EMBANKMENT AND CHANGING MICRO-TOPOGRAPHY OF LOWER AJOY BASIN IN EASTERN INDIA

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Abstract

This paper deals with the impact of river embankment on the physical environment of the river. Different types of flood control measures are in practice. Embankment is supposed to be an important structural measure of flood control. The performance of embankment varies from case to case. It is quite effective for short term flood alleviation, but it puts a question regarding the long term viability of the embankment and become harmful to the adjacent floodplain. Morphology of the river as well as the micro-topography of the floodplain undergoes great changes as a result of confinement of river flow due to construction of embankment. With this concept in background a geomorphological study has done in the Lower Ajoy Basin of Eastern India. The chronological study about cross-sections of some selected sites of the river, have proved the reduction of the channel depth. Huge sandsplays over the floodplain after the breaching of embankments have changed the micro-morphological character. The present study is to find out the extent of change in the micro-topography caused by Ajoy embankment.

Key Words: *Embankment, Floodplain, Micro-topography, Sandsplays,*

Introduction

Structural flood control measures are quite prevalent in the developing countries like India. Embankment is such an important structural measure that is in practice since time Indus Civilization. Embankment constructed since long time past has played a formidable role in saving life and properties. A question, however, remains regarding the efficacy and necessity of embankment. It creates drainage congestion in the protected areas. In the post construction period, the floodplains get deprived of silt deposition and thereby, choking the natural process of floodplain development. Due to confinement of river flow within embankments, rapid siltation takes place on the river bed. It reduces the depth of the river and raises the flood height.

Ajoy is an important river in Eastern India. Embankment constructed along Ajoy subject to frequent breach. Breaching of embankment causes devastating flood and results huge sand deposition on the floodplain. Sir William Wilcox (1930) while dealing with the flood problem of in Eastern India, accused the river side embankments as the 'Satanic Chains' and proposed canals for draining out the flood water. Embankments can give freedom only from low intensity flood but it is neither possible to control the flood totally by embankments nor desirable too. The river embankments bring adverse impact on the riparian environment by hampering the natural evolution of the floodplain of by interfering with the geomorphological processes of the river. As far as embankments are concerned, when a river is strait-jacketed between them, its spills are prevented and hence the area outside them is, apparently, protected against floods. However, several consequences are conveniently ignored: for one, the sediment in the river flow is prevented from spilling over and slowly gets deposited within the embankments, raising the bed level of the river (Jha, 2008). Confinement of river flow within embankment does affect the river and its flow characteristics which in turn induces social and economical impacts in the area (Mani, *et al*., 2006). India experienced the Koshi flood in 2008, which entails us that embankment cannot be a permanent solution of flood.

This paper contains the following objectives.

1. To find out the efficacy of embankment as a flood control measure.
2. To analyze the present flood character of the study area in response to its past history.

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3. To detect the change in the micro-topography caused by embankment.

Methodology

The research method is primarily based on field survey to detect the micro-topographical changes. Survey of India's toposheets have been consulted thoroughly and satellite imageries have been analyzed for change detection. Moreover, some secondary data have been collected from various sources like Irrigation and Waterways Department and River Research Institute, Government of West Bengal. Both primary and secondary data have been processed with the help of GIS software to explain the result.

Study Area

The study area i.e. Lower Ajoy River Basin extends from 23˚25' N. to 23˚45' N. latitude and from 87˚ 16' E. to 88˚ 15' E. longitudes. The long profile of Ajoy shows a rapid change in channel gradient at the point of Pandabeswar(23˚44' N, 87˚ 17' E). Average gradient above Pandabeswar is quite steep (1 in 713) that suddenly decreases (1 in 2273) downstream from Pandabeswar to Katwa(23˚39' N, 88˚ 08' E).

At Pandabeswar there is a fault line from which the geological formation has been changed and slope in the long profile of the river has also been decreased significantly. Therefore, the lower course of the river has been determined below 80 metres contour near Pandabeswar where abrupt change in the slope of the long profile is found due to differential geological formation (Mukherjee, 2002). Therefore, the Lower Ajoy Basin has been demarcated from Pandabeswar to Katwa. It covers an area of about 2816.65 square kilometers In Lower Ajoy River Basin there are 12 C.D. blocks which comprise 619 moujas. Out of 12 C.D. blocks 5 fall in Birbhum district and rest 7 blocks are in Burdwan district.

