli called Mathura bil [lake] are purely conjectural. As indicated by Sol map #79B09 (two editions, surveyed...
made clear that there is no record of formation of any bar obstructing the Bhagirathi–Hugli at Tribeni at any point of time. Bars are common all along the lower course of the Bhagirathi–Hugli (Sanyal and Chatterjee, 1995) and none of these prompted the river to form a new channel orthogonal to its direction of flow. It was rightly explained by Rudra (2014, section 3.4) that the place ‘Tribeni’ means ‘three braids’ in Bengali and it is traditionally held that this stands for three rivers: the Saraswati, the Hugli, and the Jamuna that used to get separated at its vicinity (Hunter, 1875a, pp. 25, 29; Reaks, 1919). Among these, the Bhagirathi–Hugli is active at present, the Saraswati is degraded but is still connected to the Bhagirathi–Hugli, and the Jamuna got detached from it sometime between 1849–55 (Atlas of India, map #121) and 1917–18 (Sol map # 79A08) as one of the Bhagirathi–Hugli’s oxbow lakes — the Baisar bil — formed. The Jamuna is now connected to this cutoff. As shown in the previous section, the existence of the upper Bidyadhari is purely conjectural and therefore can have little relation with the formation of the Jamuna.

In the same section, Rudra (2014) noted a contradiction that although Rennell’s 1767–74 survey showed the Jamuna as a feebile channel, Hunter (1875a) described it as a sizable stream, navigable year round by trading boats of the largest size. The east-flowing Jamuna falls into the Ichhamati and the latter continues southward along the present India–Bangladesh border into the Sundarban. In fact, Hunter’s (1875a, pp. 24–26) account referred to this south-flowing river as ‘the Jamuna or Ichhamati’. It designated the tidally active lower Ichhamati of today by the name of Jamuna and described a number of riverside settlements along it, all of which currently line the Ichhamati. This nomenclature was also shown in a foldout map that accompanied the publication. Thus, no contradiction was introduced by Hunter (1875a) in describing the Jamuna depicted by Rennell.

### 3.4.4. The Adi Ganga

Rudra (2014, p. 97) wrote that ‘even the recent satellite images and air photographs do not give any conclusive trace of the lower course of the Adi Ganga beyond Jaynagar’ (22.169’N, 88.416’E). On the contrary, space images do show a continuation of the levees of the Adi Ganga for 19 more kilometres south of Jaynagar with little ambiguity. This was already reported and mapped in one of the references (Bandyopadhyay, 1996) cited by Rudra (2014).

Rudra (2014, p. 97), citing Hunter (1875a), stated that a channel called Piyali used to connect the Bidyadhari with the Adi Ganga up to the late nineteenth century and that ‘it has also become moribund’.

---

**Table 1**

Formation of oxbow lakes and changes in sinuosity index of the Bhagirathi–Hugli between off-take and southernmost cutoff (314 km): evidence from maps and images.

<table>
<thead>
<tr>
<th>Source</th>
<th>Scale/resolution</th>
<th>Year of survey/date of image</th>
<th>Number of oxbow lakes formed since the preceding survey/image</th>
<th>Sinuosity index (channel length/valley length)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Atlas of India maps: # 120, 121</td>
<td>1:253,440</td>
<td>1849–55</td>
<td>a</td>
<td>1.73</td>
</tr>
<tr>
<td>Nine Survey of India maps: # 78D03–04, 78D08, 79A01–02, 79A06–08, 79B05</td>
<td>1:63,360</td>
<td>1916–28</td>
<td>3</td>
<td>1.94</td>
</tr>
<tr>
<td>Seven Survey of India maps: # 78D04, 78D08, 79A01–02, 79A06–08</td>
<td>1:63,360</td>
<td>1949–51</td>
<td>2b</td>
<td>1.96</td>
</tr>
<tr>
<td>13 Corona KH4A images:</td>
<td>~2 m</td>
<td>21-Jan-1967</td>
<td>1</td>
<td>1.89</td>
</tr>
<tr>
<td># D51038-2102DA170–182</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Landsat-1 MSS images: Path 149, Rows 43, 44</td>
<td>60 m</td>
<td>22-Feb-1973</td>
<td>2</td>
<td>1.82</td>
</tr>
<tr>
<td>Two Corona KH9-15 images: # DZB1215-50258U005001, 6001</td>
<td>~9 m</td>
<td>19-May-1979</td>
<td>0</td>
<td>1.75</td>
</tr>
<tr>
<td>Three Landsat-5 TM images: Path 138, rows 43, 44, path 139, row 43</td>
<td>30 m Path 138:</td>
<td>11-Nov-1989</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Three Landsat-7 ETM + images: Path 138, rows 43, 44, path 139, row 43</td>
<td>30 m Path 139:</td>
<td>17-Nov-2000</td>
<td>2</td>
<td>1.76</td>
</tr>
<tr>
<td>Four Resources at-1-L4-mono images: Path 107, row 54, subscene D; path 108, row 55, subscene A, C; path 108, row 56, subscene A</td>
<td>5.6 m Path 107:</td>
<td>25-Aug-2007</td>
<td>0</td>
<td>1.75</td>
</tr>
<tr>
<td>Three Landsat-8 OLI images: Path 138, rows 43, 44, path 139, row 43</td>
<td>30 m Path 138:</td>
<td>16-Nov-2014</td>
<td>1</td>
<td>2.96</td>
</tr>
<tr>
<td>Path 139:</td>
<td>23-Nov-2014</td>
<td>1</td>
<td>1.75</td>
<td></td>
</tr>
</tbody>
</table>

