# CHAPTER - I

# Introduction

## 1.1 Problem

Flood and bank erosion since pre historic periods have become one of the major aspects of discussion for its direct interaction with physical and socio-cultural environment. Bank erosion by large channels and rivers is an important environmental issue, as it leads to huge national loss in terms of agricultural land and agricultural output. It causes untold misery to a large section of rural population who become homeless destitute, a future imposed upon them, for which they are in no way responsible; (Sarkar, 2004). Actually alluvial channels play independently and almost irrespective of topographic control to erode and to disfigure the playfield i.e. flood plains, vigorously. Alluvial channels, as they flow over the easily erodible sediments are characterized by time dependent stability factors. Instability is often accentuated by changes in sediment load, discharge, and flow pattern and channel geometry. Energy disequilibrium, thus generated gives the system entropy a tendency to increase with immediate behavioral responses in the form of radiation, avulsion, and Thalweg shift and thereby bank erosion. Here in this work such hydro-physical system entropy in relation to consequent response in the form of bank slumping, wasting; liquefaction etc. is trusted in reality. Though rivers of such sections are always in grasping attitude but, since time immemorial, many people in the world have depended on mighty rivers for their livelihood (Ramasastri, 2003). Many of the geographers of the world are engaged, now-a-days, in prediction of when and where future erosion will occur but the extent of such erosion is very uncertain because of the many interacting factors involved. In this present work the eastern bank of the river in Malda District has only considered for study as the right bank along Rajmahal side is not pronounced to bank erosion. A river is in a state of equilibrium if the discharge, sediment load, sediment size and slopes are delicately balanced, such that there is no change in bed elevation in a given reach over a long period of time. A change in any of these controlling variables or the imposition of an artificial change by the construction of structures along or across the stream will disturb its equilibrium and the stream then aggrades or degrades (Ramasastri, 2003). River Ganga in Malda district taking the

western margin of the district is a unique example of such instability and is highly susceptible to swinging in a serpentine form and thereby resulting into the age old problem of bank erosion. Ganga River is eroding its bank at the faster rate (highly up to 2007-2008) in the Manikchak (Gopalpur to Ganga bhawan), Kaliachak II and Kaliachak III (Pardeonapur) blocks of Malda. In the last decade hundreds of acres of land with fertile topsoil and orchards and thousands of houses have been lost, that together has given rise to thousands of environmental refugees (Sarkar, 2004). Recurrent wet seasons and incessant raining provide the prominences to accentuate the vigorosity of the disaster. Till 1931 such phenomena was almost static but started to be chronic from the1960s and onwards and the problem has manifested itself to a formidable magnitude during the last ¾ decades. The very recent devastating flood and bank failure in this stretch of the Ganga, Ganga-Padma River during August-September, 1998 is the finest example of the existing *'geo-bio-cultural'* interactions (Chakraborty, 1998). In their natural condition rivers seldom reach to a state of equilibrium, even over short reaches. Meandering is one of the means through which rivers tend towards the so-called dynamic or quasi-equilibrium state (Ramasastri, 2003).Here also the river is in such action to meet up that quasi-graded stage creating the curvature of steady meandering. The proper understanding of meander development and channel pattern changes of alluvial rivers is of vital importance for citing varied river valley development and water hazard control structures in the backdrop of proliferation of human settlements in the flood plains. The main channel of the River Ganga between Rajmahal and Farakka is shifting continuously and steadily to the left since the starting of the last century. The erosion of the left bank in this reach is the manifestation of this lateral shift. As many as eight groups of experts were appointed by the Central Government, State Government, and project authorities to deal with the problem since 1980s. Up to 1978 total area of habitation eroded was about 14,335 ha which reached to 310 ha in 1996. During last 10 years, natural morphological changes of the river reach have resulted in the development of two spill channels which are carrying considerable amount of river flow. Nature has thus offered an opportunity of flow diversion through any one of these two newly developed channels by way of acceleration of its natural growth. Available annals display that the main channel of the river in this reach is oscillating from left to right. At present, the river is experiencing the tremendous over curvature due to left-ward

swing. In 1963, Panchanandapur was subjected to serious phases of erosion. But the attack subsided within a short span of time. The next phase was predominating near Toffi during the early seventies. Charbabupur on the left bank of the river, immediately upstream of the barrage was the point of focus in the late 1970s which turned again to Panchanandapur. By 1988 the bank between Manikchak Ghat and Moynapur was the alarming reach in terms of rapid erosion. But during the years followed by the late 1980s such focal area lost the vigorous rate of erosion and the erosion of the reach immediately downstream got accentuated. Following 1990s the lower reach downstream of Moynapur i.e. parts of Domhat, Nathinagar, and Khaskol-Panchanandapur bend were the areas to be diminished. The situation continued to a faster rate up to 2005.Thus it is evident that the nature of erosion in this reach has been manifested to an intermittent nature and attack to the alternate parts in the alternate decades and can be generalized by close observations as well as from available data. Panchanandapur (Downstream part) was attacked in 1963, early 1970s, late 1990s and continuing till now. Manikchak Ghat (upstream part) was attacked in late 1980s and again in 2003.