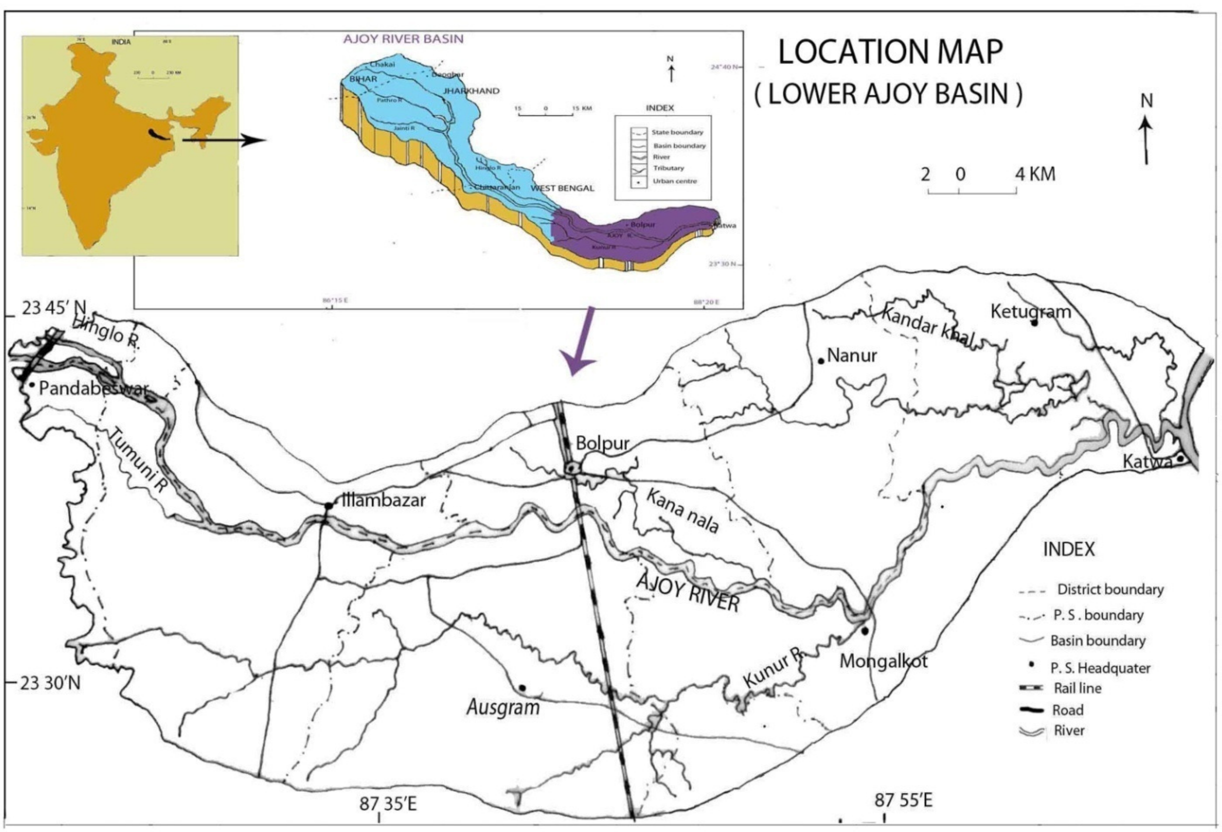

Figure 1 Location Map

Results and Discussion

Embankment and Flood Control Scenario in Lower Ajoy Basin

Embankment is a ridge built with earth or rock to contain flood water or to construct a road, railway, canal, etc. According to Petroski (2006) embankment is a natural or artificial wall or slope to regulate the water level. It is usually earthen and parallel to the course of a river or the coast. The embankments or 'bunds' vary in nature and function under a variety of situations. The main purpose of embankment is to prevent flooding of the adjoining countryside. Embankments can be, mainly, found along the sea where dunes are not strong enough, along rivers for protection against high flood, along lakes or along polders. Furthermore, embankments have been built for the purpose of empoldering or as a boundary for an inundation area.

Embankments were first constructed in the '*Indus Valley Civilization'* (2600 B.C.) on which the agrarian life of '*Harappan'* people depended. Embankments also constructed about 1100 B.C. in ancient Egypt, where systems of embankments were built along the left bank of the river *Nile* for more than 600 miles (966 km), stretching modern *Aswan* to the *Nile Delta* on the shore of *Mediterranean*. The '*Mesopotamian Civilization'* and the ancient *China* also built large levee system.

The earliest recorded embankment in Bengal was built during the Sultani Period (1213 – 1519). In British period, the responsibilities were attributed to the so-called Zamindars, regarding the construction and maintenance of embankments along different rivers. The main purpose was to protect the important settlements and to protect the fertile agricultural land to increase more revenue collection.

