SPATIO - TEMPORAL MORPHOLOGICAL ANALYSIS USING SATELLITE DATA FOR A REACH OF RIVER BRAHMAPUTRA

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
WATER RESOURCES DEVELOPMENT (CIVIL)

By
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CANDIDATE'S DECLARATION

I do hereby certify that the work which is being presented in the dissertation entitled "**SPATIO-TEMPORAL MORPHOLOGICAL ANALYSIS USING SATELLITE DATA FOR A REACH OF RIVER BRAHMAPUTRA**" in partial fulfillment of the requirements for the award of Degree of **Master of Technology** in ***Water Resources Development (Civil)*** submitted in the **Water Resources Development Training Centre, Indian Institute of Technology, Roorkee** is an authentic record of my own work carried out since July, 2001 to February, 2002, under the active guidance and supervision of **Dr. Nayan Sharma**, *Professor*, **WRDTC** and **Dr. S. K. Ghosh**, *Associate Professor*, **Department of Civil Engineering, IIT Roorkee**, India.

I have not submitted the matter embodied in this dissertation for award of any other degree or diploma.

Place: -Roorkee,

Dated: - February 28, 2002.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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NOTATIONS

A	Cross-sectional Area
B	Top Width of River/Channel
D	Depth of Flow
m	Suffix for Model
n	Manning's Roughness Coefficient
Q	Discharge of Water
S	Longitudinal Slope
V	Velocity of Flow
p	Suffix for Prototype
r	Suffix for prototype & model ratio

ABBREVIATIONS

ADV	Acoustic Doppler Velocimeter
BL	Bed Level
Img.	Imagery/Imageries
km	Kilometer
LB	Left Bank
mt	Meter
RB	Right Bank
Sat. Img.	Satellite Imagery/Imageries
Sur. map	Hydrographic Survey Map/Maps

SYNOPSIS

The Brahmaputra river during the days of peak flow is a terror in Assam. The flood discharge upto the magnitude of 72000 cumec and even more has been measured in the past. Discharge of this magnitude submerges a number of villages in the plain of Assam valley. Every year so many lives and properties are being engulfed into this. In order to get respite from this a number of measures, such as strengthening of embankments, construction of spurs, ringbunds have been taking place involving cores of rupees. But these majors have not proved fool proof as these steps are taken studing the local behaviour of the river only.

In order to achieve more reliable, safe and permanent measures, detailed study of river morphology should be carried out. The present work is an attempt in this direction. With the help of satellite imageries of years 1997 and 2000 and the hydrographic survey map prepared by Brahmaputra Board based on data prior to year 1986, the change in river morphology has been studied for the entire reach of Brahmaputra in Assam.

INTRODUCTION

1.1 GENERAL

The river Brahmaputra originates at an altitude of 5300 mt in Kailash range, 63 km. South East of Mansarovar. It passes through Tibet (now china), India and Bangladesh to finally join Bay of Bengal. Its total length of 2897 km is divided among three countries as follows.

Tibet (China)	-	1625 km
India	-	918 km
Bangladesh	-	354 km

In India 278 km is in Arunachal Pradesh and 640 km in Assam. Thus it is a true international river. With all its tributaries and vastness, it is considered a notorious river having immense damaging potential during flood. It is also one of the most braided rivers of the world. Its width at Pandu (near Guwahati) is just 1.2 km. and just a few km d/s of this the width is as large as 23 km. The total catchment area is 5,80,000 sq. km out of which only 60,000 sq. km. is alluvial. Sediment discharge at Pandu is 757.23 cum/sq.m. The composition of sediment is coarse 12.7% medium 14.12% and fine 73.33%.

Its origin point is at an altitude of 5300 mt where as its level at Pasighat (Arunanchal Pradesh) is just 155 mt and at kobo –120 mt at Guwahati 50.5 mt and at Dhubri 28.4 mt. Thus the river slope in gorge is 4-17 mt/km while at Pasighat it is 27 cm/km and at Guwahati it is just 10 cm/Km.

1.2 PROBLEMS IN BRAHMAPUTRA RIVER

The river Brahmaputra, at present, appears out of control of mankind during the days of flood. Throughout its course River Brahmaputra is joined by nearly 15 tributaries in the northern bank and more than 100 tributaries in the southern bank. Most of the tributaries have their own flood problem in their respective basins in addition to severe erosion problem in a few of them. The worse situation occurs when the tributary rivers flood their own basin simultaneously with the Brahmaputra spilling its own bank. The erosion capabilities of the northern bank tributaries of the Brahmaputra have been increasing due to large-scale deforestation in the catchment areas.

In most of the reaches, the bank of the Brahmaputra is so fragile in nature that the concentration of velocity at the bank forces the materials to slide down. General scour of the river bed takes place due to the continuous process of rise and fall of water level with the transportation and deposition of silt. Equilibrium scour is not excepted to be achieved because the flood is not sustained for a longer period. Excessive scour occurs during the rising period specially when the current is skew to the bank of the protection structure.

The following observation of Er. P. K. Das, Additional CE. Brahmaputra Board is enough to make clear how much serious is the flood problem in Assam that "there is perhaps no other better relief from flood than to co-exist with it in view of Assam's recurring flood problem. The parameter so fixed in the early eighties with wide spectrum of flood control such as head water storage seems to go a long way to achieve even the beginning of it. The sufferings of the state are being compounded annually with the half hearted approach towards permanent solution to the problem. At this cross road the need of the hour is to emphasise removal of the already committed defects followed by renovation /modernisation of the existing measures, intensify continuance of such measures having passive role and accelerate effective treatment of the water shed areas with a more rational and scientific outlook to facilitate paving the way for flood moderation vis-à-vis socio-economic development of the state". [IE(I) Journal –CV Aug. 1994].

The most dangerous erosion problem that has created panic over the last few years is the south bank of Majuli island which is also a part of this study. Located between cross sections no. 44 to 54 and between latitude 26^0 45' N to 27^0 10' N and Longitudes 93^0 40' E to 94^0 35' E. Majauli is the largest river island of the world (about 875 sq.km in area). Hence the river which has eaten up a substantial area of the island to the extent of 370 sq. km. over the past 50 years there by shrinking to 875 sq.km. has , for obvious reasons, posed a serious threat not only to its socio-economic values but its cultural importance is also at stake.

The reported commitment of former Honorable prime minister of India for protection of Majuli area from the onslaught of river Brahmaputra, to the delegation comprising of few elities including a few satradhikars of Majuli in September 1996 is yet to be transformed into reality. The people of Assam have been eagerly awaiting implementation of the assurance given by the then premier, else they apprehend that the biggest and prestigious island of the world will be extinct within a few years.

1.3 ROLE OF REMOTE SENSING

With the recent advancement in remote sensing specially in the field of ariel and satellite photography, the morphology of any river can easily be predicted. This will help in planning the river training works. Now the detailed manual survey is not needed which was very much cost intensive and time consuming. Digital data from satellite are available with NRSA Hyderabad which can be used for the study of change in river configuration. India has launched so many satellites during the past three decades the latest one being IRS-3C which has become operational since Feb. 20, 2002.

1.4 OBJECTIVE

Keeping the above problems in mind, the objective of the present work is to study the morphological change in river Brahmaputra during the past years. The Atlas made available by Brahmaputra board has been compiled in year 1986 and the data presented in them do belong to the period prior to 1986. The satellite imageries covering the Indian portion of Brahmaputra are available for year 2000 and there are some satellite imageries of years 1997. So river morphology for these years have been compared with the survey maps and changes has been measured.

