FLOW AND EROSION PROCESS AND ITS LOCAL IMPACT ALONG A DEVELOPING BEND BETWEEN TWO RIVER TRAINING STRUCTURES IN A BRAIDED RIVER

FARZANA MAHMUD

INSTITUTE OF WATER AND FLOOD MANAGEMENT
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

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Flow and Erosion Process and Its Local Impact along a Developing Bend between Two River Training Structures in a Braided River

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Farzana Mahmud

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The thesis titled **'Flow and erosion process and its local impact along a developing bend between two river training structures in a braided river'** submitted by Farzana Mahmud, Roll No. M10072823P, Session: October 2007, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of M.Sc. in Water Resources Development on April 2011.

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Gulshan-1, Dhaka-1212
Bangladesh

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree.

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Farzana Mahmud

Roll No. M10072823P

Session: October 2007

Dedicated to
My parents, my In-laws and my Husband

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ABSTRACT

River bank erosion in the braided Jamuna River is one of the major natural phenomenon in Bangladesh. Bank erosion and channel developments are closely related to river flow processes and river morphology. The erosion processes resulting from the changes of flow and morphology in a bend channel in between Sirajganj hard point and right guide bund of Bangabandhu Bridge within the braided Jamuna River has been explored in this research. The effect of such erosion processes on day to day activities of the local people is also investigated.

The bend has been developing very quickly during the last three years making the bank profile very steep. The research has been conducted through analysis of dry season satellite images and field survey. Float tracking has been conducted several times to get surface stream lines and its convergence characteristics towards bank line. The spatial and temporal variation of erosion along the developing bend are represented with convergence point of surface stream lines. It has been revealed that surface flow velocities are concentrated and converged at the point of active erosion.

Bankline shifting has also been calculated from bankline survey using hand held GPS. The river bend has shifted approximately 1.3 kilometers during the last three years and engulfed 400 ha of agricultural and homestead land in the floodplain. PRA tools have been used to determine the local difficulties related to land and water use practices of the people vulnerable to erosion. These vulnerabilities vary with different processes of erosion. During the active erosion processes, the eroding bank became almost vertical having an average dry season exposed bank height equal to 6 meter. The near bank inhabitants, especially women, do not have access to river water and river bank to accomplish their daily requirements. Local people who previously engaged with agriculture related activities in the River mild slope bank and used the river bank as ghat are now forced to change their usual practices. River bank side inhabitants are also facing problems in different day to day activities such as vegetables production and water collection.

The extent to length ratio of the embayment has exceeded the previously observed maximum ratio (=0.21) along the right bank of the Jamuna River, which indicates that the bend may not continue to develop.

ABBREVIATIONS

BRE	Brahmaputra Right Embankment
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CB	Crossing Boundaries
CEGIS	Center for Environmental and Geographic Information Services
FAP	Flood Action Plan
FGD	Focus Group Discussion
GPS	Global Positioning System
IWFM	Institute of Water and Flood Management
KII	Key Informant Interview
PRA	Participatory Rural Appraisal
PWD	Public Works Datum

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Channel development and its abandonment are common characteristics within a braided river. Usually, high eroding bends (erosion rate>250 m/year) within the braided Jamuna river develops for 2-3 years after which the bend development processes cease and siltation influences the channel abandonment processes (Halcrow et al. 1994; Thorne and Russel, 1993; CEGIS, 2007). On the other hand, the life cycle (development and abandonment) of low eroding bends (erosion rate<100 m/year) are relatively longer (5-10 years). The spatial and temporal variation of bank erosion and channel development are closely related to the shape, size, location and orientation of braided sand bars. Also the rate of bank migration is linearly related to the magnitude of the near bank velocity (Pizzuto and Mecklenburg, 1989; Silva, 2006). Once a bend channel starts developing through bank erosion as a result of flow diversion by sand bar towards the bank line, curvature effect will have additional impact on the erosion and deposition processes. Secondary currents are generally significant in bend channels and responsible for erosion and sediment transport processes in an eroding bank (Thorne, 1991). The exposed bank profiles are usually very steep (nearly vertical) along an eroding bend, while gentle bank profiles in a siltating bank normally observed during the channel abandonment processes (Uddin and Rahman, 2009).

The scale of yearly river bank erosion is considered in most of the cases to estimate the national, regional and local losses. These losses are considered as economical losses and displacement of the local people forced by erosion is considered as social losses and in combined form, the loss is expressed as socio-economic impact (Elahi et al., 1991). A wide range of socio-economic problems is created by bank erosion process in Bangladesh (Bhuiyan, 2007). There is a severe impact on the land and water use practices of the local community during the channel development along an eroding bank. These issues are usually unnoticed considering its insignificant impact at national level.

A developing bend at Kalia Haripur along the western side of braided Jamuna River is exhibiting severe erosion. The bend has great spatial importance as it is forming between two important bank protection and river training structures: Sirajganj hardpoint and right guide bund of Bangabandhu Bridge in Sirajganj Sadar upazilla under Sirajganj District. During field visit to the area it was observed that the local people are facing difficulty to river water access. Usually local communities are accustomed with the use of river bank and river water for their daily household activities. When a channel is in abandonment process (siltating stage), the local community have easy access to nearby river water and land as the bank profile is very mild. While during the developing stage, the local community will have to search for alternative sources of water and land to accomplish their daily livelihood requirement (basically by women) as the bank profile becomes very steep during these processes. Thus the erosion processes have significant impact on the daily activities of the local community. Therefore, this study is intended to assess the flow and erosion processes of the developing bend in between the Sirajganj hardpoint and the right guide bund of the Bangabandhu Bridge and to assess its local impact.

1.2 Objectives of the Study

The main objective of the study was to assess the erosion processes and its local impact adjacent to the eroding bank. The specific objectives were as follows:

1. To assess the translation process of large scale bed forms such as sand bars around a developing bend.
2. To clarify spatial and temporal variation of flow processes and erosion along a developing bend at the downstream of a River training work.
3. To assess the local impact adjacent to the eroding bank.

1.3 Rationale of the Study

Erosion cannot be completely avoided in a riparian deltaic country like Bangladesh, but damages from severe erosion can be reduced if effective erosion prevention scheme is adopted. To implement the prevention scheme effectively, it is necessary to know the erosion processes clearly. This can be achieved if the sufficient erosion related information is acquired and analyzed in a systematic way. To understand the erosion processes, field investigation is essential. The use of GIS and Remote Sensing tool would accelerate the procedure for such analysis and would provide clear interpretation of result and understanding of the impact of erosion.

1.4 Limitations of the Study

It became difficult to acquire bankline data during monsoon and peak monsoon when bankline became submerged due to high water level. Also due to high velocity, float tracking was not possible during peak monsoon. Thus the bankline and float tracking data that are used here are for pre-monsoon and post monsoon but not for peak monsoon. The local impacts that are identified in this study may not be applicable to other reaches of the same river due to different physical settings. Extrapolation of the result to other areas should be done carefully.

1.5 Structure of the Report

Chapters two, three and four focus on the literature review, study area and methodology of the study, respectively. Chapters five and six explain the flow and erosion processes in a developing bend of a braided river and its local impact. Finally, conclusion and recommendations for further research are summarized in chapter seven.

CHAPTER TWO
LITERATURE REVIEW

2.1 River Pattern

Rivers are the channels through which water and sediment flow from their catchment area to the sea or lake. A river is shaped by the flow, quantity and character of the sediment and the character or composition of the bed and bank materials (Leopold et al., 1964). Natural controls, human interference through construction of bridges, revetments and the dikes also influence the shape of an alluvial river. An alluvial river can be defined as a river which has formed its channel in the sediments that is transported or has been transported by the river (Schumm and Winkley, 1994). An alluvial river can be classified on the basis of appearance of a reach in a plan view, such as braided, straight or meandering. A braided river differs from the other types of rivers as it consists of more than one channel. The straight and meandering river is generally identified by the sinuosity i.e. the ratio of river reach length to valley length. These types are shown diagrammatically in Figure 2.1. Although these three types represent the major divisions, it is common in any single river to find more than one type of pattern occurring along its length. For the present study the braided rivers are of main interest.

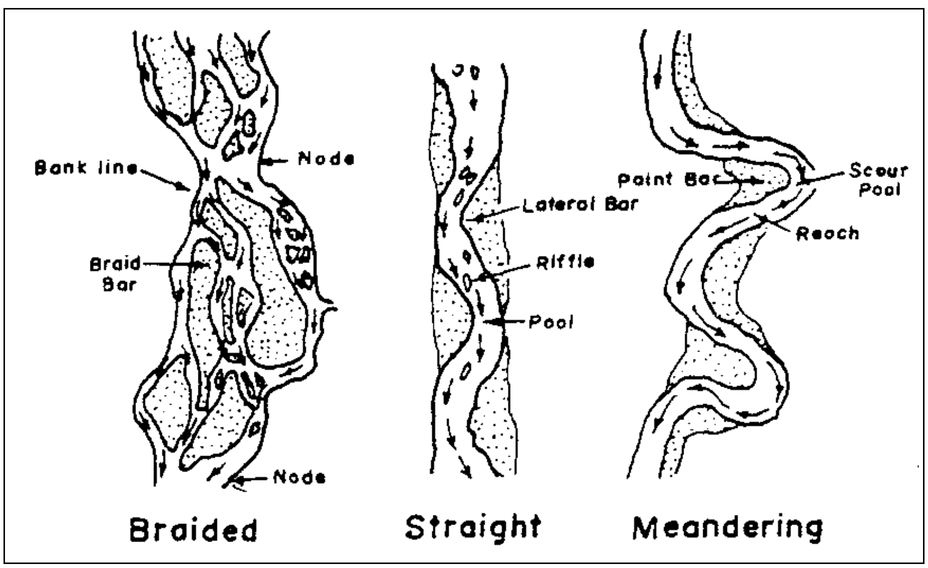


Figure 2.1: Definition diagram of the channel pattern (FAP 24, 1996)

2.2 Causes of Braiding

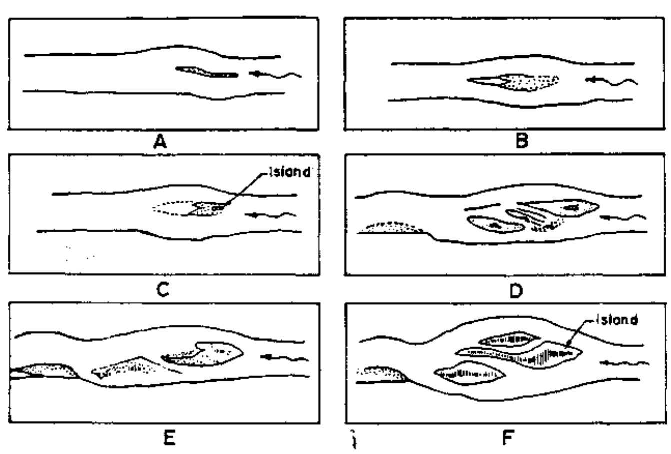
There are three kinds of theories on the cause of braiding in alluvial systems. First is a practical explanation relating the braiding to a combination of external forces, environmental factors such as discharge and the supply of sediment. Second is the formation of braids to theoretical stability analyses of channel bars in two dimensional flow regimes. Finally the focus on physical processes such as sedimentary and hydraulic conditions that begin the braiding process (Ashmore, 1991) have been explored.

The general conditions required for the development of a braided planform described by Knighton (1984) are as the necessity of a large amount of sediment to provide an abundant bed load. Coarse fractions, which the stream is locally unable to transport, can provide the initial deposits for bars, which then divert the flow towards the river bank. Erodible banks are therefore another requirement as these are not only a readily available source of sediment but also allow the widening of the channel. Generally, rivers with erosion-resistant banks meander rather than braid. The highly variable discharge is not a prerequisite for braiding. But the rapid variation of discharge often accelerates the bank erosion and thus contributes to braiding process.

In the literature a number of methods of classification of channel patterns are available, which provided the threshold between the braiding and the other channel patterns. This can also provide a fair understanding of the causes of braiding. Studies on the channel classification based on stability analysis, indicate that braiding initiates from the instabilities in the riverbed (Struiksma and Klaassen, 1988). The threshold parameter is the width-depth ratio which should be higher for braided river. It appeared that braiding is likely for the river with highly erodible bank, higher slope, higher discharge and width-depth ratio. However, the width-depth ratio is the function of sediment size, slope, sediment transport and the characteristics of the bank material.

2.3 Formation and Characteristics of a Braided River

The detailed formation processes of a braided river are still poorly understood and the hydraulic parameters of a braided stream are extremely complex (Coleman, 1969). Leopold and Wolman (1964) described the development process of a braided bar in a laboratory flume is shown in Figure 2.2. The uncemented sandy flume channel was straight initially. A small deposit of grains in Figure 2.2 "A" of coarser sediment was introduced by lag deposit of the coarser fraction, which could not be carried by the flow. The probable reason for this initial deposition given by Leopold and Wolman was that the turbulent flow creates the fluctuation of instantaneous velocity, which causes a brief decrease in intensity allowing some particles to rest. Velocities required to keep them moving, are less than those required for reinitiating movement after they have come to rest, once concentrated, the particles form a locus for continued deposition. Once initiation of the bar has occurred it accretes vertically (shown in "B" and "C") as well as in down-stream direction. The presence of a bar reduces the flow area and diverts the flow towards the bank (shown in "D"), initiating bank erosion thus increasing the flow area. The velocity distribution over a mid-channel growing bar reduces after accreting the bar to a certain level shown in "E" (Ashworth, 1995). This forces the flow further towards the bank attributing the further widening of the channel. Widening of the channel increases the flow area and drops the water level, which results in the bar emerging ("F") for constant discharge. These are the mechanisms of the mid-channel bar initiation as based on Leopold and Wolman (1957).



Legend:
Deposit more sand than original sand
Island or area out of water

Figure 2.2: Steps in the development of a braided river (Leopold and Wolman, 1957)

The braided river transports huge volume of sediment load. The channel shifts it courses due to deposition of the excess sediment load and rapid bank erosion (Bristow and Best, 1993). Braided rivers are characterized by having a number of alluvial channels with bars and islands in a sequence of confluence and bifurcation. The planform appearance of braided river can change rapidly with flow stage. At higher flow stages when the largest volumes of sediment are transported, the channel are often scoured, bars may be reduced in height or in some cases completely eroded. During falling stage maximum deposition occurs as discharge and flow capacities are reduced. Channel beds accreted, the high stage bedforms may be modified and new bars may be formed or enlarged as sediment is deposited. As discharge continues to fall, bars may become emergent and dissected by low stage channel.

In a braided river three orders of channels are present (Williams and Rust, 1969; Bristow and Best, 1993 and Bridge, 1993). The order of channels depends upon total discharge and fluctuation of discharge. The first order comprises the whole river. Second order channels are the dominant channels (Figure 2.3) within the river whilst third order channels are primarily low stage features which modify the bars deposited by the second order channels (Bristow and Best, 1993).

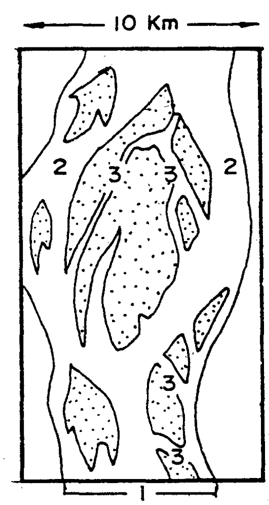


Figure 2.3: Channel classification in the Jamuna River (Bristow, 1987)

According to Leopold and Wolman (1964) 'there is a close relation between braiding and meandering: braided channels may exhibit curves that have a characteristic relation of radius to channel width, and the river has at least some reaches that would be called meandering'. Also it is found from the study on a large scale sand bed braided river that the flow structure in a bend of an anabranch channel (i.e. second order channel) of a braided river is similar to a meander bend of single thread rivers (Richardson and Thorne, 1998; FAP24, 1996).

2.4 Channel Characteristics of the Jamuna River

In a braided river, there exist a number of channels within the braided belt. As noted earlier in section 2.3, Bristow (1987) classified various types of channels for the Jamuna River (Figure 2.3). When comparing braided rivers to differently classified systems such as meandering rivers there has been little studying of braided river systems. The reason for lack of study is that braided rivers are hard to study due to the difficulty of measuring their flow, sediment transport, and their morphology in a quickly shifting environment of a braided river. Klaassen and Vermeer (1988) studied the geometry of the second order channels of the Jamuna River considering those channels as individual channels. Leopold and Wolman (1960) derived empirical relations for meandering rivers, which are as follows:

$$\lambda = 10.9B^{1.01} \tag{2.1}$$

$$A = 2.7B^{1.1} \tag{2.2}$$

$$\lambda = 4.7R^{0.98} \tag{2.3}$$

in which λ = meander length, A = amplitude and R = radius of curvature. The definition diagram of these parameters is shown in Figure 2.4.

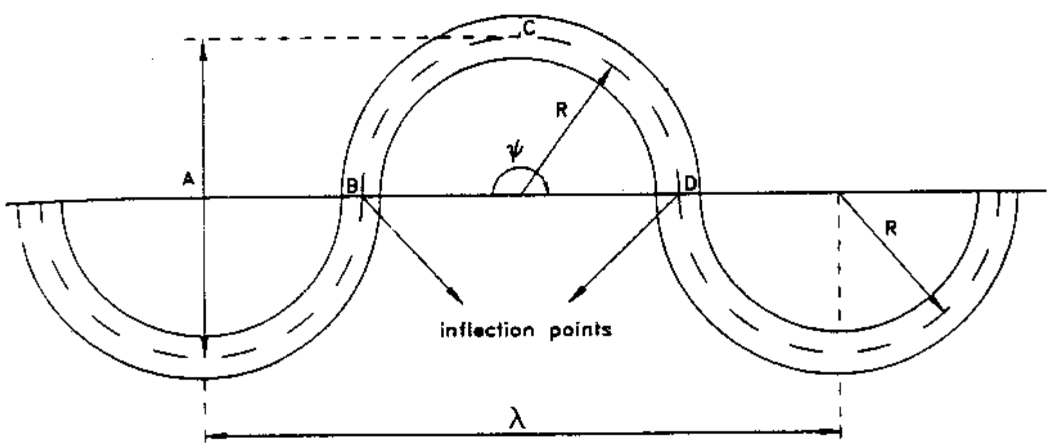


Figure 2.4: Definition diagram of meandering wave length, amplitude and radius of curvature

Relating the second order braided channel with the meander formation Klaassen and Vermeer found some deviations. They derived a relation at a station of the Jamuna River based on Lacey's regime elation, considering different levels in the cross-sections for different discharges and corresponding water surface width and average depth which they estimated from the BWDB measured cross-section. The discharge in an individual channel was estimated as indicated in the regime relations. In average, the flow depth and width relations with discharge are expressed as below:

$$h = 0.56Q^{0.23} \tag{2.4}$$

$$B = 18.9Q^{0.51} \tag{2.5}$$

These relations indicate that the channels of the Jamuna River are quickly responding to adjust their depth and width with the variation of discharges. However, no channel in the Jamuna River is in regime condition and continuous change of channel development and abandonment is a common phenomena.

2.5 Channel Shifting Processes

The channel shifting processes in the Jamuna River are quite rapid. The abandonment of large channels and the development of new channels in a few years are common features in the Jamuna River. Klaassen and Masselink (1992) found that three types of processes are related to the channel shifting processes, viz. bar-induced shifting, cutoff development and eroded outer bend channels. The angle of deviation from upstream channel direction is a more important factor in channel abandonment than sinuosity or cutoff ratio, whereas abandonment generally takes place when the deviation angle is greater than 40° (FAP 21/22, 1993). Also there are more chances of abandonment for a channel located in an inner bend whereas an outer bend channel has fair chances of developing cutoff.

2.6 Flow Processes at Bends

The flow in meandering channels under centrifugal acceleration induces a secondary current or transverse circulation and super-elevation in water surface. A secondary current grows upon entering a bend. The growth and decay of a secondary current, as explained by Rozovskii (1957), is due to the interaction of centripetal force and turbulent shear stress that the flow has to overcome in transforming from the secondary pattern into a parallel flow and vice versa. Research in meandering channels has established that patterns of primary isovels and pathways of bed material transport are strongly influenced by a secondary current (Thorne et al., 1985). At bends with steep outer banks, the secondary current consists of a main cell of primary downstream flow and an outer bank cell of reverse circulation which in turn drive helical circulation (Bathurst et al., 1979). Thomson (1876) found the reason for this phenomenon is the centripetal force driving fast surface-flow jets towards the concave bank and inducing a transverse gradient of the water surface. As a result of the extra hydrostatic pressure, near-bed jets deflect towards the convex bank (Figure 2.5). According to both theoretical investigations and direct measurements, Milovich (1914) found that maximum velocity of the helical circulation is located in the near-bed zone towards the convex bank. Its magnitude is directly proportional to mean downstream flow and depth and is inversely proportional to the radius of meander curvature depending on the friction factor (Goncharov, 1954; Rozovskiy, 1957; Falcon & Kennedy, 1983; Odgaard, 1989).

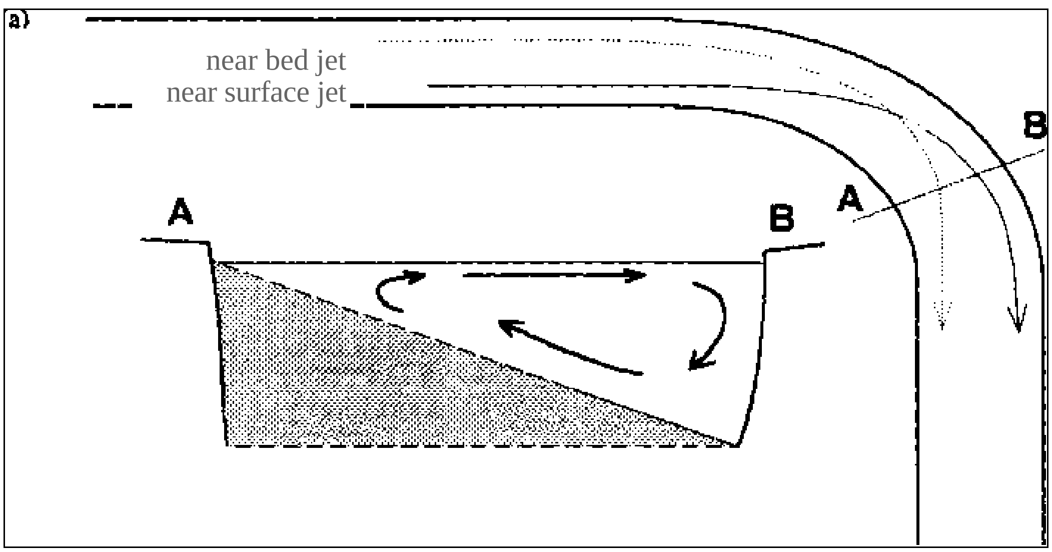


Figure 2.5: Secondary flow in river bends, proposed by Thomson (1876)

The influence of secondary currents on a flow and sediment dynamics cause meander shifting through river bank erosion and bar formation in a typical meandering river (Thorne, 1991; Thorne and Hossain, 1995). It is found from the study on the Jamuna

River that the flow structure in a bend of an anabranch channel (i.e. second order channel) of a braided river is similar to a meander bend of single thread rivers (Richardson and Thorne, 1998; FAP24, 1996). The evolution and decay process of secondary currents in a doubly meandering compound channel and the influence of water depth on the position and strength of the secondary currents in the main channel have been investigated by Islam et al. (1999). The effect of bed slope on flow pattern in a doubly meandering compound channel is also studied by Islam et al. (2007). They found that the flow patterns in the cross-over sections are different between mild and steep slopes. Erosion often occurs at the outer banks of a meander bends as a result of amplified flow velocities and shear stress. A relationship has been established by Thorne et al. (1995) between section-averaged velocity and outer bank velocity that is related to the geometry of meander which is the channel width and the radius of curvature.

The location in flow plan of the laterally adjacent erosion- deposition zones in sine – generated meandering streams have been investigated by Silva and Tahawy (2008). They found that for small deflection angle ($<30^0$), the maximum erosion deposition zone occurs very near the crossover-sections and for large deflection angle ($>100^0$), the maximum erosion deposition zone occurs very near the apex section. And when the deflection angle is intermediate the erosion deposition zone occurs in between the apex section and the crossover-section. The location of the upstream end of erosion-deposition zone gradually moves upstream from the apex to the crossover as deflection angle increases from 0 to 126^0 providing that all other conditions remaining same. They also found that with the increase of water level the erosion zone shifted from the bend apex towards the downstream crossover for a particular deflection angle.

2.7 Bar Migration through Bends

Flow deflected by the bed topography forces near-bank local boundary shear stresses which are sufficient to erode the channel bank either across the bank surface or at the base through undermining the bank collapse. In many channels, the time scale of bank erosion may be far longer than that of bar migration; consequently, there are transient interactions between the topography associated with the developing channel curvature and the bathymetric oscillations associated with the alternate bars. Channel curvature acts to create regular changes in flow direction which, through the centrifugal force and the pressure gradient, establish a regular and repeated variation in the boundary shear stress. This regular pattern of shear stress variation scours and deposits sediment to mold repeated topography. Kinoshita and Miwa (1974) showed that alternate bars could migrate through bends and the curvature-induced topography (bends like those that might be created by the initial bank erosion forced by bars). If bars can migrate freely through bends, even rather gentle bends, the spatial persistence of erosion forced by the bars would seem to be lost. Kinoshita and Miwa (1974), the pioneers, investigated the behavior of bars in bends of different low angles and documented the existence of a critical bend angle above which migrating alternate bars did not propagate through bends. The terms "free" and "forced" bars, the following terminology, first used by Kinoshita and Miwa (1974) but explicitly defined by Seminara and Tubino (1989). Alternate bars are called "Free" bars because they develop spontaneously and are migrating, and curvature induced. bars (i.e., point bars) are called "forced" bars. Kinoshita and Miwa (1974) conducted a flume experiment based on 13-cm-wide, straight segments joined at various angles, to mimic the repeated change in direction of meandering channels. The critical bend angle determining migration decreased from 10° to less than 7° as the length of straight channel segments increased from six to ten channel widths. They reported, but did not show, that rounding out the sharp bend crests increased the critical angle, and the radius of curvature-to-width ratio. Kinoshita and Miwa suggested graphically that the criterion for bar migration through a bend is whether flow impinges upon the inner bank of the downstream bend. While they made no measurement of hydraulic conditions, they reasoned that if stress divergence is sufficient to evacuate the sediment delivered to the bar front, bar migration ceases. Based upon this work Whiting and Dietrich (1993) explore both the qualitative and quantitative behavior of bars in bends. They explore, over a broader range of conditions and with more appropriate bend geometry, how this behavior is influenced by curvature, planform wavelength, and width-to-depth ratio. Whiting and Dietrich found that in straight channel the alternate bars, once develop, maintain their morphology and wavelength and migrate steadily downstream but the morphology and migration were non-uniform in low curvature meander bends. They also found that bars are less prone to migrate in more curved bends and also when the width-to-depth ratio and wavelength-to-width ratio decreases.

2.8 River Bank Erosion and Associated Impacts in Bangladesh

The unique natural setting of Bangladesh in the South Asian Sub-Continent and the characteristics of tropical monsoon are greatly responsible for flood, riverbank erosion, sedimentation and population displacement in Bangladesh. River bank erosion is closely related to the magnitude of flood and bank materials of alluvial character. Rivers flowing through these loose alluvial soils carry most of the eroded materials as sediment on their way to the Bay of Bengal (Elahi, 1991; Islam, 1985). It is a frequent natural disaster in Bangladesh. CEGIS annually estimate the amount of erosion and accretion along the three main rivers: (the Jamuna, the Ganges and the Padma) of Bangladesh (CEGIS, 2010). From the study it was found that Jamuna River is widening and both banks are migrating outwards at a high rate for the last few decades. During the last three and half decades (1973 to 2010), the net erosion along the 220 km long Jamuna River was about 71,068 ha. The rate of erosion has varied over time. For example, the rate at which the Jamuna River has been widening declined from 150 m/year in the 1970s and 1980s to 48 m/year during the last 14 years. Between 1973 and 2010, erosion and accretion along the Jamuna River was 87,710 ha and 16,642 ha respectively. This imbalance between erosion and accretion is endorsed to the widening of the river. The highest erosion was in Sirajganj district (20,967 ha). The annual erosion along the Jamuna varies from one year to the other and also from one reach to the other reach (CEGIS 2010).