History of Ajoy Embankment

Since long time past embankments had been constructed along Ajoy river. In ancient period, partial attempts were made to control the flood by embanking the river. It was very much sporadic in nature. In British period embankments were constructed and maintained by the so-called Zaminders. The British Government permitted them to construct embankments according to their need. These 'Zamindary embankments' were constructed mainly to protect their cultivated land. Side by side the British Government itself had constructed some segments of embankments. The main purpose was to increase revenue collection by protecting cultivable land. It is noteworthy that the embankments constructed by the government itself were scientific to some extent. But the Zamindary embankments were totally unscientific in nature. They were frequently subjected to breach causing devastating flood in the basin area.

The landlords appear to have been responsible for the maintenance of embankments. But they did not pay proper attention to the embankments. Being dilapidated conditions, breaches were frequent. The British East India Company at first appointed local officers to keep vigil on their state of affairs. It did not yield much result and the problems remained. To overcome such complication, 'Bengal Embankment Act,' 1873 was passed and according to specification, the embankments were classified under four categories viz. scheduled 'A', 'B', 'C', and 'D'. This act distinctly defined the liability of the Government for maintenance of certain embankments as enumerated in scheduled 'D'. Power was taken by the Government to take the responsibility of other embankments as well, not included in scheduled 'D'. After independence the scenario of flood control has been changed. Directorate of Irrigation and Waterways Department, Government of West Bengal, has made extensive attempts to control flood of Lower Ajoy Basin. On the right bank continuous scheduled 'D' embankment was constructed long ago and the ex-Zamindary embankments thereafter have since been remodeled in design section in 'seventies' (Project Report, 1999). Spilling on left bank is almost an annual feature. Before 'seventies' the embankments were all ex-Zamindary except for a small one near Bolpur. However, the Directorate of Irrigation and Waterways Department, Government of West Bengal, in 1968 has taken control over the left bank embankment of Lower Ajoy River. Thereafter the ex-Zamindary embankments have been remodeled, realigned and maintained by the concerning authority.

As already mentioned, construction of embankments is the only structural measure available with the Irrigation Department to give relief to the people from the menace of flood. The department has made some remarkable advancement renovating embankments in flood control sector by taking up remodeling and strengthening of its existing embankments ravaged by 1999 and 2000 flood with NABARD (National Bank for Rural Development) loan.

Present Status of the Embankment

1. Left Embankment

Segment of Embankment	Covering Police Station	Length (km)	Present Status
Bhimgara to Parulbana	Khoyrasole	4.80	Earthen embankment
Santoshpur to Pratappur	Illambazar	4.50	Earthen embankment partially supported by boulders to reinforce the embankment
Joydev-kenduli to Tikarbeta	Illambazar	2.0	Earthen embankment partially supported by boulders to reinforce the embankment
Nelegarh to Sahebdanga	Illambazar	3.0	Embankment made of sandy soil
Halsidanga to Ramchandrapur	Illambazar,bolpur	7.55	Embankment made of sandy soil, near Senkapur, bank erosion has made the embankment most vulnerable
Nurpur to Gheropara	Bolpur	1.72	Embankment made of sandy soil, partially reinforced by boulders. Gap between left and right embankment ids only 718 metres.
Gheropara to Nutangram	Bolpur	7.62	Embankment made of sandy soil. Previous breached portions are repaired by boulders.
Nutangram to Chorkhi	Bolpur, Nanur, Mongalkot, Katwa	31.17	Embankment made of sandy soil

The total length of the Ajoy embankment is about 136.16 km, out of which the right bank accounts about 80.97 km and left bank comprises about 55.19 km. The total area protected by the right bank embankment is about 37040 hectares and the left bank embankment protects about 29785 hectares. Due to the existence of a remodeled and well maintained scheduled embankment on the right bank, the embankment on the left bank remains most vulnerable.

2. Right Embankment

Segment of Embankment	Covering Police Station	Length (km)	Present Status
Gotholu to Kherobari	Faridpur to Kanksa	14.0	Earthen embankment, reinforced by boulders in places.
Kherobari to Kotalpukur	Kanksa	4.5	Embankment made of sandy soil
Satkahonia to Kogram	Kanksa, Ausgram, Mongalkot	47.0	It is long and continuous embankment primarily made of earthen materials. In places of Malancha, Maliara Kogram, previously breached portions are repaired by boulders
Joykrishnapur to Kherura	Mongalkot	8.3	Though some boulders are used to reinforce the embankment but the recommended height and width of the embankment are not maintained properly. Embankment is very much affected by human activities.

Source: Directorate of Irrigation and Waterways Department, West Bengal – 2008.