Keeping the importance and urgency of the protection works needed for Majuli island, the morphological behaviour of River Brahmaputra for different years using hydrographic data and maps along with satellite imageries have been studied. Emphasis has been put to accurately calculate Bank line shift. It is already known that model study helps to formulate the proper protection measures by observation of different phenomena of the river in its different stages of flow. So taking the advantage of existing infra-structural facilities in the WRDTC River Engineering Lab, an attempt has been made to study the erosional activities and other fluvial behaviour of Brahmaputra in Majuli section.

The confluence zone of Dihang, Dibang & Luhit has also been studied with the help of satellite imageries and the findings summerized in the thesis.

1.5 LAYOUT

The report has been presented in different chapters. Chapter 2 is just a review of literature on river morphology and mentions some work already done with the help of satellite imageries. Chapter 3 deals in detail about river Brahmaputra basin system Chapter-4 describes the methodology for this work. Data used in this work are also listed in this chapter. Chapter 5 is analysis of the work and results produced in tabular and graphic from. Chapter-6 discusses the results and conclusion

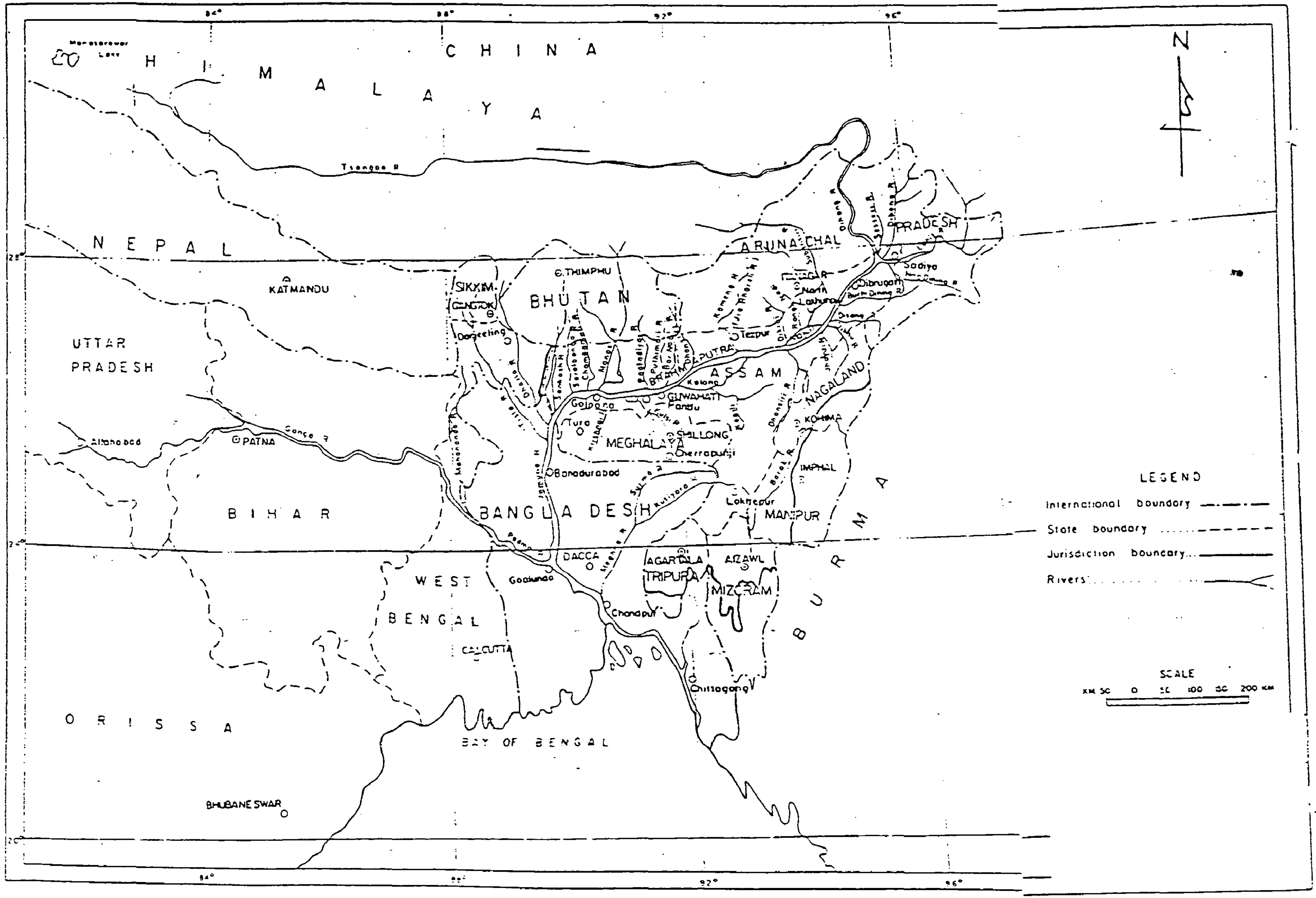

FIG.II INDEX PLAN OF BRAHMAPUTRA

REVIEW OF LITERATURE

2. 1 RIVER MORPHOLOGY

Rivers show complex combinations of various morphological elements. Thus river morphology is concerned with river planform, channel geometry, bed form and longitudinal profiles. Channel morphology changes with time and is affected by water and sediment discharge including sediment characteristics, composition of bed and bank materials, and vegetation. Because of the complex interrelation between river channel variables it is still not possible to give a complete physical and mathematical description of various morphological processes. For this reason two approaches have been commonly used (Ackers, 1982)

1. Empirical studies:
   - field studies of plane geometry of natural rivers,
   - laboratory studies of small self-formed meandering,
   - criteria for the classification of plan form,
   - correlations of geometry (e. g. meander length) with discharge,
   - the formative (or dominant) discharge when flow is not steady,
   - statistical analysis of geometric data,
   - measurements of flow patterns including secondary current,
   - observation of sediment motion, including bank erosion and sedimentary features.

2. Theoretical studies:
   - the solution, with various degrees of simplification of the Navier-Stokes equations for flow in curvilinear channels, including secondary current generation,
   - variation of shear stress and other flow properties in rigid boundary curved channels, supported by laboratory research,
   - instability in water movement as a cause of meander in e.g. transverse seiching,

- instability in sediment movement as a cause of meandering,
- numerical modelling of the interaction between flow and sediment in curved flow,
- the theory of minimum rate of energy dissipation (Yang and Song, 1989),
- theoretical analogues, e. g. random walk, free chain most probable path.

All these topics are relevant to an understanding of meander process.

2.1.1 Planform-Meandering and Braiding

The planform of rivers has traditionally been classified into broad types of straight, meandered or braided. A meandering river has a single channel while a braided river has a number of channels. This division is in part arbitrary as it is difficult to distinguish between a straight cannel and a meandering channel of low sinuosity and not everybody agrees on what constitutes a meandering or braided channel. A classification of river channels in terms of relative stability and sediment load characteristics and flow properties has been suggested by Schumm and Meyer (1979) and Schumm (1981). The most unstable channels are characterized by braiding, rapid shift in the thalweg and steep slope

Kellerhals et.al. (1976) described channel properties under three main headings.

A) Channel pattern

1. Straight: Very little curvature, occurs mainly in braided channels, delta distributories, and structurally controlled rivers.
2. Sinus: Slight curvature with a belt width of less than approximately two channel widths.
3. Irregular: No repeatable pattern. Many braided and split channels fall into this category.
4. Irregular meander: A repeated pattern vaguely present in channel plan; free meanders of sand-bed channels with high bed load, and many entrenched meanders are irregular.
5. Regular meanders: Characterized by a clearly repeated pattern. The angle between the channel and the valley axis is less than 90^0.