Earlier reach between Rajmahal and Farakka indicate wide lateral shift of the main channel over the years. Survey maps of 1922-1923 and 1936-37 (Topo-Sheet nos. 72P/13 and 72O/16) show a straight course of almost zero sinuosity between Rajmahal and Farakka followed by number of successive crescent shaped abandoned paleo channel loops and the crescent shaped settlement lines along the channels near the left bank at that time which evident the truth. Recent image plan forms also show clearly the existence of a part of this line of demarcation. The alignment of the abandoned loops and differential settlement lines are similar to that of the eroding left bank line subsequent to 1922-23 (I & W, West Bengal, 2004) *(Fig. 1.1)*..The line which joins these pools is named as 'MARGANG' (Dead River). In flood plains such relics are indicative of the old paleo features of the river. Thus the interfluve area between left bank line of 1922-1923 and the crescent shaped settlement line is indicative of purely riverine char lands and incidents of flood. The highest elevation of this area was low than that of the land outside the settlement line. The existing height of these in channel bars or chars near the water edge ranged between 2.0 to 3.5m whereas the normal heights of the older bank ranged between 5.5 to 6.0 m .The inference drawn obviously is that the settlement line at the extreme left was once the

abandoned bank line of the river from where the mighty river skirted to take the line roughly joining Manikchak, Enayetpur, Dharampur, Chandipur, Nathinagar, Bhawanipur, Mohonpur, Khaskol and Gosainpur following Panchanandapur, Rajnagar and Farakka. From such a state the trunk flow of the river gradually swinged to the right and in this process left the successive paleo-loops. But such a journey towards the massif of Rajmahal was during the starting of the last century and again the Thalweg became straight and hugged the right bank similar to that of 1922-1923 survey. The situation did not last for long periods and started to be skirted to the left over the alluvium of the loose 'entisols' that can be traced from the alignment of the main channel in the topo sheet (SOI) of 1971.Now the river is facing intermittent phase of extreme leftward movement. Presently the reach between Farakka and Khaskol receded further inside the country. The reach between Khaskol and Manikchak is yet to reach to the extreme left position. Prior to 1930s the left bank line was located far off left to the present one. Between Farakka and Khaskol, the earlier bank line was located to the right of the present one and aligned along Gosainpur, Hussainabad villages. These focal points demark the location of recent left ward movement of the river. During 2000 to 2006 actually Manikchak-Gopalpur sector (SOI sheet 72O/16) was active zone of bank erosion as about 700 m shifting of river bank between April 1997 and November 1997 was revealed from the multi-seasonal imagery. Morphological arrangements of the older meander scrolls are indicative of further eastward extension of this zone up to Pagla River (Chakraborty, 1998). These have been proved within 4 and half years and Pagla-Ganga are no longer separate identities after 2003. Well marked eastward shifting of the Ganga River in comparison to SOI toposheet nos. 72P/13 (1970-1971) with the help of imagery of 1997 showed that the Ganga River swinged to a large extent and engulfed the meander loops of the Pagla River. Such prediction held true as was exemplified by the devastating flood of 1998 in Malda District as a whole. Thus in a nutshell the prolonged history of riverine morphometry in the light of river metamorphosis of the river Ganga displayed an erratic nature. And in such a way that properties worth to several thousands of crores have already been destroyed (Table 1.1).