Flood Scenario

In South Asian countries, flood is a serious natural hazard. It is estimated that between 2 to 16 per cent of the GDP of different South Asian countries get wasted every year due to natural disaster (Chakraborty, 2006). Floods form the major domain among all the natural disasters to take a heavy toll of lives and properties in the South Asian countries. In India, typical behavioural pattern of monsoon makes the country most vulnerable to flood.

Lower Ajoy River Basin is a well known flood prone area in West Bengal. Flood is the most common attribute of the *hydrological cycle* particularly in this part of the Subtropics where variability rainfall exceeds 25 per cent. From the records of Irrigation and Waterways Department, Government of West Bengal, it is evident that the major floods occurred in the river basin in the year of 1956, 1959, 1970, 1971, 1973, 1978, 1984, 1999, 2000, 2005 and 2007. Before Independence (1947), high floods occurred in this basin in 1913, 1916, 1938, 1942, and 1946. Besides these occurrences, major floods occurred 1867, 1877, 1885 and 1896. Even earlier to these, the record shows that devastating floods had also occurred in Ajoy basin in the year of 1730, 1816 and 1856. Lower Ajoy Basin bears a typical character of flood situation. From Pandabeswar to Loba (confluence point of Hinglo with Ajoy), there is little spilling of flood water. Here flood occurs with short duration of inundation. The area lies between Loba and Mongolkot (confluence of Kunur with Ajoy), is characterized by flash flood caused by frequent breaching of embankments. Drainage congestion in this area is the typical feature and the low-lying areas of Bolpur, Nanur, Ausgram and Mongolkot get inundated due to back pushing effect of flood water. The area from Mongolkot to Katwa (confluence of Ajoy with Ganga), is characterized by low-lying plain and water logging is the prominent feature in this region. In the Ajoy-Bhigarathi interfluves, particularly in the *Katwa Surface,* swampy depressions are found. Several small swamps are formed due to accumulation of spill water from the channel of Kunur and Kandar. In the lower reach of Ajoy, the flood is essentially devastating in nature.

Spatio-Temporal Pattern of Flood

The nature of flood in Lower Ajoy Basin shows a typical changing pattern since 1956 (table 1). Though several flood years have been recorded in the Lower Ajoy Basin, but the floods occurred in the year of 1978, 1995, 1999 and 2000 were most devastating.

From the analysis of the table 1, it is evident that the trend of flood affected area has gradually been increased since 1956. The minimum affected area was in the flood of 1984 and about 305.72 square kilometers areas were flood affected, which accounts for 10.85 per cent of the total Lower Ajoy Basin. On the contrary, the maximum inundation has been taken place in the flood of 1978 and about 1680 square kilometers areas were affected, which accounts for about 59.64 per cent of the total area. In 1956, about 680 square kilometers areas were inundated comprising total 185 mouzas. In 1984, total 98 mouzas were affected by the flood while in 1978, total 374 mouzas were flood affected. The flood occurred in the year of 2000 was also notorious in the basin. About 1488 square kilometers areas comprising total 369 mouzas were affected by the flood of 2000 and it accounts about 52.82 per cent of the total Lower Ajoy Basin.

In Lower Ajoy Basin, most of the flood prone areas lie from Hinglo outfall (Loba) to the confluence of Ajoy with Ganga (Katwa). The flood status of the basin shows that the flood affected areas are more on the right bank of Ajoy than the left bank (Figure: 2). In the blocks of Dubrajpur, Illambazar, and Kanksa, the flood prone area is confined along a narrow strip of the river but downstream of Illambazar, the flood affected areas are vastly extended particularly in Bolpur, Nanur, Mongolkot, Ausgram, and Ketugram C.D. blocks.