6. Tortuous meanders: A more or less repeated pattern with angles grater than 90^0 between the channel axis and the valley trend, this pattern is often associated with free meanders of sand-bed rivers in flood plains dominated by vertical accretion.

B) Island : Islands are relatively stable, frequently vegetable, and reach to or at least close to the valley flat level.

C) Channel Bars

1. Side bars: In entrenched straight or sinuous channel, side bars may developed. In very straight channels they can migrate. More frequently their position is associated with slight channel bends and therefore stable.
2. Point bars: These features form on the inside of well-developed bends.
3. Channel junction bars: Where a tributary joins a larger river, a bar frequently occurs immediately downstream, or on both sides of the tributary mouth.
4. Midchannel bars: The bar position remains stable over decades with bed load transport taking place across the bar. Deposition of suspended load in the lee sometimes converts them into islands.
5. Diamond bars: Also called linguoid bars or 'spool' bars by sedimentologists, they are an extreme development of midchannel bars characteristic of braided rivers in sand or gravel.
6. Diagonal bars: This bar type occurs only in gravel bed channels
7. Sand waves, linguoid bars, or large dunes: This type of bar is common in relatively active sand-bed channels . The most characteristic property is the dune-like profile. The length of such bars is of order channel width, and the height is normally more than 50% of mean bankfull depth.

2.2 STUDIES OF RIVER MORPHOLOGY USING REMOTE SENSING DATA

The studies of river morphology with the use of remote sensing data is a relatively new development and have been in practice for not more than the last 20 to 25 years in India.

P. Rama Krishna Murthy (1989) has studied the flood plain of Brahmaputra River using satellite imageries.

Lt. Col. A. K. Kher (1994) has carried out morphological studies in a reach of river Ganga using satellite data.

Md. Arshad (1996) through satellite imageries has done morphological analysis for identification of River training sites in a stretch of Ganga River.

Manoranjan Kalita (1993) has also carried out morphological studies of river Brahmaputra with the help of satellite imageries.

DETAILS OF RIVER BRAHMAPUTRA

3.1 INTRODUCTION

The Brahmaputra river known as the Tsangpo in Tibet, the Siang or Dihang in Arunachal Pradesh and Jamuna in Bangladesh, is one of the biggest rivers in the world. The 2880 km. long Brahmaputra bigger than Ganga in length and volume traverses its first 1625 km in Tibet (China) the next 918 km. in India and the remaining 337 km in Bangladesh. Before entering India the river flows in a series of big cascades as it rounds the Namcha Barwa massif. In its length of about 640 km in Assam valley, the river is aligned almost east-west. The valley is enclosed by the eastern Himalyas on the north and Assam range of hills on the south. The average width of the valley is about 80 km of which the river occupies 6 to 19 km. The river forms almost a trough receiving the flows of its tributaries both from North and South.

Throughout its course within India, the Brahmaputra is braided with some well defined nodal points where the river width is narrow and is restricted within stable banks. All along its course in the valley, abondoned wet lands and back swamps are common. The river drains an area of 5,80,000 sq.km above its confluence with Ganga near Goalundo in Bangladesh, the average annual flow of river there, is of the order of 61.4 mha m. (497.1 M. Ac.ft) & it carries about 735 Million metric tons of suspended sediment load annually.

The statistical details of main river are as below:

1.	Total catchment area from its source to its confluence with Ganga at Goalundo in Bangladesh	580,000	Sq.km.
	i) Catchment area within Tibet	293,000	„
	ii) Catchment area in Bhutan & India	240,000	„
	iii) Catchment area in Bangladesh	47,000	„
2.	Length from its source to outfall in Bay of Bengal	2880	KM
	i) Length within Tibet	1625	„
	ii) Length within India	918	„
	iii) Length within Bangladesh	337	„

3.	Gradient		
	i)	Reach within Tibet	1 in 385
	ii)	Reach between Indo-China border and Kobo in India	1 in 515
	iii)	Reach between Kobo and Dhubri	1 in 6990
	iv)	Reach within Bangladesh	
		First 60 km from Indian Border	1 in 11340
		Next 100 km stretch	1 in 12360
		Next 90 km stretch	1 in 37700

4.	i)	Maximum observed discharge at Pandu (on 23.8.1962)	72,727 cumecs
	ii)	Minimum observed discharge at Pandu (on 20.2.1968)	1757 cumecs
	iii)	Average dr season discharge at Pandu	4420 cumeces

Normal annual rainfall within basin ranges between 2125 mm in Kamrup district of Assam and 4142 mm in Tirap district of Arunachal Pradesh.

3.2 THE TRIBUTARIES OF THE BRAHMAPUTRA

In the past, the Dibang and the Luhit, two major rivers joined the Dihang a short distance upstream of Kobo to form the Brahmaputra.Now the situation has quite changed. Dibang and Luhit are joining Dihang through another channel (called Dibru) developed due to phenomenon called river avulsion. Dibru is receiving for the last few years major part of the discharge of Luhit. The river receives numerous tributaries from both sides all along its course thereby progressively growing in its size. Some of the tributaries are trans-Himalayan rivers with considerable discharges. In the north the principal tributaries are the Subnsiri, the Jia Bhareli, the Dhansiri (North), the Puthimari, the Pagladiya, the Manas the champamati and the Sankosh. On the south bank the main tributaries are the Bhuri dihing, the Disang, the Dikhu, the Dhansiri (South) and the Koppili.

The Brahmaputra also has some important tributaries flowing through North Bengal. They are the Tista, the Jaldhaka, the Torsa, the Kaljani and the Raidak.

The Important tributaries on both the north and the south bank of Brahmapurta in the valley are listed along with chainage in Km. of their present outfalls from Indo Bangladesh border (vide Table 3.1). The position of the outfall changes whenever bank erosion takes place there. Besides these tributaries there are many other small streams which drain directly into the River.

Certain features which are found in the Brahmaputra basin have a significant bearing on the characteristics of the north and south bank tributaries. On the north the rainfall is heavier and the hills are less stable and more liable to soil erosion and land slides. In consequence the north bank tributaries carry larger silt charge. The Brahmaputra river is closer to the hills on the south as if the river has been pushed southwards over geological period by the more numerous and heavier silt carrying north bank tributaries. The characteristics of north bank and south bank tributaries are as follows:-

The North Bank Tributaries

i) They have very steep slopes and shallow braided channels for a considerable distance from the foot of the hill and in some cases right upto the out-fall.

ii) These tributaries have boulder, pebble and coarse-sandy beds and carry a heavy silt charge.

iii) These tributaries generally have flashy floods.

The South Bank Tributaries.

i) These tributaries have comparatively flatter grades and deep meandering channels almost from the foot hills.

ii) The tributaries have beds and banks composed of fine alluvial soils.

iii) These tributaries have comparatively low silt charge.

TABLE 3.1

A.	**North Bank Tributaries**	**Chainage in km.**
	1. The Simen	580
	2. The Jiyadhol	540
	3. The Subansiri	430
	4. The Burai	392
	5. The Bargang	382
	6. The Jia Bhareli	338
	7. The Gabharu	300

8. The Belsiri	280
9. The Dhansiri	270
10. The Noa Nadi	230
11. The Nanai Nadi	215
12. The Bar Nadi	205
13. The Puthimari	172
14. The Pagladiya	170
15. The Beki	115
16. The Manas	85
17. The Champamati	63
18. The Gurang	43
19. The Tipkai	40
20. The Sankosh	0

B. South Bank Tributaries	Change in km.
1. The Dibru	592
2. The Burhi Dihing	540
3. The Disang	515
4. The Dikhu	505
5. The Jhanzi	495
6. The Dhansiri	420
7. The Kopili	220
8. The Kulsi	140
9. The Deosila	130
10. The Dudhnai	108
11. The Krishani'	107
12. The Jinari	100
13. The Jinjiram	0

Note. Chainage measured from Indo Bangladesh Border i.e. near Dhubri along the upstream.