Under the Riverbank Erosion Impact Study (REIS) program, Elahi (1991) observed the bank erosion problems of Kazipur on the right bank of Jamuna River at the upstream of Sirajganj town for the period of 1983-86. It was found that Kazipur was totally eroded away within the period of 1980-84. The perception of the respondents of Kazipur Upazilla expressed their opinion that the high velocity is a major cause of such massive erosion in the floodplain (Haque, 1997). Apart from the above reason, a number of chars, shallowness of the Jamuna River, high precipitation in the region, unconsolidated soil of the floodplain and the nature of the river are the causes of such erosion.

In the recent research of Uddin (2010), it was found that the floodplain people can forecast erosion and accretion for a majority of the river sections based on their wisdom and experiences. Local people used to observe certain phenomena through which they can estimate the severity of erosion: (i) when two major channels flow around a char, the danger of erosion is very high, and (ii) when the flow attacks a bank directly, the banks are steep and the channels are deep. Since the construction of the Jamuna Bridge, the behavior of the river has changed and the river did not follow its natural processes, stated by the local people. According to the local people, accurate forecast of erosion can be made as soon as the water level starts rising at the beginning of the flood season. The local-people emphasized that all developments depend on the strength of the floods, the speed of the rise and fall of the water level, and the number of floods in a monsoon season. Some flood plain-dwellers believed on the following statement: "Three years strong floods, three years weak floods".

The principal resources of Bangladesh are its land, water and people. With such resource base, hazardous events like bank erosion and consequent flooding makes the life and living too vulnerable for the affected people. Baki and Bhuiyan (2007) summarized that, bank erosion and sudden channel migration deteriorate the socioeconomic conditions of floodplain inhabitants due to loss of valuable agricultural land and settlements. A large part of population becomes landless and homeless by this process each year. The impact of land loss involves primarily the loss of homestead land, housing structures, crops, trees and households. Loss of homesteads force people to move to new places without any option and puts them in disastrous situations. In erosion-prone areas, most families have witnessed a displacement in their lifetime. The displaced people usually move to nearby areas but migrations to distant places are not uncommon. Displaced people lose their rural livelihood and face increasing impoverishment. The majority of displaced floodplain inhabitants are forced to live on the periphery of urban life, resettling in *bastes* or squatter settlements located along railway lines, abandoned brick yards, or flood protection embankments.

Baki and Bhuiyan (2007) also noted that most of the erosion-induced displacers adopt the job of day-labor or rickshaw-puller. A large proportion of the victims remain unemployed due to lack of work opportunities. In the wake of destitute condition, many families are shattered where women may become the head of the family. Such families are normally the most deprived group. Haque (1997) mentioned the three common effects of erosion induced displacement which influenced the well-being of family members: 1) a severe cut in their standard of living, 2) the occurrence of mental illness in the family, and 3) the loss of valuable assets.

2.9 Summary

The literature review discussed the river pattern, classified on the basis of appearance in a plan view as braided, straight and meandering river. Although these three types represent the major divisions, it is common in any single river to find more than one pattern occurring along its length. The braided rivers are of main interest in this study. Some conditions, which promote the formation of a braided channel, are erodible banks, an abundant supply of sediment, instability in the riverbed and the frequent and rapid changes in the discharge of water in the drainage basin. In a braided river three orders of channels are present and the order of channels depends upon total discharge and fluctuation of discharge. The literature review emphasis mainly on the characteristics of the Jamuna River, flow process at bends and bar migration through bends with limited emphasis on bank erosion and associated impacts in Bangladesh. From the literature review, it is concluded that very limited research work had been done along the present study reach in the Jamuna River. Recently, CEGIS observed and predicted that during the last three and half decades (1973 to 2010) the net erosion along the Jamuna River was about 71,068 hectares of which 16,122 hectares in Sirajganj district. CEGIS also identified the most vulnerable location of the reach is Kalia Haripur area in between two important structures: Sirajganj hardpoint and right guide bund of Bangabandhu bridge. So a complete study is necessary for the understanding of overall situation of the Kalia Haripur reach. The present study assesses the flow process and bank erosion of the Kalia Haripur (most active bend) reach and its impact on the local inhabitants. The present study will be useful for conducting future development action and policy formulation related to bank erosion.

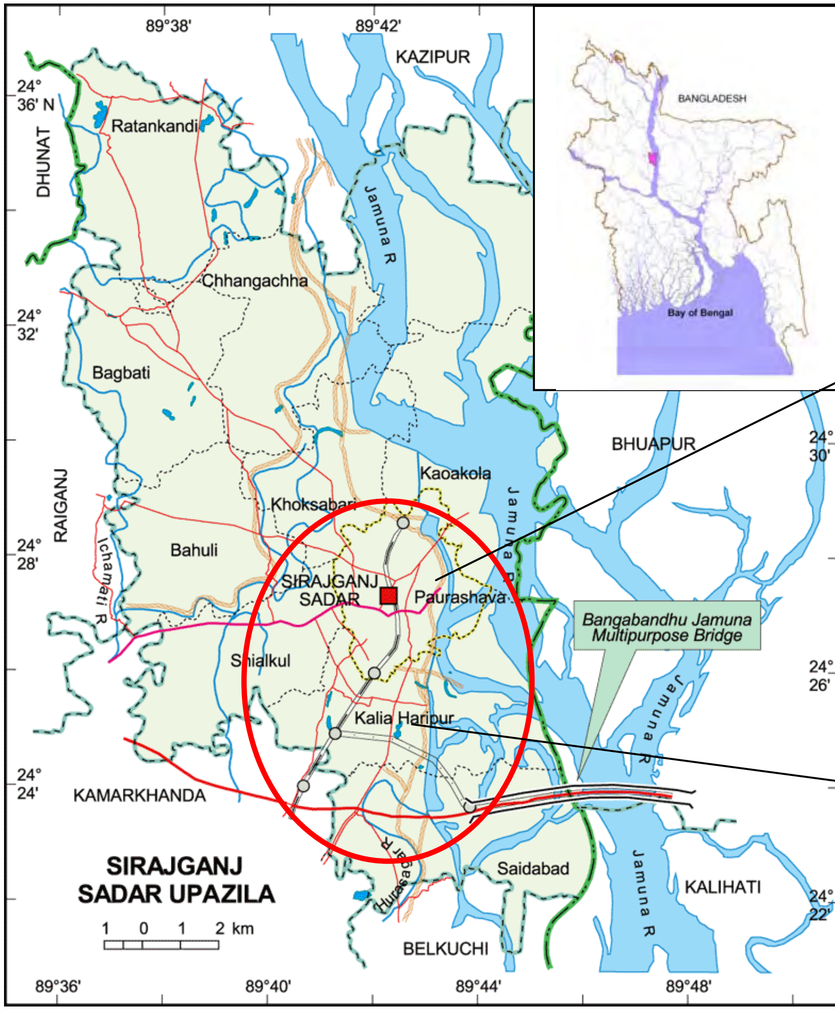
CHAPTER THREE
STUDY AREA

3.1 Location

The study area was selected on the basis of the new developing bend at right bank of the Jamuna River. The bend is amplifying between two important structures: upstream one is Sirajganj town protection revetment known as Sirajganj hardpoint and downstream one is the right guide bund of the Bangabandhu Bridge. Jamuna is eroding its right bank at Paurashava and Kalia Haripur unions of Sirajganj Sadar upazilla under Sirajganj district. The bend is developing with high erosion rate and the inhabitants near the bank facing difficulties in their day to day life. Char Malshapara Gram and Mara Gram (locally named as Mor Gram) are two most vulnerable villages, have taken randomly as study area of Paurashava and Kalia Haripur unions respectively of Sirajganj Sadar upazilla. Due to erosion process the river bank became very steep and the villagers who were dependent on river bank and river water for their daily life faced trouble. The river bend starts from Latitude 24°27'32.56" N and Longitude 89°43'15.2" E and ends at Latitude 24°24'35.73" N and´ Longitude 89°44'33.39" E. The vulnerable Char Malshapara is located at Latitude 24°27'6.07" N and Longitude 89°43'1.78" E with 60 meter radial buffer zone and Mara Gram is located at Latitude 24°25'14.43" N and Longitude 89°43'25.44" E with 150 meter radial buffer zone. The location map of the study area is presented in Figure. 3.1.

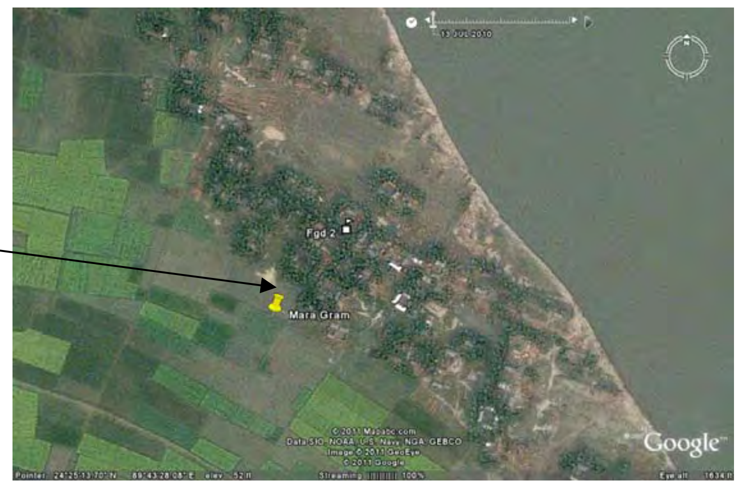
3.2 Topography

The area is a low lying flood plain area. Char Malshapara Gram and Mara Gram villages are located at 400 to 650 meter inside from Brahmaputra Right Embankment (BRE) respectively. Homesteads are located in a scattered way where lands are relatively high and trees found to give them privacy and shade. According to local people, due to consecutive river bank erosion people have to shift their houses several times and they take shelter near BRE in make-shift houses. The upstream Sirajganj Hardpoint crest level is (+) 16.75 m, PWD, whereas approximate ground level is (+) 13.00 m, PWD (Uddin, 2010).



(a) Map of the Study area

(b) Char Malshapara Gram



(c) Mara Gram (locally named Mor Gram)

Figure 3.1: (a) Location of the Study Area (Banglapedia) and (b)-(c) Its Landscape (Google Earth)

3.3 Demography

As the study area is located in Sirajganj Sadar Upazila, the demographic characteristics of the Upazilla are reflected there. Sirajganj Sadar Upazila with an area of 325.77 sq. kilometer has a population of 389160. Among them, the number of male is 51.54%, female 48.46%; Muslim 95.16%, Hindu 4.80% and others 0.04%. Average literacy of the area is 29.8% amongst which male literacy is 35.6% and female is 23.5%. The significant educational institutions are BL High School (1869), Gyandayini High School (1884), Islamia College (1887), and Sirajganj Government University College (1940).

Main occupations are agriculture 25.17%, agricultural labourer 15.76%, wage labourer 4.37%, commerce 16.09%, service 12.55%, weaving 4.10%, transport 3.53%, industrial labourer 4.12%, and others 14.31%. Total cultivable land is 23872.93 hectares, fallow land 772.16 hectares, single crop 21.44%, double crop 47.54%, and triple crop land 31.02%; and cultivable land under irrigation is 42.38%. Among the peasants, 7.53% are landless, 10.12% are marginal, 61.99% are small, 17.81% are intermediate and 2.55% are rich.

3.4 Hydro-Morphology

The Brahmaputra-Jamuna River originates in Tibet on the northern slope of the Himalayas and drains snowmelt and rainfall from China, Bhutan, India and Bangladesh. Before it meets with the Ganges River at Aricha in Bangladesh, the river travels a length of 2,740 km. Its total catchment area is 570,000 km^2, of which only 7% is within Bangladesh. Annual average precipitation in the catchment is 1,900 mm, of which more than 80% occurs during the 5 months of the monsoon. The river starts rising in March/April due to snowmelt in the Himalayas and may attain its peak between the beginning of July and mid-September. The annual average flow is 20,000 m^3/s as measured at Bahadurabad and the maximum estimated discharge is 1,00,000 m^3/s in 1998 (EGIS, 2000). Minimum flow in the river generally occurs at the end of February or the beginning of March. The recorded low flow was 2,860 m^3/s in 1971(FAP-24, 1996).

In the study reach, there is no discharge measurement station but one water level station is found near hardpoint is in operation by BWDB. The average water level slope of the Jamuna River is 7.5 cm/km, varying from 8.5 cm/km in the upstream part to 6.5 cm/km at the downstream end of the river (EGIS, 2000).

The Jamuna River is a braided river with a braiding index that varies spatially and temporally. The range of variation is 2 to 5 (Klaassen and Vermeer, 1988). The overall width of the river is also varied spatially and temporally, from 6 to 14 km (FAP 24, 1996). Generally, the braiding index and the overall width are larger at the upstream part than farther downstream, probably due to the effects of higher slope and grain sizes (Klaassen and Vermeer, 1988). The overall width of the river shows an increasing trend towards westwards, especially at the upstream part of the river within Bangladesh (Halcrow, 1993).

3.5 Sediment Transport

The bed material size of the Jamuna River was decreased from the upstream towards the downstream and ranged from 0.22 mm to 0.16 mm. The average annual sediment discharge of the river is 590 million tons, which is consisted of 200 million tons of sand (diameter above 0.06 mm), and the remainder are silt and clay. Bank material of the Jamuna River consists of loosely packed silt and fine sand, highly susceptible to erosion. The average concentration of sand fraction varies between 300 to 500 mg/l (FAP 24, 1996).

3.6 Infrastructures

The study bend area is a flood plain area with cluster homestead, cultivable land and fallow land. The study area is surrounded by Sirajganj Hardpoint revetment at north, Bangabandhu right guide bund at south, Brahmaputra Right Embankment (BRE) at west and the Jamuna River at east. There were few schools, mosques, madrasa, bazaar which had to shift several times and gradually being lost due to erosion. Inside the study area there is no regulator and drainage channel.

To protect Sirajganj town a massive Sirajganj hardpoint was constructed in 1998 under FAP 1 (1994). High Flood Level (HFL) and Low Water Level (LWL) are considered (+) 15.75 m, PWD and (+) 6.80 m, PWD respectively and design flow velocity is 3.7

m/s. The crest level is (+) 16.75 m, PWD, whereas approximate ground level is (+) 13.00 m, PWD. The side slope of the hardpoint is 1V: 3.5H. The Sirajganj hardpoint faced the high flood in the history of the Jamuna in 1998 just after its construction. The Brahmaputra Right Embankment (BRE) was built during the late 1950s and mid 1960s to protect the flood plain against flooding.

3.7 Bank Erosion Situation

Sirajganj is an old established town in Bangladesh. The urban and peri-urban development has been expanded close to the river bank. It is reported that one kilometer of right bank has already shifted in the westward direction since 1830 (Halcrow, 1994). The increased river flow is attacking the bank directly at Kalia Haripur bend. Local people informed that some of them had to shift their homesteads from the bank four to six times and many of them lost their agricultural lands into the river. At Char Malshapara, a school and a madrasa went into the river. Char Malshapara mosque shifted three times. Potential erosion at downstream of hardpoint brought the bank line near BRE. The people of these areas have become landless as well as poor. According to the information of the Union Parishad member and the common people of Char Malshapara and Mara Gram, 40% of the total people, being landless, shifted from the villages. Bank erosion has made their life miserable.

CHAPTER FOUR
METHODOLOGY

4.1 Introduction

A proper methodology is always necessary for the successful completion of any research work. It helps to organize and conduct the study. The following methods have been undertaken to complete the research work.

4.2 Selection of the Study Area

The Jamuna River, which is the lower reach of the Brahmaputra River in Bangladesh, is very dynamic in nature. It always changes its course, and the sand bars gradually move towards downward direction. Due to its dynamic characteristics, the erosion problem is severe in the Jamuna River. The Brahmaputra Right Embankment (BRE) was built during the late 1950s and mid 1960s to protect the flood plain against flooding. About 30 river training structures have been constructed along Brahmaputra Right Embankment (BRE) mostly during the last 1-2 decades. Among these, Sirajganj hardpoint and the guide bund of Bangabandhu Bridge are two most important structures according to their uses. During 1998, Sirajganj town protection revetment was constructed to protect the Sirajganj town which has commercial importance in the north-western part of Bangladesh. Bangabandhu Bridge is a mile stone to boost up the communication system of Bangladesh especially linking the north-western part with other parts of the country.

It is a common practice that the upstream approach flows are often guided to pass through a constricted section during construction of a bridge to reduce its effective length of the bridge. The structures used for this purpose are usually called as guide bunds. In the case of Bangabandhu Bridge, about 7 km width was reduced to 4.8 km by the guide bunds. During field visit to Jamuna River in April 2010, seven kilometer long developing bend at Kalia Haripur between Sirajganj hardpoint and right guide bund of Bangabandhu Bridge was identified which has been exhibiting severe erosion and might be a threat to the guide bund in the future. Through this investigation it was felt that the process which guides this severe erosion needs to be clarified. Therefore, this site was selected as a study area for this research. The study area is shown in Figure 4.1.

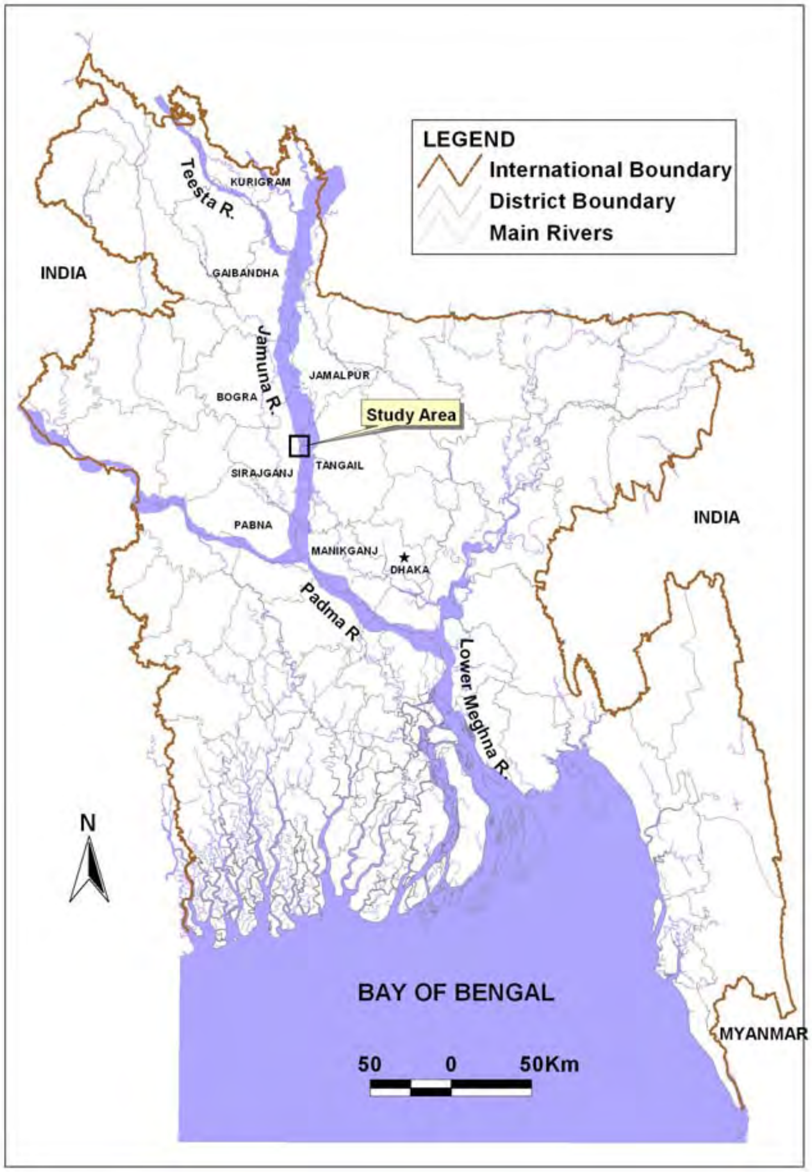


Figure 4.1: Study area shown with respect to the river systems of Bangladesh

4.3 Data Collection

This study is based on mainly primary data. Primary data was used to clarify spatial and temporal variation of flow processes and erosion along the bend and to evaluate the local impact. Also secondary data was used to establish linkage among large scale bed forms and flow processes towards the eroding bend.

4.3.1 Primary data collection

Primary data was collected through field visits in the study area. Data collection was completed within April, 2010 to March, 2011. Seven field visits were conducted are shown in Table 4.1.

Table 4.1: List of field survey dates

Date	Purpose of Field Visit			Remarks
	Float Tracking	Bankline Survey	Social Survey	
23rd April, 2010	√	√	√	1 Float, Reconnaissance survey
4th May, 2010	√	√	-	2 Floats
1st June, 2010	√	√	√	4 Floats, PRA tools
20th June, 2010	√	√		4 Floats
13th July, 2010	√	-	√	3 Floats, PRA tools
25thNovember, 2010	√	√	√	3 Floats, PRA tools
14th March, 2011	-	-	√	Resource mapping, PRA tools

Primary data collection included the following items: A) Hydraulic data collection, B) Soil sample data collection and C) Social survey

A) Hydraulic data collection

Bankline data: To assess the extent and location of erosion, Hand GPS was used for tracking bank lines along the seven kilometer bend. Banklines were measured five times. Initially, it was collected at an interval of 2-4 weeks on 23rd April, 4th May, 1st June, and 20th June of 2010. But with the increase of water level the bank was submerged. And then, when the water level decreased the bankline data was collected on 25th November of 2010.

Float tracking data: Surface floats mounted with hand GPS were used to track surface stream lines. Floats track the surface stream lines and its convergence characteristics towards bank line. The method permits an immediacy of visual assessment of water movements and explores a reproducible and reliable technique for monitoring surface and subsurface current patterns (Duck et al., 1985). Total four floats were used to track surface stream lines within the developing channel. The flow tracker is a floating buoy having a fixed steel fin (Figure 4.2) hanging beneath the float. Fin works as propeller to keep the float stable in the wavy and windy condition during measurement. The mounted GPS is programmed for collecting data every 20 seconds continuously. The data was collected on the basis of increasing water level data. Approximately around 15 days of interval, data was collected so that the change of water level, change of flow hit point and active erosion point at bank is also clearly identified.

Surface float　　　　Bottom fin

Figure 4.2: Surface floats with fin

The collected float track and bankline data through Global Positioning System (GPS) were processed by using Path Finder Software, and then projected in Bangladesh Transverse Mercator (BTM) projection system. Then the data was plotted on geo-referenced Satellite image of 2010 to clarify spatial and temporal variation of flow processes and erosion along a developing bend at the downstream of the river training work. Using Co-ordinate Calculator, Tecplot 7.5 and Microsoft Office Visio 2003 software, two dimensional (2-D) surface velocity vectors were generated from the collected data and plotted in the planform.

B) Soil data collection

Grain size is one of the prominent factors for river erosion, so it is necessary to know the grain size distribution for understanding the river erosion. In the present research soil samples were collected from the upstream bed and bank and from the downstream bank. Sieve and hydrometer analyses were conducted for grain size distribution.

C) Social survey:

This study is basically a qualitative assessment to understand the local impact due to flow and erosion processes on the local community. The local impact emphasizes the use of river bank and river water of the poor local people living near the eroding bend of Paurashava and Kalia Haripur unions under Sirajganj Sadar upazilla of Sirajganj district. The study area is seven kilometer convex bend at the right (west bank) bank of the Jamuna River. Here the people who live very near to the bank are my study concern. Among six villages, two near bank villages are selected randomly which are good representative of the rest villages. To conduct the study, Participatory Rural Appraisal (PRA) tools like Key Informant Interview (KII), Focus Group Discussion (FGD), resource mapping, cause and effect diagram (Tree diagram) as well as matrices like pair-wise ranking method were adopted.

Key Informant Interview (KII): Key informant interview is qualitative in-depth interviews with people who know what is going on in the community. KII is conducted to get information about a pressing issue or problem in the community from a limited number of well-connected and informed community experts (UCLA Center for Health Policy Research). KII was conducted with Union Parishad member, village leader, and aged people who were well-aware about the relevant issues for major information and group formation for FGD.

<u>Focus Group Discussion (FGD</u>): Focus Group Discussion (FGD) was conducted to collect qualitative data and information regarding local impact of river bank erosion and flow process. The focus group discussion (FGD) is a rapid assessment, semi-structured data gathering method in which a purposely selected set of participants gather to discuss issues and concerns based on a list of key themes drawn up by the researcher/facilitator (Kumar 1987).

For the study six FGDs were conducted with the landless or partially landless erosion affected farmer group, wage labourer (Rickshaw puller, van puller, and boatmen), day labourer (earthen worker, sand collector) and female group of the community people. Around three sessions were conducted in each union which was affected by erosion. A good size for a discussion group is between 8 to 10 participants per session (Debus and Novelli; 1986). During this study, some focus group discussion consisted of 4 to 5 participants who have provided valuable information about their activity.

<u>Resource Mapping</u>

Resource Mapping is a method for collating and plotting information on the occurrence, distribution, access and use of resources within the economic and cultural domain of a specific community. For this study two resource maps were prepared by the villagers of the two villages in the drawing sheet to identify their resources such as houses, trees, roads, water bodies, water sources, etc.

<u>Cause and Effect diagram (Tree diagram):</u> Cause-and-Effect Diagram is a tool that helps to identify, sort, and display possible causes or different effects of a specific problem. A Cause-and-Effect Diagram is a tool that is useful for identifying and organizing the known or possible outcomes of a particular problem. The structure provided by the diagram helps team members think in a very systematic way.

Due to erosion process at Kalia Haripur bend, near bank inhabitants are facing difficulty in land use and water access due to high steep slope in river bank. The local problems that are faced by the local people were collected through cause and effect diagram to utilize group knowledge and easy-to-read format of the process.

Pair wise ranking method**:** Pair-wise ranking is a structured method for ranking a small list of items in priority order to prioritize a small list and make decisions in a consensus-oriented manner. It is a good tool to rank problems. Discussion was conducted in the light of the objectives to gather qualitative information on the impact of flow and erosion processes of the local people. The problems identified by cause and effect diagram were ranked by pair-wise ranking to have the priority based idea.

4.3.2 Secondary data collection

Time series satellites images were used in studying the flow and erosion processes of a developing bend of the Jamuna River between two important river training structures: Sirajganj hardpoint and the right guide bund of Bangabandhu Bridge (Table 4.2). Dry season satellite images were used for the analysis as cloud free optical images were available during this period.

Processed satellite images were used in this study as a good source of information. Satellite imageries were collected from Center for Environmental and Geographic Information Services (CEGIS). Images available in CEGIS had been subset using ERDAS IMAGINE 8.5 software. Geo-referenced images were used to delineate the large-scale bed-forms such as sandbars for analyzing the spatial and temporal variation. The delineated sand bars were superimposed in GIS environment to assess the shifting pattern of the sandbar. This analysis facilitated to assess the translation process of large scale bed forms such as sand bars. Also time series JPEG imageries (1973-2010) were used to assess the long term channel development and abandonment processes. Table 4.2 shows images acquisition date, type, and resolution. All images acquisition dates were of dry seasons.

Table 4.2 List of Imageries that are used in the analysis

Year	Image acquisition date	Image type	Resolution
2007	14 January 2007	ASTER	15m×15m
2008	9 December 2007	IRS LISS	24m×24m
2009	13 February 2009	IRS LISS	24m×24m
2010	15 January 2010	IRS LISS	24m×24m

4.4 Schematic Diagram of the Methodology

The overall study methodology is shown by schematic diagram in Figure 4.3. The details of the methodology are given in the subsequent section.