## RIVER GANGA AND ABANDONED LOOPS

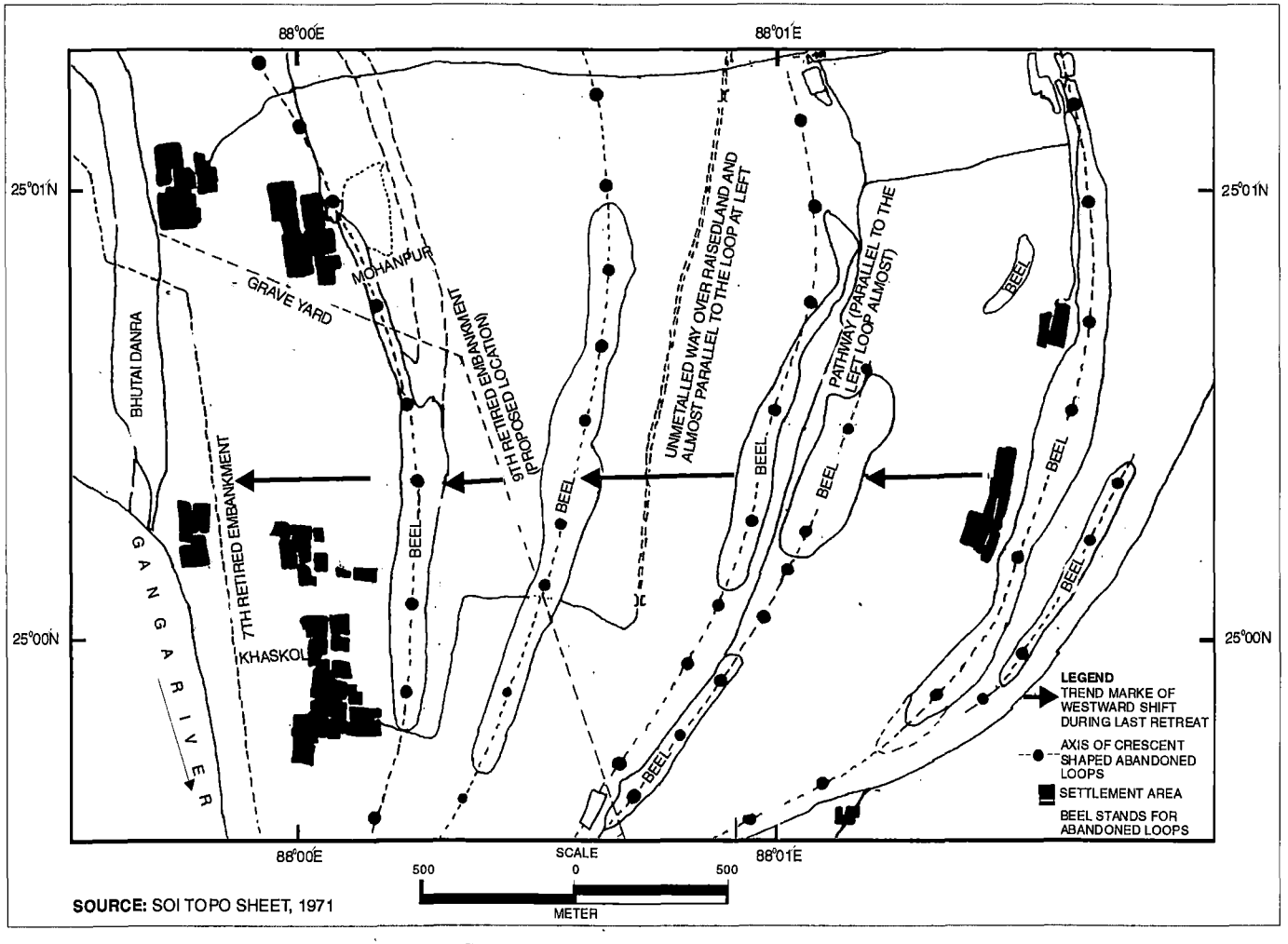



**Figure 1.1** River Ganga and its Abandoned left-out Loops during the Last Retreat.

**Table 1.1** Area of left Bank Erosion (Period 1922-23 to 2003).

| Reach | Area eroded (sq. km) | | Total area (sq. km) |
|---|---|---|---|
| | 1922-23 to 1971 | 1971 to 2003 | |
| Farakka to Panchanandapur | 46 | 38 | 84 |
| Panchanandapur to Manikchak | 58 | 27 | 85 |
| **Total** | **104** | **65** | **169** |

**Source:** I & W. Department, Govt. of West Bengal, 2004.

At Rajmahal site the river flows through a narrow neck like channel of about 2.0-3.0 km width with an average depth of about 9.0 m below pond level (+21.96 m GTs) of Farakka Barrage. The thalweg skirts the right Rajmahal bank of the river. Downstream of Rajmahal the river fans out and within a distance of few kilometers the width enlarges to about 10.0 km to 11.5 km at the bank full stage. The master channel of the river Ganga in this reach before taking a curve turn from shields of Rajmahal towards Manikchak throws two secondary channels from its right. At present (pre freshet 2004) such two channels have developed significantly as viewed in the image plan forms of 1997, 1998 and 2003 from normal to critically developed channels. The channels take their passages through the convex sand bars. The Right channel designated as RC takes off at location at about 2.0 km downstream of Rajmahal and RC traverses for about roughly 17 km (Imagery 2003). Through the channel charlands it finally pours into the master one (MC). The average depth of the channel is about 4.0 m below the pond level. The central channel designated as CC flows for a distance of 7.0 km taking off from the main one and again joins the same river with an average depth of about 5.0 m below the pond level. At this level the average width of both the channels are about 550.0 m and 350.0 m respectively. Such a right channel was hardly found in existence prior to1980s. Since the Main Channel designated as LC started to be swinged and was developed by eastward cutting of the bank taking Malda side country soil and reappearance of areal extent of the sand bars on the right of the thalweg line of LC extended.

On crossing from right bank to the left bank, the thalweg line abruptly hugs the left bank i.e. turning diametrically from one to the banks adjacent to Manikchak Ghat. From there it follows the course for a distance of about 7.5 km and again the thalweg hugs the left bank near Khaskol and Sakullapur and continue to remain close to the bank up to Panchanandapur. On field observations as well reports estimate a

near bank depth of averagely 20.0 m below pond level here. The face of the bank is almost vertical. The width ratio of the river is almost 1:10 compared to Manikchak in the north and Farakka to the south whereas the av. channel width is 1,500m at pond level. The thalweg as viewed in the image plan forms of 2003, it leaves the left bank at Panchanandapur and crosses over to reach to the right just upstream of Barrage. The straight line or crow fly distance between Rajmahal and Farakka Barrage is only 29km and the Thalweg is about 43.5km which indicates a high index of sinuosity.