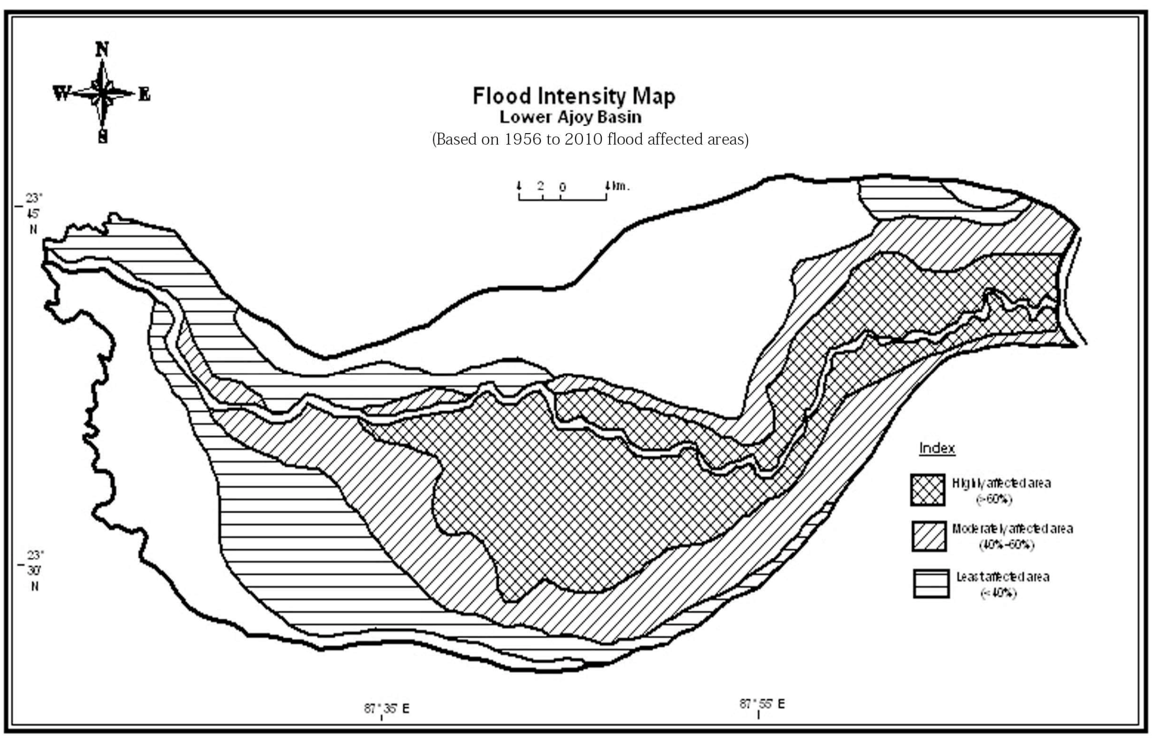

Figure 2 Flood Intensity Map

Embankment and Changing Micro-Topography
Breach of Embankment

There are various ways in which the term ‘breach’ can be used, but it typically refers to the failure of a flood defense structure, such as a flood embankment or the failure of a dam. Breach of a flood embankment occurs when water flows over or through the embankment at such a rate that the embankment is eroded and a hole created through it that permits flood water to pass through. In Lower Ajoy River Basin, breaching of embankment is very common in every major flood year. It occurs through various ways like overtopping, meandering nature of the river, alignment of embankment, poor maintenance of the embankment and other anthropogenic activities.

If we look into the previous records, we will find that breaches are historically known to occur within a certain river basin in a certain region and the records show the typical size of breach is fairly similar. In Ajoy River Basin, it has been found that the breaching tendency of embankment is more on the right bank from Illambazar to Bhedia and from Bhedia to downstream the breaching tendency is more on the left bank of the river. However, it is very important to understand the breach processes because this will allow emergency services to undertake the most appropriate actions in terms of warning and/or evacuating people at risk from flood water.