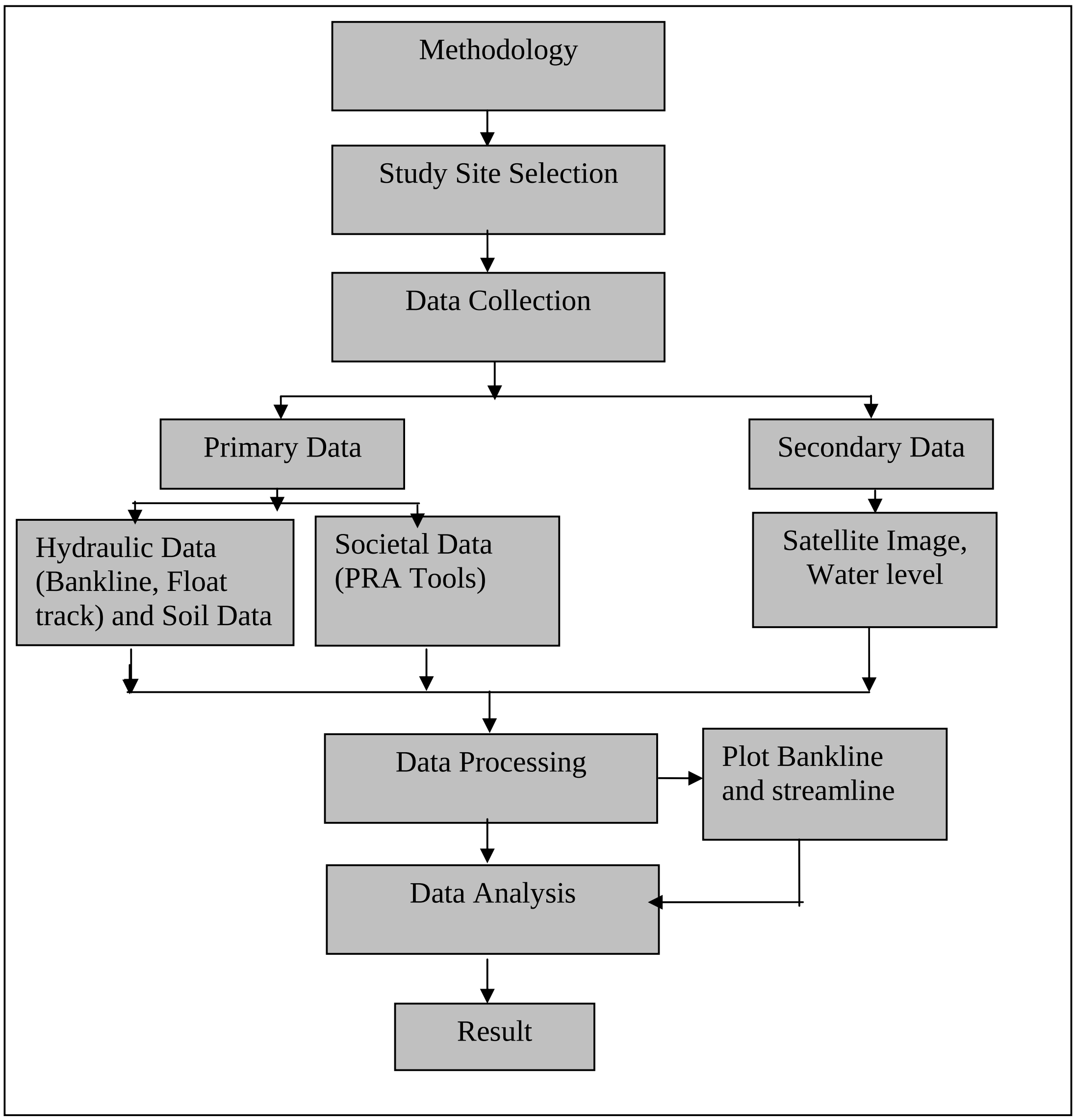


Figure 4.3: Schematic View of the Methodology

CHAPTER FIVE
FLOW AND EROSION PROCESSES IN A BEND

5.1 Introduction

River bank erosion is a severe problem in Bangladesh especially along the braided Jamuna River considering both the scale and intensity of erosion. Thousands of hectares of floodplain land are eroded each year, leaving many people homeless with damaging or destroying infrastructures by the mighty Jamuna River. Because of the dynamic nature, it causes the sufferings to the people along with damages to public and natural resources. To prevent bank erosion, different types of protection structures have already been constructed at the erosion prone areas of the river. The structural measures are sometimes ineffective due to the morphological change of the river and rapid erosion occurs at the upstream and downstream of the structure of non-cohesive bank materials. Also discontinuous construction of the structures may often become threat to the structures. Along with these structural measures some non-structural measures, management options need to be introduced to minimize the loss of erosion. Before taking these measures a thorough understanding of flow characteristics and their interaction with channel geometry and planform is essential (Bathurst, 1997).

The Jamuna River is a braided river with a braiding index that varies spatially as well as temporally. Braiding index plays a significant role in the erosion and sedimentation processes along the braided location. As stated in FAP 24 (1996) study, the range of variation of braiding index of Jamuna River is 2 to 5 while, the estimated braiding index using Brice (1964) method of the study site is around 6. This higher range of braiding index indicates that the study reach is quite active and erosion-deposition occurs with very short time scale. Figure 5.1 shows the estimation of braiding index of the study site according to Brice (1964) method where channels having width above 150 meter is considered. According to Brice, braiding index is defined and calculated as follows,

Braiding Index (BI) = (2* Length of the all islands or bars of the reach)/ (length of the reach measured midway)

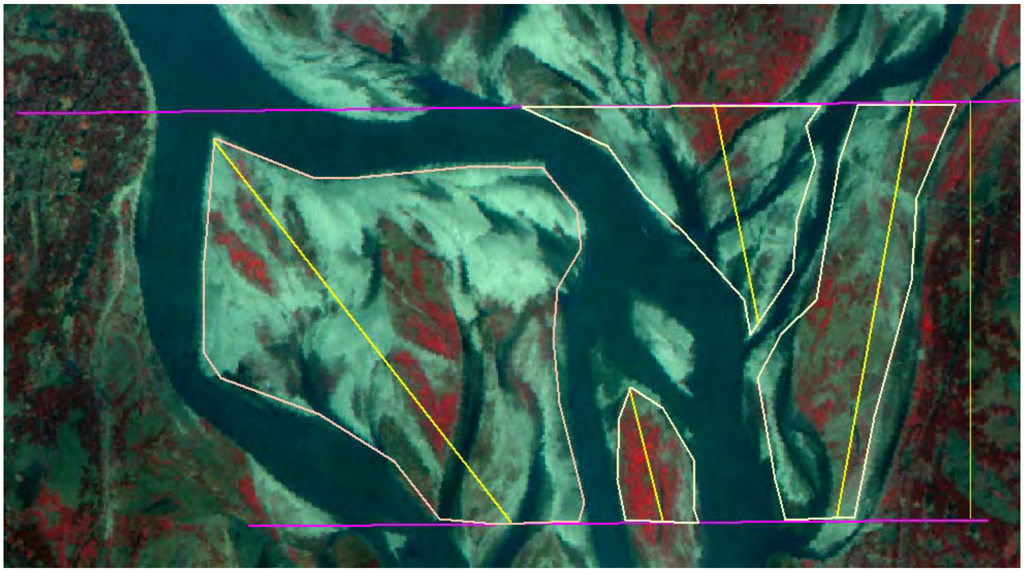


Figure 5.1: Braiding Index estimation of the study site according to Brice (1964) method

The bend or embayment is developed in the Jamuna River due to rapid erosion. The magnitude and direction of near bank flow at bends accelerate the erosion processes. The near bank flow process is governed by the dry season bed features to some extent, specially, at the beginning of the rising stage. The large scale bed features such as sand bars are the major flow guiding factor towards bank line and channel shifting. To understand the dynamics of the upstream morphology and to clarify the flow processes in a developing bend, the present research has been conducted in a second order (Bristow, 1987) channel within the braided Jamuna River.

5.2 Upstream Morphology of the Bend

Bars are the part of the fluvial dynamics of the rivers. Bar dynamics relate to the morphologic behavior of rivers and in particular to the bank erosion processes and the prevailing trends of flow processes of rivers. To understand the dynamics of the upstream morphology such as large scale sand bars, a time series satellite image based analysis has been conducted. One ASTER image of 2007 and three geo-referenced IRS LISS images of 2008 to 2010 have been superimposed to assess the changes of sand bar movement and channel shifting over the years. Bar characteristics are also significant for the bar translation process.

5.2.1 Bar characteristics

The main channel of the Jamuna River is flowing parallel to the Sirajganj Hardpoint structure along the western side and then bifurcated at the downstream of the Hardpoint (Figure 5.5). The bifurcated right channel is the study Kalia Haripur bend which has been developing towards the south-west direction about three and half kilometer and then turns in the south-east direction. From the dry season ASTER (2007) and IRS LISS (2008, 2009, and 2010) images it can be seen that two sandbars are present at the upstream and beside the study bend. The sand bars at the upstream and adjacent to the study area are referred to as sandbar 1 and sandbar 2 (Figure 5.2, 5.3, 5.4, and 5.5), respectively. In general, boundaries of the sand bars were defined as a line, which separates the land area (sandy bare land and vegetated land). These bars are of different size and shape and they translate both laterally and longitudinally at different rates during the study period. Their length, width, area and translation processes are described in the following sections.

Bar length

Bars have different sizes within the braided belt of the Jamuna River. Bar length is defined here as the longest distance along the longitudinal direction. An assessment of the images show that the length of Sandbar 1 varies from 5 to 6.5 kilometer and for Sandbar 2 that is of 3.5 to 5.9 kilometer during 2007 to 2010 (Table 5.1).

Table 5.1: Changes in length of the sandbars of the study bend

Year	Length of Sandbar 1 (km)	Length of Sandbar 2 (km)
2007	5	5.9
2008	5.6	3.5
2009	6.5	4.6
2010	5	5.6

The length of the Sandbar 1 increased from 2007 to 2009 and after that it stopped increasing. The reason for the increase of length is related with the upstream erosion and huge sediment intake. On the other hand sandbar 2 had maximum length of 5.9 kilometer during 2007 and after that its length was reduced to 3.5 kilometer. The reason of the reduction of bar length is probably due to the protection of upstream erosion by means of Sirajganj Hardpoint structure. During 2009 to 2010, sandbar 2 translated downstream and its length increased from 3.5 to 5.6 kilometer due to high erosion of the western study bend (Figure 5.4 and Figure 5.5).

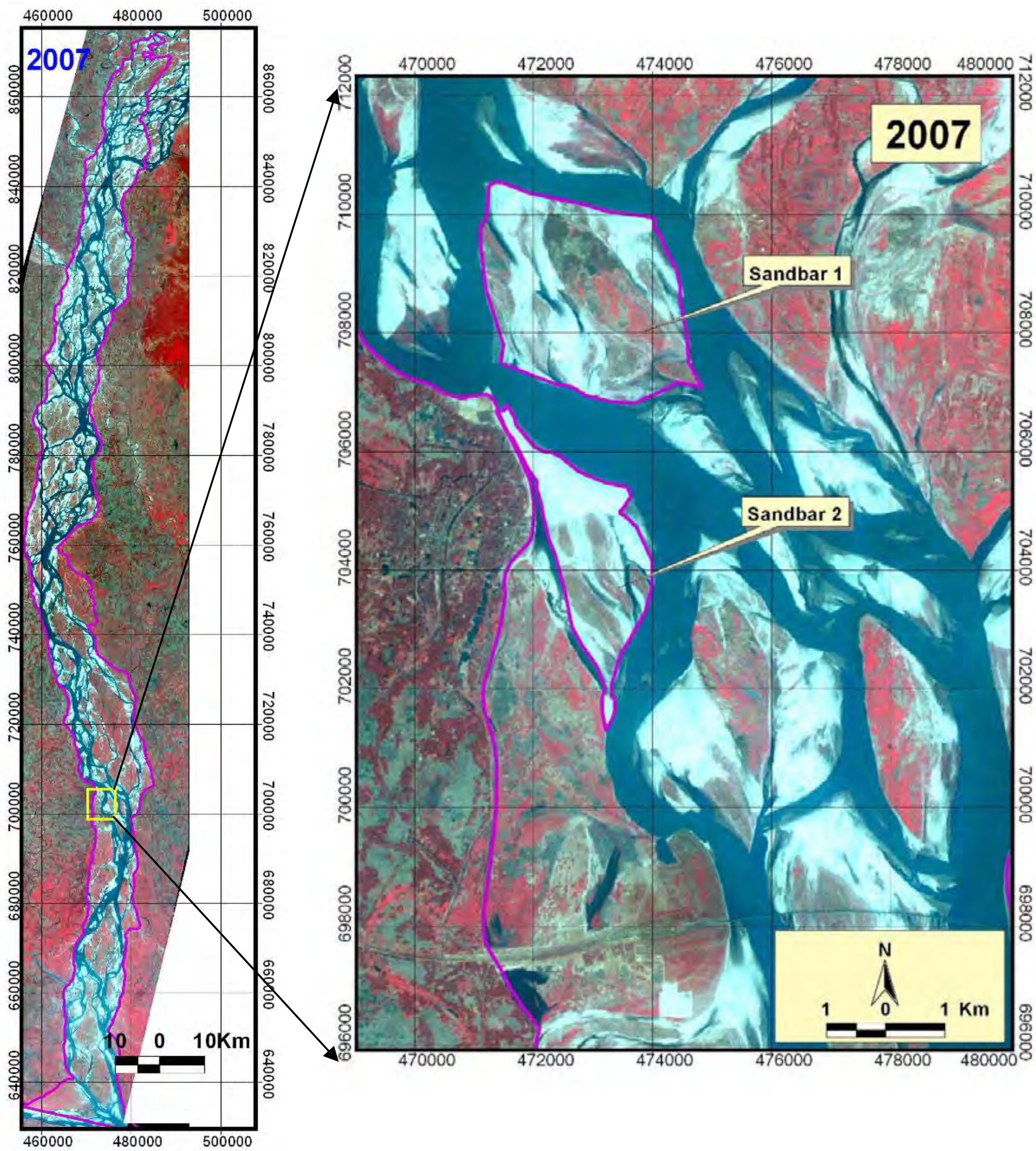


Figure 5.2: Satellite image of 2007 Jamuna River showing the bar formation of the study bend

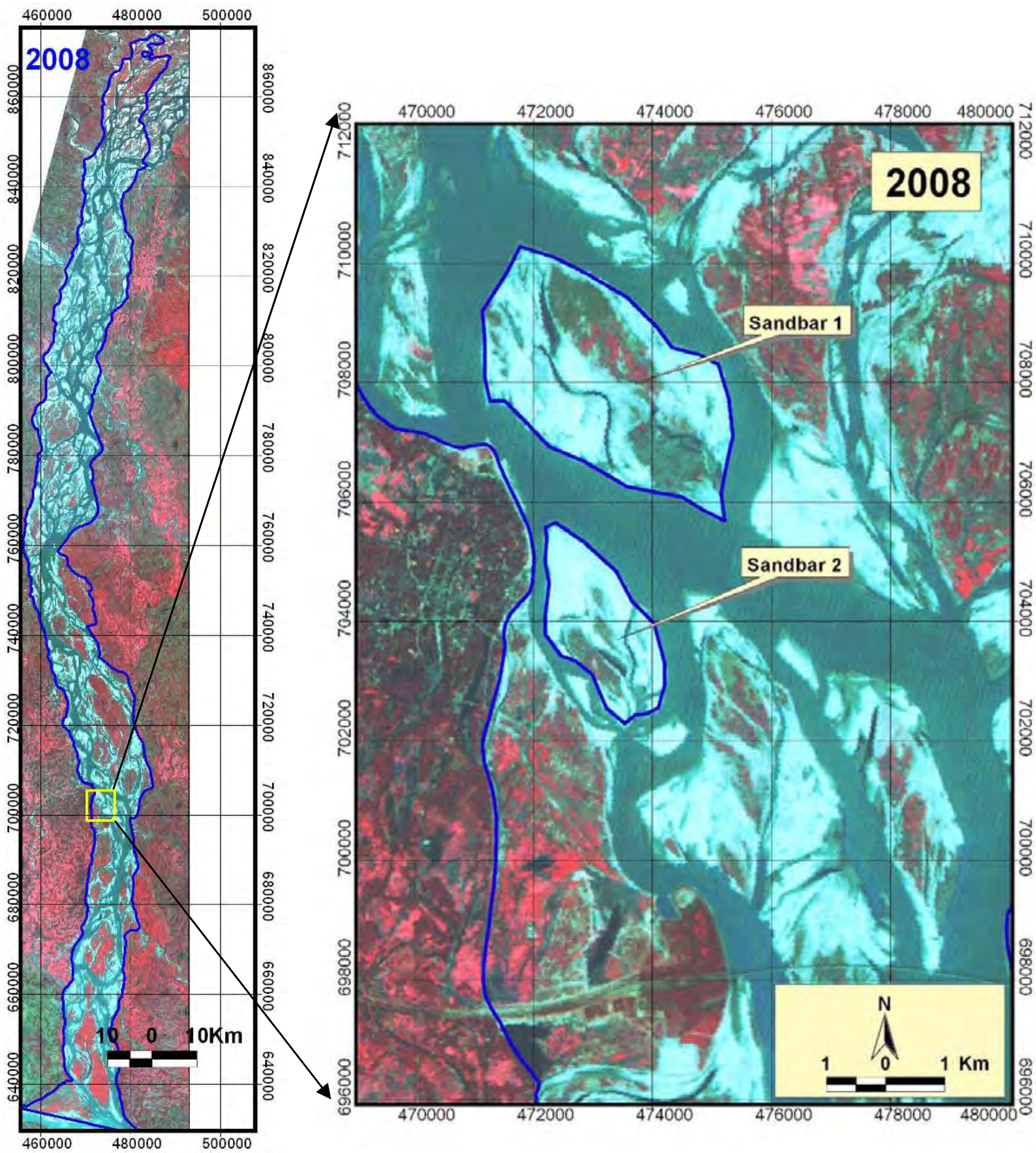


Figure 5.3: Satellite image of 2008 Jamuna River showing the bar formation of the study bend

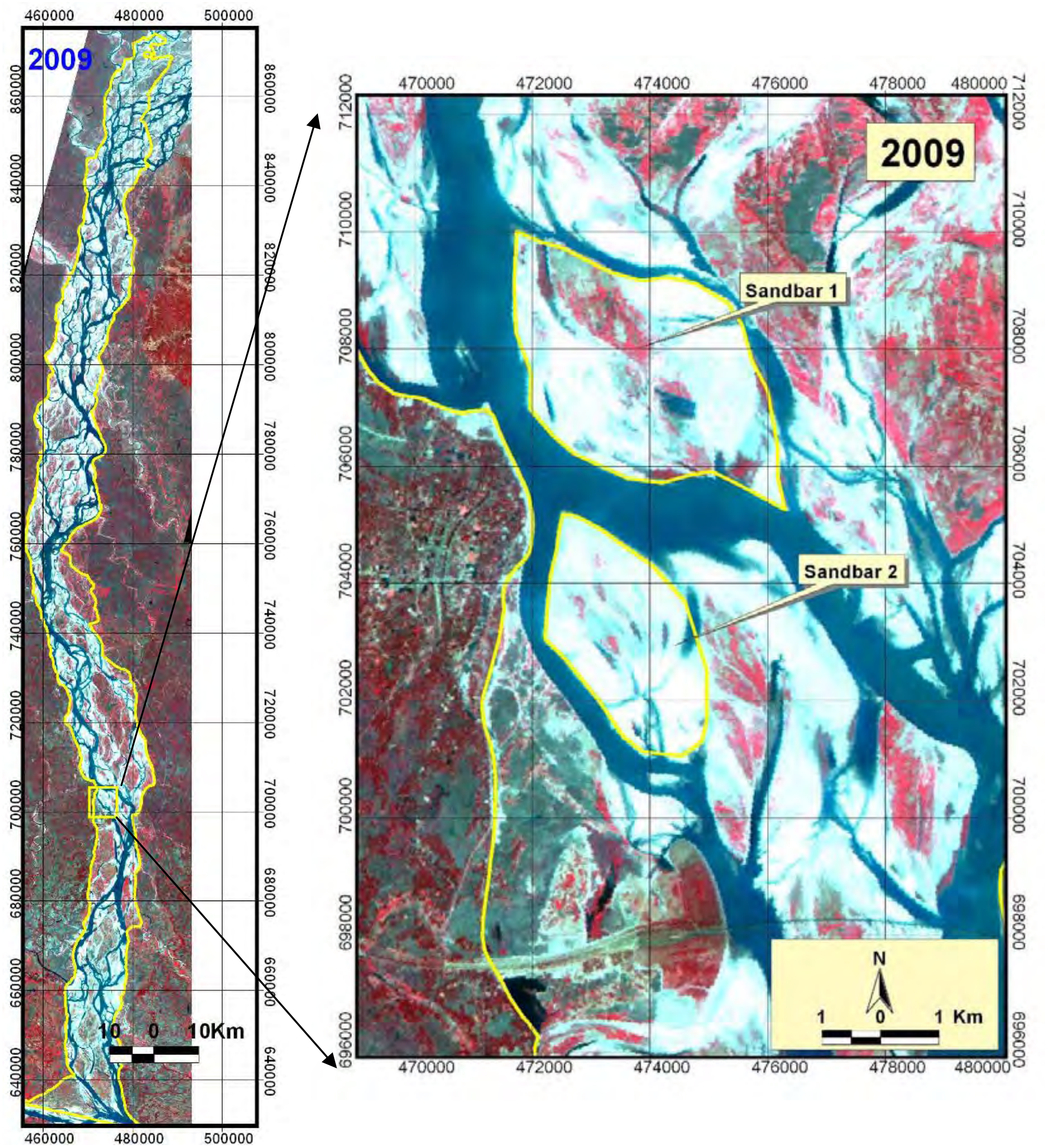


Figure 5.4: Satellite image of 2009 Jamuna River showing the bar formation of the study bend

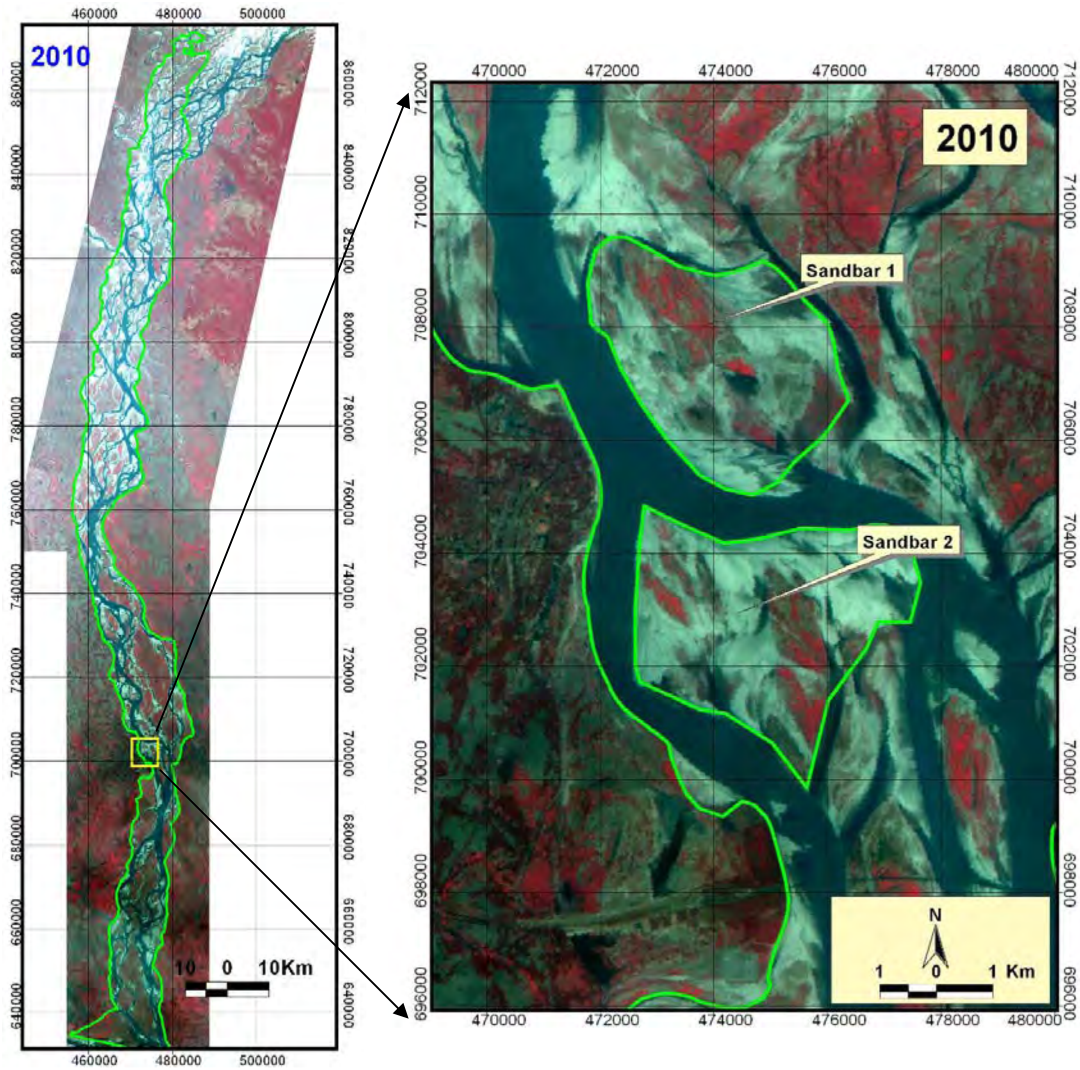


Figure 5.5: Satellite image of 2010 Jamuna River showing the bar formation of the study bend

Bar width

In case of bar dimension, width is defined as the shortest distance between two dimensions. In this analysis, the width of the bar was estimated as the land area divided by the length of the bar measured through the centerline. The length-averaged width of the bars of Jamuna River varies over time and space. The maximum width of the upstream sandbar 1 was found 3.5 kilometer during 2009 though the length-averaged width varied from 1.97 to 2.66 kilometer during 2007 to 2010 (Table 5.2**,** Figure 5.6). The width of sandbar 1 increased gradually during 2007 to 2009, only 17% of the total increase and the rest 83% increased within the following 1 year period. The reason is sandbar 1 could not extend western side due to Sirajganj Hardpoint structure but later on it translated downstream extending in the eastern side.

The maximum width of the sandbar 2 varied from 1.5 to 4.9 kilometer, but the length-averaged width varied from 0.81 to 2.61 kilometer as measured using the satellite images of 2007-2010 (Table 5.2**,** Figure 5.7). The width of sandbar 2 increased at a rate of 0.4 kilometer per year during 2007 to 2009 and that of 1.02 kilometer per year during 2009 to 2010 due to massive at the adjacent western bank of the river and as a result the study meander bend developed.

Table 5.2 Changes in length-averaged width of the sandbars adjacent to the study bend of the Jamuna River

Year	Width of Sandbar 1 (km)	Width of Sandbar 2 (km)
2007	1.97	0.81
2008	2.02	1.13
2009	2.09	1.59
2010	2.66	2.61

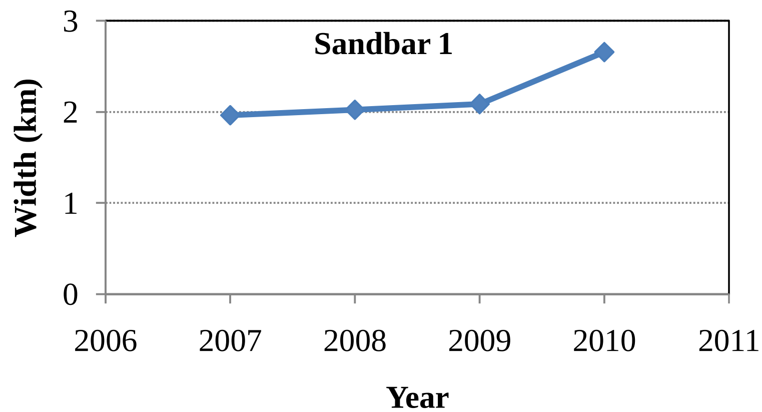


Figure 5.6: Changes in length-averaged width of sandbar 1 upstream of the study bend of the Jamuna River over time

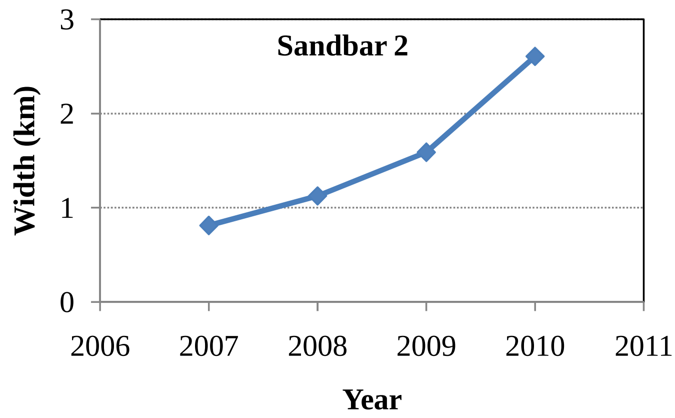


Figure 5.7: Changes in length-averaged width of sandbar 2 adjacent of the study bend of the Jamuna River over time

Bar area and width-length ratio

The area of the sandbar 1 varied from 9.83 to 13.56 sq. km and that of sandbar 2 varied from 3.94 to 14.61 sq. km during 2007 to 2010 (Table 5.3). The area of the sandbar 1 increased from 2007 to 2009 and after that it stopped increasing. The reason for the increase of area is related to the upstream erosion and massive sediment intake. On the other hand sandbar 2 had an area of 4.79 sq. km during 2007 and after that its area reduced to 3.94 sq. km. The reason of the reduction of bar area is probably due to the protection of upstream erosion by means of Sirajganj hardpoint structure. During 2008 to 2010, sandbar 2 translated downstream and its area increased from 3.94 to 14.61 sq. km due to high erosion of the western study bend (Figure 5.8).