3.3 RIVER REACHES

Taking into consideration the river flows, the gradients and the confluence of important tributaries, the main river has been divided into seven reaches. They are:

1. The reach in Tibet from source to Border
2. Border to Kobo
3. Kobo to Dihingmukh
4. Dihingmukh to Dhansirimukh
5. Dhansirimukh to Pandu
6. Pandu to Dhubri
7. Dhubri to outfall

3.3.1 The Reach in Tibet (from source to Border)

The Brahmaputra known as Tsangpo in Tibet originates at an altitude of 5,300 m about 63 km. south east of the Mansarover lake in the South-west Tibet. According to Tibetans the source of the river lies in the knoggyu Tso lake (4,877 m) and the Kailash range of the Himalayas. Many tributaries join the infant river from the passes of Mayum-La (5150m) and Marnyak La (5303 m). These passes separate the Brahmaputra basin from Mansarowar Lake district in which two other great rivers of India, the Indus and the Sutlej have their source. Near its origin, the river is known as Matsang Tsangpo. Many other glaciers contribute their snowmelt all-along the river in its upper reaches. The river in its eastward journey through south of Tibet traverses about 1700 km keeping a course roughly parallel to ànd about 160 km away from the main Himalayas.

The important tributaries on left bank are Raga Tsangpo which joins Tsangpo west of Shigatse and Kyichhu (300 km long on which stands the capital city of Lhasa). On the right bank the important tributary is Nyangchhu which flows by the side of big trade centre of Gyangtse on the Tsangpo itself. In this reach from Lhatse Dzong and upto 80 km from the confluence of Gyachhu river, the Tsangpo has a wide navigable channel. It is one of the most remarkable inland navigation system in the world at an altitude of 3659M. After meeting the Gyachhy river on its left bank the Tsangpo flows in almost straight eastward direction to about 110 km upto longitude 92^0 E and then changes its direction from east to north-east near Long 94^0 E until Tsela Dzong (town). At Tsela Dzong the river turns abruptly to north east and it makes its way by succession of stupendous gorges between the huge mountain masses of Gyala Peri and Namha Barwa. Through these narrow gorges, the Tsangpo rushes down in a series of cascades and rapids taking the flanks of the range in a hairpin bend .It takes another river the Po Tsangpo and then turning south and south west emerges from foot hill in Indian territory in Arunachal Pradesh.

3.3.2 Reach from Border to Kobo :

After crossing the Indo China border the Tsangup changes its name to the Siang or Dihang in Arunachal Pradesh. This reach of the river Dihang starts at the Indo-China Border and ends at Kobo. The total length of the river in this reach is 278 km and it has an average gradient of about 1:515. It flows in Arunachal Pradesh in south-west direction to a distance of 226 km through steep mountains and gorges before reaching Pasighat. Upto Routíung which is upstream of Pasight, the river flows almost in a straight channel. Between Routung and Renging the river meanders as is evident from the numerous point bar deposits on either bank. Near Pasighat the River flows in a braided pattern with as many as four channels, though the main flow presently is through two alternating channels. The bar deposits in the Pasighat reach consists of assorted bouldes, gravel and sand heaps. River terraces are also noticeable along the river streches between Inkiyong and pasighat and some of them are at height of 250 m above the present flood level. Form Pasighat, the Dihang flows for another 52 km before it is joined by two major rivers from the east and north east namely the Luhit and the Dibang. The combined flow of these three rivers forms the Brahmaputra at Kobo.

3.3.3 Reach from Kobo to Dihingmukh

This reach starts from Kobo and ends at Dihngmukh with a total length of 100 km. In this reach the river flows south west-ward initially and then westward upto the out fall of the tributary Dibru and finally south west-ward upto Dihangmukh. Flowing turbulently through alluvial plain, the river has braided channels, changes its channel courses and forms large sand banks (Chars). These chars are not habitable as they are prone to submergence during the rainy season and get inter laced by numerous channels of varying sizes during the dry season. The banks of the river are either abrupt on both sides or abrupt on one side. The gradient of the river is 1 in 3700 between kobo to Dibrugarh and 1in 5595 from Dibrugarh to Neamati. The river is navigable throughout the reach and has the important towns of

Dibrugarh on its south bank. In this reach one large tributary joins from the north and two from the south. Of these the Burhi Dihing is the Largest.

3.3.4 Reach from Dihingmukh to Dhansirimukh

This reach of the river runs for 130 km in length. The gradient in this reach is steep being 1 in 5595 between Dibrugarh and Neamati. The river flows through alluvial plain with easily erodable bed and bank materials. The river has braided channels with larger sand banks or chars between them. The chars remain uninhibited as they get submerged.

During flood season the river becomes a sheet of water which covers a width of 15 km in the upper portion. The biggest river island 'Majuli' of Jorhat district lies in this reach. The important towns are Sibsagar and Jorhat on the south bank and north Lakhimpur on the north bank. The river is navigable in the entire reach.

In this reach two tributaries join the Brahmaputra from north and four from south. The north bank tributaries are the Jiya-dhol and the Subansiri. The south bank tributaries are the Disang, the Dikhu, the Jhanzi and the Dhansiri. Among these Subensiri and Dhasiri are the most important as they carry maximum discharge of 18799 cumecs and 2296 cumecs respectively.

3.3.5 Reach from Dhansirimukh to Pandu:

The river Brahmaputra runs in this reach for a length of 212 km from Dhansirimukh to Pandu. The river flows through alluvial valley with rock-out crops at some points. The river gradient is 1 in 6425 from Neamati to Tezpur and 1 in 6750 from Tezpur to Guwahati. The bed and bank materials are easily erodable and bank erosion in this reach is conspicuous. The river has braided channels except at Pandu where it is restricted into single channel of 1.2 km width. This is the narrowest point in the entire length of the river in the valley. The river in this reach is navigable throughout the year and has the important towns Tezpur on the north bank and Guwahati on the South bank.

Nine sub-Himalayan tributaries join this river in this reach from the north and one tributary from south. Out of these the Bhareli from north and the Kopilli from south are noteworthy.

3.3.6 Reach from Pandu to Dhubri Border

This reach starts at Pandu and end at Dhubri, the international Border and the river runs for a length of 198 km. The river in this reach has constricted width at some points with rockout-crop confining the river. Elsewhere the river flows in braided channels between erodable alluvial banks. During floods the river here is one sheet of water from bank to bank. The gradient of the river in this reach is 1 in 8875 from Guwahati to Goalpara and 1 in 14,650 from Goalpara to Dubri.

In this reach of river Brahmaputra, eight tributaries join on north bank. Among which the Manasa, the Gaurang the Puthimari, the Sankosh ad the Champamati are worth noting. On south bank six tributaries join the river in this reach among which Kulsi and Jinjiram are woth mentioning. The river is navigable throughout the year. The important towns in this reach are Goalpara on the South bank and Dhubri on the north bank.

3.3.7 Reach from Dhubri to Outfall

After crossing the international boarder near Dhubri, the Brahmaputra turns southwards and enters Bangladesh where it is named 'the Jamuna'. From Dhubri it traverses nearly 250 km to join the Ganga at Goalundo in Bangladesh. Above this confluence, the Ganga is also known as Padma.