## 1.2 Objectives

The following objectives have been considered:

i. To analyse the nature and extent of bank erosion of river Ganga in Malda district.

ii. To find out the causative factors of bank erosion.

iii. To analyse the soil and terrain characteristics of the bank of River Ganga.

iv. Documentation of Spatio-temporal variations of bank erosion along the river Ganga in Malda district.

v. Assessment of bank erosion protection measures taken so far. An attempt has also been made to assess the impact of such so called protective measures.

vi. To assess the socio-economic consequences of bank erosion with reference to social disruption, land and property loss, rehabilitation and local agro-economy.

vii. Suggest remedial measures including (i) short term and (ii) long term measures.

## 1.3 Methodology

Study of satellite imageries of different years and morphological arrangement of older meander scrolls over the base maps has been done associated with field records of river shifting. For understanding the extent of erosion BEHI (Bank Erosion Hazard Index) has been performed with that of calculation of horizontal displacement of the channel over timeframe taking the thematic maps from secondary sources. Study of the bank sections regarding hydraulics of the channel and analysis of the river power has been carried out.

Study of Published articles, Books, memoires, historical literatures, historical maps and sketches has been performed to make out the responsible causative factors of bank erosion. Schedule survey was also carried out in this connection to know the perception of the affected people regarding causative factors of bank erosion.

Soil samples of selected spots have been studied in the Pedological Laboratory, NBU with special reference to mechanical properties of the bank soil (sand, silt, clay content). Also the secondary informations on mechanical composition of bank soil have been taken. Soil map of the District prepared by NBSS and LUP (ICAR undertaking) has been helped to know the soil characters elaborately. Literature study from different sources on drainage and physiography has been helped to understand the terrain characters as well as field observations have also been done.

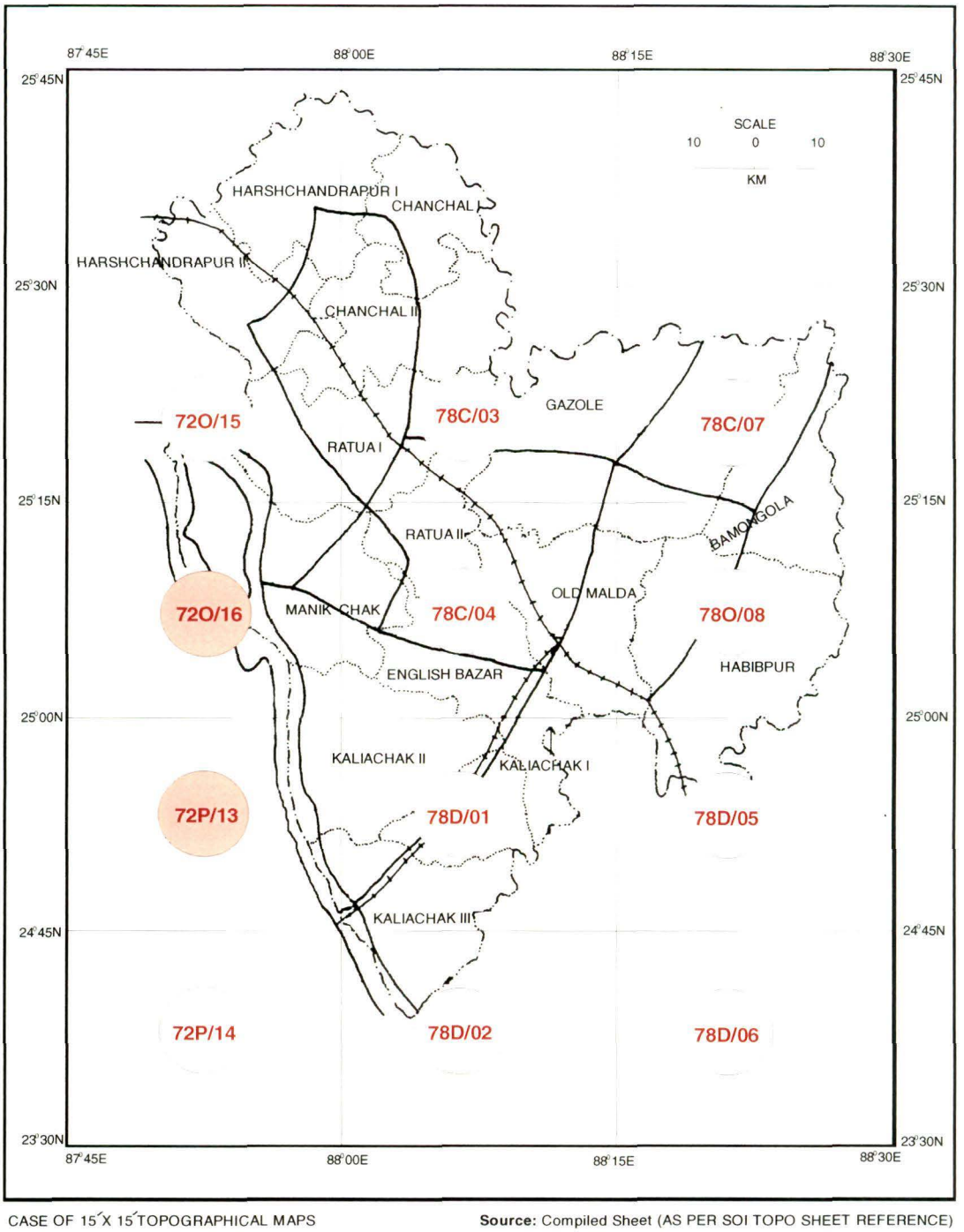
Superimposition of time series imageries, thematic maps of District Land Reform Office, maps of Department of Irrigation and waterways, Govt. of W.B. have been done taking toposheets as base maps (SOI Topo-Sheet No. 72O/16 and 72P/13) in unity scale to mathematically measure the rate of shifting *(Fig.1.2)*.In doing so the following sites have been taken to perform case treatment (a) Panchanandapur, (b) Khaskol, (c) Aswinitola, and (d) Manikchak.