* 26 oxbow lakes were present in the 1849–55 maps.
* Incomplete coverage: river represented between 23° and 24°15’ N (79% of 314 km).

in 1919–20 and 1968–69), the Nona originated from the Chendu bil, a wetland situated 15 km southeast of the Mathura bil.

A gazetteer of the old world with geographical coordinates was compiled by Claudius Ptolemy in the second quarter of the second century A.D. on the basis of astronomical observations and was published in 1482 from the original Latin edition of his Geographica (Thrower, 1972, p. 19; Black, 2003, p. 24). It included probably the oldest representation of the GBD with its five estuarine outlets clearly identified and named (McCrindle, 1885, pp. 72–75). The longitudinal span of the coastal GBD given in Ptolemy’s data roughly correlates with its modern extension. In an attempt to establish the age of the estuaries of the major distributaries and their relative position in the past, Bhattachari (1941) and later Rudra (1981) interpreted Ptolemy’s coordinates of Indian locations and correlated the modern estuaries of the GBD with that of Ptolemy’s time. Both suggested that the Kambponge, Kamborkhin, Pestudemom, and Antibole estuaries of Ptolemy correlate with the modern Hugli, Hariyabhanga, Haringhata, Shababazpur, and Sandwip estuaries, respectively.

Firstly, there are not five but 13 large (width > 5 km) estuaries in the GBD, almost at every 10 to 12 min of the longitude. So, one if not the other of these is almost bound to correlate with Ptolemy’s estuarine outlets. Secondly, the lowermost GBD, like any other delta is an ever transforming zone. As suggested by recent dates (Allison et al., 2003; Sarkar et al., 2009), the central and eastern parts of the lower delta were still forming during Ptolemy’s time, and it is inconceivable that its distributaries remained fixed for the last 1850 years. Finally, the maps compiled before advection of the land survey were largely the result of guesswork and hearsay (Gole, 1976, p. 11) where decoration was no less important than their content (Carr, 1962, p. 135). It seems therefore, Ptolemy’s representation, which completely failed to recognise as important a feature as the Indian peninsula and made it smaller than the island of Sri Lanka (Black, 2003, p. 24), was given undue importance by Rudra (2014).

### 3.4.3. The Jamuna and the Ichhamati

Rudra (2014, p. 97) referred to one of his earlier works (Rudra, 1990) in elaborating that ‘when both the Saraswati and the Bidyadhari channels were active, the tides advancing northward through these two distributaries would meet at Tribeni. The extensive sedimentation resulted in the formation of a channel bar in the Hugli River at Tribeni. The southward flow of the Hugli being obstructed, the river was compelled to open a new outlet along the Jamuna’. It needs to be...
This seemed odd because the Adi Ganga was not active in the nineteenth century and the present Piylai, as actually described by Hunter (1875a, p. 25), was ‘a cross-stream from the Bidyadhar to the Matla’, not to the Adi Ganga. As noted earlier, little trace of Hunter’s Bidyadhar remains at present, and the Piylai is now fed by regional drainage from the southern Kolkata Metropolitan District including Tolly’s Nala. Far from being moribund, its 28-km lower course remains deep and active, controlled by sluices close to its head and outfall.