Table 5.3 Changes in area and width to depth ratio of the sandbars of the study reach

Year	Area (Sq. km)		Ratio of width to length	
	Sandbar 1	**Sandbar 2**	**Sandbar 1**	**Sandbar 2**
2007	9.83	4.79	0.39	0.14
2008	11.33	3.94	0.36	0.32
2009	13.56	7.31	0.32	0.35
2010	13.29	14.61	0.53	0.47

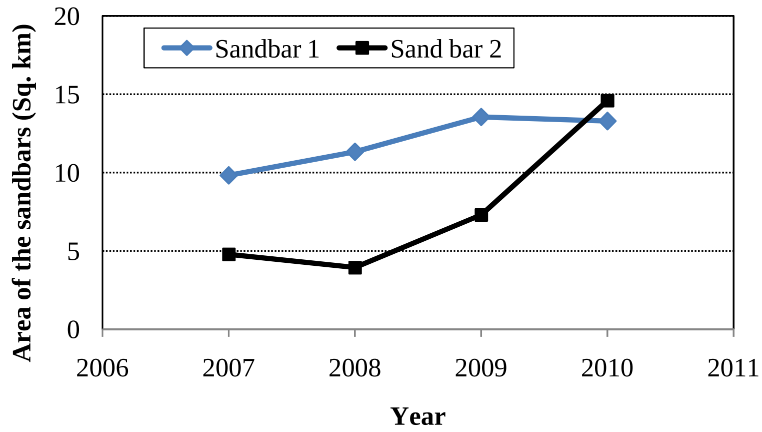


Figure 5.8: Changes in area of the sandbars over time

The ratio of width to length of the sandbar 1 varied from 0.32 to 0.53, while for sandbar 2 the ratio varied from 0.14 to 0.47. Sandbar 1 received sediment from upstream bank erosion which caused the higher value of width to length ratio than that of sandbar 2.

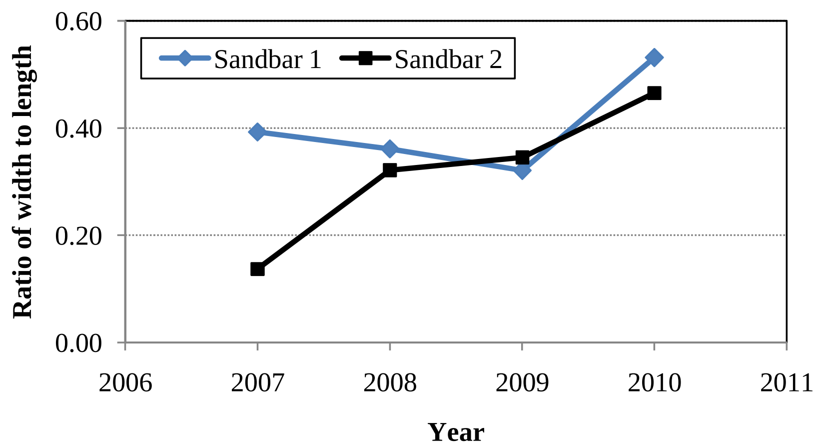


Figure 5.9: Changes in ratio of width to length of the sandbars over time

Bar translation

Bars translate both in lateral and longitudinal directions. In this analysis, lateral translation in each year was measured from the centreline of the 2007 bar towards the western direction. Eventually, longitudinal translation was measured from the head end of the sand bar of 2007 towards the downward direction (Figure 5.10). The maximum lateral translation is defined as the maximum distance of a bar that extends along western side from the centreline of 2007 bar.

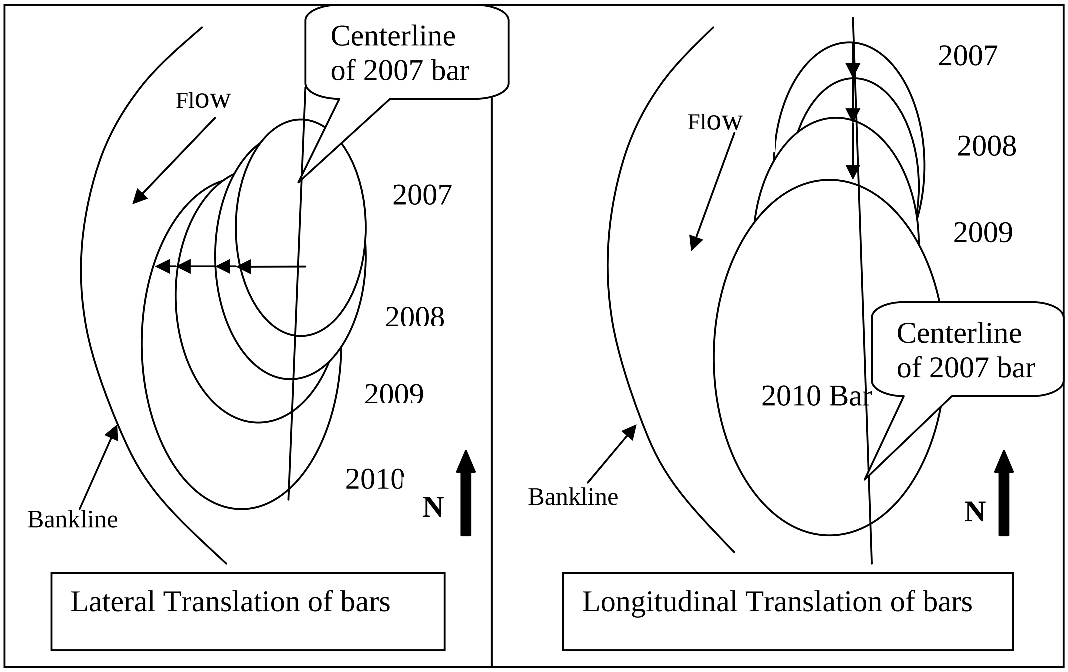
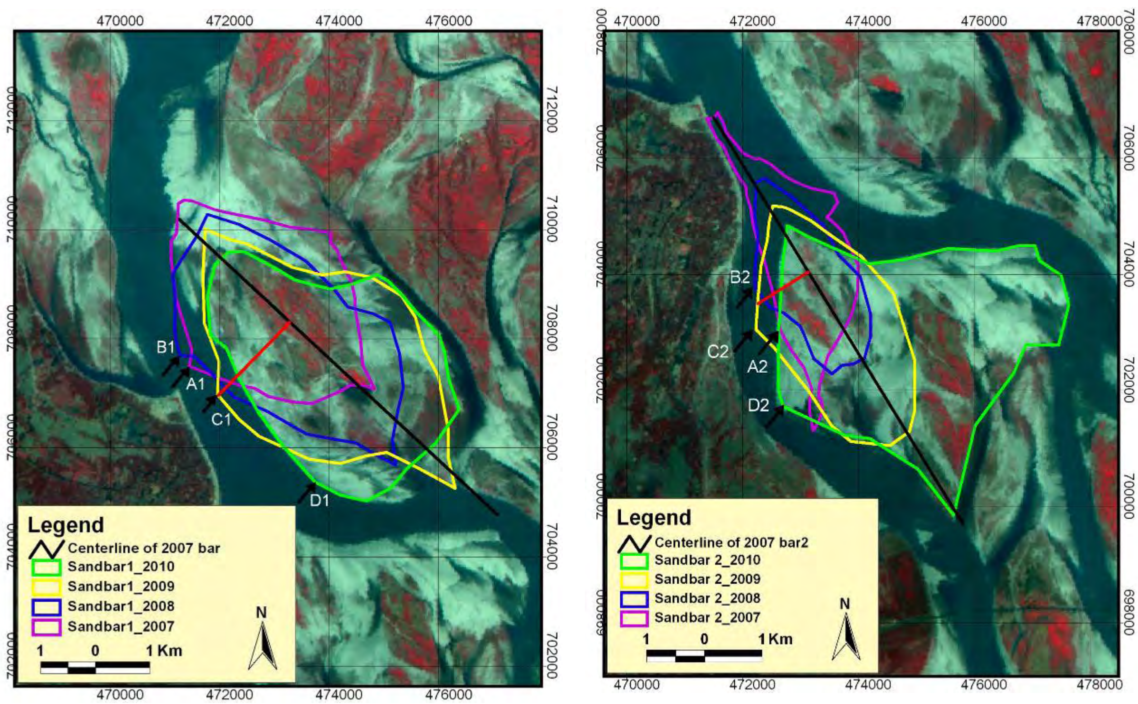


Figure 5.10: Definition diagrams of lateral and longitudinal translation of bars



(A, B, C and D indicates the maximum lateral translation points for 2007, 2008, 2009 and 2010 , respectively, while 1 and 2 stands for sand bar 1 and sand bar 2, respectively)

Figure 5.11: Lateral translation of sandbar 1(left) and sandbar 2 (right)

Lateral translation

Figure 5.11 shows the lateral translation of sandbars at a section by red line and maximum lateral translation point A1, B1,C1, D1; A2, B2, C2, D2. During 2007 to 2009 both sandbars extended gradually along western side i.e. the bank side but after that, the extension was reduced (Table 5.4). The reason for the variation of lateral extension was different for bar 1 and bar 2. In case of sandbar 1, the western side revetment structure (Sirajganj Hardpoint) made obstruction to extend the bar and divert the flow to erode the west part of sand bar1. And for sandbar 2, due to upstream revetment the bar could not manage enough sediment to extend at that section. Rather it washed away and deposited sediment downstream of the sandbar 2. Also the rate of extension of sandbar1 was higher than sandbar 2 resulting sandbar 1 had got upstream sediment but Sirajganj Hardpoint constrained the bank erosion and sediment availability of sandbar 2.

Table 5.4 Changes in lateral translation of the sandbars

Year	Lateral Translation of Sandbar1 (kilometer)	Lateral Translation of Sandbar2 (kilometer)
2007	1.54	0.73
2008	1.69	0.91
2009	1.87	1.06
2010	1.36	0.56

The maximum lateral translation of sandbar 1 during 2007 and 2008 was at A1 and B1 (Figure 5.11 left) which was just upstream of the upstream termination of Sirajganj Hardpoint. The flow was guided by the sandbar and diverted towards the upstream termination which caused undermining in 2007 and damage in 2008 (Uddin and Rahman, 2009). The maximum point C1 of 2009 bar and D1 of 2010 bar (Figure 5.11 and 5.12) translated downstream from the upstream termination which caused damages of the hardpoint downstream from the termination. During 2009 the maximum translated point was just upstream of northing 706000 and the damage was also near northing 706000, which clarify the bar effect (Uddin, 2010). The west ward translation of the sandbar 1 diverted the flow towards the Hardpoint structure and caused undermining and damages during different years.

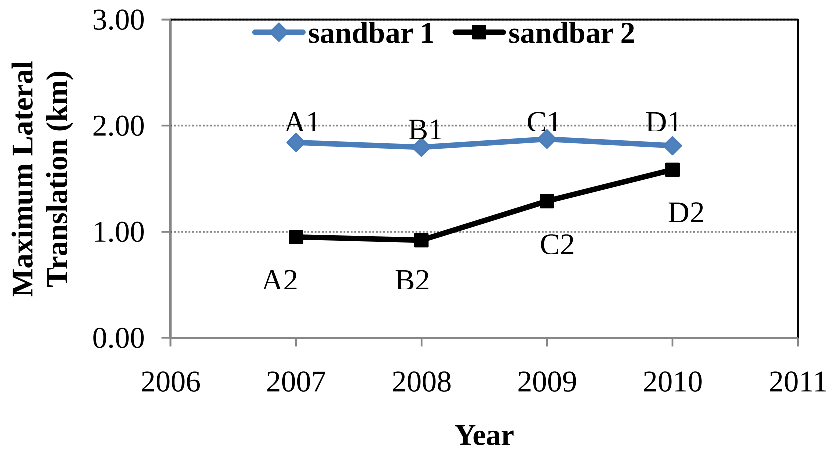


Figure 5.12: Maximum lateral translations of sandbar 1 and sandbar 2

Due to the position of sandbar 2 in 2007 a very narrow channel (100 to 150m) was flowing through the study bend (Figure 5.2). The maximum lateral translation of sandbar 2 during 2007 was below 1 kilometer and occurred quite downstream at A2 point (Figure 5.11 right). After that the maximum lateral translation of sandbar 2 increased (Figure 5.12) and occurred at B2 in 2008, at C2 in 2009 and at D2 in 2010 which also translated downstream consecutively (Figure 5.11 right). Flow was diverted by the sandbar 2 extreme west point towards the bank and by eroding the bank the bend consequently developed.

Longitudinal translation

Sandbars are also moving towards longitudinal direction. Longitudinal movement is measured as a distance travelled by the upstream end of the bar towards the downstream direction in the consecutive years. The longitudinal translation of sandbar 1 and sandbar 2 during 2007-2010 is shown in Figure 5.13. During 2007 to 2010, sandbar 1 translated 150 to 600 meter per year and sandbar 2 moved 450 to 1300 meter per year (Figure 5.14 and Figure 5.15).

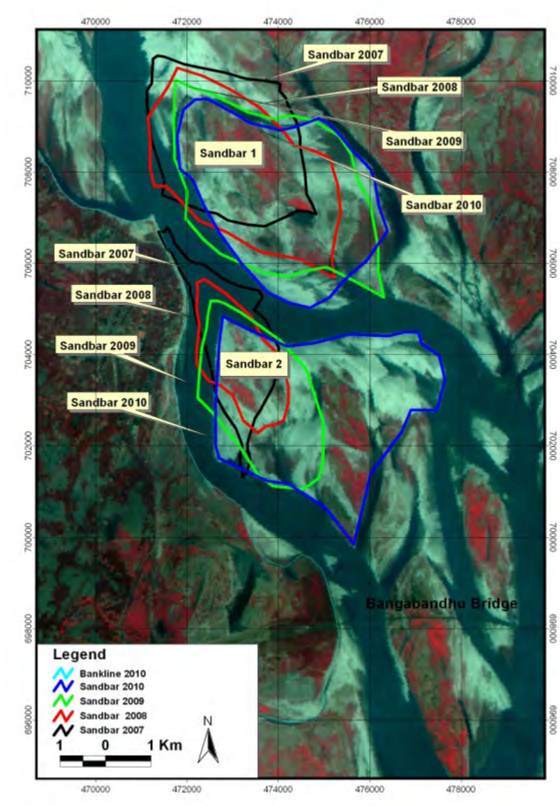


Figure 5.13: Longitudinal translations of sandbars around the study area

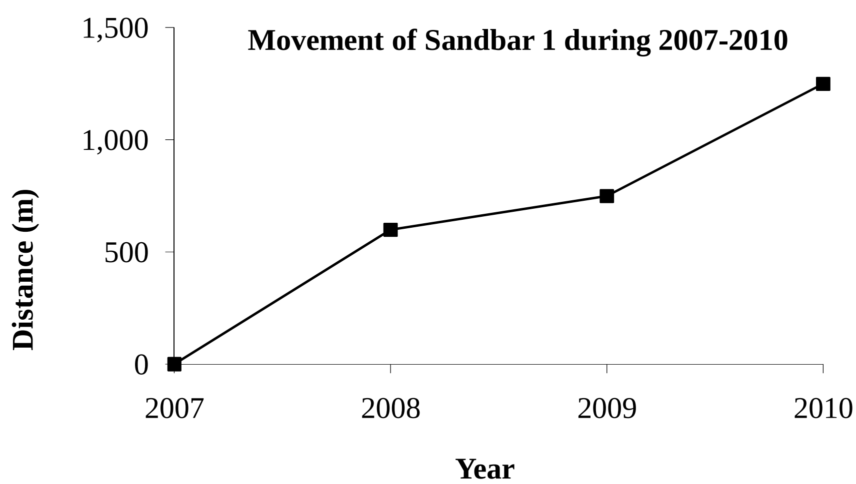


Figure 5.14: Downstream translation of bar front of sand bar 1

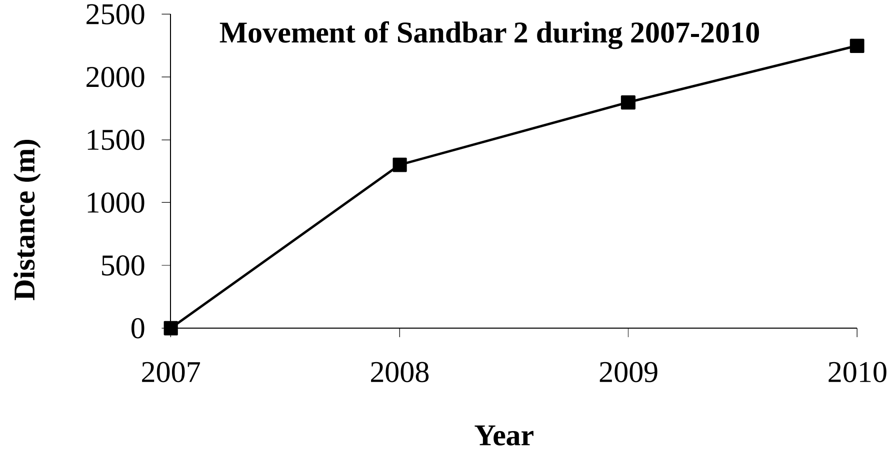


Figure 5.15: Downstream translation of bar front of sand bar 2

The rate of movement of sandbar 2 is higher than that of sandbar 1 because sandbar 1 was obstructed by the revetment structure as well sandbar 2 could move downstream without facing any obstacle. In 2010, sandbar 2 diverted flow towards downstream bend and caused huge erosion at the downstream part of the bend. As a whole, due to the translation of sandbars along downstream, flows were diverted towards the bank and caused bank erosion.

5.2.2 Prediction of failure point of structure

Analysing the previous history of the location of failure point of Sirajganj Hardpoint, a schematic diagram was drawn in Figure 5.17 which tried to predict failure point of the structure in the coming year using the dry season satellite imageries. Failure points were investigated from previously available information (Uddin, 2010) for the years of 2008 and 2009 as shown in Figure 5.16. With the help of that information a tangent was drawn at the upstream western side of the bar which directly hit the failure point. Adopting this method a hitting point was predicted for the year of 2010, which was quite close to the actual damage point. For the practical use of this approach, further analysis is required.

(a) (b)

Figure 5.16: Failure of Sirajganj hardpoint structure at different locations, (a) Failure of the Sirajganj hardpoint near upstream termination in 2008, (b) Failure of the Sirajganj hardpoint near northing 706000 in 2009, Uddin (2010)

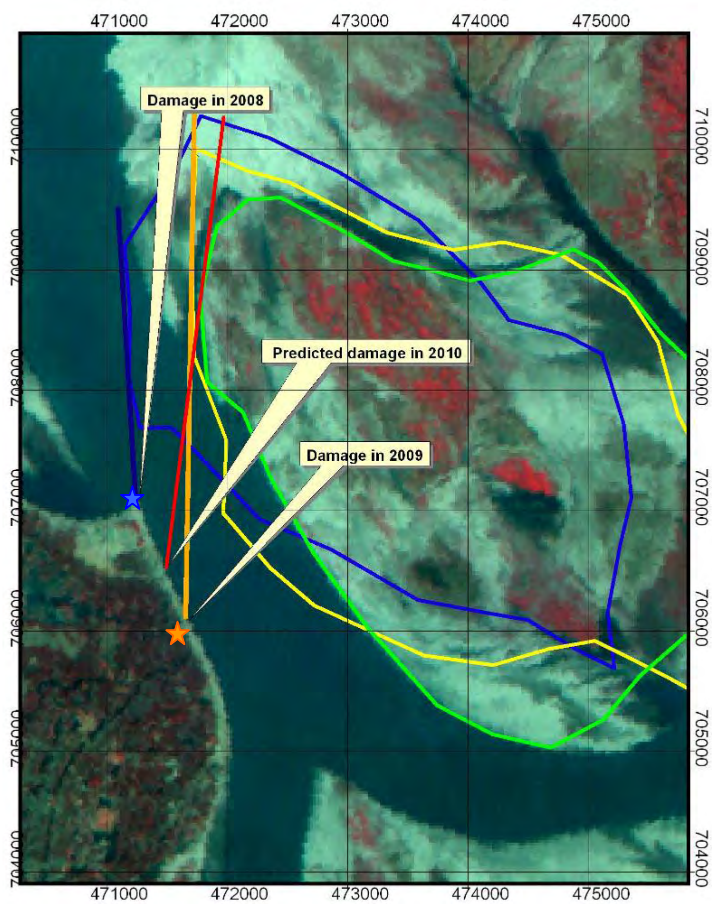


Figure 5.17: Failure points of Sirajganj Hardpoint at different years shown in IRS LISS image of 2010

5.2.3 Bar migration cessation: Comparison with typical meander bend

In a typical sine-generated meander bend, whether bars migrate with various bend angle and wavelength at various discharges is shown in Figure 5.18. Migration is defined explicitly as translation of the bar unit beyond one planform wavelength with a maintenance of symmetry, that is , pools and oblique faces along one bank remain along that bank. In Figure 5.18 data have been plotted from the empirical threshold curve of Kinoshita and Miwa (1974) where channels with straight segments joined at an angle, the theoretically derived threshold curves of Hasegawa (1983), Seminara and Tubino (1989) and the data from Whiting and Dietrich (1993) experiments for sine curved channel follow the equation

$$M\ /W\ = (\cos\omega \sin\omega)^{-1} + 2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (5.1)$$

Here M= Meander wavelength, W= Channel width and ω =Bend angle. Figure 5.18 shows that bars are capable of moving through larger-angle bends as the relative wavelength decreases. For a characteristic eight-width channel the critical angle is near 10° and this value increases to near 15° for six-width channels. An angle of 7° is sufficient to trap bars when channel wavelength is near 10 widths.

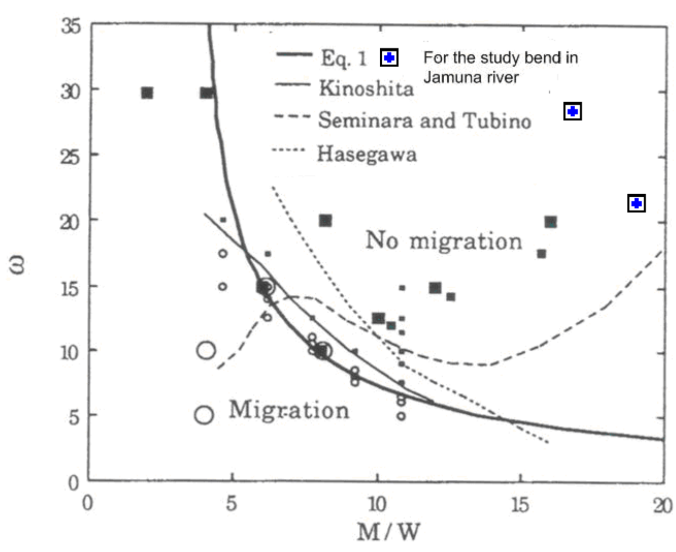
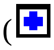


Figure 5.18: Behaviour of bars in plan forms with various bend angles and wavelengths.

Migration is indicated by circles, non-migration by squares. The largest circles and squares are data from experiments reported from Whiting and Dietrich (1993); intermediate size squares are from Colombini et al. (1992) and the smallest symbols are from Kinoshita and Miwa (1974). The geometric relation delineating migration (equation (5.1)) is shown and compared to the migration criterion of Kinoshita and Miwa (1974), Hasegawa (1983), and Seminara and Tubino (1989). Also data obtained for the study bend of Jamuna River plotted on Figure 5.18 by the symbol () which fall in the non-migrating zone, though the bars are migrating. This indicates that the characteristic of a bend channel of braided river exhibits difference as compared with a sine generated single thread meandering channel. The reason for this difference is the curvature effect diminishes when sand bars are submerged and the unsteady flow becomes nearly straight. The bend channel is then no longer behaving as a meander channel; rather it is functioning as a straight channel.

5.3 Grain Size Analysis

Soil properties have great influence on the development and abandonment processes of river bank. Erosion scale can be different along the same reach due to the different grain size distribution. The grain size analysis is performed to determine the percentage of different grain sizes contain within a soil. The sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

Table 5.5: Location and date of sample collection and value of d_{50}

Date	Location	Value of d_{50}
4.05.2010	Upstream bank	0.075
	Downstream bed	0.12
	Downstream bank	0.14

Figure 5.19 shows the grain size distributions of the study bend. The grain size distribution d_{50} of upstream bank is 0.075 mm, downstream bank is 0.14 mm and downstream bed is 0.12 mm as shown in Table 5.5. So the d_{50} of the study reach is around 0.11 mm which represent the soil of the bend is non-cohesive silty sand and that type of soil is vulnerable to erosion. In the previous studies the value of d_{50} of the bed materials of Jamuna River varies between 0.35 to 0.1 mm (FAP 24, 1996) and average d_{50} is 0.2 mm (CEGIS, 2010), which are very close to the d_{50} found in the study bend. The Upstream bank soil is finer than the downstream bank soil which is the cause of huge downstream erosion than the upstream of the study bend.

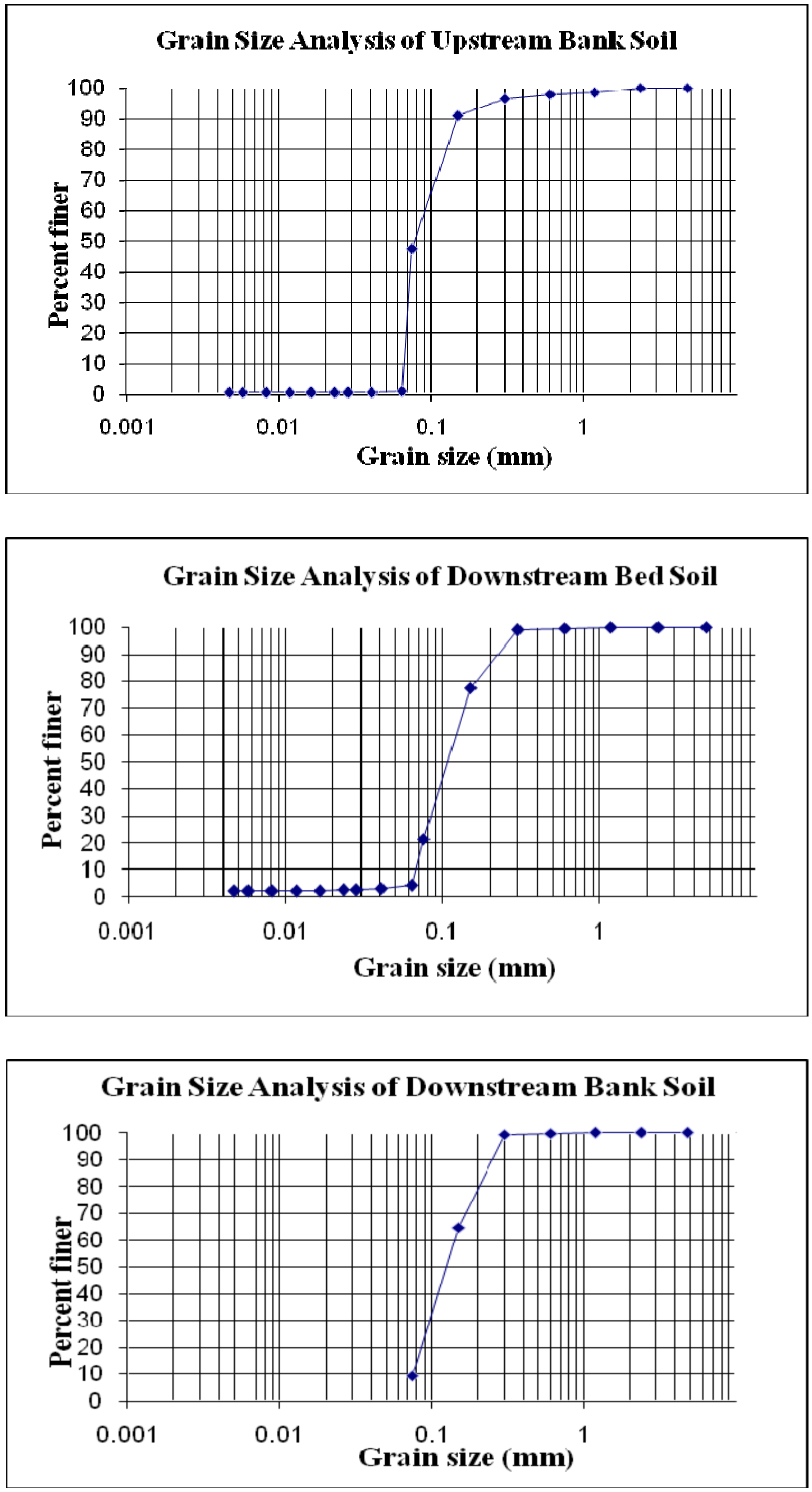


Figure 5.19: Grain size distribution in the study bend

5.4 Flow and Erosion Processes Along the Study Bend

5.4.1 Spatial and temporal variation of flow and erosion processes

The float tracking data were collected at the rising stage (April to July, 2010) and at the falling stage (November 2010). The floats were deployed from the downstream end of the Sirajganj hard point and collected from the belt mouth of the Bangabandhu Bridge. The number of floats was selected on the basis of the width of the channel and the availability of floats. During the dry season, when the channel was around 600 meters two floats were deployed. With the velocity variation of different section of the river both the floats had different velocities. With the change of the season from dry to wet, the width of the channel was increased due to water level rise, and the nearby sand bars were submerged. At that time the width of the channel was more than one kilometer and the number of float tracks also increased. Total four floats were used to track surface stream lines within the developing channel. The data were collected on the basis of increasing water level (Table 5.6, Figure 5.20). Around 15-25 days interval data were collected so that the change of water level, change of flow convergence point and active erosion point at the bank were also clearly identified.