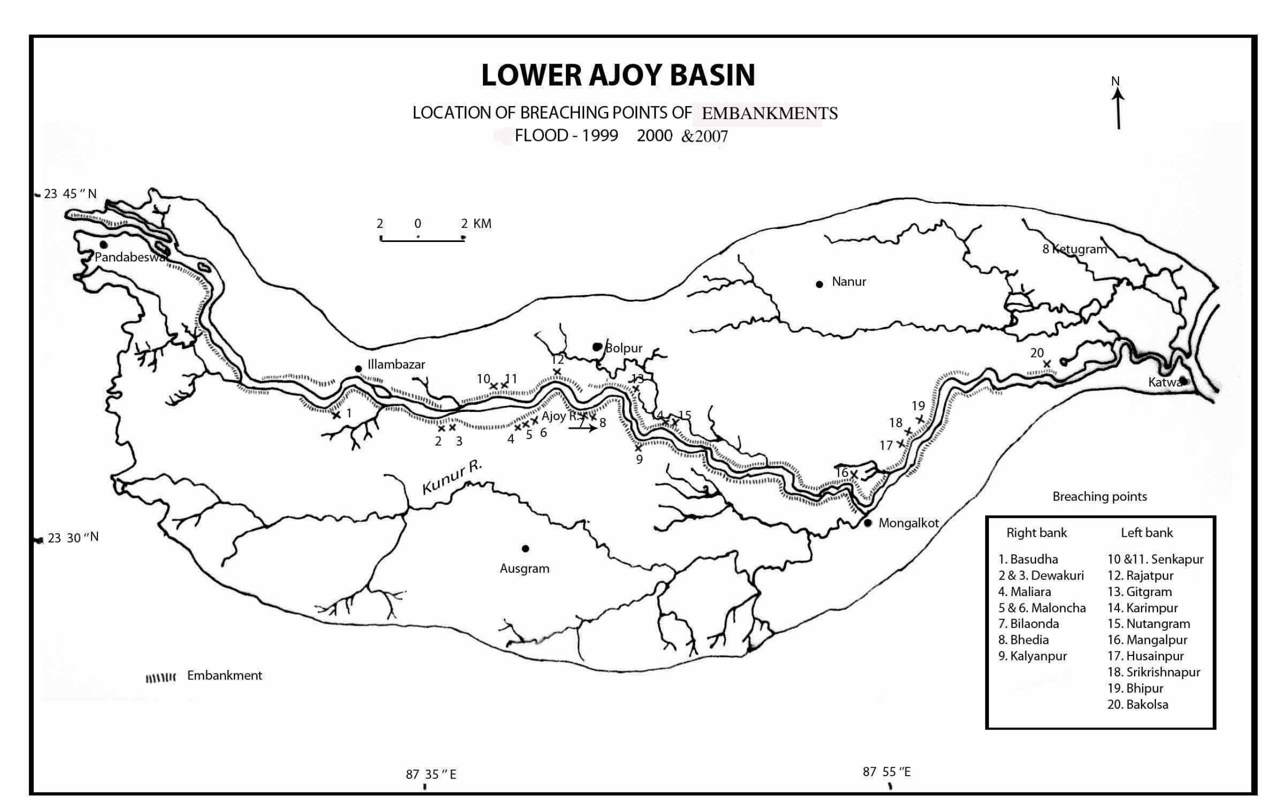

Figure 3 Breaching Points of Embankments

Sandsplay and Micro-Topographical Change

The most prominent effect of the breaching of embankment and the occurrences of flood is the sandsplay as post flood hazard (Mukhopadhyay, 2010). Sandsplays bring about modification of the alluvial riverine land, both in short term and long term basis. Due to breaching of embankments thick deposition of sand takes place on the river astride areas. So the fertile alluvial land is converted into sterile sandy land. Along the both sides of the Ajoy river, particularly downstream of Illambazar, sand depositions have been taken place in isolated pockets as a result of breaching of embankments. Table 4 shows the name of different mouzas and their respective coverage of sandsplays areas. In Gitgram and Hussainpur mouzas, almost 50 per cent of the total mouzas were covered by sandsplays. The maximum thickness of the sandsplays has been found up to 1.5 metres. On the basis of field survey conducted at Hussainpur, a cross section has been drawn. It shows that the depth of sand deposition is inversely proportional to the distance from the river bank. It has been observed that at the breaching place of embankment, the thickness of sand deposition is not considerably higher, but immediately after the breaching place at about 50 – 100 metres distance towards countryside, the thickness of sand deposition is maximum and the thickness gradually decreases afterward. From the laboratory analysis of the samples collected from the field, it has been found that about 90% of the sand varies its grain-size from 0.1 mm. to 1 mm. The grain-size of sand become coarser near breaching places of embankment and become finer towards the countryside.