From Dhubri to Goalundo, no notable tributary joins the river on its eastern bank but some major tributaries such as Torsa, the Jaldhaka and the Tista join on western bank. From Goalunde, the combined flow of Brahmaputra and the Ganga crosses down for about 120 km in south eastern direction under the dual name of Ganga or the Padma before it is joined by a major tributary Meghna near Bhairab bazaar, This forms the apex of delta of Meghna.

3.4 DETAILS OF MAJULI ISLAND

3.4.1 Location

Majuli, the largest river island in world is situated in the upper reaches of the river Brahmaputra between chainage 435 km and 520 km from Indo-Bangladesh Border. The island extends for a length of about 80 km along East to west and about 10 to 15 km along north south direction. It lies between latitudes 26^0 45'N to 27^0 10' N and longitudes 93^0 40'E to 94^0 35'E. It covers an area of about 875 sq. km and has a population of 1.354 lakh as per

1991 census. The revenue records show that the area of the island during 1950 was 1246 sq.km.

The island is bounded by the river Subansiri on north west. The Kherkatiya-suti (a spill channel of Brahmaputra) on north-east and the main river Brahmaputra on south and south west. The main town in the vicinity of the island are north Lakhimpur in the north, Golaghat in south west, Sibsagar in south-east, island's district head quarter Jorhat in the south and Dibrugarh in the extreme east. . Garamur is the sub-divisional headquarter of Majuli sub-division. The average height of the island varies between 85 to 95 meters above mean sea level.

An administrative sub-division of Jorhat district, the Majuli island represents a colourful rainbow of cultural integration with 70 percent of its population belonging to tribal communities such as Mishing, Deuri, Kachari and Koch Rajbongshi.

3.4.2 Formation of island

The word Majuli is claimed by some to be derived from the word 'Majali' meaning an area surrounded by water. Geological history indicates that the landform of this area is depositional in origin and is of recent and sub-recent age. The island has been formed by the action of the river Brahmaputra. the Subansiri and their tributaries As the consequence of earthquake in 1691 and 1696, the Dihing river changed its course to join upper Lohit. This new channel of Dihing is known as Nao-Dihing. Subsequently, a flood of great intensity occurred in Dibang river and devastated the entire area in 1735. During this flood, the Brahmaputra river after abandoning its course followed the old channel of Dihing river making access to Majuli more difficult from southern side.

The existence of the Majuli island is threatened by severe bank erosion and flood inundation. The southern shore of the island along the Brahmaputra main channel is the worst affected.

3.4.3 Socio-Cultural Background

The Majuli island has played a very important role in the history of Assam and achieved a significant identity. In old legend, Ratanpur in Majuli has been mentioned as the capital of various kings. Around the year 1189 AD sri Gauri Naragan established his capital at Ratanpur which was situated near kherkatiya-Suti river on the southern bank of Luit (a channel of Subansiri river) As two channels were flowing on either sides of Ratanpur, it was also called as Majali or Majuli.

Majuli is the home of the Vaishnavite religion established in the last decade of the 15^{th} century. It was the great Sri Sankardev who first pronounced the doctrine of salvation by faith and prayer rather than by sacrifice.

It is in Majuli where Sankardev spent a couple of months and here the historic and auspicious MANIKANCHANSANJOG (Meeting of two great saints) between Sankardev and Madhabdeb took place at Belaguri where the first Vaishnava monastry or satra was founded. It is said that there were 65 satras in Majuli of which 22 satras are existing even now. Most of the satras have shifted out of Majuli to safer places due to the ravages of perpetual flood and erosion. Some of the large satras still flourshing in Majuli are Dakhinpat, Garmur, Kamalabari, Auniati, Bengenati, Samoguri and Bhogpur etc.

3.4.4 Socio Economic Attributes

Population

The important population statistics as per 1991 census is given below

Scheduled Tribe :	57, 357
Scheduled Cast	19,278
Others	58,743
Total	1,35,378

Male population	:	70, 410
Female population	:	64,968
Male Literacy	:	41,658(59%)
Female Literacy	:	25,090(38.6%)
Literacy rate	:	49.3%
Population density	:	146 per sq. km

3.4.5 Climate

The climate in the island is characterised by a highly humid atmosphere, abundant rains and general coolness. Winter sets in the month of December and continues till February. This is followed by the season of severe thunder storms from February to May.

Monsoon starts in June and ends in September. Maximum rains occur during the month of June and July. The average rainfall observed at the Majuli island is about 1922 mm.

3.4.6 Land Use

The land is very fertile. The islanders living in 244 villages are mostly dependent upon agrarian economy. Area-wise distribution of various land covers is given below in the table 3.2 and shown in figure No. 3.1

Table : 3.2 Land use Pattern of Majuli

Sl. No.	Category	Area in ha.
1	Net area sown	30,584
2	Current fallows	3,745
3	Old fallows	902
4	Cultivable waste	4,621
5	Land put to non-agricultural use	75,943*
6	Barren and un-cultivable land	7,461
7	Permanent pasture and grazing land	544
8	Forest	Nil
	Misc tree crops not included in Sl. 1	80

The total land area given above (1239 sqkm.) is almost the same as shown in revenue records of 1950. Again, the land shown under non-agricultural use (*) in above table is about 61% of this area. As per the data supplied by the local office of agriculture department in Majuli, the land under non-agriculture use is 46264 ha. It seems, the revenue records are yet to be updated.

3.4.7 Communication

The island is approachable both from its northern side as well as from southern side. The easiest way to reach Majuli is by regular ferry on recognized river route across the Brahmaputra main channel from Neematighat to Kamalabari. Buses ply from Jorhat public bus stand to Neemati Ghat, a distance of about 14 km, daily to connect ferry services at 10 AM and 3 PM. The ferrying across the river takes about 90 minutes. The other such route is