Table 5.6: Field survey dates and corresponding water level data at Sirajganj hardpoint

Date	Water Level (m PWD)
23rd April	9.98
4th May	10.59
1st June	11.28
20th June	12.19
13th July	12.89
25th November	8.6

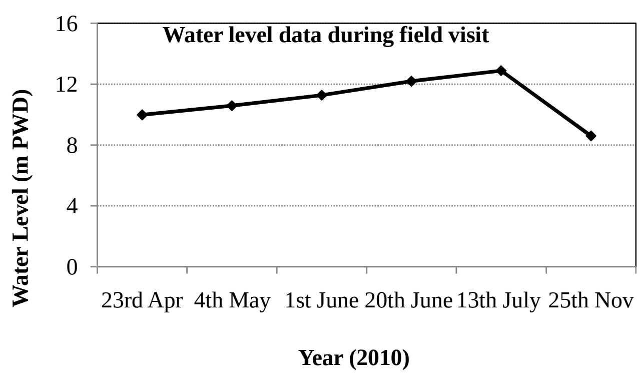


Figure 5.20: Variation of water level during differrent months of 2010 at Sirajganj station

After the plotting of float track data in Satellite image using Path Finder and ArcView softwares, it was found that, with the floats which were deployed near the bank line moved straight and reached up to a certain point (say, convergence point) of bank line and then sharply turned and moved towards the downstream maintaining a distance from the right guide bund of the Bangabandhu Bridge. With the increase of the water level, the convergence point was shifted from upstream of the bend apex towards the downward (Figure 5.21). And the distance between the right guide bund and the float was decreasing. It clearly indicated that, with the increasing water level the convergence point was also moving downward which was quite similar to the laboratory findings of Silva and Tahawy (2008). Severe erosion was also observed near and around the convergence point. This types of situation observed on 23rd April, 4th May, and 1st June of 2010 when the water level was 9.98 m, 10.59 m and 11.28 m respectably (Table 5.6). After that on 20th June though the water level was also rising, the convergence point remain near the previous date (1st June) convergence point and erosion occurred downstream of convergence point (Figure 5.21 and Figure 5.22). Up to these dates, the bank line was visible. But later, on 13th July, it was found that, the water level (12.89 m) was too high and it overtopped the bank and submerged the floodplain for that the bank line was not visible. The convergence point of that date was found at upstream of all other previous convergence points. But after a long time period on 25th November of 2010, when the water level reduced to 8.6 m the convergence point was observed at the upstream of the bend (Figure 5.21 and Figure 5.22) and erosion was also observed near the convergence point.

It was observed that at the rising stage, the near bank convergence point was at upstream of bend apex and with the change of time and water level the convergence point shifted downstream from the bend apex. At that time the developing bend of the braided river behave like a confined meander bend. But after a certain increase of water level when water level overflowed the sandbar and also the bankline, the convergence point did not shift further downstream. Rather it was shifted towards the upstream. At this stage the flow coming over the submerged sandbar had little influence in causing erosion. In such situation, the bend channel within a braided river was no longer behaving like a meander channel. Rather it was functioning as a straight channel.

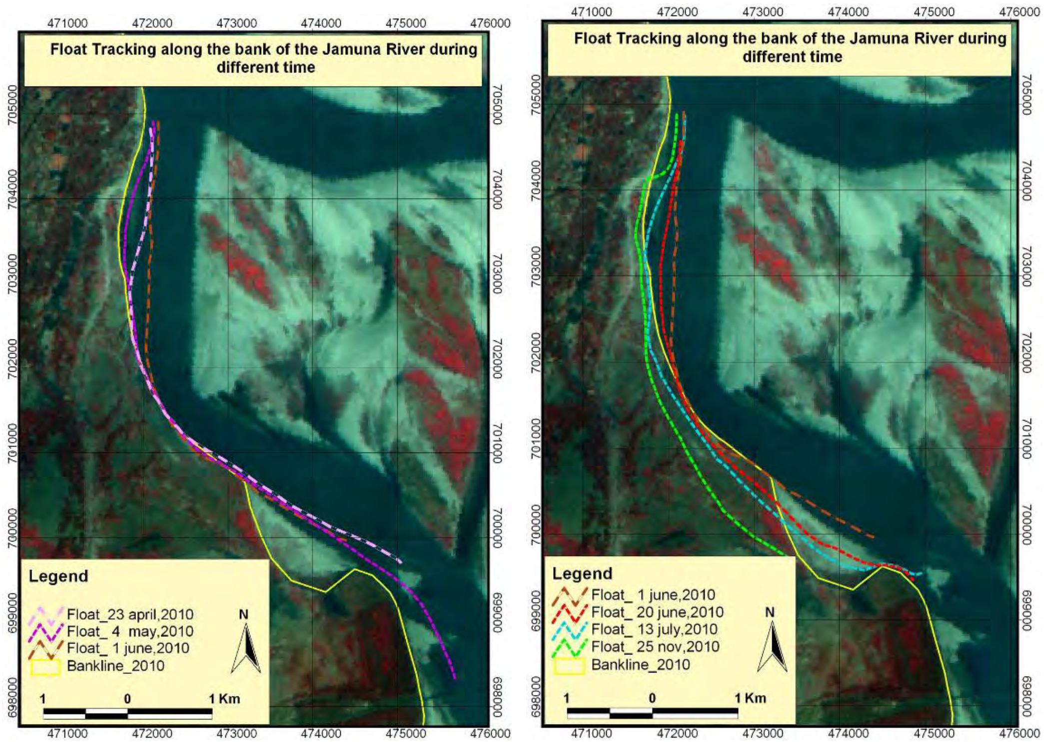


Figure 5.21: Spatial and temporal variation of near bank flow processes along the develping bend

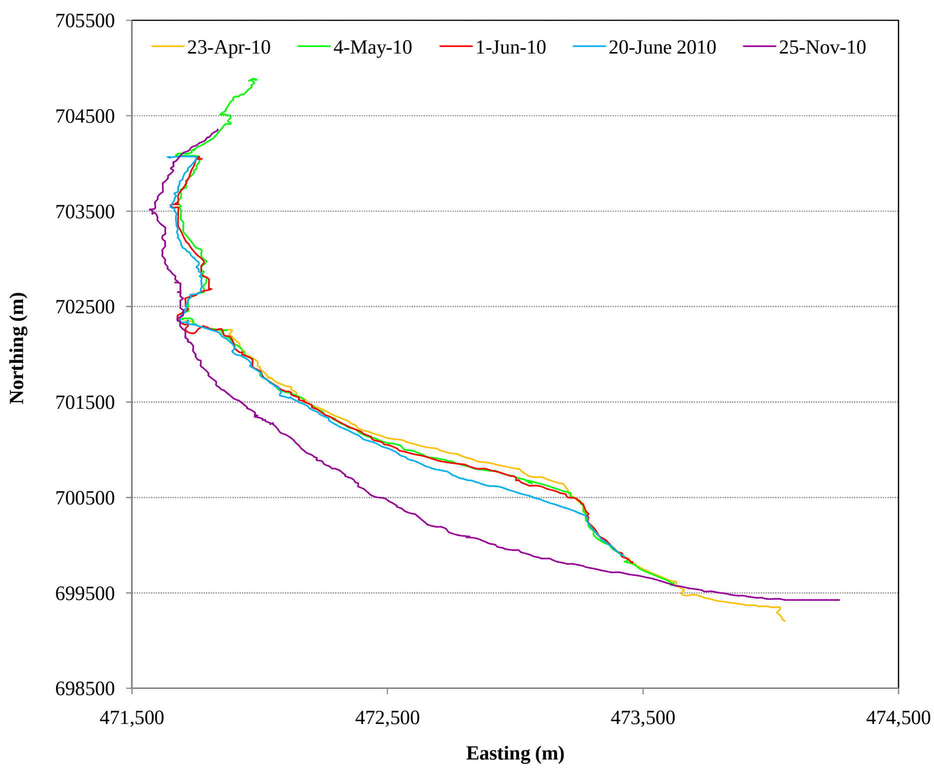


Figure 5.22: Spatial and temporal variation of bankline shifting along the study bend

5.4.2 Two dimensional (2D) surface flow velocity vector

From the data measured by GPS mounted on the float, 2-D surface flow velocities were generated as shown in Figure 5.23. The whole processes are described in Appendix- A. It can be seen that the surface flow velocities were concentrated and converged at the point of active erosion.

From the Figure 5.23, it is clear that, with the change of time the velocity vector was also changed. From the Figure of 23rd April, 2010, it is found that the flow velocity was near 1 m/s at the upstream up to the point where streamlines were converged to the bank and after that the flow velocity increased to 2 m/s towards the downstream direction. The flow was almost like a smooth line and no significant left and right movement was observed.

On 4th May, when the water level started rising, the velocity vector was also changed. Flow at the upstream was near about 1 m/s, but near to the converging point or apex the velocity decreased, and after hitting the apex the velocity increased up to more than 2 m/s. A little west and eastward movement was also observed. The flow which was far from the bank a large west and eastward movement was observed. From the figure it is also found that the apex was shifted downstream than the earlier apex.

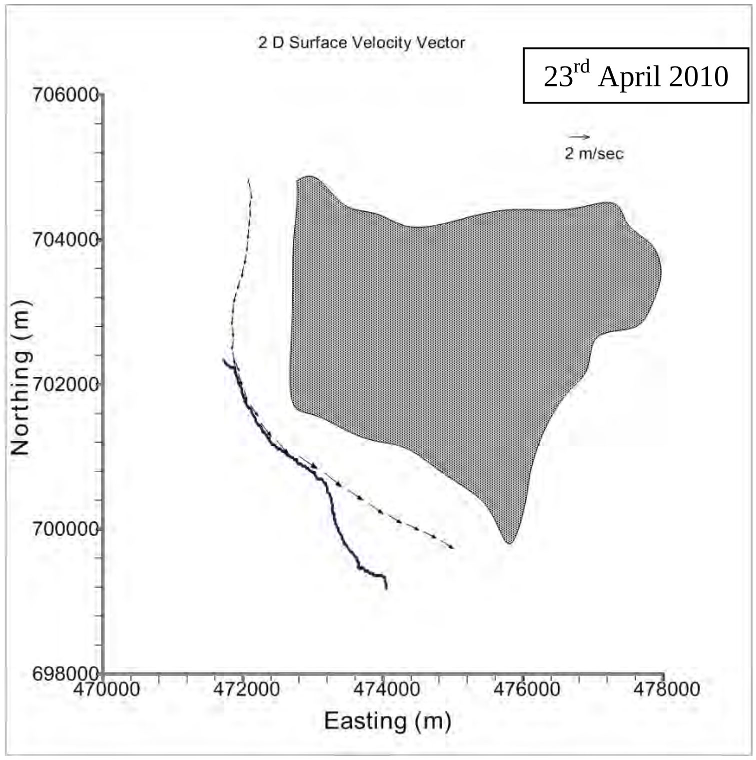
On 1st June, from the velocity vector it is found that the flow was almost straight and directly converge the bank. The apex for that date was also found downward then the previous two apexes. Velocity was also very high, almost 2 m/s. but the velocity of far bank current decreased below 1 m/s after crossing the apex. The velocity vector tells us that the current had west and eastward movement near the bank.

From the figure of 20th June it is found that, there were some changes in flow. The straight flow changed into curved flow. The velocity increased a little bit. Flow concentration point and the apex were shifted slightly down ward. After converging the apex, the velocity of flow also increased. A movement of left and right direction of current was also observed.

From the figure of 13th July, it is found that the flow was concentrate at a point which was downstream of all previous apexes. At that time the water level was too high (12.89m), the bank was overflowed and bankline became submerged. Though the flow converging point was not clearly visible but the flow concentration was clearly visible near the right guide bund of the Bangabandhu Bridge. The flow concentrated at a narrow place and passed in a high velocity after making an apex near the right guide bund of the bridge. The near bank velocity was small compared to the bar side velocity. This implies that near bank flow got small depth due to flooding whereas the bar side act as steep bank.

On 25th November, when water level decreased, near bank float converged the bankline at the upstream bend and erosion was also observed around the converging point. Due to velocity decrease there formed a shoal near the upstream bend. It was found that the floats which were deployed near the sand bar move faster than the float deployed near the bank line. It indicates that the velocity of water was higher near the sand bar. On the other hand, the near bank float moved slowly straight up to the converging point and then its velocity increased and moved faster. It indicates that, at converging point another influence of current (secondary current) was present which was diverted by hitting the bankline.

From the above observation it can be concluded that the convergence point of streamlines in a bend channel within a braided river move gradually downstream with the increase of water level.


2 D Surface Velocity Vector
23rd April 2010
2 m/sec
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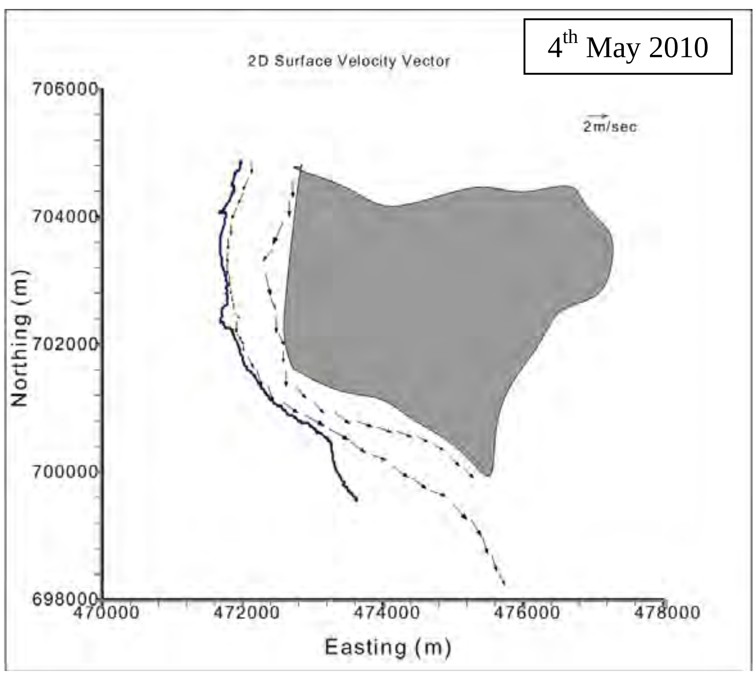
704000
702000
700000
698000
Northing (m)
470000
472000
474000
476000
478000
Easting (m)


2D Surface Velocity Vector
4th May 2010
2 m/sec
706000
704000
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Northing (m)
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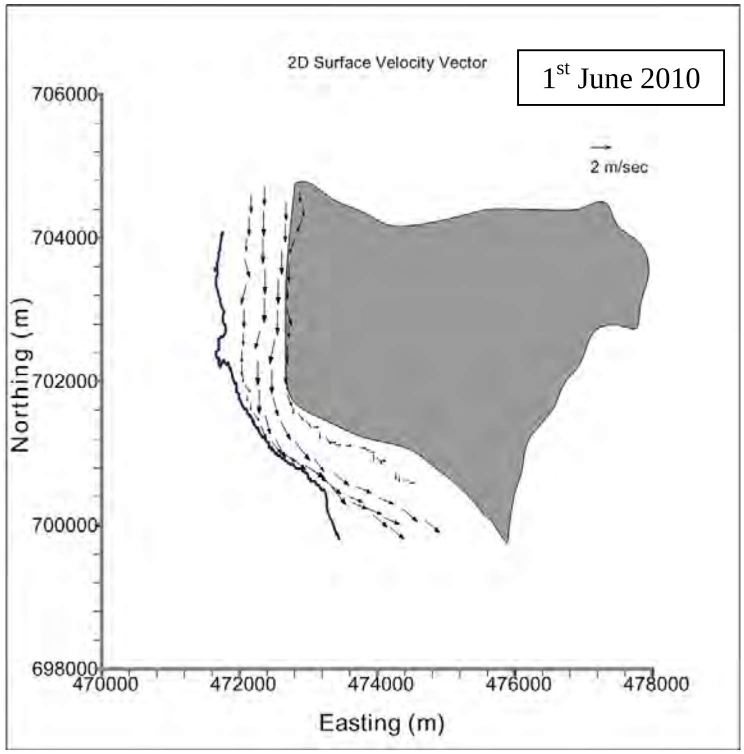
Easting (m)


2D Surface Velocity Vector
1st June 2010
2 m/sec
706000
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Northing (m)
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476000
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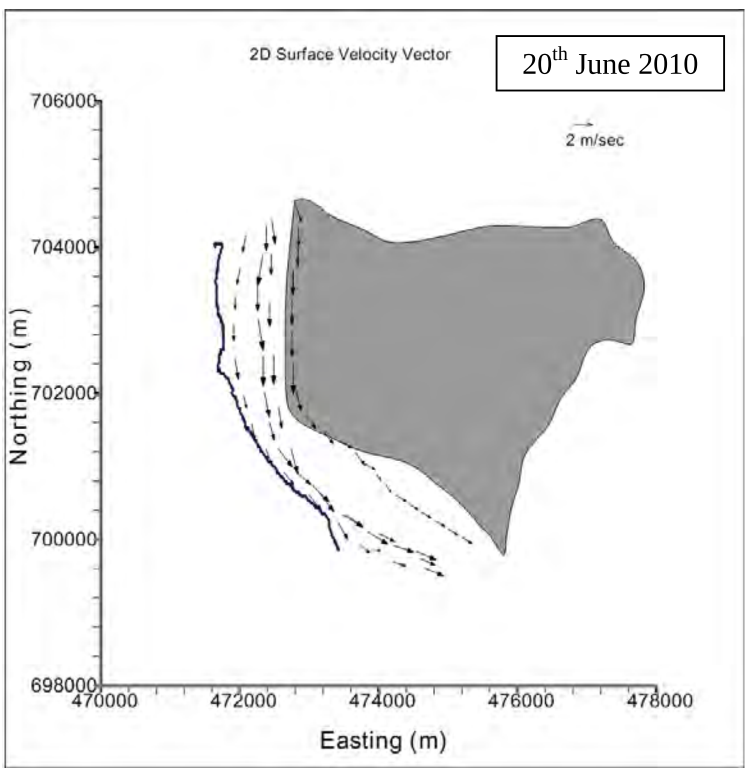
Easting (m)


2D Surface Velocity Vector
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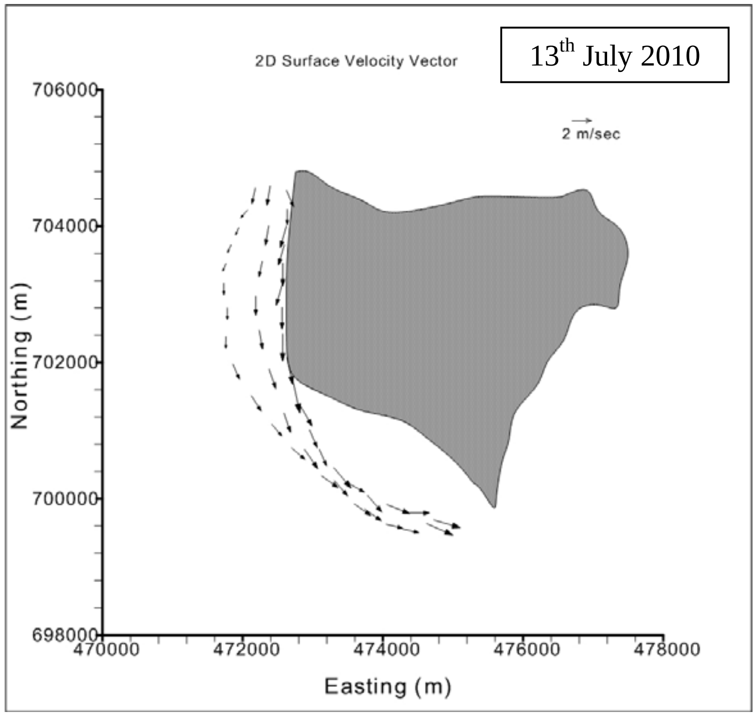

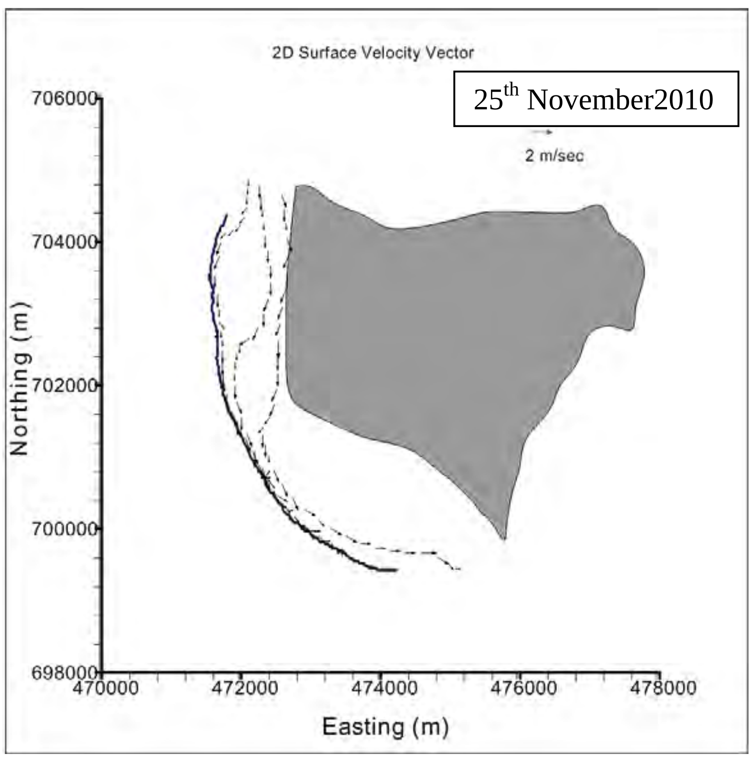

Figure 5.23: Two dimensional (2-D) surface flow velocities estimated from float movement

5.5 Planform changes of the study bend during 2007 to 2011

The study bend is about 7 kilometer long consisting two unions: Sirajganj Sadar Paurashava and Kalia Haripur. The Satellite Imageries of 2007-2010 and field survey during 2010 indicate that the erosion is high in the downstream of the study bend at Kalia Haripur union (Figure 5.24). During this period, the total river bank (right) erosion of the study bend was 400 hectares (Table 5.7). The maximum bank shifted in Paurashava union was 150 m during 2007-08 and in Kalia Haripur was 450 m during 2008-09, 580 m during 2009-2010 and 630 m during 2010-2011.

Table 5.7: Erosion from 2007 to 2010 at the study bend of Paurashava and Kalia Haripur unions of Sirajganj Sadar Upazilla

Year	Eroded Land Area (ha)
2007	30
2008	106
2009	119
2010	145

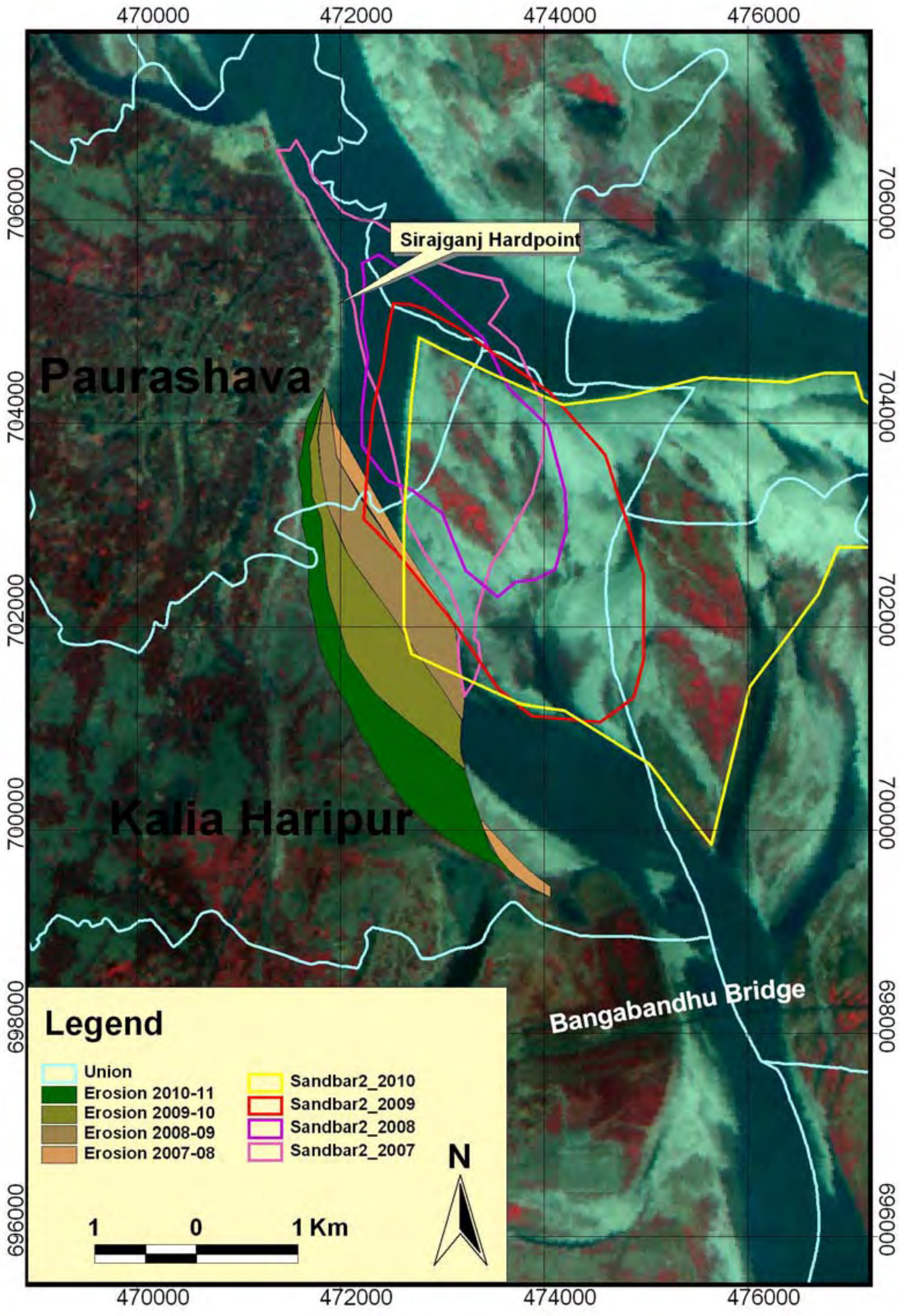

Figure 5.24: Erosion affected areas along the western bank of the Jamuna River at Kalia Haripur bend from 2007 to 2011

5.6 Life span of the eroding bend

Life span assessment is important for understanding the erosion processes of an eroding bend. Halcrow et al. (1994), Thorne and Russel, (1993), and CEGIS, (2007) studied the life span of eroding bends along the right bank of the Jamuna River. They found that the life span generally varies from 1 to more than 12 years. CEGIS found that the average life span of the bends along the right bank varies within the range of 4 to 5 years. Also there were three bends along the right bank, the ages of which found to be more than 12 years and also found that one bend had life span more than 18 years.