Study of thematic maps depicting location of spurs, embankments etc. with a view to know the negative impact of the structural measures on the riverine ecology has been performed.

Study of local news papers, little magazines, articles has been done. Schedule surveys on socio-economic lifestyle of the dwellers have been initiated to investigate the ground reality with that of group discussions with the local inhabitants. Secondary data records from authentic sources have been taken so far to know the chronological records of land loss and agro-economic losses.

In-depth study of the remedial cum protective measures being used worldwide and understanding the fitfulness of them in the concerned study area especially treatment of mighty rivers like Ganga has been performed.

**TOPOSHEET PLAN**
MALDA DISTRICT




CASE OF 15′X 15′TOPOGRAPHICAL MAPS **Source:** Compiled Sheet (AS PER SOI TOPO SHEET REFERENCE)

**Figure 1.2** Comprehensive Plan of Topographical Sheets (15′X15′; 1:5,000 scales) of Malda District.

## 1.4 Study Area

Malda District has been chosen as study area as a whole, with reference to site study of Panchanandapur and adjacent areas. The district comprises about 3,566.17 Sq. km area and is located within latitudes of $24^0 30'$ N to $25^0 32'$ N and longitudes of

$87^0 49'$ E to $88^0 33'$E.The district Malda is situated keeping Jharkhand in the West, Bangladesh in the east, and Murshidabad district in the south, whereas the River Ganga delineates its western boundary and the northern part of the North Dinajpur district *(Fig. 1.3)*.

Manikchak- Gopalpur sector (SOI toposheet No 72 O/16) is an active zone of bank erosion along the left bank of Ganga River. About 700 m shifting of river bank between April, 1997 and November, 1997 as revealed from the multi-seasonal imagery, has been noticed clearly (Chakraborty, 2000). Further study of images 1998, 2001, 2002 and 2003 reveal evidences of eastward shifting and such extension is proved by morphological rearrangement of older meander scrolls. Well marked eastward shifting nature of the Ganga River in comparison to SOI Topo-Sheet No. 72O/13 and 72O/16 (Surveyed year 1970-1971) further reveals the same progressive proceedings in the Khaskol Farakka sector also.

From the view point of physical set up, the district is divided into 3 identified parts, namely, Tal (in the North and North West), Diara (in the Southwest) and Barind (in the East). Barind is characterized by undulations with successive mounds and depressions, Diaras are alluvial lands created mainly by the joint action of deposition by the rivers Mahananda and Ganga probably in the Pleistocene-Holocene (Recent) age. The Tal tract is dotted with many small depressions or lakes which are practically low lying areas. Being in the alluvial flood plain with a mean flow of 3,400 cusecs year $^{-1}$ and a bed slope of 1 in 21,000; river Ganga flows in a meandering stage (Mazumder, 1992).

The river enters the district near Gaduri of Bhutni char of Manikchak block and flow for a length of 172 km including its tributaries and leaves far below Panchanandapur of Kaliachak block. Till 1931 the reach of the river was more or less straight between Rajmahal and Farakka, but after the construction of the Farakka Barrage meandering of the river towards the left bank reached to a vigorous situation.

To be specific it is also to be noted that the reference of the study area has been elaborately viewed by arranging the Topo-Sheets with reference numbers 72O/13, 72O/16 and 72O/14 (remaining parts up to Farakka Barrage).