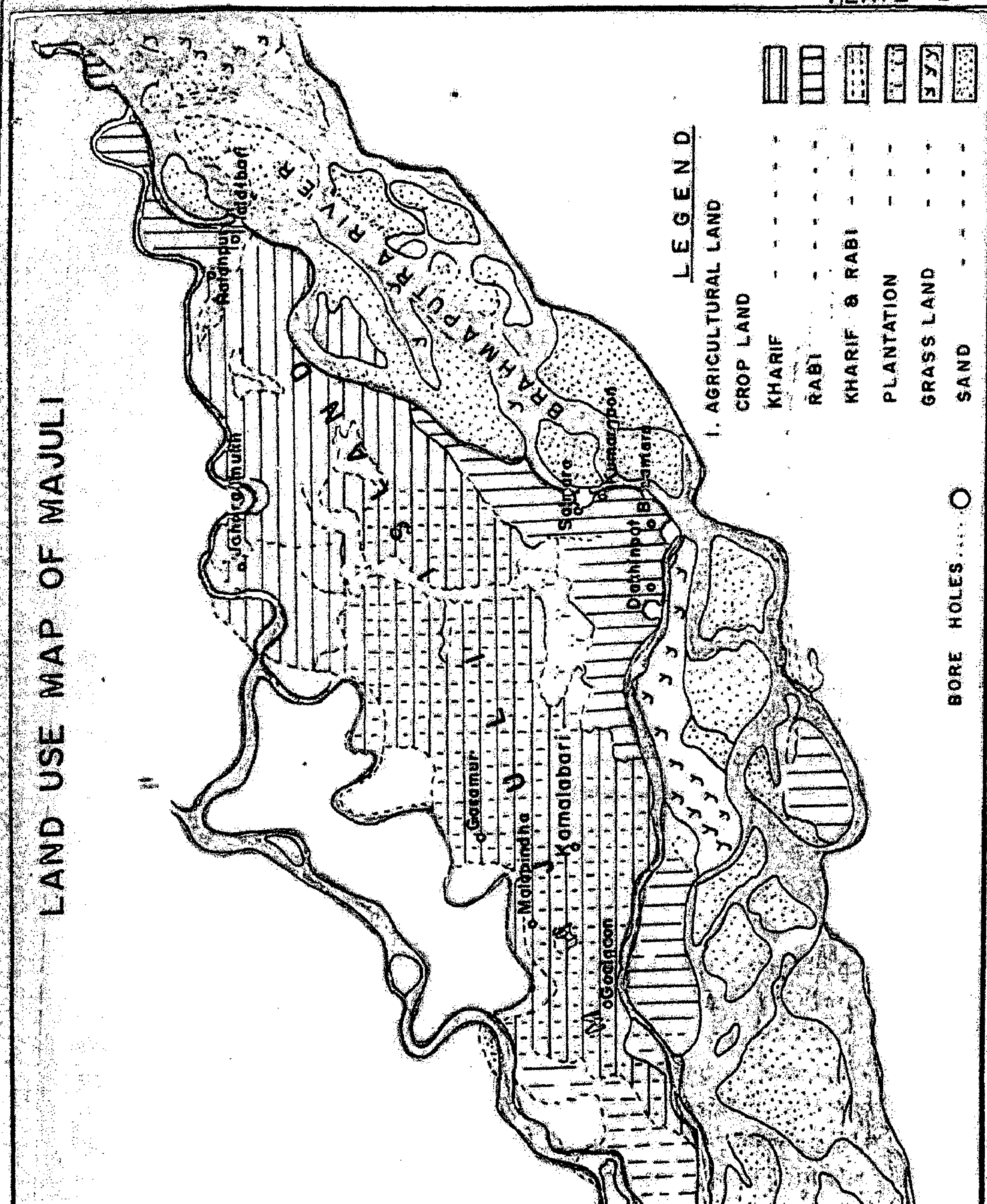

PLATE - 2
LAND USE MAP OF MAJULI
LEGEND
I. AGRICULTURAL LAND
CROP LAND
KHARIF
RABI
KHARIF & RABI
PLANTATION
GRASS LAND
SAND
BORE HOLES
BRAHMAPUTRA RIVER
Kamalabari

Fig- 3.1

from North Lakhimpur via Luit channel and Khabolighat which is about 30 km. from North Lakhimpur town by road. The Luit channel at Luit Ghat and the river Subansiri at Khabolighat are required to be crossed by ferry boats.

In addition to above, there are large number of Ghats ferrying people to and from Majuli with single engine machine boats both on the Northern and southern side of the island. All the ferry services operate during the day time only.

Kamalabari-the major townnship of the island is connected by cirss-cross internal road network of about 360 km length (mostly fair weather) to reach almost all the places on the island. The internal road communication supplemented by flood embankments is vulnerable to disruption by breaching during flood seasons. Majuli also gets connected in the non flood season with the main land in Dhemaji district of Assam by road with the help of the existing earthen dam (1.2 km. length) on the Kherkatia-Suti. Several spill channels, depressions and breaches cause communication disruption during flood season and movement of men and other essential commodities is greatly hampered. The left-over stagnant water in these water bodies continues to hinder easy mobility during the major part of the year. A telephone exchange has been setup and trunk dialing facilities are available in the island.

3.4.8 Occupation

The main occupation of the people of Majuli island is agriculture. Due to yearly occurrence of floods, the rabi crop is more successful although kharif crops are also grown in area already protected by embankments. The island is not self-sufficient in food grains. Paddy is the principal crop. In addition maize, other cereals, black gram, vegetables, cotton, jute, castor, mustard and sugarcane etc. are also grown. The island has a diverse agricultural tradition, growing several varieties of paddy without any kind of artificial fertilizer or pesticides. The floating logs and tree stumps carried by water are intercepted by some families for supply of firewood inside and outside the island through contractors. Fishery, handicraft, pottery and dairy are the part-time occupations of some of the islanders.

3.4.9 Infra-structural facilities.

The island is an administrative sub-division having one Revenue Circle and 3(three) Mouzas namely, Kamlabari, Salmara and Ahatguri two Development Blocks and one Mahkuma Parishad Other infra-structural facilities with 2(two) anchalik Panchayats and 20 (twenty) Gaon Panchayats are also functioning in the island. To manage the law and other situation, 3 (three) Police Stations and 3 (three) Police Out Posts have been established in the island.

Other infra-structural facilities available in the island area as follows:

Primary Health Centres	5
Mini Health Centres	2
State Dispensary	4
Rural Hospital	1
Veterinary Hospital	4
Veterinary sub-Centre	11
Primary School	97
Middle School	67
Higher Secondary School	5
College	4 (Recognised)
	3 (Not recognised)
A.S.T.C. Bus station	1
State Highway	9. 00 Km.
P.W.D. Road	257.00 Km.

3.4.10 Geomorphological Characteristics

3.4.10.1 General Features

Geomorphologically the island forms a part of the alluvial floodplain of the Brahmaputra river. The top soil is composed of inorganic silt of medium plasticity and mostly has medium compressibility followed by poorly graded sandy silt which is susceptible to erosion. The dry strength of the soil is poor. The river flows through erodable bed and banks forming braided channels separated by shoals and sand bars. The gradient of the river in Majuli reach is 1 in 5595 and the velocity during flood varies from 3m to 4.5 m/sec at

Neematighat. Heavy sediment load of about 800 million tons in the Brahmaputra river, results in formation of innumerable longitudinal channel bars and some of them have formed mid channel island-the biggest among them is Majuli. The middle and lower portion of the island has few old meanders, abandoned channels and water bodies, which are good source for ground water extraction. The general features of Majuli Island has been shown in figure 3.2.

The frequent earthquakes in Assam and faulty land management practices in upper catchment are responsible for large sediment load causing substantial rise in the bed levels. The average effect of earthquake on morphological behaviour of the Brahmaputra river has been analyzed by a committee of experts from the historic data of low and high water levels for the period from 1930 to 1965. . It indicates that the river had shown rise in bed level at the rate of 2.13 cm per year up to 1947. After this the rise was steeper tat 8.53 cm per year. This sudden rise in aggradation was primarily due to the earthquake of 1947 and 1950. The subsequent studies made on the basis of river cross-sections covering a period of 28 years from 1957 to 1985, have reportedly shown degradation in almost entire length of the river. .

The problem in Majuli island is the part of the larger problem of shifting pattern caused by the braided nature of the Brahmaputra. Alluvial rivers carve out their own section & river channel keeps on shifting . It is generally observed that for particular combination of river slopes and sediment concentration, the river have a meandering nature. However if the slopes are larger than a threshold, the rivers have a braided formation. While rivers with both braided and meandering patterns are liable to change in course, meandering rivers will cause less problems for the following reasons.

a) The meandering river, at any time, would occupy less area of floodplains, and thus larger area of the floodplain can be used for some what stable economic activities, even if permanent structures may not be advisable. The braided rivers with numerous channels and chars (island surfacing in low flow but submerged in high flows) would make a larger width of land unfit for economic use.

b) Some meandering river forms follow a set pattern. The control of a meandering river at one point through engineering works, if successful, would control the river form for a considerable length in the downstream. Such possibility would be less for the braided rivers.

Perhaps there are some theoretical possibilities of changing the nature of form from that of a braided stream to that of a meandering stream, and then to control the general pattern of meanders so as to reduce the river shits. These possibilities would require much more detailed studies and costly pilot projects before deciding about their efficacy. Although this approach may have a possibility of finding a more permanent solution to the problem of erosion of Majuli, but at this stage it is out of scope of the present study.