### 3.4.5. The Hugli estuary

The landward limit of the trumpet-shaped estuary of the Bhagirathi–Hugli, defined on the basis of morphological constriction, is at Diamond Harbour, 70 km from the Bay of Bengal. The maximum tidal range (5 m) of the river is also achieved here (Sol, 2010), and it also marks the limit of upstream penetration of saltwater (Sengupta et al., 1989). Rudra (2014, p. 97) designated this roughly N–S oriented estuary ‘unique’ among the outlets of the Ganga because, according to him, the other estuaries follow a southeasterly direction. In reality, all estuaries of the GBD up to 200 km east of the Hugli are aligned N–S for their final 60–90 km to the sea; between 200 and 310 km east from the Hugli, the estuaries are oriented NNE–SSW.

The tidal range of a coast, measured on the basis of highest and lowest water levels during springs, is designated microtidal, mesotidal, or macrotidal if its value represents <2, 2–4 or >4 m, respectively. Besides waves and fluvial forcing, tidal range is a major variable that controls coastal morphology (Johnson and Baldwin, 1996; Woodrofe, 2002, pp. 349–351). Rudra (2014) presented tidal data of six observatories along the Bhagirathi–Hugli in his Table 2. The table, however, did not mention the relationship of the figures with the mean sea level and fell short of representing the macrotidal characteristics of the lower Bhagirathi–Hugli. We try to rectify this in Table 2 of this discussion. It shows that the limits of tidal ranges of the six stations vary between 4.2 and 5.0 m versus 2.8 and 3.68 m from Rudra (2014). Moreover, the tide levels of 6.66 m (7.35 m) and 0.21 m (0.54 m) at Sagar (Diamond Harbour) can never occur ‘within a span of 6 h’ as envisaged by Rudra (2014, p. 97). Among these four figures, the upper values represent the highest high water levels ever recorded by the Sagar and Diamond Harbour gauges above Chart Datum, both occurring in October 1985. The meaning or source of the two lower values stated by Rudra (2014) are not clear; but the lowest low water levels ever recorded at Sagar and Diamond Harbour are 0.21 (March 1940) and 0.08 m (September 1976) above Chart Datum respectively (Sol, 2010). These values are shown in respect to the mean sea level in Table 2. As seen before, the time–velocity characteristics of the tides in the flood-dominated Hugli estuary are highly asymmetrical and do not observe 6- and 8-hourly rhythm as stated by Rudra (2014) but follow an approximate 3.4- and 9-hourly semiidiurnal cycle (Sanjay and Chakrabarti, 1995), similar to other estuaries of the Indian GBD (Chatterjee et al., 2013).

#### 3.4.6. Sediment load

It is important to appreciate that the FBP was commissioned mainly to improve navigability of the Bhagirathi–Hugli between Kolkata and the head of its estuary at Diamond Harbour. As Roy (1969) had shown, the maximum possible augmentation of 1135 cumecs from the barrage can increase the ebb flux at the seaface to only about 2%—hardly influencing flow characteristics of the estuary. The FBP did improve navigability of the reach it was intended for as evidenced by substantial reduction in the amount of dredging of bars and general improvement in channel capacity. It also helped to considerably reduce the tidal bores that used to travel upstream along the river (Sanjay and Chakrabarti, 1995; Parua, 2010, pp. 299–300).

Annual terrestrial sediment discharge through the Bhagirathi–Hugli was variously estimated at 328, 473, and 616 million tonnes by Wasson (2003), Bandyopadhyay and Bandyopadhyay (1996), and Sengupta et al. (1989) mostly using indirect methods. Rudra (2014), citing an unpublished work (Rudra, 2012a), stated that the net annual input of sediments into the Bhagirathi–Hugli from its five major western and two main eastern tributaries besides the FBP is just 4.63 million tonnes a year. This leaves only the sediments added by bank erosion of the Bhagirathi–Hugli and contribution from its minor tributaries to add up to the final figure at the estuary. Although this figure was not given by Rudra (2014), it would at least be a couple of magnitudes lower than the published data cited above and seems untenable unless the methods of estimation are elaborated and they stand scientific scrutiny.

### 4. Coastal erosion

Rudra (2014, p. 99) again cited an unpublished work (Hazra, 2010) and stated that the sea level at Sagar increased at a phenomenal 12 mm y⁻¹ between 2002 and 2009 versus 3.24 mm y⁻¹ in the ‘past decade’. The perils of using such short-term decadal data in the computation of sea level trends were emphatically brought out by Pugh (2004, p. 177). It is widely held that, for trend estimations, close to 50 years’ record of sea level is required to offset all local and short-term variations like the effects of ENSO and tropical storms (Pirazzoli, 1986). Permanent Service for Mean Sea Level (PSMSL: www.psmsl.org) is the world’s repository of the mean monthly and mean annual tide-gauge records. There are eight PSMSL stations along the Bhagirathi–Hugli, of which Diamond Harbour has the longest record of 61 years. This data set indicates that the mean sea level rose at 4.85 ± 0.42 mm y⁻¹ between 1948 and 2006 at this point (Nandy and Bandyopadhyay, 2011). The rate changes to 4.61 ± 0.37 mm y⁻¹ if the data between 1948 and 2010 are considered. The PSMSL record at Sagar does not continue beyond 1988; therefore, the data referred to by Rudra (2014) were obviously not obtained from this source, making their calibration open to question. Sea level trends of the Hugli have little apparent relation with accretion and erosion of its tidal islands, which are controlled by tidal reworking of sediments in an out-of-equilibrium, flood-dominated, macrotidal estuary (Nandy and Bandyopadhyay, 2011). Mostly formed