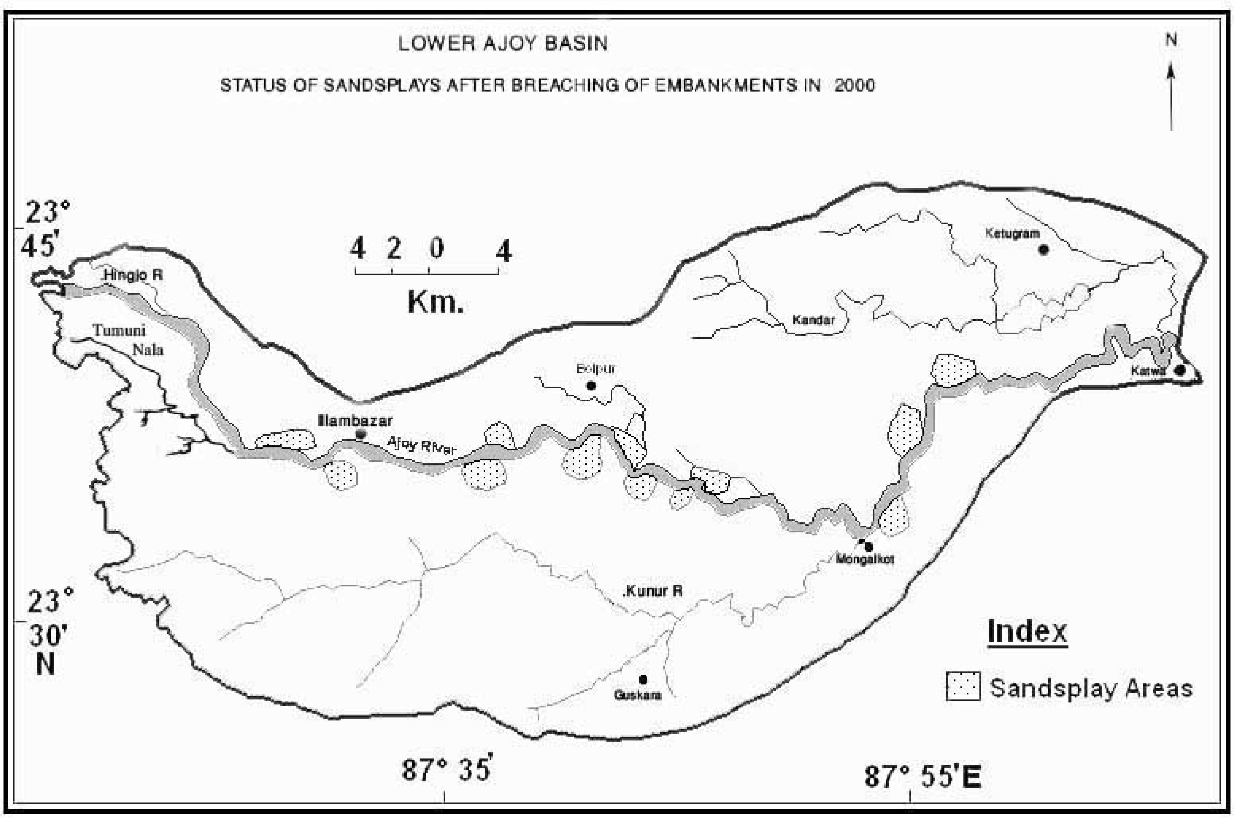

Figure 4 Status of Sandsplay Areas

Siltation on the River Bed

Construction of embankments results in increasing the silt charge in the flow due to prevention of spill of silt laden water. In case of unembanked river, the flood water enters into the floodplain and the silts carried by flood water get deposited in the floodplain. A negligible amount of silt is deposited into the channel bed. But after the construction of embankments the river flow is confined between the embankments. So, the huge volume of silt, entrapped into the river water, gets deposited in the river bed in the absence of spilling into the floodplain. Consequently the depth of the channel is reduced. Cross sections taken annually at some selected sites have proved conclusively, that the average bed level of Ajoy river has become higher in certain reaches. The depth of the river has been reduced significantly as a result of siltation on the river bed. Due to progressive siltation of the river bed, the bed level of Ajoy river becomes higher in the places of Satkahonia, Mailara, Bhedia, Mongolkot, Palita. From the field survey it has been studied that at Bhedia the bed level of the river is 0.68 mteres, higher than the adjacent floodplain. At places of Mongolkot, Hussainpur and Palita the values are 0.74 metres, 0.91 metres and 0.52 metres respectively. During the peak discharge period, frequent breaching of embankments occurs in these places and cause devastating flood. In the flood of 1999 about 17 and in 2000 about 20 breaching points were recorded in Lower Ajoy Basin (Table: 2). These breaching of embankments caused a devastating flood in the basin. Almost 1408 square kilometers and 1488 square kilometers area of the basin was inundated in the flood of 1999 and 2000 respectively.

Embankments have often been constructed close to the river bank and parallel to its course. In such situations, the discharging capacity of the river between the embankments is very much reduced causing general increase in flood height upstream and downstream of the embanked section. After the construction of embankments, most of the sediment will tend to flushed through the confined reach. Rapid aggradations of the sediment may occur downstream of the confined reach, particularly if the slope decreases appreciably below the confine reach. In the long run, downstream aggradations may initiate further slope adjustments along the river, eventually causing backwater effects to propagate the aggradational process upstream of the river. It leads to further increase in water levels in the embanked reach. In case of progressive rise in the bed levels, the high flood levels also increases and exceed those of the previous years for the same discharge (Mani, *et al*., 2006). The result is that if the embankment has to continue to give the same degree of protection as initially designed, the progressive raising of the embankment becomes inevitable. If so, a stage may come when it may no longer be possible to contain the river by embankment. Under such circumstances, if breaching of embankment takes place during peak discharge period, the magnitude of flood will be devastating in nature.