From time series satellite images of 1973 -2010 (Appendix B), it was found that the study bend was ceased from 1973 to 1979 and then developed during 1980-92. Again from 1993 to 2000 the bend ceased and after that the bend developed very slowly from 2001 to 2008. It started developing very rapidly from 2009 and continued developing in 2011 as well. The whole development and siltating processes are described in the following Table 5.8.

Table 5.8: Life cycle of the study bend

Year	Duration	Developing Process	Siltating Process
1973-1979	6 years		√
1980-1992	12 years	√	
1993-2000	8 years		√
2001-2008	8 years	√ (slow rate)	
2009-2010	2 years	√ (high rate)	

The life span of this bend would be around 20 years, where first 12 years considered as development phase and next 8 years recognized as siltation phase. There was no intervention during development phase but during siltation phase, hard point and guide bund were constructed. After that the bend was developing very slowly for 8 years (2001- 2008) and have been continuing to develop very fast for the last 2 years. The recent development stage may differ from the previous development stage (12 years) due to the major river training interventions. Also the development of the channel is dependent on the upstream morphology that is subject to change within a short time in a braided river like the Jamuna.

5.7 Embayment Development

A bend channel generally creates higher pressure near the concave outer bank which promotes high near bank velocities and consequently high shear stresses on the bed and bank over there. These high velocities produce severe bank erosion of the non-cohesive sands and silts in the channel boundary, leading to rapid bank retreat. As erosion progresses, embayment develops towards both sides of the sand bar. Definition of the parameters used to explain the embayment development is shown in Figure 5.25. In a study by CEGIS (2007), it is found that the mean length of the embayment along the right bank was 5.6 km and average ratio of the extent to length of the embayments varies within the range of 0.17 to 0.21, while, the maximum value was found to be 0.40 along the left bank.

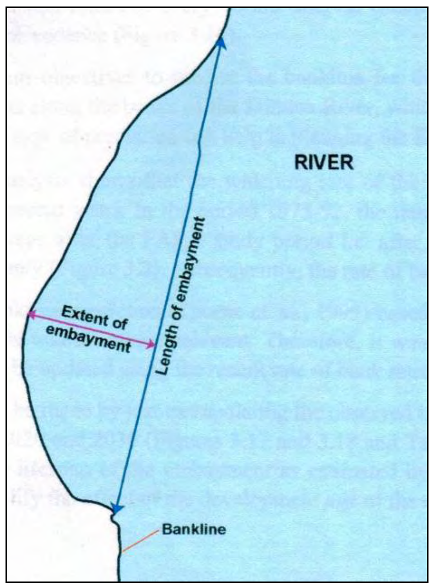

Figure 5.25: Definition diagram of embayment

The characteristic length of the study embayment was found to be 5.87 km. The ratio of the extent to length of the study embayment is shown in Table 5.9, which is increasing from 0.08 to 0.27 during the period of 2007 to 2011. The ratio is in increasing trend and its value is exceeded from the previously observed ratio (=0.21) which indicates that in average the developing bend may not continue its further development in the future. However, if the ratio of the extent to length of the study bend increases up to the maximum observed value along the left bank (=0.4), the embayment would extend up to 2.35 km that will breach the BRE.

Table 5.9: Embayment development of the study bend

Year	Length of the Embayment (L) kilometer	Extent of the Embayment (E) kilometer	Ratio of E/L
2007	5.87	0.49	0.08
2008	5.87	0.49	0.08
2009	5.87	0.70	0.12
2010	5.87	1.32	0.22
2011	5.87	1.59	0.27

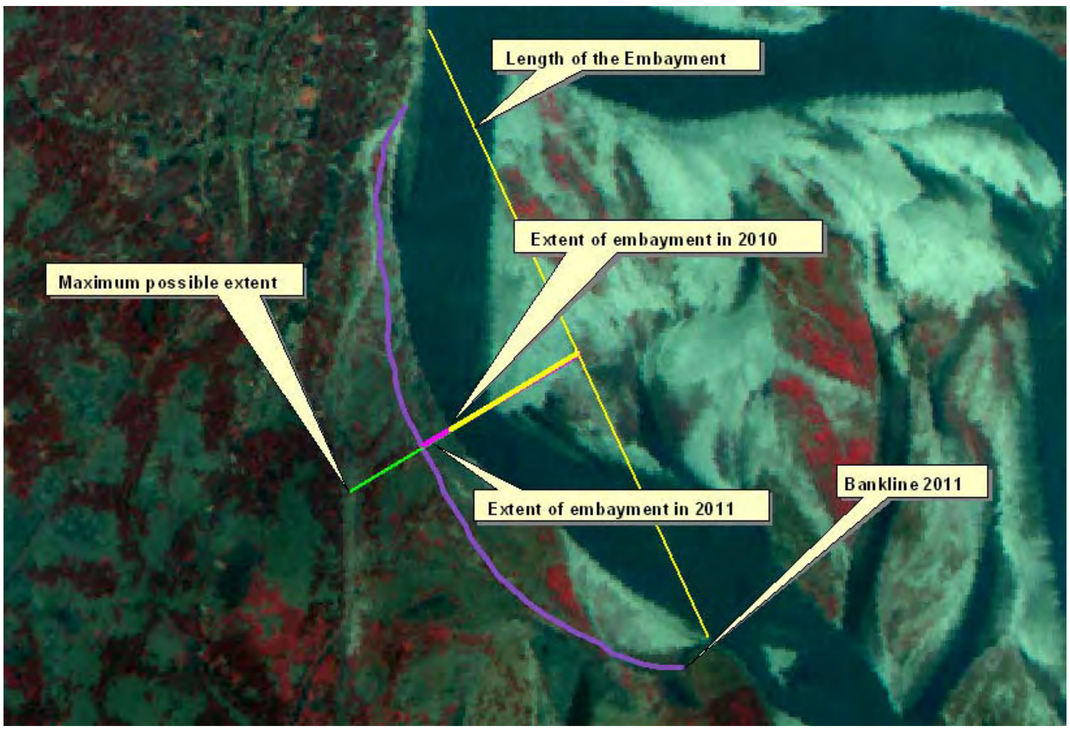

Figure 5.26: Embayment development of the study bend

From the above analysis it is clarified that the erosion processes in a bend channel of braided river are reliant on the upstream morphology as well as on the flow processes. These flow and erosion processes also have significant impact on the daily activities of the inhabitants adjacent to the eroding bank. Those local impacts are discussed in the following chapter.

CHAPTER SIX
LOCAL IMPACT OF FLOW AND EROSION PROCESSES

6.1 Introduction

Field investigation was made to understand the local impact due to flow and erosion process on the local inhabitants over the study reach. The study reach is a developing bend with very steep slope of river bank. During field visit to the area it was observed that the local people are facing difficulty to river water access. Usually local communities are accustomed with the use of river bank and river water for their daily household activities. When a channel is in abandoned process (siltating stage) the bank profile is very mild, therefore the local community has an easy access to nearby river water and land. While during the developing stage, the local community has to search for alternative sources of water and land to accomplish their daily livelihood requirement (basically by women) as the bank profile becomes very steep during these processes. Thus the erosion processes have significant impact on the daily life of the local community (Appendix C). To figure out the impact of flow and erosion processes, the local landless and partially landless groups such as farmer group, wage labourer, day labourer and another vulnerable women group have been selected. It started with resource mapping of the study area and then focus group discussion with different groups about river bank and river water use impacts. The details of the activities are discussed below.

6.2 Resource Pattern of the Study Area

To explore the resource pattern of Char Malshapara and Mara Gram, two resource maps were prepared by the villagers. In these maps, the existing natural and infrastructural assets which local people can use for their daily life were illustrated. Figure 6.1 and Figure 6.2 shows the prepared resource map for the Char Malshapara and Mara gram, respectively.

The most vulnerable village Char Malshapara is located at one kilometer downstream from Sirajganj hardpoint which is very close to the river bank. Here homestead is located in a clustered way and severe erosion brought the river bank about 200 meters close to the BRE.

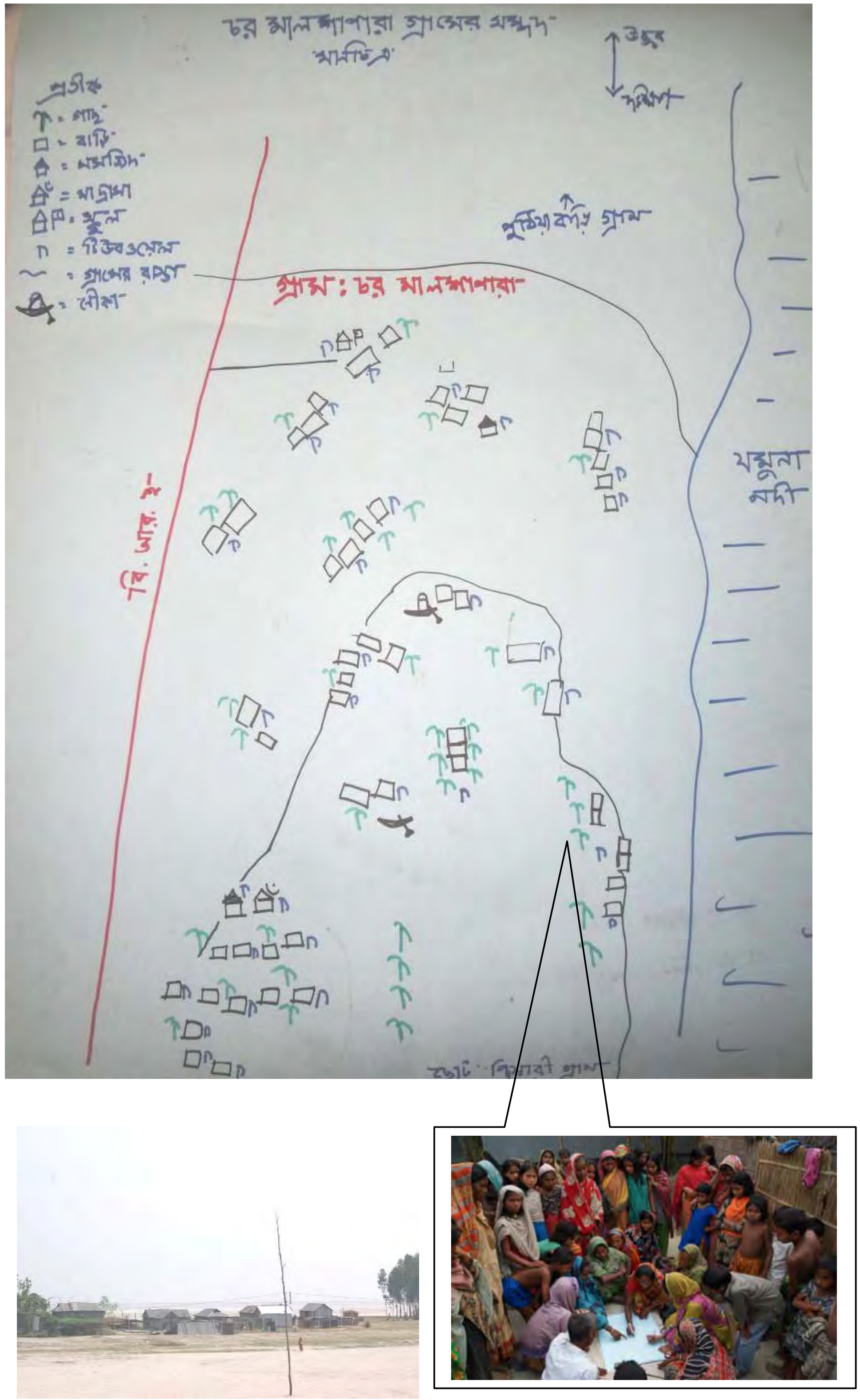

Figure 6.1: Resource map of Char Malshapara and the real view of the village where the villagers preparing the map

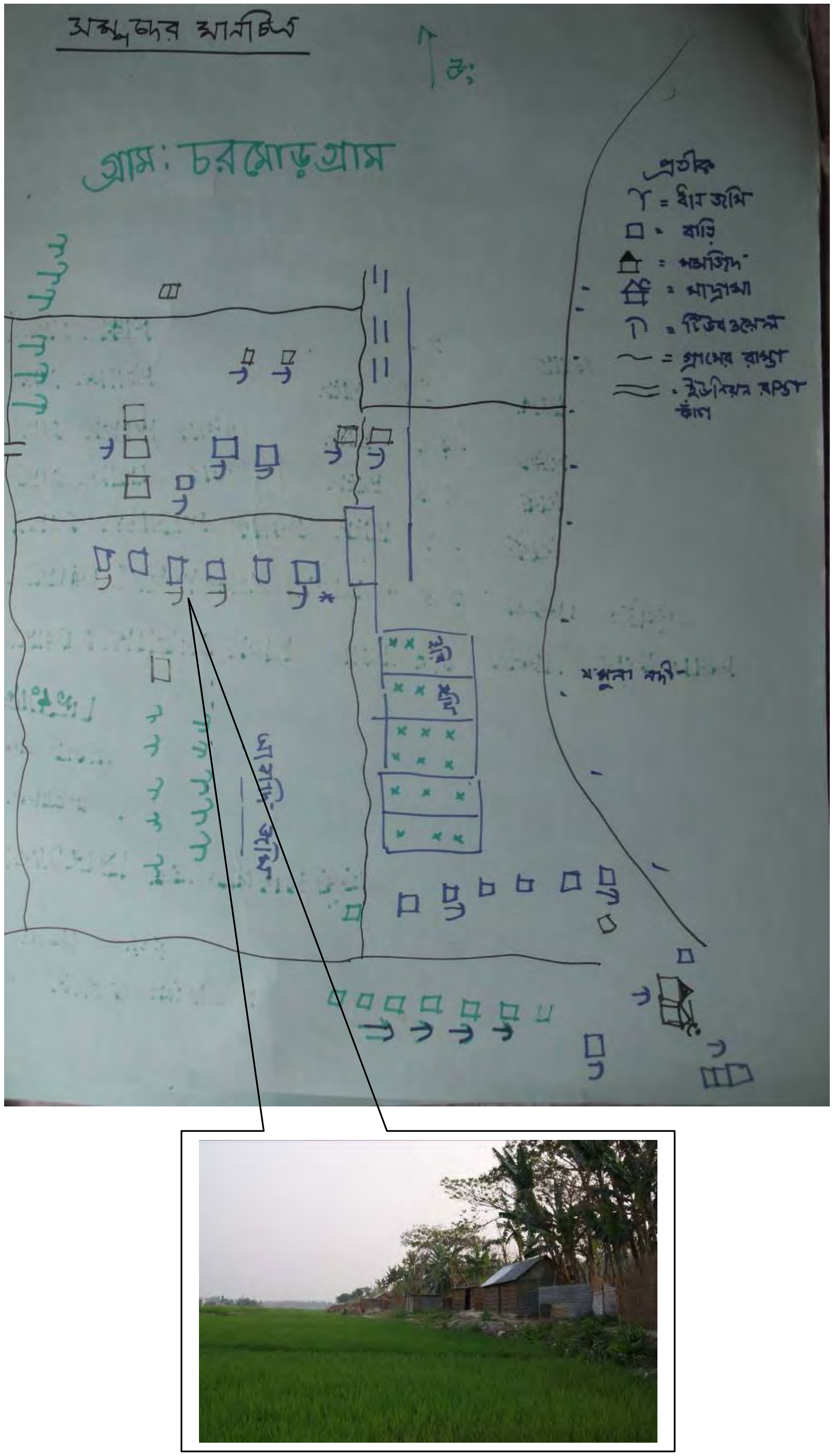

Figure 6.2: Resource map of Mara Gram drawn by the local people with actual view of the village

Another village Mara Gram is located in 2.5 kilometer upstream from the right guide bund of the Bangabandhu Bridge (Figure 6.2). Upstream Char Malshapara village did not have cultivable land; on the other hand, Mara Gram had mostly cultivable land. In such condition, farmers were not found in Char Malshapara. Wedge s (Rickshaw and Van puller) were found in Char Malshapara but not in Mara Gram as it is very close to Sirajganj town.

6.3 Land and Water Use Problem Identification

Six FGD were conducted in the study area for this perspective shown in Figure 6.3 and Figure 6.4. The FGD groups in Char Malshapara village were wedge labourer, day labourer and female group and in Mara Gram were farmer group, day labourer and female group. The target of this activity was to get the detail problems they are facing due to steep slope in river bank created during active erosion stages. The problems were identified through Tree diagram tool, and then the local people prioritized their problems with the help of pair wise ranking tool.

Figure 6.3: FGD with erosion affected groups at Char Malshapara village

(a) **(b)**

Figure 6.4: FGD with (a) landless and partially landless groups and (b) Erosion vulnerable groups at Mara village

Tree diagram helps the local people to think in a systematic way about their land and water use problems due to flow and erosion processes shown in Figure 6.5. Though land loss and displacement are the main problems of the people, but here the identified additional problems are stated below:

- Difficulty in crops and vegetable production like: Boro rice**,** Irri rice, Jute, Wheat, Dhoincha, Pulses (lentil), chilli, onion etc.
- Difficulty in cattle rearing
- Fuel drying like: cowdung, jute stick
- Cannot use the steep bank to tie the boat and trollers
- Very difficult to go with a cattle in the river to wash and give them water
- Difficulty in fetching drinking and cooking water
- Difficulty in dish washing
- Problem in Bathing and cloth washing
- Difficulty in fetching sanitation water which creates health problem specially for children

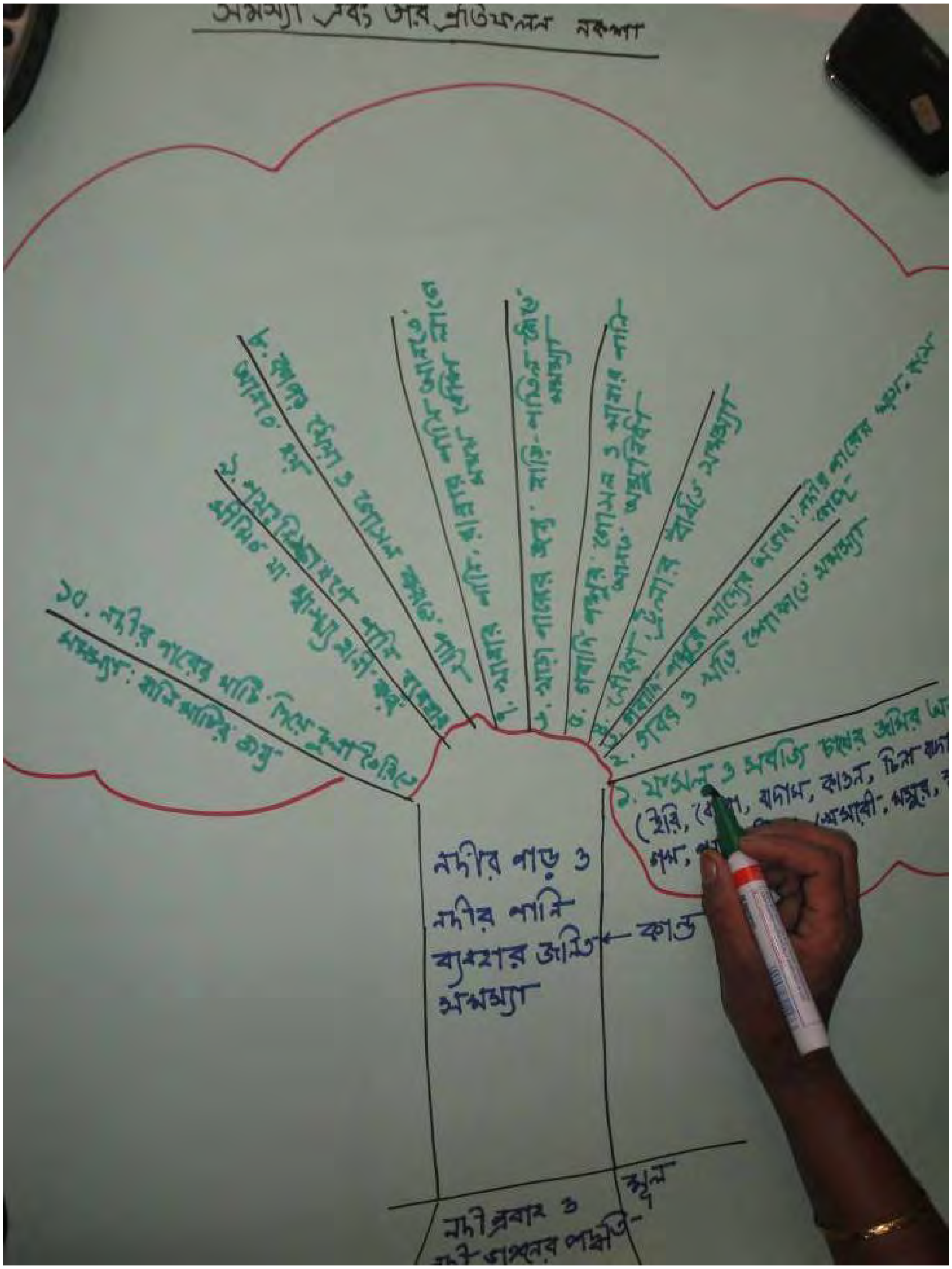

Figure 6.5: Tree diagram showing identified problems by the villagers

6.4 Prioritization of Selected Problems

The identified problems were prioritized by the local people according to their needs with the help of pair-wise ranking tool. Figure 6.6 and Figure 6.7 shows the pair-wise ranking of the problems identified by the villagers in Char Malshapara and Mara Gram, respectively. Also Table 6.1 shows the summary of the findings.

Table 6.1: Prioritized Selected Problems

Char Malshapara Village	Mara Village	Remarks	
		Char Malshapara Village	Mara Village
1.Cattle bathing	1.Vegetable and tree plantation	Almost all villagers have cattle.	Landform is agriculture based.
2.Dish Washing	2.Cattle bathing	Difficult to carry dishes in the steep slope.	Difficult to bring cattle through steep slope.
3.Cloth washing	3.Boat resting	Carrying difficulty.	Very difficult to bring boats at home.
4.Bathing	4.Dish washing		Carrying difficulty.
5.Cattle grazing	5.Cloth washing	Lack of cattle grazing land.	
6.Boat resting	6.Crop production		Bankside soil suitable for crop production.
7.Collecting cooking and drinking water	7. Bathing	River water seldom use for cooking and drinking.	
8.Sanitation water	8.Cattle grazing	Children do not want to use water for carrying difficulty.	Have long distance cattle grazing land.
9.Fuel drying	9.Fuel drying	Use BRE.	
	10.Collecting cooking and drinking water		
	11.Sanitation water		

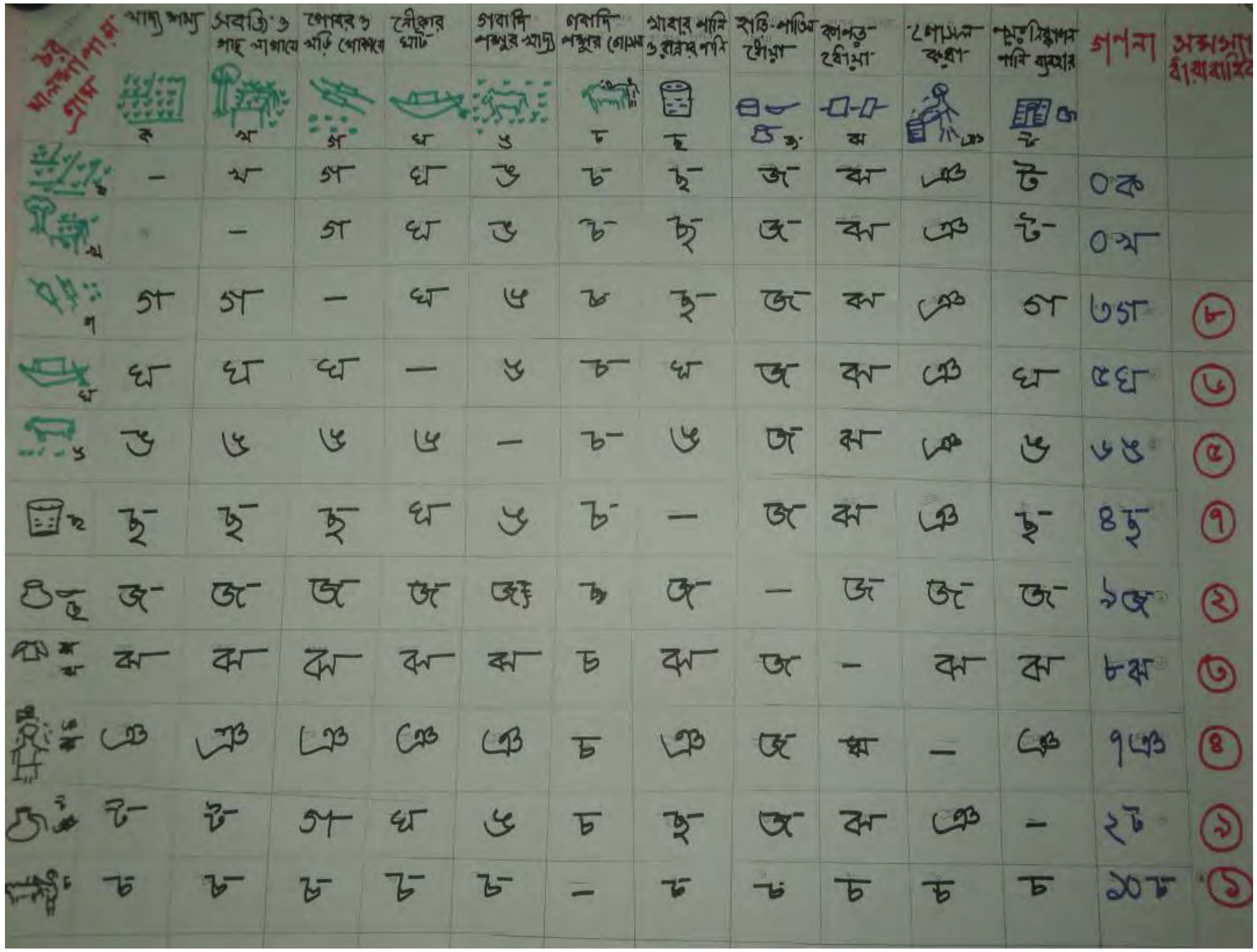

Figure 6.6: Problem Prioritization of Char Malshapara village (Pair wise ranking)

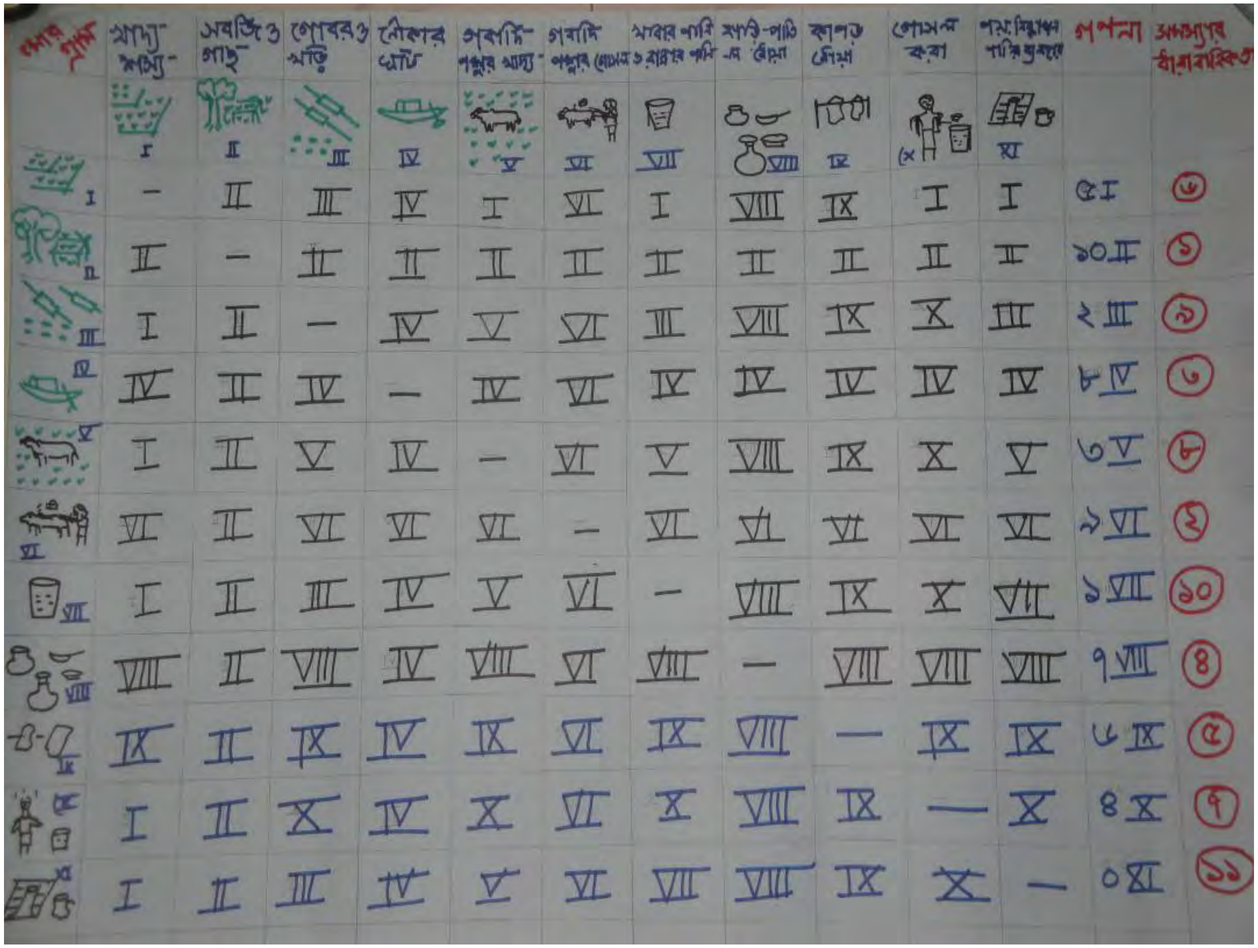

Figure 6.7: Problem Prioritization of Mara Gram village (Pair wise ranking)

6.5 Changes of land and water use pattern before and after bend development

For flow and erosion processes, the river bank became steep in the study area. This impact on local people's use of river bank and river water. In the FGD, a checklist formed about the use of river bank and river water before bend development and after band development. Five options were placed for each use which represents villager's use of river bank and river water from very high use to very low use such as shown in Table 6.2. Villagers who were engaged in crop production in the river mild slopping bank (Figure 6.8) forced to change their occupation due to erosion processes. Those people who did not have own land either migrated to the town or became day labourer. Few families were shattered where women become the head of the family. Bank erosion had broken their social bondage. Moreover migrated people became extra burden to the urban life.