### Table 2

<table>
<thead>
<tr>
<th>Stations</th>
<th>Distance from sea (km)²</th>
<th>Estuary width (km)²</th>
<th>Local mean water level (m)³</th>
<th>Mean high water springs (m)³</th>
<th>Mean low water springs (m)³</th>
<th>Tidal range (m)²</th>
<th>Tidal range derived from Table 2 of Rudra (2014)</th>
<th>Highest high water ever recorded (m)³</th>
<th>Lowest low water ever recorded (m)³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sagar ²</td>
<td>0.0</td>
<td>51.6</td>
<td>0.18</td>
<td>2.40</td>
<td>−1.90</td>
<td>4.30</td>
<td>3.13</td>
<td>3.84</td>
<td>−3.03</td>
</tr>
<tr>
<td>Gangra</td>
<td>31.4</td>
<td>17.3</td>
<td>0.34</td>
<td>2.78</td>
<td>−1.99</td>
<td>4.77</td>
<td>3.54</td>
<td>4.43</td>
<td>−2.79</td>
</tr>
<tr>
<td>Halda ²</td>
<td>43.4</td>
<td>10.5</td>
<td>0.41</td>
<td>2.88</td>
<td>−2.02</td>
<td>4.90</td>
<td>3.67</td>
<td>4.44</td>
<td>−2.89</td>
</tr>
<tr>
<td>Diamond Harbour ³</td>
<td>70.1</td>
<td>1.9</td>
<td>0.48</td>
<td>3.12</td>
<td>−1.88</td>
<td>5.00</td>
<td>3.68</td>
<td>4.53</td>
<td>−2.74</td>
</tr>
<tr>
<td>Mayapur</td>
<td>115.1</td>
<td>1.0</td>
<td>0.64</td>
<td>3.18</td>
<td>−1.45</td>
<td>4.63</td>
<td>3.29</td>
<td>4.74</td>
<td>−2.33</td>
</tr>
<tr>
<td>Garden Reach (Kolkata)</td>
<td>142.1</td>
<td>0.5</td>
<td>0.83</td>
<td>3.26</td>
<td>−0.95</td>
<td>4.21</td>
<td>2.80</td>
<td>5.34</td>
<td>−2.22</td>
</tr>
</tbody>
</table>

Notes:


³ Source: Sol (2010).

¹ Datum: Chart Datum, 2.82 m below mean sea level, 0.46 m below Khidirpur Old Dock Sill.

² Datum: Khidirpur Old Dock Sill, 2.36 m below mean sea level, 0.46 m above Chart Datum.
on the estuary's tidal sand ridges, appearance and dissipation of some of these islands pursue 50- to 100-year cycles (Roy, 1969; Bandyopadhyay, 2000).

James Rennell and his associates undertook the first comprehensive survey of Bengal between 1764 and 1777. The results of this survey were brought out in 16 separate 1:316,800 (1 in. to 5 miles) sheets with two maps covering the area from the Hugli to the Haringhata estuaries. Of these, Rudra (2014: Fig. 12) apparently used sheet #14, which was mapped during 1767–74, not in 1764–77 as stated. Rennell’s surveys were carried out using compasses and surveyor’s chains supplemented by astronomical observations. The accuracy of both of these instruments was questionable (La Touché, 1910, p. 4). It was also reported that in coastal surveys, time-lapse between flash and sound of gunfire was sometimes relied upon for certain linear measurements (Fawcus, 1927, p. 4). Rennell’s maps, therefore, did not possess high planimetric accuracy, especially on a large scale. This becomes apparent during any attempt of georeferencing them on the basis of later cartographic materials. Their primary value lies in recording relative position or the importance of transient features like rivers and villages in respect to more permanent landmarks like hills and major towns. Thus, generation of data on coastal shifts using Rennell’s map does not seem justified.