Conclusion

Construction of embankment as flood control measure has now become the most controversial issue. Various studies conducted regarding the evaluation of embankment shows that the merits and demerits varies from case to case and cannot be generalized. Embankment has of its immense importance for protecting the countryside settlements from flood and thereby saving lives and properties. But the construction of embankments leads to change in the natural course of the river and therefore the flow characteristics and flow conditions are bound to change. Therefore, it puts a question regarding the long term viability of the floodplains. The river channel geometry, longitudinal profile, river morphology, etc. also get changes. Lower Ajoy river basin is a well known flood prone area in West Bengal. Since long time past embankment had been constructed along Ajoy river to control flood. It is quite natural that every river has of its own ‘arena’ in which the river performs its various natural processes, like bank erosion, meandering, shifting of river channel etc. But due to construction of embankments along sides of the river Ajoy, silt deposition is taking place within the river bed that reduces the channel depth. Therefore in every flood year the discharge exerts a tremendous pressure on the embankment causing breach of the embankment. It causes a devastating flood and results in sandsplays. Therefore instead of fertile silt deposition, the flood plain is getting sterile sand deposition and consequently it brings far reaching economic consequences to the farmers as well as to the agricultural labourers. As flood cannot be totally controlled and it is not possible to provide protection against all magnitude of flood, we have to adjust with the flood and implementation of proper flood management programmes become very much necessary (Molla, 2010). From the previous experiences, like breach of Koshi and Bagmati embankment, the fact becomes clear that embankment cannot be a permanent solution of flood; rather, in the name of flood control, embankment changes the existing micro-topography and ecological settings of the floodplain as well as the economic status of the bank dwellers. Therefore, construction of embankment as a flood control measure would be like mortgaging the future generations to derive some temporary benefits for the present generation.

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Table 1 Spatio-Temporal Pattern of Flood in Lower Ajoy Basin

Year	Flood Affected Mouzas			Affected Areas (square kilometers)	Per cent to the total basin
	Entirely	Partially	total		
1956	153	32	185	680.0	24.14
1959	120	27	147	584.38	20.74
1970	186	36	222	812.24	28.83
1971	130	31	161	624.71	22.81
1973	124	36	160	639.02	22.68
1978	307	67	374	1680.0	59.64
1984	78	20	98	305.72	10.85

1995	227	49	276	1380.82	48.99
1999	237	60	297	1408.0	49.98
2000	263	106	369	1488.0	52.82
2005	136	39	175	706.54	25.08
2007	152	46	198	764.23	27.12

Source: Irrigation and Waterways Department, Government of West Bengal, 2010

Table 2 Number of Breaching Points in Major Flood Years

Year	No. of breaching points	Year	No. of breaching points
1978	12	2005	7
1999	17	2007	6
2000	20		

Source: Directorate of Irrigation and Waterways Department, West Bengal – 2008

Table 3 Coverage of Sandsplays Area in Lower Ajoy Basin in major flood year (1956 – 2012)

Year	Area covered by sandsplay (hectate)		Total sand covered area (hectare)	Maximum extension of sandsplay from river (distance in km.)
	Left bank	Right bank		
1956	102.20	119.25	231.45	0.38
1959	133.42	136.21	269.63	0.38
1970	248.76	444.72	693.48	o.47
1971	368.39	396.18	761.57	0.78
1973	497.66	695.54	1193.20	1.12
1978	1432.32	1989.0	3421.32	2.42
1984	335.23	530.30	865.53	0.68
1995	643.27	602.40	1245.67	1.40

1999	1097.74	1469.49	2567.23	2.12
2000	1478.98	2309.29	3788.25	2.57
2005	538.40	372.12	910.52	1.05
2007	596.52	618.46	1214.98	1.26

Source: Directorate of Irrigation and Waterways Department, Govt. of West Bengal – 2010.

Table 4 Loss of Cultivated Land Caused by Sandsplay

Name of the Block	**Name of the Mouza**	**Total amount of cultivated land (hectare)**	**Loss of cultivated land (hectare)**	**Percentage to the total cultivated land**
Ausgram	Bhedia	335.0	61.66	18.41
	Bramhandihi	164.0	21.47	13.10
	Maloncha	303.46	15.06	4.96
	Maliara	286.90	28.25	9.85
Kanksa	Basudha	593.47	140.0	23.59
Bolpur	Gitgram	110.0	30.80	28.0
	Natunpur	90.0	40.20	44.67
	Rasulpur	110.0	28.65	26.05
	Haripur	60.0	36.80	61.33
Mongolkot	Nabagram	66.60	20.45	30.71
Nanur	Srikrishnapur	130.0	80.50	61.92
	Hussainpur	180.0	30.0	16.67
	Vepura	50.0	17.0	34.0
	Gangnara	42.0	15.50	36.90
	Gomra	170.0	12.0	7.06
Ketugram	Bira	46.0	18.78	40.83
	Bankai	44.0	10.64	24.18
	Narenga	75.0	22.38	29.84

Source: Birbhum and Burdwan Zila Parishad, Govt. of West Bengal, 2007-2008.