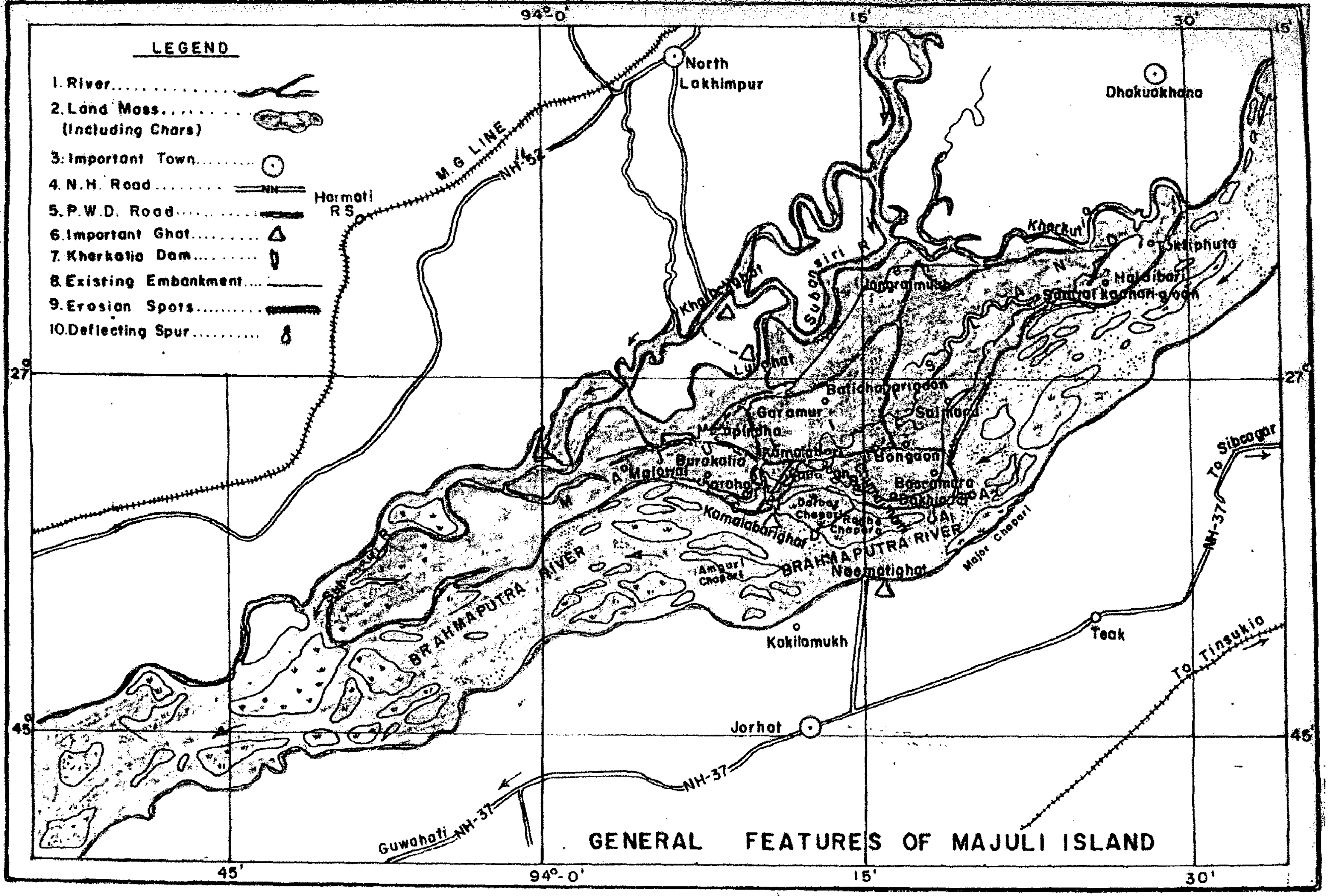
LEGEND
1. River
2. Land Mass (Including Chars)
3. Important Town
4. N.H. Road
5. P.W.D. Road
6. Important Ghat
7. Kherkatia Dam
8. Existing Embankment
9. Erosion Spots
10. Deflecting Spur
North Lakhimpur
Dhakuakhana
Harmati RS
M.G LINE
NH-52
Subansiri R
Kharkuti
Haldibari
Jorhat
Teak
Kokilamukh
Neamatighat
Kamalabarighat
BRAHMAPUTRA RIVER
Majar Chapori
Amguri Chapori
Garamur
Bongaon
Burakatia
To Sibsagar
To Tinsukia
NH-37
Guwahati
94°-0'
15'
30'
45'
27°
GENERAL FEATURES OF MAJULI ISLAND

Fig-3.2

METHODOLOGY

4.1 LOCATION OF STUDY AREA

The reach selected for the present study lies mainly in the state of Assam. The morphological change between Pasighat (Arunachal Pradesh) to Dhubri (Assam)

After Pasighat the river enters into the plains of Assam. In this reach the river is confined between longitudes 90^0 0' E & 95^0 18' and Latitudes $26^0$0' N & 28^0 06' N.

4.2 DATA USED & METHOD OF WORK

The hydrographic survey data collected by The Brahmaputra Board and Digital Satellite data procured from National Remote Sensing Agency (NRSA) Hyderabad have been used in this work.

The Brahmaputra Board has collected a great deal of data and information regarding the river from various sources. The Board has also prepared a large number of maps and charts for graphical representation of data collected. All these data have been collected in big size books named Atlas of Brahmaputra Board which is in two volumes. Volume –1 Contains plates pertaining to index maps, hydrometerology and embankments. Volume –2 contains plates of longitudinal and Cross-section of the river. So the hydrographic plan maps of Brahmaputra available in the Brahmaptura Board Atlas have been used to know the initial morphology of the river. The 12 initial sheets covering the river area between Longitudes 90^0E to 97^0E and between Latitudes 26^0 N to 28^0 N were scanned separately. The latitudes and longitudes at 15^0 minutes interval are already plotted on the sheets. So all these sheets were registered giving co-ordinates through keyboards. These partly registered sheets (images) were mosaiced. After mosaicing they were digitized on the screen. These all works have been carried out on ERDAS IMAGINE package.

The following digital satellite data were used in this work.

Table 4.1: Years 1997 (Satellite Data)

Satellite	Sensor/sub-sensor	Path/Orbit	Row/Sector	Date of Pass
IRS-1C	LISS-III	110	53	05-03-1997
IRS-1C	LISS-III	112	53	02-01-1997
IRS-1C	LISS-III	113	52	24-02-1997
IRS-1C	LISS-III	113	53	24-02-1997

Table 4.2 : Year 2000 (Satellite Data)

Satellite	Sensor/sub-sensor	Path/Orbit	Row/Sector	Date of Pass
IRS-1C	LISS-III	109	53	13-02-2000
IRS-1C	LISS-III	110	53	25-01-2000
IRS-1C	LISS-III	111	53	23-02-2000
IRS-1C	LISS-III	112	52	11-01-2000
IRS-1C	LISS-III	112	53	11-01-2000
IRS-1C	LISS-III	113	52	28-03-2000
IRS-1C	LISS-III	113	53	28-03-2000
IRS-1C	LISS-III	114	52	22-12-2000
IRS-1C	LISS-III	114	53	14-02-2000

These satellite data were loaded (called decoded) in the hard disc. With the help of ground control points available through the hydrographic survey map they all were registered. Now two mosaic were prepared one for 1997 images and other for 2000 images. After mosic these were digitized on ERDAS IMAGINE package itself. After digitization of survey maps and satellite image, editing was carried out. The measurement (offsets) were taken using ARC VIEW PACKAGE Then finally analysis has been carried out. The algorithm of these works has been shown in the flow chart.