People became apathetic to plantation and gardening (Figure 6.9) in the river bank which filled up their need of food and shelter in daily life. River bank served as grazing place for the cattle. Due to steep slope and lack of vegetation, women need to go distance places to collect cattle food which was tiring, time consuming and costly. Thus the number of goat was decreased in the study area. Villagers were very much concern with their fuel collection as they did not get electricity and cylinder gas. Normally cattle graze in the river bank, so it is easy to dry cowdung in the river bank (Figure 6.10). But due to steep slope villagers required alternative sources (fallow land, slope of BRE) for cowdung and jute stick drying. Usually boat men use the mild slopping bank as boat resting place (Figure 6.8) and also they keep their boat whole night safely. But due to steep bank, the neighbouring boatmen cannot keep their boat in the river so they bring their boat at home which is very tough work (Figure 6.11).

People living near river bank are very much dependent on river water for their day to day life. Being the flood plain area, there are no beel, khal and pond in the study area. Also all households do not have tubewell and some times tubewell water is not available in the dry season (October to March). Except for drinking, villagers need to use river water for cooking, dish washing, cloth washing and bathing, but due to the steep slope they face difficulty in collecting it. This can be seen in Figure 6.12 and Figure 6.13**.** Almost all villagers keep their livestock for their livelihood security. It's become difficult when they cannot wash their cattle in river water (Figure 6.14)**.** Also for sanitation water, villagers now need to use tubewell water. Also children often do not use water at all which is un-hygienic.

To get the changing pattern of river bank land use and river water use, the qualitative analysis was done in before and after bend development is shown in the following Table 6.2.

Table 6.2: Changes in land and water uses

Identified Uses of river bank and river water	**Before bend development (Mild slope)**		**After bend development (Steep slope)**		**Remarks**
	Char Malsha para	**Mara Gram**	**Char Malsha para**	**Mara Gram**	
1. Crop production	---	Low use	---	Very Low use	People changed their occupation due to steep bank formation.
2. Vegetable and tree planting	---	Low use	---	Very Low use	Due to rapid erosion people cannot use the bank for plantation.
3. Cattle rearing	Moderat e use	Low use	Very Low use	Very Low use	River mild slope bank suitable for cattle rearing, but due to steep slope women need to go nearby chars to collect cattle food, also goat reduced in the villages due to lack of food.
4. Fuel drying (cowdung, jute stick)	Low use	Low use	Very Low use	Very Low use	Now dry in fallow land and slope of the BRE.
5. Slope bank use as ghat for boats and engine boats	Very Low use	Very Low use	Very Low use	Very Low use	Need to bring the boats in houses
6. Cattle washing	Very high use	Very high use	Very Low use	Very Low use	Access difficulty

7. Collection of drinking water	Very Low use	Very Low use	Very Low use	Very Low use	Use tubewell
8. Collection of Cooking water	Moderate use	Low use	Very Low use	Very Low use	Use tubewell
9. Dish washing	Very high use	Very high use	Very Low use	Very Low use	Carrying dishes became difficult in the steep slope
10. Cloth washing	Very high use	Very high use	Moderate use	Moderate use	Access became difficult
11. Bathing	Very high use	Very high use	Very high use	High use	Older people and pregnant women cannot go to river
12. Use of river water for sanitation purpose	Very high use	Very high use	Very Low use	Very Low use	Children don’t want to pump tubewell which create hygiene problem

Figure 6.8: Mild slope bank of Jamuna River used for crop cultivation as well as boat stand (Kheya ghat)

Figure 6.9: Various uses of mild slope bank: vegetable and tree plantation as well as drying cloths

Figure 6.10: Fuel drying in mild slope

Figure 6.11: Boat keeping in the river became difficult due to steep slope

Figure 6.12: Difficulty to go through the steep slope

Figure 6.13: Villagers facing difficulty for bathing and fetching river water due to steep slope

Figure 6.14: Cattle washing became most difficult according to villagers

CHAPTER SEVEN
CONCLUSION AND RECOMMENDATION

7.1 Conclusion

- The erosion situation in the study reach is very much severe. The channel is developing very fast along the western bank of the Jamuna River and eroding the river bank very quickly. The river bend has been shifted approximately 1.3 kilometers during the last three years and engulfed 400 ha floodplain of agricultural and homestead land.

- The spatial and temporal variation of erosion along the developing bend is resembled with converging point of surface stream lines. From the satellite images and field survey it has been found that, the near bank flow processes are governed by the dry season bed features to some extent, specially, at the beginning of the rising stage. But with time, the near bank flow processes and location of active bank erosion changes significantly due to changes in large scale sand bar feature (morphology) and changes of surface stream lines with water level.

- Though in literature the flow structure in a bend of an anabranch channel (i.e. second order channel) of a braided river is resembled similar to the meander bends of single thread rivers but in this study it is found that the characteristic of a bend channel within a braided river exhibits difference with a classical single thread meandering channel, specially at the high water level.

- Bank profile became very steep almost 6 meter vertical according to the local people and field survey. Near bank inhabitants cannot use river water and river bank to accomplish their daily livelihood requirement, basically by women.

- Local people who were engaged with crop production, vegetation and tree plantation, cattle rearing, and fuel drying in the river bank have to change their usual practice by either changing their occupation or by using other fallow land of a long distance.

- River bank side inhabitants are facing problems in cattle washing, drinking and cooking water collecting, dish washing, cloth washing, bathing, sanitation water collecting as well as in using the river bank as boat stand place due to access difficulty to the river. People are facing crisis in need of water. Villagers are becoming dependent on tubewell water and sharing with others limited tubewell. Hence the use of ground water has increased instead of surface water. Sometimes during dry season (December to March) they do not get water from these tubewells. People have to minimize their need of water in this situation.

- The ratio of extent to length of the embayment is exceeded from the previously observed maximum ratio (=0.21) along the right bank of the Jamuna river that indicates the bend may not continue for further development. Therefore, it is difficult to conclude whether the bend would be developed or abandoned in the future which needs further monitoring in order to make convincing conclusion on this issue.

7.2 Recommendations

- With the development of river training and bank protection works, the natural erosion and sedimentation processes are changing at the upstream and the downstream of the study reach. Therefore, the study period consists of bend development and abandonment at both the natural and intervened condition. Therefore, long term monitoring on the behavior of the erosion and sedimentation processes at the study bend together with upstream morphology need to be explored for future development.

- The local impacts that are identified in this study are usually unnoticed considering its insignificant impact at national level. The changing pattern of the use of river bank and river water may vary from location to location. Therefore, such findings are case specific and should not be extrapolated to the other places directly. Rather similar study in the concerned river reach need to be explored when necessary.

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APPENDIX: A

Development of Two-Dimensional Surface Velocity Vector

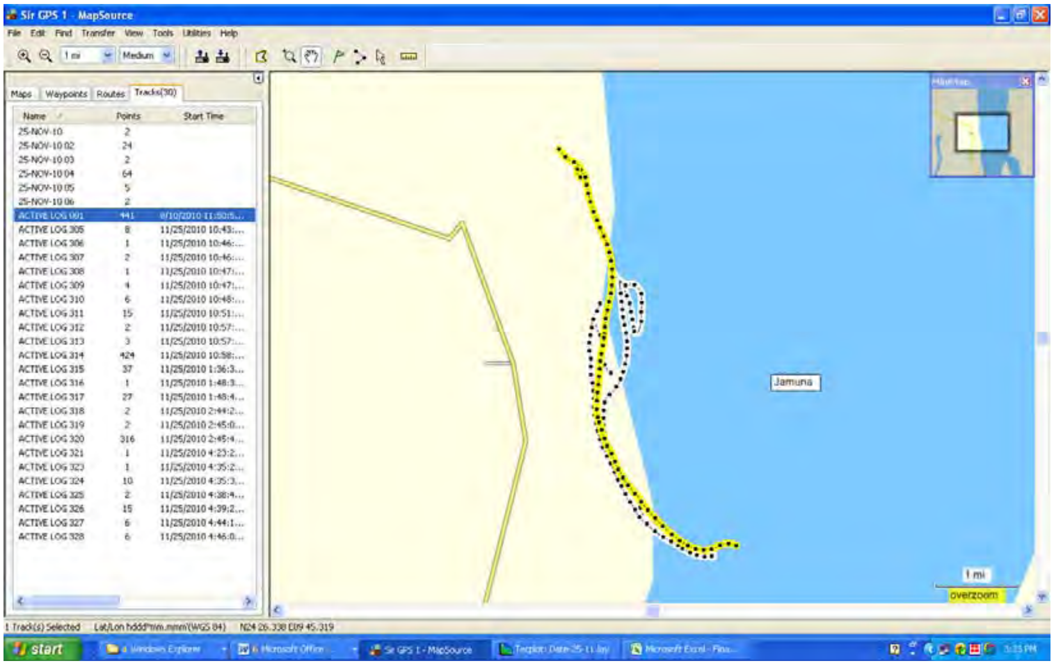


Figure A1: Float data was collected by GPS and transferred by Map Source

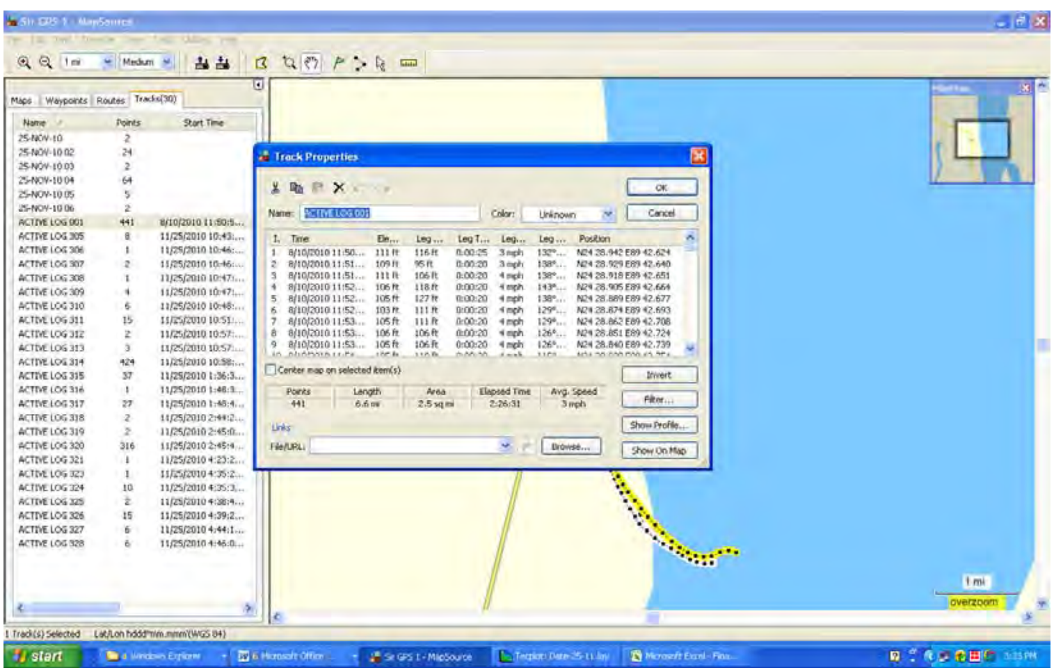


Figure A2: Position data of bankline and float tracking extracted by Map Source

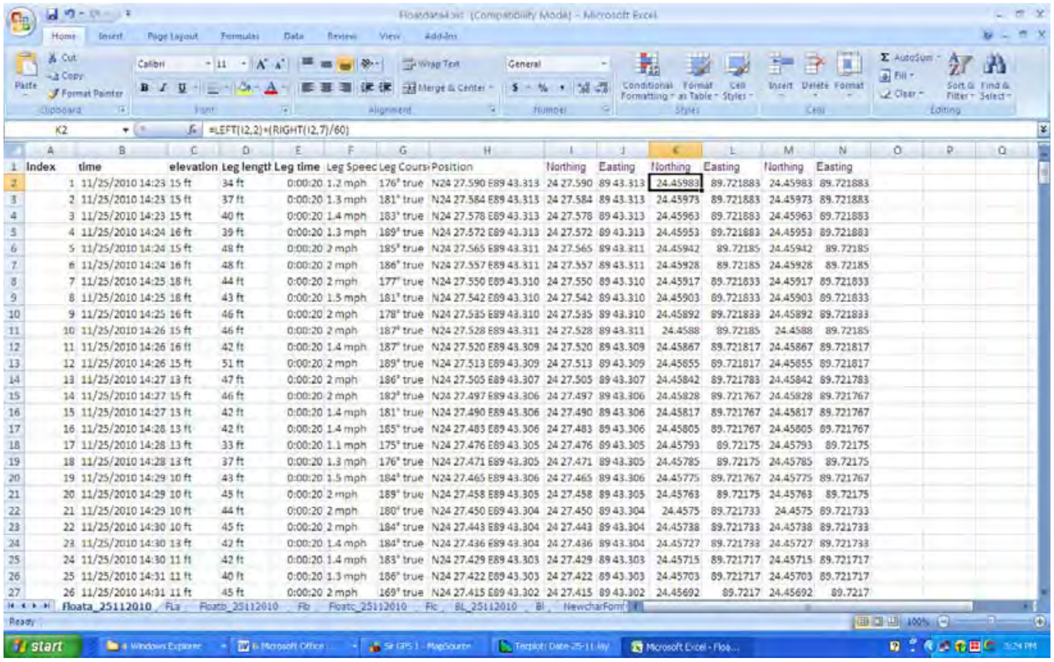


Figure A3: Position data analyzed through Spread sheet

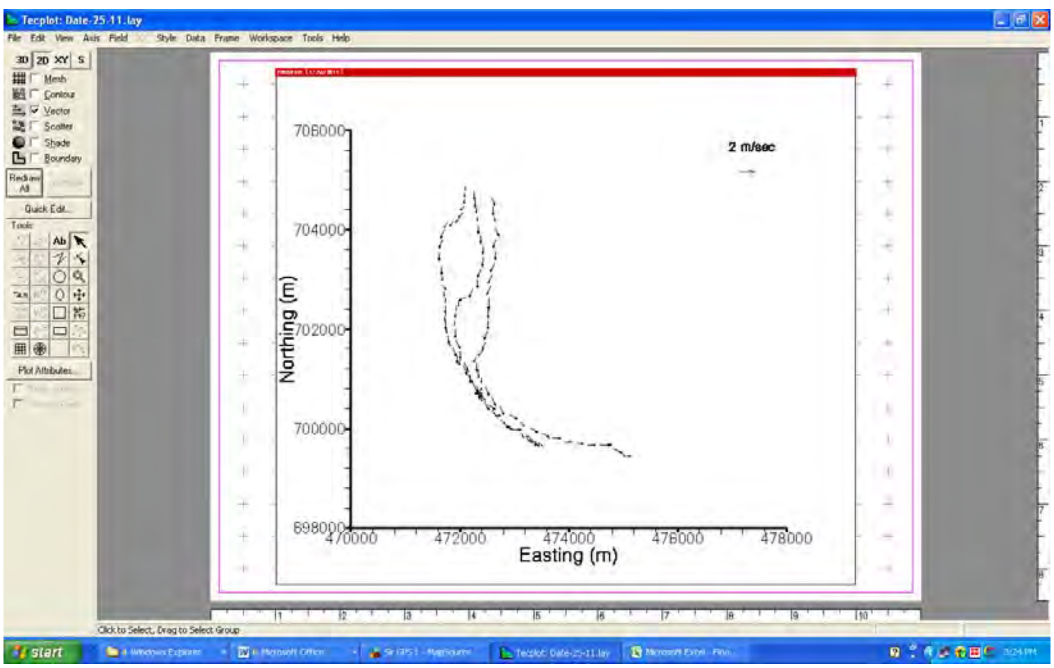


Figure A4: 2-D Surface velocity vector generated by TecPlot 7.5 software

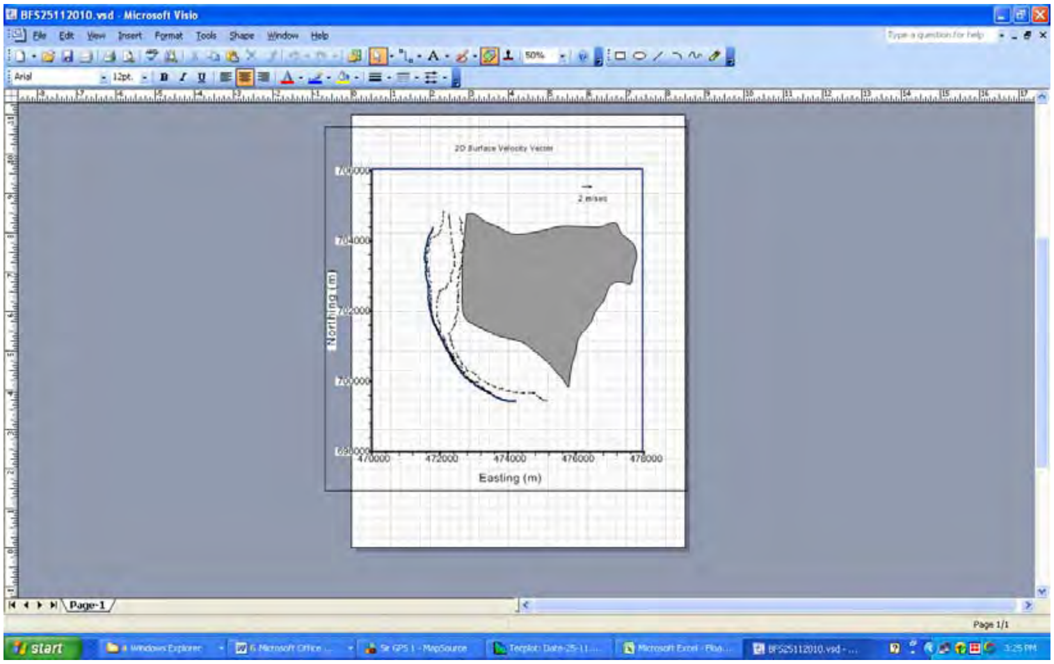
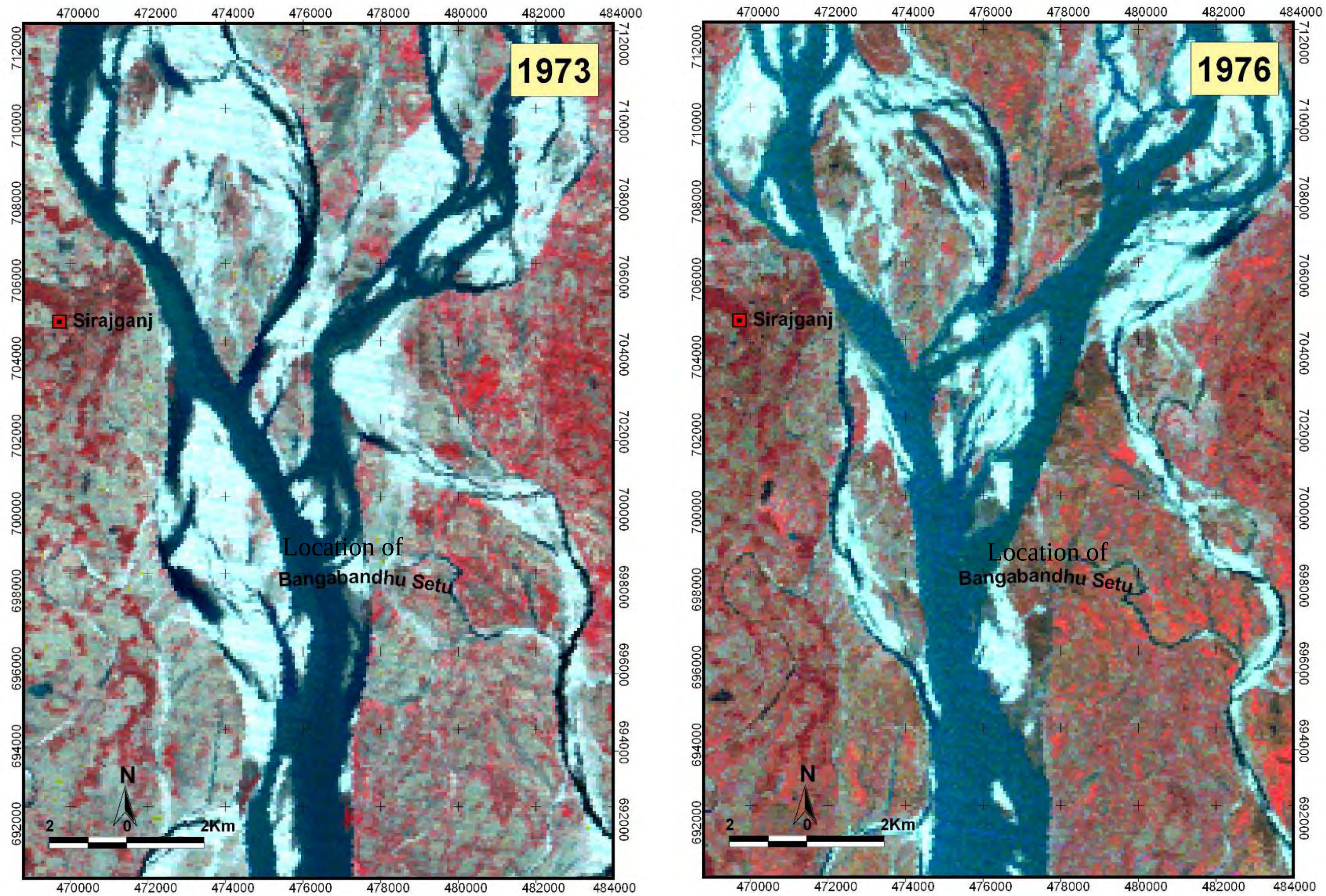


Figure A5: Sandbar drawn with the generated velocity vector with Microsoft Visio 2003