## LOCATION MAP

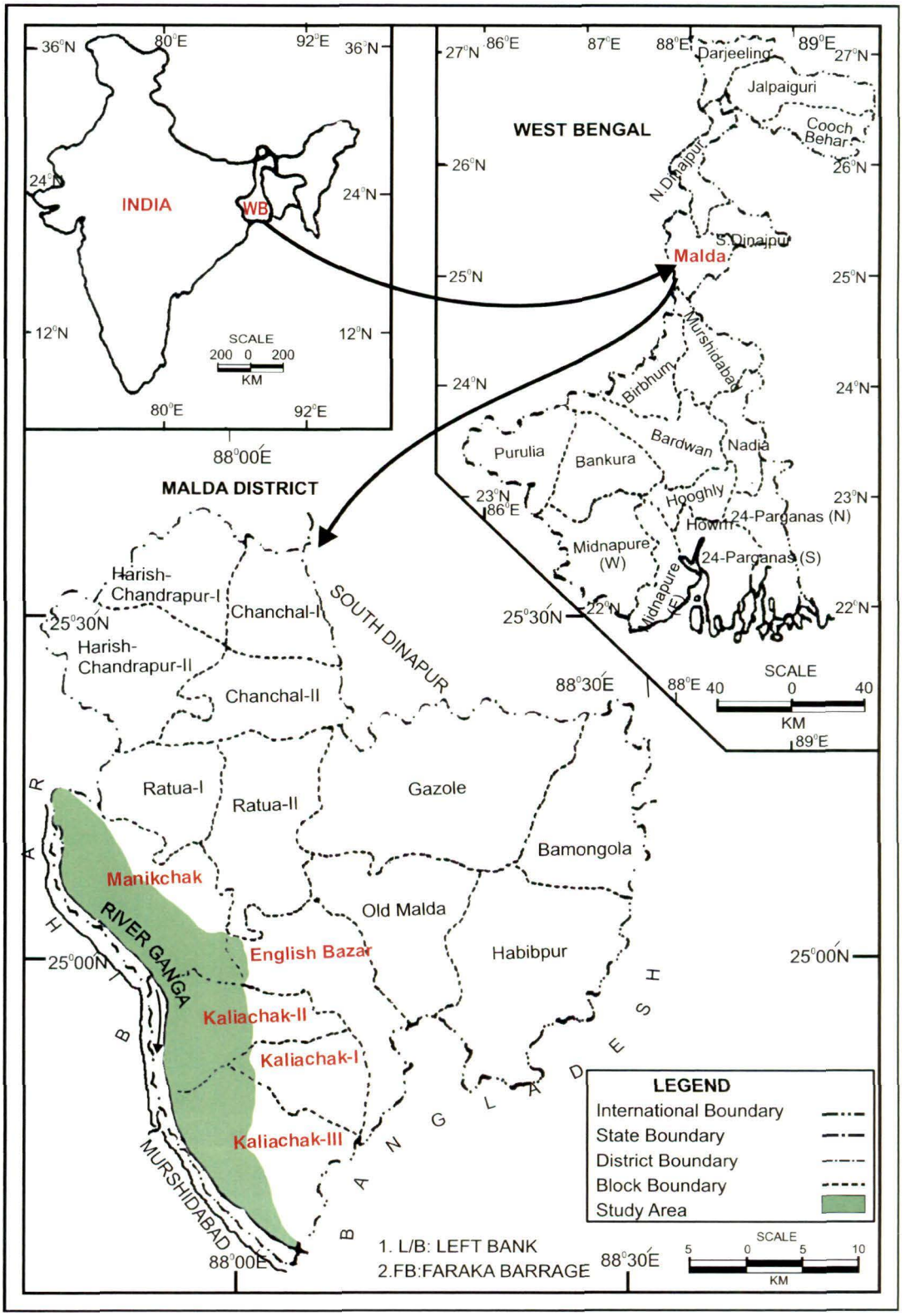



**Figure 1.3** Location of Study Area with Affected Blocks.

## 1.5 Review of Literatures

The following aspects of review of literature related to river migration studies have been done as discussed below:

### 1.5.1 Channel Geometry related works

Knighton in 1972 studied distinctive attitude of rivers with single or multiple channels even single channel having occasional development of islands. Single channels have also been described specially meandering called as wandering. In the Soviet literatures, up to eight mender processes are distinguished, for example works of Makkavyeyev, *et al,* 1969, kondart' yev, 1968 and Kulemina 1973. Crude distinction of pattern change involving metamorphosis from single to multiple channels has been studied by Schumm, 1969.Now-a-days very recent studies exhibit illustrated maps superimposed through computer soft wares and plan form building by serial air photographs. Related works can be cited as follows, Alexander and Nunally, 1972, Blench 1969, Brice 1974, Burkham 1972, Everitt 1968, Fahnestock and Bradley, 1974 etc. Burkham in 1972, Lewin in 1976, Schumm and Lichty, 1963 followed such methodology by arranging ground snapped photographs.