It also needs to be pointed out here that the Indian Sundarban was covered by 17 sol topographical maps on 1:63,360 (79B, 79C, 79F and 79G series). Among these, two maps were surveyed in 1905–21, seven in 1919–23, and eight in 1922–23. Considering this, it is not clear on which sources Rudra’s (2014) estimations of area change of the Indian Sundarban between 1917 and 2010 were based. None of the particulars on the materials and methods adopted for this exercise was given in his work. This follows that the coastal retrogradation of the Indian part of the GBD is reported for a long time in the literature (Reaks, 1919; Chakrabarti, 1995; Bandyopadhyay and Bandyopadhyay, 1996; Allison, 1998; Giri et al., 2007). The two most significant reasons for this went unnoticed in Rudra’s (2014) article: abandonment of the western GBD and interception of westward movement of shelf sediments by the Swatch of No Ground submarine canyon (Kuehl et al., 1989). Both of these had cut off the sediment supply into the seafront of the western GBD and interception of westward movement of shelf sediments by the Swatch of No Ground submarine canyon (Kuehl et al., 1989). Both of these had cut off the sediment supply into the seafront of the western GBD, therefore the region is not entirely non-tidal as designated in the figure caption.

Rudra (2014, p. 99) observed that, in Sundarban, ‘parts reclaimed for agriculture and settlement stand at least at [sic] 2 m lower than the non-reclaimed mangrove areas’ due to exclusion from tidal inundation. No evidence however, was given or methodologies elaborated on how he obtained this figure, which had never been reported from this region previously.

Finally, Rudra (2014) stated that the Ghoramara islet of the Hugli estuary was a part of Sagar Island during Rennell’s time in the late eighteenth century and was separated subsequently. It may not be out of place to mention here that according to the River Survey Department navigational charts, this separation took place between 1903–04 and 1904–05 (Bandyopadhyay, 1997).

Besides text, many of Rudra’s (2014) figures contained misrepresented information. Some of these errors are pointed out in discussions above; the rest are enlisted in Table 3.

5. Conclusion

The above discussion shows that there is hardly a section, table, or figure in Rudra’s (2014) contribution that is not open to question and that can be accepted unequivocally. Four types of issues were detected in the work: (i) misrepresentation of information already existing in reports and maps; (ii) incomplete or partial representation of previous works done on the area; (iii) non-disclosure of source materials and methodologies for reaching certain important conclusions; and (iv) computations that produced doubtful results, having little similarity with previous estimates.

Table 3 Issues detected in figures of Rudra (2014).a

<table>
<thead>
<tr>
<th>Figure #</th>
<th>Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>• Linear scale of the map is approximately 1.5× exaggerated. The extent of the scale is shown as 60 km but should have been 40 km.</td>
</tr>
<tr>
<td>3</td>
<td>• Tide enters up to Nadabip utilities the Bhagirathi–Hugli, therefore the region is not entirely non-tidal as designated in the figure caption.</td>
</tr>
<tr>
<td>4</td>
<td>• Orintation of Bansloi and Pagla rivers and extension of the Ahiron wetland are misrepresented.</td>
</tr>
<tr>
<td>5</td>
<td>• The Anjana river is identified as the Ajanta.</td>
</tr>
<tr>
<td>6</td>
<td>• Position of Akheriganj is shown 5.5 km S76°E of actual location.</td>
</tr>
<tr>
<td>7</td>
<td>• Position of Balagachhi is shown 2.8 km S70°W of actual location.</td>
</tr>
<tr>
<td>8</td>
<td>• Place Baui is shown 2.6 km N80°W of actual location, wrongly referred to as Barui.</td>
</tr>
<tr>
<td>9</td>
<td>• Position of Basabari is shown 3.8 km N8°E of actual location.</td>
</tr>
<tr>
<td>10</td>
<td>• Position of Dasturhat is shown 5 km N9°E of actual location — this settlement is actually situated outside the bounds of this figure.</td>
</tr>
<tr>
<td>11</td>
<td>• Position of Chandraketugarh is shown 22 km N21°W of its actual location.</td>
</tr>
</tbody>
</table>

a Additional issues related to some other figures are discussed in the text.

It is expected that Rudra’s (2014) work would be widely consulted for basic information on the western GBD. Especially because many of the source materials on the region may not be accessible to all and it has been the first conscious attempt to deal with the region’s manifold geomorphic issues and characteristics. Therefore, we feel that rectification of the facts misrepresented in Rudra (2014) is urgently necessary as they would probably influence future research on the western GBD.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version, at http://dx.doi.org/10.1016/j.geomorph.2015.02.037. These data include Google map of the important areas described in this article.