APPENDIX: B

Satellite Images of the study bend of the Jamuna River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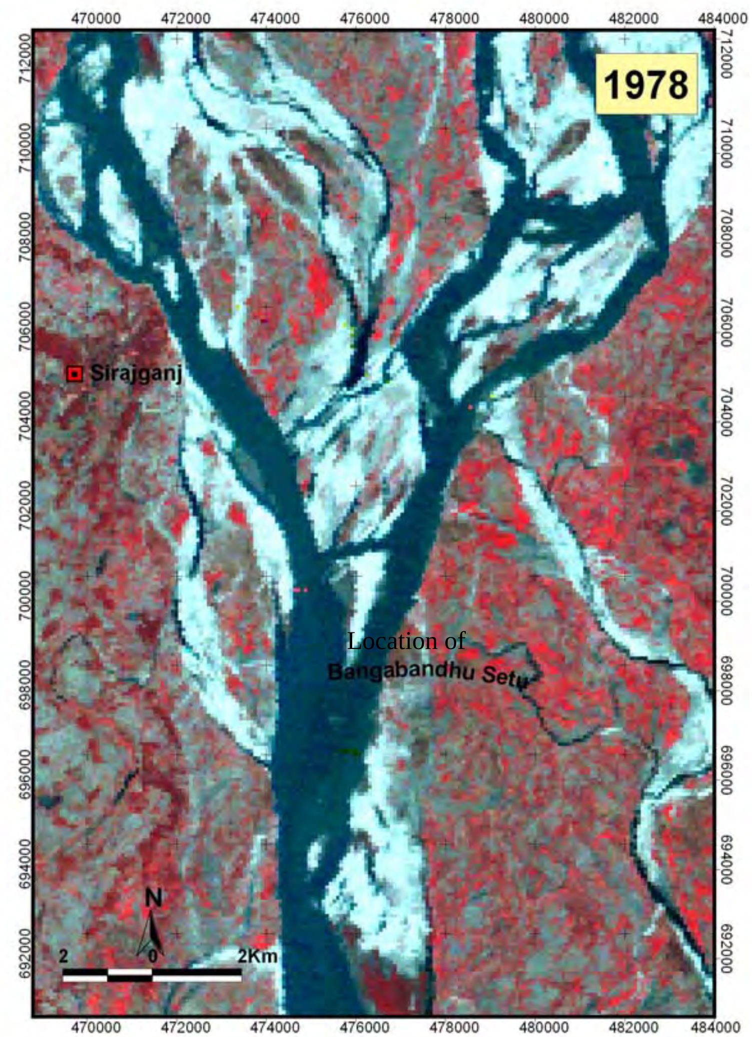
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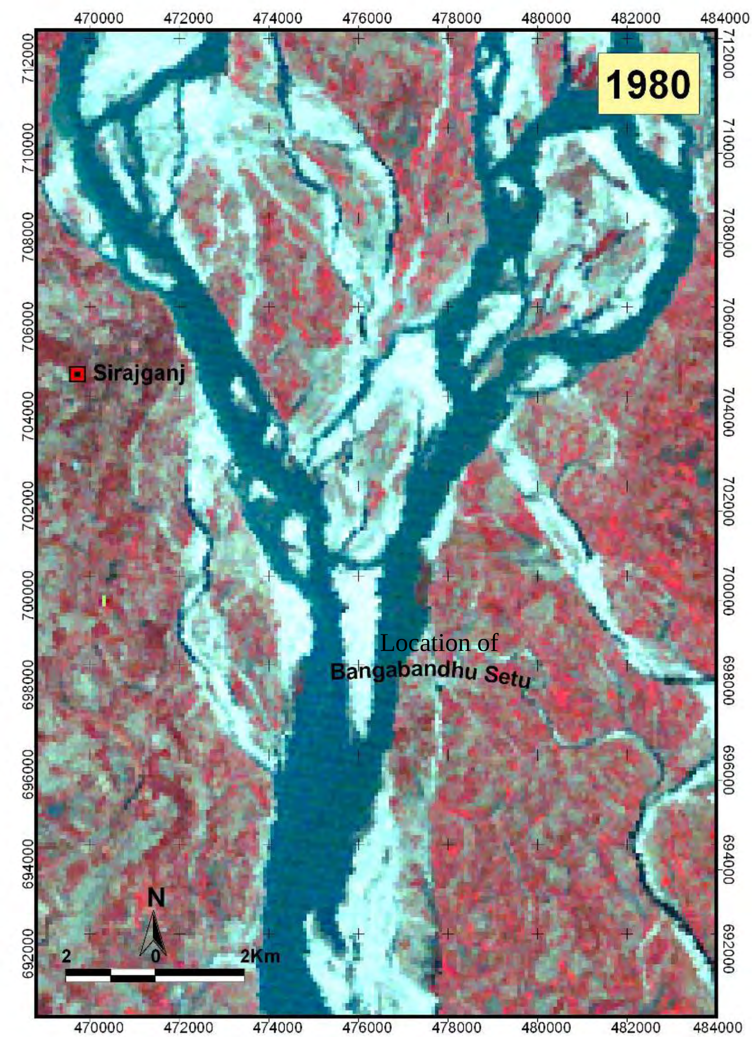
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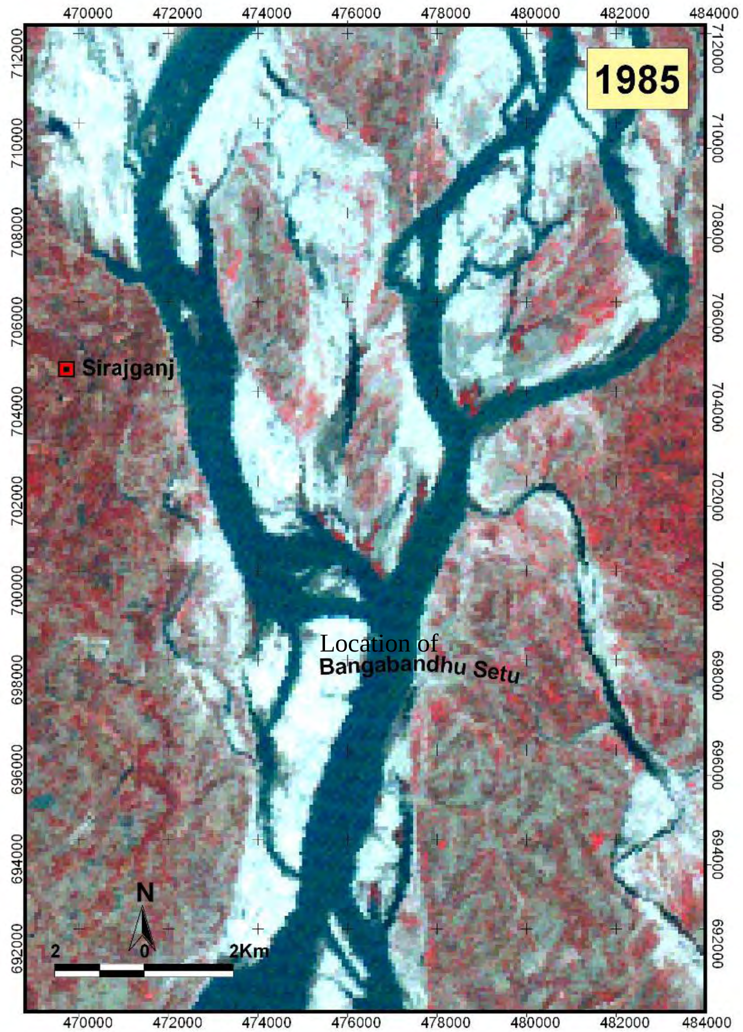
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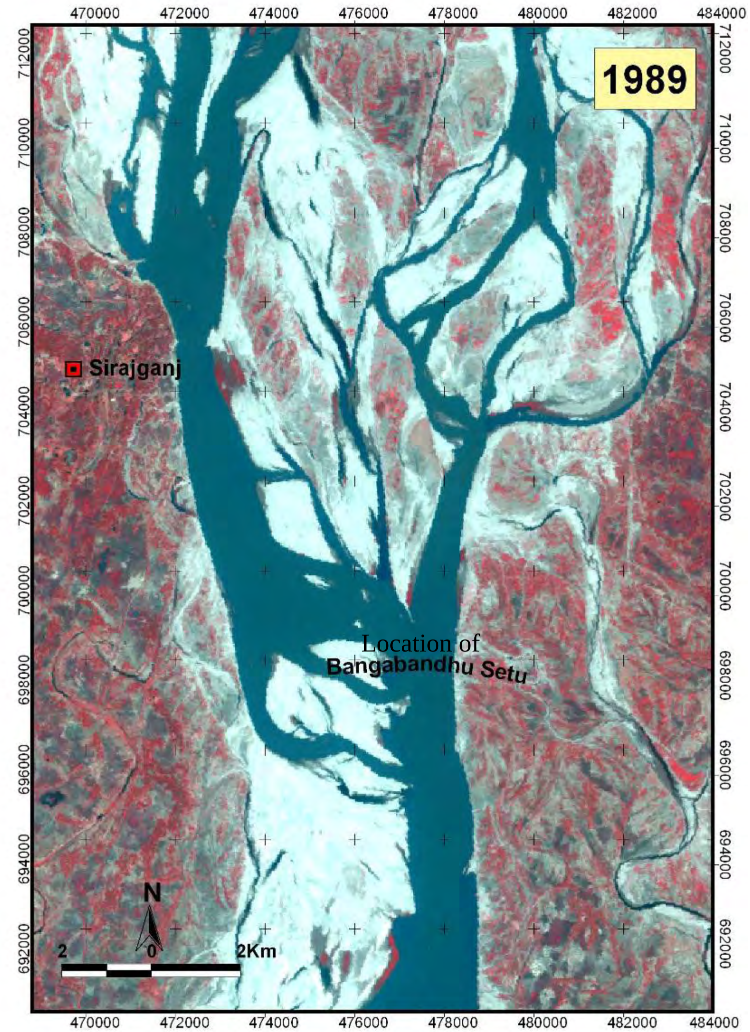
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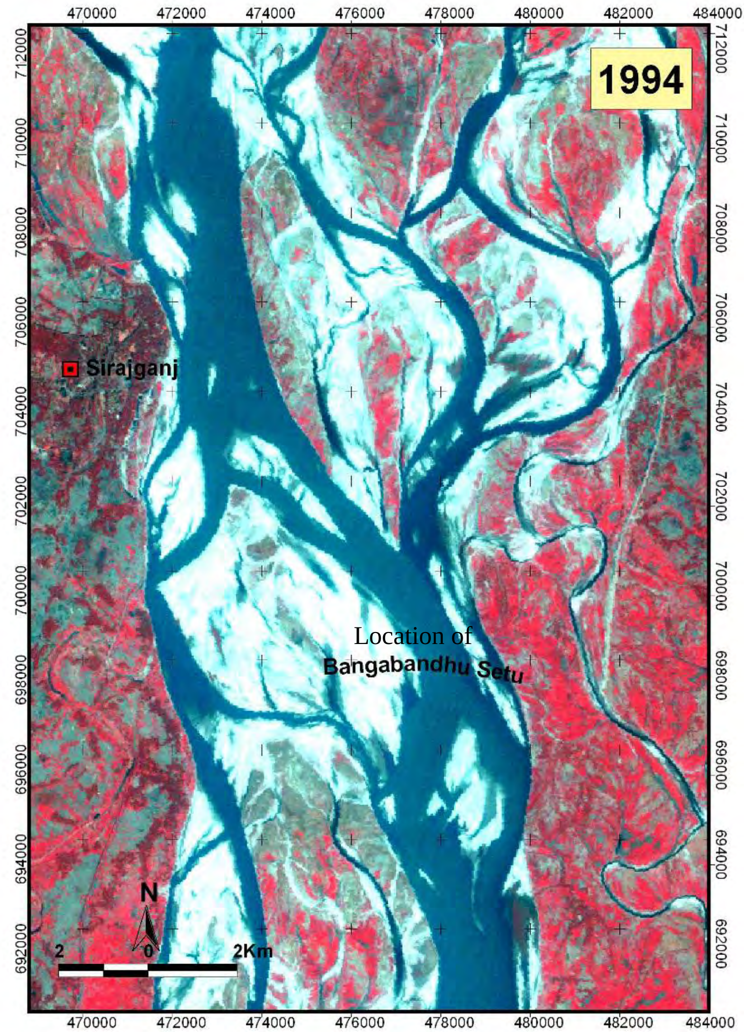
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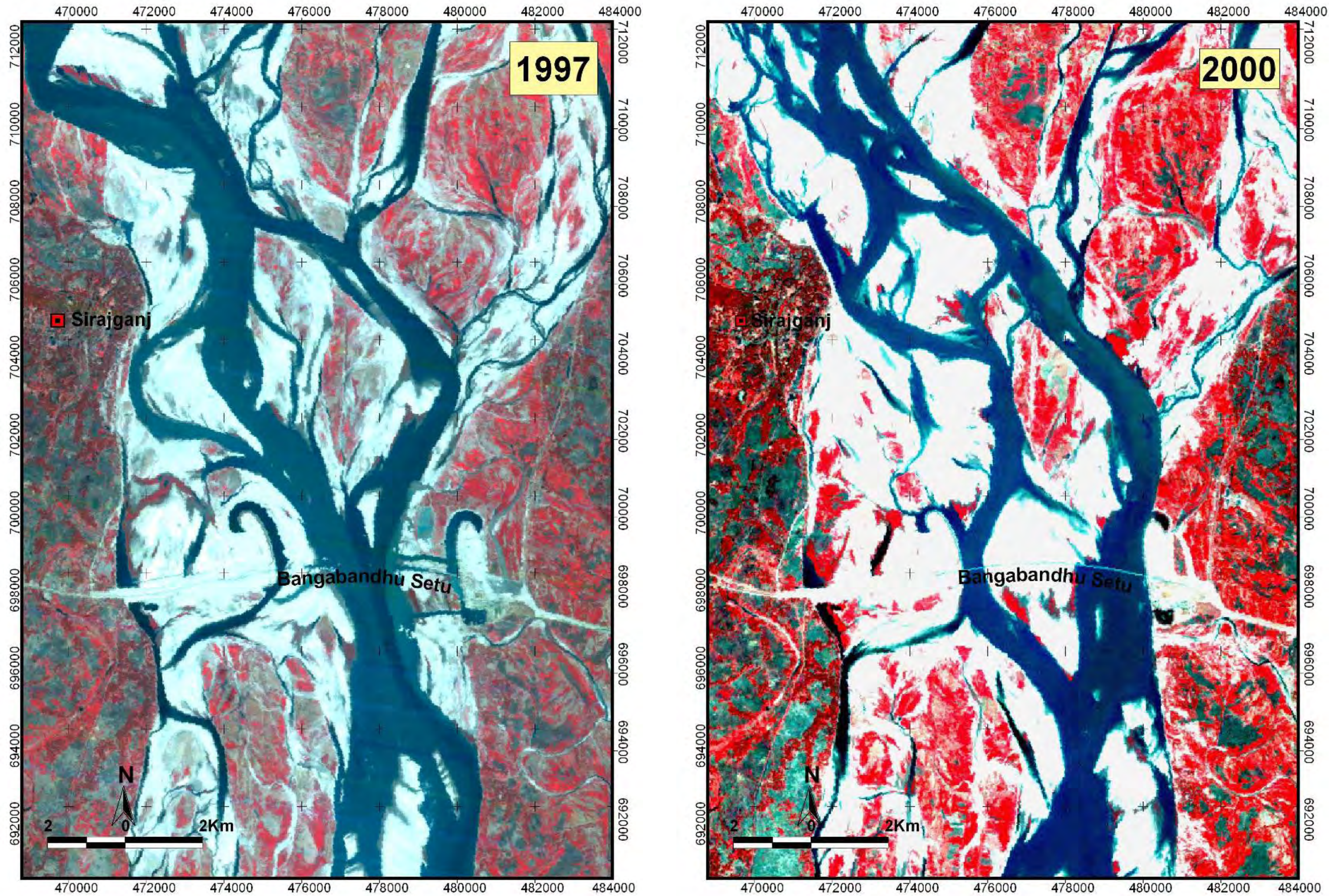

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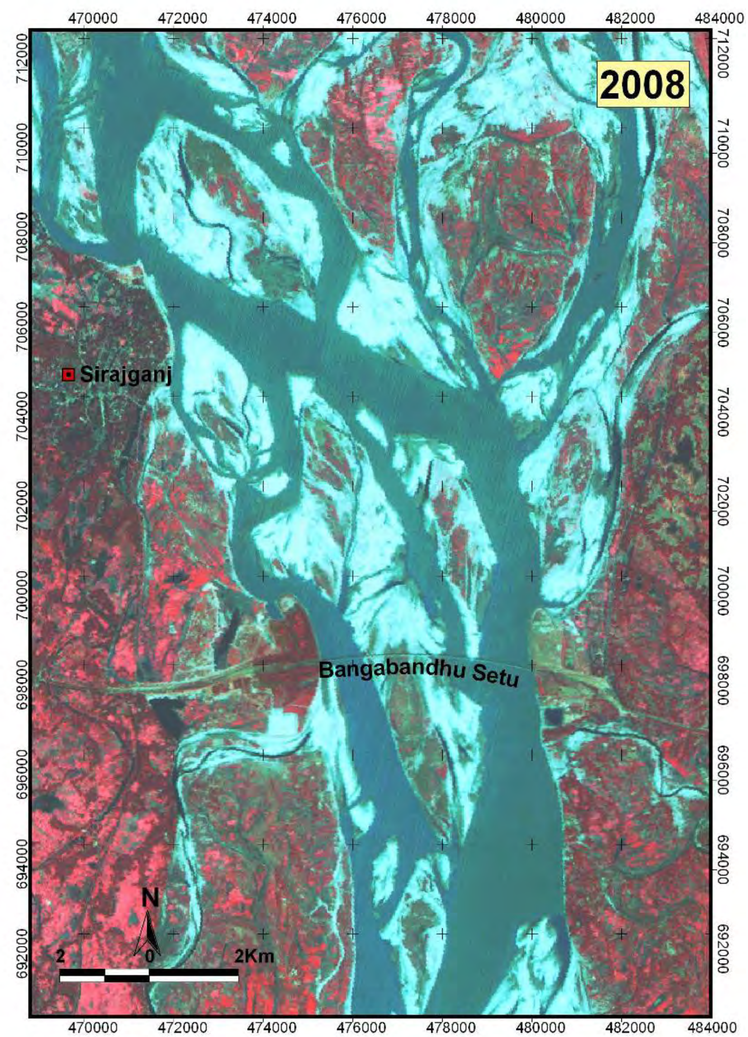
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APPENDIX: C

Photographs of Field Investigation

Fig C1: Sudden bank failure on 23rd April 2010

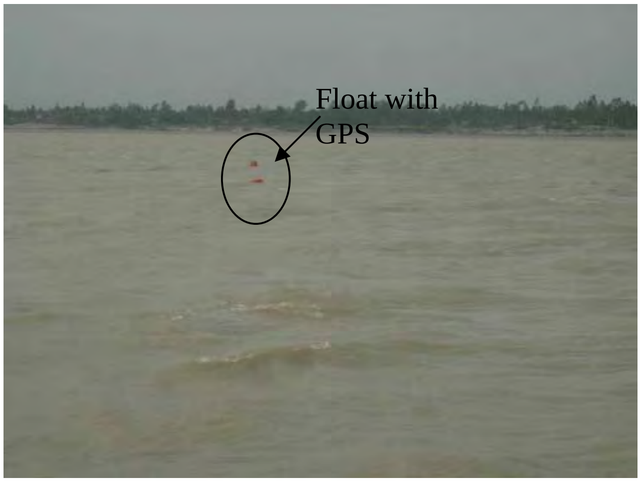

Fig C2: Float tracking along bank side on 23rd April 2010

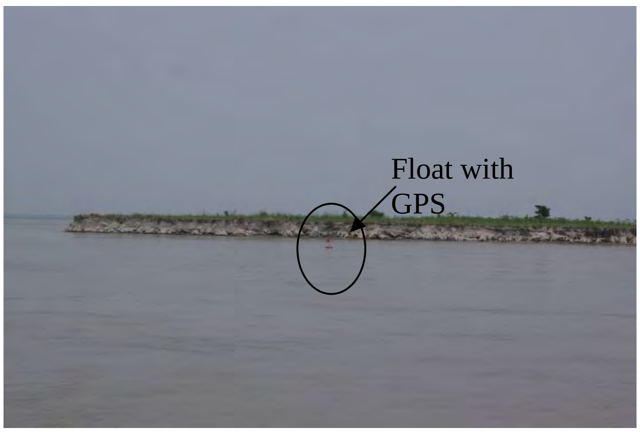

Fig C3: Float tracking along bar side on 1st June 2010

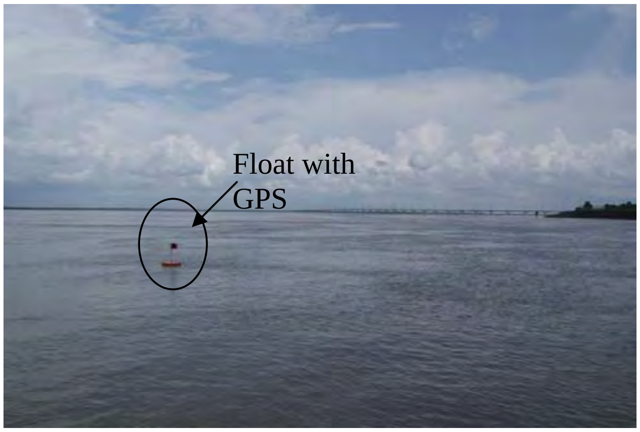

Fig C4: Float tracking on 20th June

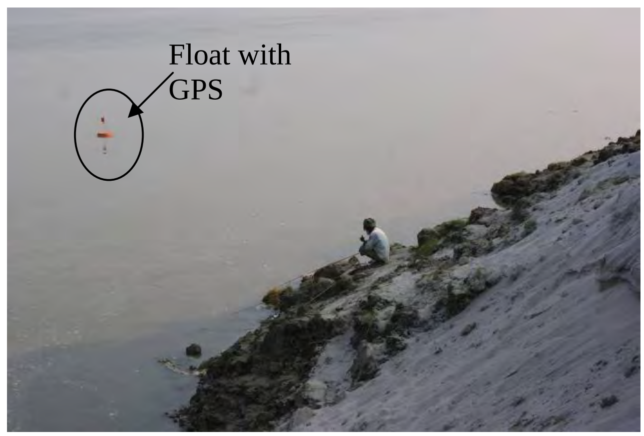

Fig C5: Float tracking along bank side on 25th November 2010

Fig C6: Bankline survey on 1st June 2010

Fig C7: Vulnerable wage labourers of Mara village on 13th July, 2010

Fig C8: Vulnerable day labourers of Char Malshapara village on 25th November, 2010

Fig C9: People shifting houses from bankside on 20th June

Fig C10: School shifting from bankside on 1st June 2010

Fig C11: Cattle rearing in mild slope on 1st June 2010

Fig C12: Mild slope makes convenience to wash cattle

APPENDIX: D

Approved Copy of the Thesis Proposal

BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY, DHAKA OFFICE OF THE MEMBER SECRETARY OF THE COMMITTEE FOR ADVANCED STUDIES & RESEARCH, BUET, DHAKA.

Application for the approval of M.Sc (Water Resources Development) Thesis Proposal.

Date: 14 February 2011

1. **Name of the student:** FARZANA MAHMUD **Status:** Part-Time

   Roll No: M10072823P **Session:** October 2007

2. **Present Address** : H# 1&3, R#1, Block A, Apt#A2, "La Fontana",
   Niketon, Gulshan-1, Dhaka-1212.

3. **Name of the Department** : Institute of Water and Flood Management (IWFM)

   Programme : M.Sc. in Water Resources Development

4. **Name of the Supervisor** : Dr. Md. Munsur Rahman **Designation:** Professor

5. Date of First Enrolment in the Programme : November 24, 2007

6. Tentative Title : FLOW AND EROSION PROCESS AND ITS LOCAL IMPACT ALONG A DEVELOPING BEND BETWEEN TWO RIVER TRAINING STRUCTURES IN A BRAIDED RIVER.

7. Background and present state of the problem:

Channel development and its abandonment are common characteristics within a braided river. Usually, high eroding bends (erosion rate>250 m/year) within the braided Jamuna river develops for 2-3 years after which the bend development processes ceases and siltation influences the channel abandonment processes (Halcrow et al. 1994; Thorne and Russel, 1993; CEGIS, 2007). On the other hand, the life cycle (development and abandonment) of low eroding bends (erosion rate<100 m/year) are relatively longer (5-10 years). The spatial and temporal variation of bank erosion and channel development are closely related to the shape, size, location and orientation of braided sand bars. Also the rate of bank migration is linearly related to the magnitude of the near bank velocity (Pizzuto and Mecklenburg, 1989; Silva, 2005). Once a bend channel starts developing through bank erosion as a result of flow diversion by sand bar towards the bank line, curvature effect will have additional impact on the erosion and deposition processes. Secondary currents are generally significant in bend channels and responsible for erosion and sediment transport processes in an eroding bank (Thorne, 1991). Bank profiles are usually very steep (nearly vertical) along an eroding bend, while gentle bank profiles are observed in a siltating bank normally observed during the channel abandonment processes (Uddin and Rahman, 2009).

The scale of yearly river bank erosion is considered in most of the cases to estimate the national, regional and local losses as an economical loss and displacement of the local people forced by erosion is considered as social losses and in combined form, the loss is expressed as socio-economic impact (Elahi et al., 1991). A wide range of socio-economic problems is created by bank erosion process in Bangladesh (Bhuiyan, 2007). But during the channel development along an eroding bank, the land and water use practices of the local community are severely impacted. These issues are usually unnoticed considering its insignificant impact at national level.

A developing bend at Kalia Haripur along the western side of braided Jamuna River is exhibiting severe erosion. The bend has great spatial importance as it is forming between two important bank protection and river training structures: Sirajganj Hardpoint and right guide bund of Bangabandhu Bridge in Sirajganj Sadar upazilla under Sirajganj District. During field visit to the area it was observed that the local people are facing difficulty to river water access. Usually local communities are accustomed with the use of river bank and river water for their daily household activities. When a channel is in abandonment process (siltating stage), the local community have easy access to nearby river water and land as the bank profile is very mild. While during the developing stage, the local community will have to search for alternative sources of water and land to accomplish their daily livelihood requirement (basically by women) as the bank profile becomes very steep during this processes. Thus the erosion processes have significant impact on the livelihood of the local community. Therefore, this study is intended to assess the flow and erosion process of the developing bend in between the Sirajganj Hardpoint and the right guide bund of the Bangabandhu Bridge and to assess its local impact.

8. Objectives with possible outcome:

The specific objectives of the proposed study are as follows:

I. To assess the translation process of large scale bed forms such as sand bars around a developing bend
II. To clarify spatial and temporal variation of flow processes and erosion along a developing bend at the downstream of a River training work.
III. To assess the local impact adjacent to the eroding bank.

Possible outcome:

This study is expected to provide linkage between flow processes and river bank erosion at the downstream of river training or bank protection structure and its consequences on local people.

9. Outline of Methodology:

The flow process will be assessed at the developing bend having a reach of around 7 km in between two important bank protection and river training structures the Sirajganj Hardpoint and Right guide bund of the Bangabandhu Bridge along the braided Jamuna River. The study will be based on the following steps: A) Hydraulic measurement, B) Satellite image analysis and C) Social survey

A) Hydraulic measurement

i. **Bankline survey:** Hand GPS would be used for tracking bank lines. Banklines will be measured five times at an interval of 2-4 weeks to assess the extent and location of erosion.

ii. **Float tracking:** Floats mounted with GPS, track the flow lines and its convergence/divergence characteristics along bank line. Total four floats would be used to track flow lines for six times at an interval of 2-4 weeks within the developing channel.

The measured data through float track and bankline survey would be processed and plotted on Satellite image of 2010 to clarify spatial and temporal variation of flow processes and erosion along a developing bend at the downstream of the river training work. Two dimensional surface velocity vectors would be generated from the collected data and plotted in the planform.

B) Satellite image analysis: Remote sensing & GIS techniques would be used to analyze the spatial and temporal variation of large scale bedform such as sand bars. Satellite images would be collected from Center for Environmental and Geographic Information Services (CEGIS). The time-series geo-referenced satellite images would be superimposed in GIS environment to assess the shifting pattern of the sandbar. This analysis will facilitate to assess the translation process of large scale bed forms such as sand bars that has significant contribution to an eroding bend.

C) Social survey: Field survey would be made to understand if there is any local impact of the local inhabitants over the study reach due to erosion. To conduct the study, Participatory Rural Appraisal (PRA) tool like Key Informant Interview (KII), Focus Group Discussion (FGD) would be adopted.

i. **Key Informant Interview:** KII would be conducted with local Government personnel, village leader and other people who are well-aware about the relevant issues for major information and group formation for FGD.

ii. **Focus Group Discussion:** A number of FGDs would be conducted with different erosion affected groups to have the knowledge about their activity.

The observed situation would be discussed so that the issues can be adequately addressed during relevant project planning.

10. References:

Bhuiyan, A.B.M.F. (2007); River Erosion Mitigation and Sediment Control Technology in Bangladesh, National Workshop on Soil, Erosion, Eco-degradation and Poverty Relation in Bangladesh Perspective, International Erosion Control Association, Bangladesh Chapter.

CEGIS, (2007); Long-term Erosion Processes of the Jamuna River, prepared for Jamuna-Meghna River Erosion Mitigation Project, Bangladesh Water Development Board (BWDB), Dhaka, Bangladesh.

Elahi, K.M., Ahmed, K.S. and Mafizuddin, M. (eds) (1991); Riverbank Erosion, Flood and Population Displacement in Bangladesh, Dhaka: REIS-JU, Bangladesh.

Halcrow, Sir William and Partners, DHI, EPC and DIG, (1994); River Training Studies of the Brahmaputra River, Final report, Annex 2: Morphology, Prepared for Bangladesh Water Development Board (BWDB), Dhaka, Bangladesh.

Pizzuto, J.E. and Mecklenburg, T.S. (1989); Evaluation of Linear Bank Erosion Equation, Water Resources Research, Vol. 25, No 5, Pages 1005-1013.

Silva, A.M.F.D. (2006); On Why and How do Rivers Meander, Journal of Hydraulic Research, Vol. 44, No. 5, Pages 579-590.

Thorne, C.R. (1991); Bank erosion and Meander Migration of the Red and Mississippi Rivers, USA. Hydrology for the Management Large River Basin, IAHS Publication No. 201.

Thorne, C.R., Russel, A.P.G. and Alam, M.K. (1993); Planform Pattern and Channel Evaluation of the Brahmaputra River, Bangladesh, Braided Rivers, J.L. Best and C.S. Bristow (eds), Geological Society of London Special Publication No. 75, ISBN 0-903317-93-1, pp.257-276.

Uddin, M.N. and Rahman, M.M. (2009), Flow pattern visualization and erosion estimation at a bend along the braided Jamuna River, River, Coastal and Estuarine Morphodynamics: RCEM 2009 – Vionnet et al. (eds), pp.1063-1070.

11. List of Courses so far taken with course no, name of the courses, credit hours, Grade, Grade Points and G.P.A:

Course No.	Name of the Courses	Credit Hours	Grade	Grade Points	G.P.A
WFM5202	Socio-economic Analysis	Pre-requisite	S	-	
WFM6207	Water Resources System Analysis	3	B	2.5	
WFM6101	Alluvial River Processes	3	A	3.5	
WFM6303	Integrated Water Resources Management	3	B+	3	3.08
WFM6301	Agricultural Water Management	3	A	3.5	
WFM6104	Gender and Water	3	B+	3	
WFM6209	Interdisciplinary Field Research Methodology in Water Management	3	B+	3	
WFM6000	Thesis	18	-	-	

Signature of the Tabulator:

Md Azad Hossain. 14/02/2011.

12. Cost Estimation:

a. Cost of materials:

i.	Photocopy of books, reports etc.	= Tk.2000
ii.	Cost of Photographs (Printing)	= Tk.1000
iii.	Secondary data and map	= Tk. 2000

b. Field survey cost:

i.	Travel cost (Micro-Bus fare) (6 visits @ Tk. 6000 per visit+1day extra for stay)	= Tk.42000
ii.	Field Survey cost (Boat fare) (6 visits @ Tk. 2500 per visit)	= Tk.15000
iii.	Living expenses (1 person 2days/visit, Tk.400 per day, 1 visit)	= Tk.800

c. Paper, Ink etc. =Tk.1000

d. Thesis typing, scanning, drafting and binding etc = Tk.3000

Total =Tk.65800

(Taka Sixty five thousands and eight hundreds only)

All costs will be borne by Crossing Boundary project.

13. Approximate time for use of Computer Lab Facilities **:** Not required

14. Name of Co-Supervisor: Not Applicable

15. RAC reference

Meeting no: 86 **Resolution no:** 5(KA) **Date:** 13.02.2011

16. Number of Post-Graduate Student(s) working with the Supervisor at Present: 7

Farzana Mahmud

....

Signature of Student

14/02/2011

....

Signature of the Supervisor

28/2/2011

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Signature: Director of the Institute