### 1.5.2 Curve fitting literatures

Channel loop plan forms (topographical maps prior to 1970s of Malda) frequently, but not invariably, have an appealing simplicity of outline which, at least in the case of individual bend attitudes have been approximated by various curve fitting methods. Langbein and Leopold in 1966 introduced sine curves and Brice, 1974 came with circular arcs to understand the degree of oscillation or looping of the channels. Empirical comparison of loop properties was also studied by Ferguson in 1973. Some related works are the works of Daniel in 1971, Brice in 1974 etc. Surkan and Van Kar, 1969 studied multi-looping having asymmetrical (axis-wise evolution) wandering.

### 1.5.3 Empirical Works

Works related to laboratory measurements, survey or photography has been used to record changes in channel behaviour. Researchers in this field are Fahrestock, 1963, Krumbein and Orme 1972, Smith 1972, Leopold 1973 Schumm 1972 etc.

Estimated changing hydraulics was done starting from for hours to years specially works of Medock, Schumm and Leopold.

### 1.5.4 Historical literatures

Though traveler's jottings, historical notes, manuscripts of older citizens are not easily available, inspite of that little documentation related to historical periods may be of worth to quote. Most of the older rivers are accomplished by rapid and lag occurrences of bank wasting and successive stages of sedimentations. Morphological forms mainly meander scrolls and paleo left outs are the imprints to trace patterns of evolving channels. Related works can be quoted, done by Koudart'yuev, 1968 Hickin, 1974, Schumm, 1972 etc. Though such understanding is decipher in reality but Hickin's work of meander curves is considered to be swaggering. For example Mississippi River Commission 1931, 1941 conducted serial surveys on river morphology for his works. Historical works on Gila River from 1846 to 1970 by Burkham, 1972 using cadastral maps, ground photographs and river cross sections, and 1937 was a remarkable study to follow up till the date. Documentary related literatures like J.C.Sengupta's District Gazetteer of Malda, 1969 and M.O.Carter's District Settlement Report, Malda have been of high worth especially for the trusting of past day Ganga course and the present day in a comparative manner. Physiographical studies especially documents on 'Tal' region of Malda can be better received from M.O.Carter's Settlement Report. The location of 'Rarh Banga' has been found along the southwestern part of mighty Ganga in the oldest dictionary called 'chalantika' and Tabakat-e-Nasiri. Information of abandoned scrolls of river Ganga in the northern part of the district around Harischandrapur called by variety of local names–*Gargariba,Gangoree,Gangnadia, Gangakura,* have been quoted in the precious records of William Hunter's 'Statistical Account of Bengal',1813.Abdus Samad's detailed records in his excellent work 'My discovery of ancient Gaur at Kandaran and its connected surrounding' and '*Zilla Maldaher Itihas O Malda Samagra,* can be of prominent utility to trace out detailed evidences of the phases of river wandering from north to northeast and northwest of the River Ganga. Fairly large number of literatures speak that the course of the Ganga has changed considerably down the ages. Regional perspectives with reasonable spatial information may best be expressed in the works of O. Mally, 1914; Ray, 1952 and Jao Barros, 1950 (works on mapping delineations). 'Rivers of Bengal' edited by Govt. of

West Bengal illustrates hundreds of date back histories of Bengal delta formation starting from south of Sagardighi in South Dinajpur, i.e. the then south eastern part of West Dinajpur. Van Den Broucke, 1660 and James Rennel 1764-76 analyzed and amplified sharply the three stages of probable shifting of river Ganga, and Ganga Padma River from west to east up to 1600 A.D. According to Rennel during 1700 A.D.Ganga had changed its course considerably and shifted towards its present course (to the west) i.e. miles away from the ruins of 'Gauda' (Gaur of Gastaldi, 1561 or 'Gorij of Barros, 1550) leaving its former flood plain deposits and some spill channels as remnants (Sengupta, 1969).

**1.5.5 Literature of Recent Past**

Chakrabarti (1998) describes the sequential changes in the courses of Ganga, Ganga-Padma River system within West Bengal through applied Geomorphological studies during pre and post Farakka Barrage period based on the comparative analysis of the SOI topo sheets/ Police station maps and multiseasonal satellite imageries. Agrawal, *et al,* (2001) studied the morphology of the river Ganga in its middle reach from Buxar to downstream of Farakka. Cain & Betty (1968) investigated of soil map units including alluvial, colluvial and high water table soils. Kiefer (1969) carefully analyzed flood plain soils through photo interpretation and utilized panchromatic air photos for diagnosis of flood plain features like in channel bars, river scrolls, paleo left outs etc. Flood plain delineation using remote sensing techniques took keener interest in the works of Milfred, *et al,* (1969). Viane (1969) computed and noted that alluvial soils are restricted to areas where deposits of alluvium are more than 12 inches thick. Wolman, 1971 studied alluvium deposits by rivers and he distinguished the nature of alluvium and colluviums i.e. deposit of slope wash. Spring floods have been studied by Hallberg (1973) for the mapping of extent of flooding of *Nishnabotna* River in Iowa. Morrison & Cooley (1973) carried out spring flood mapping on the Gila River in Arizona. Flood inundations and mapping of sedimentation zones caught interest in the works of Harker (1974), Rango & Salomonson (1974), Moore and North (1974) etc.Same studies by chaturvedi and Mohan in 1983 for the delineation of flood inundated areas received pronounced interests using Landsat 3 data of September in the southern and eastern Uttarpradesh belt. Ali, *et al,* (1989) examined the applicability of NOAA satellite AVHRR imagery to study river flood frequencies with that of hydrological conditions in Bangladesh. Nagarjan, *et al,* (1993) used

precise fields of remotely sensed data to study flood and erosion related features of river Rapti in U.P using remote sensing techniques. Jha (1993) delineated flood inundation areas and river bank side wasting of Punpun catchment of Ganga Basin in Bihar. Wang, *et al,* (1995) studied flood occurrences and collapsation of settled areas using ERS-1 SAR, 1995 of the river Rhine, Waal and Maas in the deltas of Central Netherlands. Sharma, *et al,* (1996) culled panchromatic images of IRS-1A, LISS-1 series with false colour composite (FCC) for the month of July, 1993 in Punjab and they concluded that both over flow of channel bed and breaches in embankments of rivers and canals caused such disaster. Boni, *et al,* 1996 precisely analysed the flood erosion situations of 4-6 November, 1994 in northern Italy in the perspective of flood hazard multi-sensor monitoring using traditional ground based rainfall observations.

Departmental reports like Irrigation and Waterways, 2000, West Bengal attempted details of bank line collapse, remnants of waste and slip off slopes with official records and computations and as well elaborations regarding measures taken to anti erosion achievements. K. Mazumder (2001) studied hydraulics and water resources of river Ganga using 30 years of hydrographs with rating curve statistics.

Among the competent workers in this field one of them is K. Rudra who clearly discussed the socio-political and physical issues emerging with Ganga erosion in the district Malda in his study titled '*Ganga Bhangan Katha: Maldaha-Murshidabad*' in 2002.P. Sen in 2005 studied the problem of bank erosion from engineering point of view and analysed the responsibility of Bhutni Diara embankment behind such occurrences. R. Basu in 2005 studied river dynamics of Bengal in the post Farakka periods taking the case of River Bhagirathi Hugli. S.Sarkar studied detail morphometry of River Mahananda with various hydrological aspects. J. Das, T. Dutta & K. A. Saraf in 2007 endeavored to identify the change detection of the Barak River in N.E. India by studying alluvial erosion and course oscillation. Rudra in 2000 clearly performed works on flood problems of North Bengal and related the reasoning of bank slumping to river dynamics with broad physiographic analogy of Bengal Gap.

S. Chowdhury in1998 studied the social realm of the bank side inhabitants and presented data base on erosion loss. K. Rudra in1999 clarified the reasons behind such disaster in between Rajmahal and Farakka and titled his work '*The Encroaching Ganga in West Bengal*'. Works conducted by NYSDEC (New York State Department

of Environmental Conservation) prepared check list analysis and developed worksheet based bank erosion measurement of Boquet River in USA, 1994, and 2002. A. Simon, J. Eddy, J. Langendoen, and R. Thomas etc. in 2004, U.K worked on bank toe erosion by hydraulic shear and bank stability analysis by building up standardized model studies.

O. Wilson, and Samuel, Department of Earth Science, University of South Alabama, 2003 studied on erosion and stream bank protections. L. David & P.H. Rosgen of Wild-land Hydrology, Inc. Pagosa springs, Colorado, 1973 to 1990 and onwards derived practical methods of computing stream bank erosion rate of West Fork Madison River and River Montana. Julian, Jason, Raymond Torres in 2005, Department of Geological Science, and University of South Carolina profoundly discussed hydraulic erosion of cohesive river banks by attempting flow measurements, and critical shear stress study. Not only these dozens of little magazines, convention reports, Agriculture Annual plans, Flood analysis reports of the office of the District Magistrate, Malda, reports of DLLRO office, Malda and informations from the Department of Irrigation and Waterways, West Bengal etc. helped a lot.

**References**

1. Chakrabarti, P. 1998: *Changing Courses of Ganga, Ganga-Padma River System, West Bengal, India-RS data Usages in User Orientation*, State RS Centre, DST and NES, Govt. of West Bengal, Salt Lake, vol. 25, Kolkata-91, pp. 19-28.

2. Mazumder, S. K. 2001: *Training of River Ganga Near Farakka Barrage*, ICT Pvt. Ltd., HYDRO, New Delhi-110016, pp. 220-221.

3. Ramasastri, S. K. 2003: *Evaluation of Shifting Characteristics of River Ganga between Ara and Patna using Remote Sensing Data*, May, NIH, Patna, chapter-I, pp. 1-4

4. Sarkar, A. 2004: *River Bank Erosion: Geomorphology and Environment*, acb publications, Kolkata, India, ISBN: 81-87500-19-0, pp. 86-106.