For the study of erosional behaviour of Brahmaputra on southern bank of Majuli island, a model of the reach of Brahmaputra was constructed based on the data made available from Brahmaputra Board, Dibrugarh Investigation Division. 37 Cross sections were available for this reach . Out of these 37 cross-sections 8 were selected and model was constructed and run. The initial and final readings of bed level were taken at different points of cross sections selected.

For study of channel migration problem at confluence of Dibang & Luhit, the following three digital satellite data of NRSA, Hyderabad have been used.

Table 4.3: Satellite Data for Confluence Study

Satellite	Sensor/sub-sensor	Path/Orbit	Row/Sector	Date of Pass
IRS-1B	LISS-I	13	48	8-07-1994
IRS-1C	LISS-III	114	52	14-02-2000
IRS-1C	LISS-III	114	52	07-01-2001

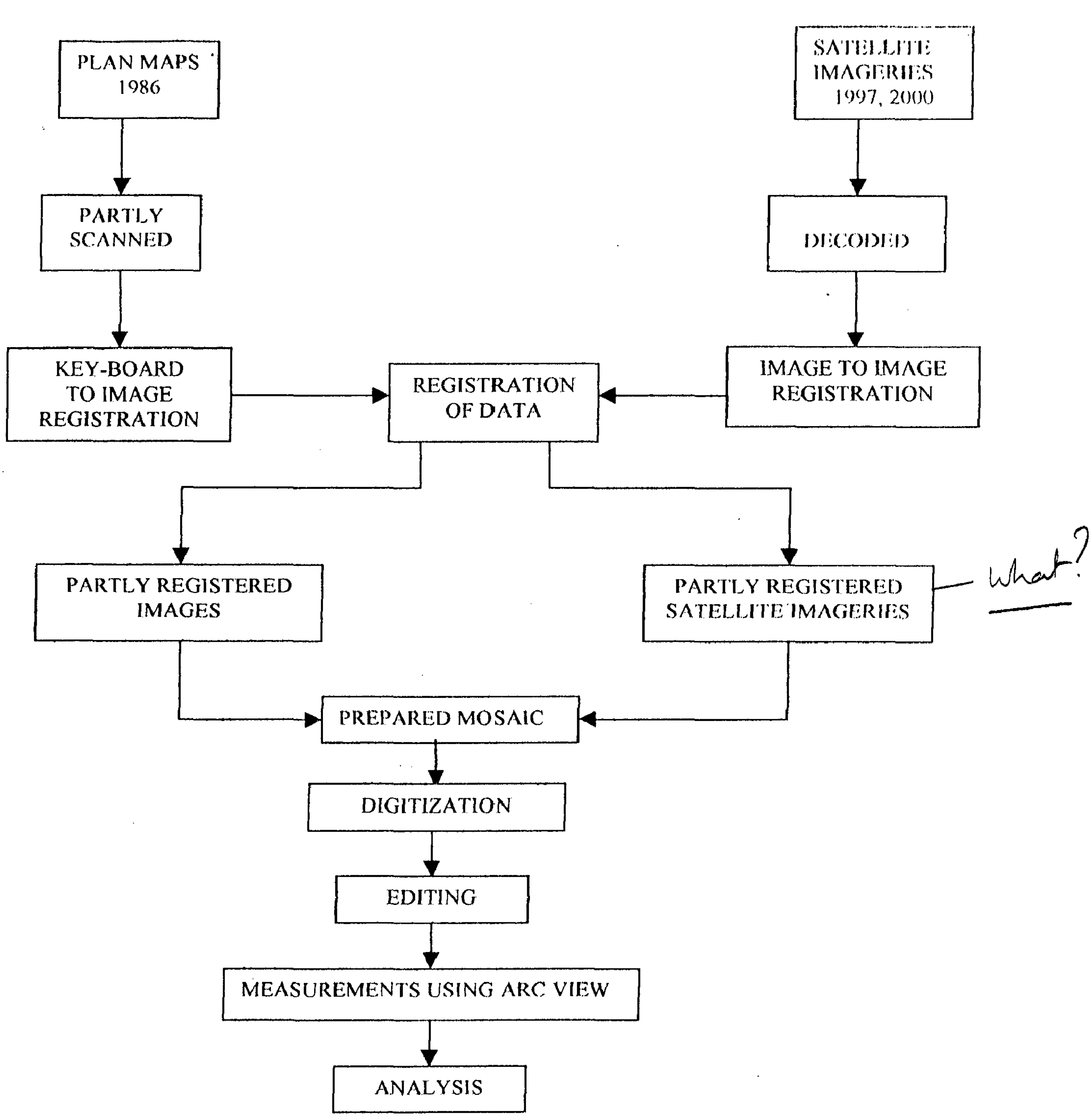

Fig. No. 4.1 : FLOW-CHART

ANALYSIS

5.1 GENERAL

In order to carry out detailed analysis of river plan form, the total length of river Brahmaputra from Dhubri to Pasighat has been sub divided into six reaches. These reaches are defined as shown in table 5.1

Table 5.1

Description of different reaches of the river Brahmaputra in the study area.

Reach No.	Lying between Longitudes	Description	Distance on base line (km)	Actual distance through Thalweg/mid-stream (km)
I	90^0E to 91^0E	Dhubri-Goalpara-Barpeta	100	107.50
II	91^0E to 92^0E	Barpeta-Guwahati-Mangaldai	100	110.75
III	92^0E to 93^0E	Mangaldai –Silghat-Tezpur	100	114.25
IV	93^0E to 94^0E	Tezpur-Behali-Gohaigaon	100	107.30
V	94^0E to 95^0E	Gohaigaon -Sibsagar-Dibrugarh	100	137.00
VI	95^0E to $95^0$24'E	Dibrugarh-Tinsukia-Pasighat	40	74.00
		Total	540	650.80

5.2 DETAILED ANALYSIS :- Detailed analysis of morphological studies have been carried out in subsequent tables and figures of this chapter.

Fig. 5.1 shows the designation of Reach under which analysis of result will be carried out in this chapter and in chapter 6. Fig 5.2 to 5.4 show the various maps as degitised from satellite data and hydrographic survey map. On the basis of these maps the offsets measurement to both banks using 26^0 N Latitude line as the base line has been carried out. Zero on base line is the intersection of 90^0 E longitude line with base line.

Table 5.2 shows the offsets on the Imagery and hydragraphic maps, while Fig 5.5. to 5.9 show the river bank offsets. Table 5.3 shows the difference of offsets for both banks of the river at different years and it is graphically represented in fig 5.10 to 5.14.

Table 5.4 shows the shifting of left & right banks for different years and has been shown in figs 5.15 to 5.20 . Figure 5.25 is the mosaic of 9 nos. satellite imagereis of year 2000 which shows the entire length of Brahmaputra from Pasighat to Dhubri. Fig. 5.26 is the Mosaic of the hydrographic survey maps for the whole Indian part of the Brahmaputra.

Since Majuli Island has been experiencing unprecedented erosion in the last one decade, special attention to this stretch has been given in this study. To simplify, the cross sections in this reach has been renumbered as given in table 5.5. The physical model for this section has been run upto peak flood discharge (Q=73000) cumec. Table 5.6 gives the detail of bed levels at different cross-sections before and after run. Figs 5.21 to 5.24 and again 5.27 to 5.30 shows the bed level of model before and after run. Fig. 5.31 shows offsets of bank for all the three images (survey maps, 1997 & 2000 imageries on a single sheet for all six reaches)

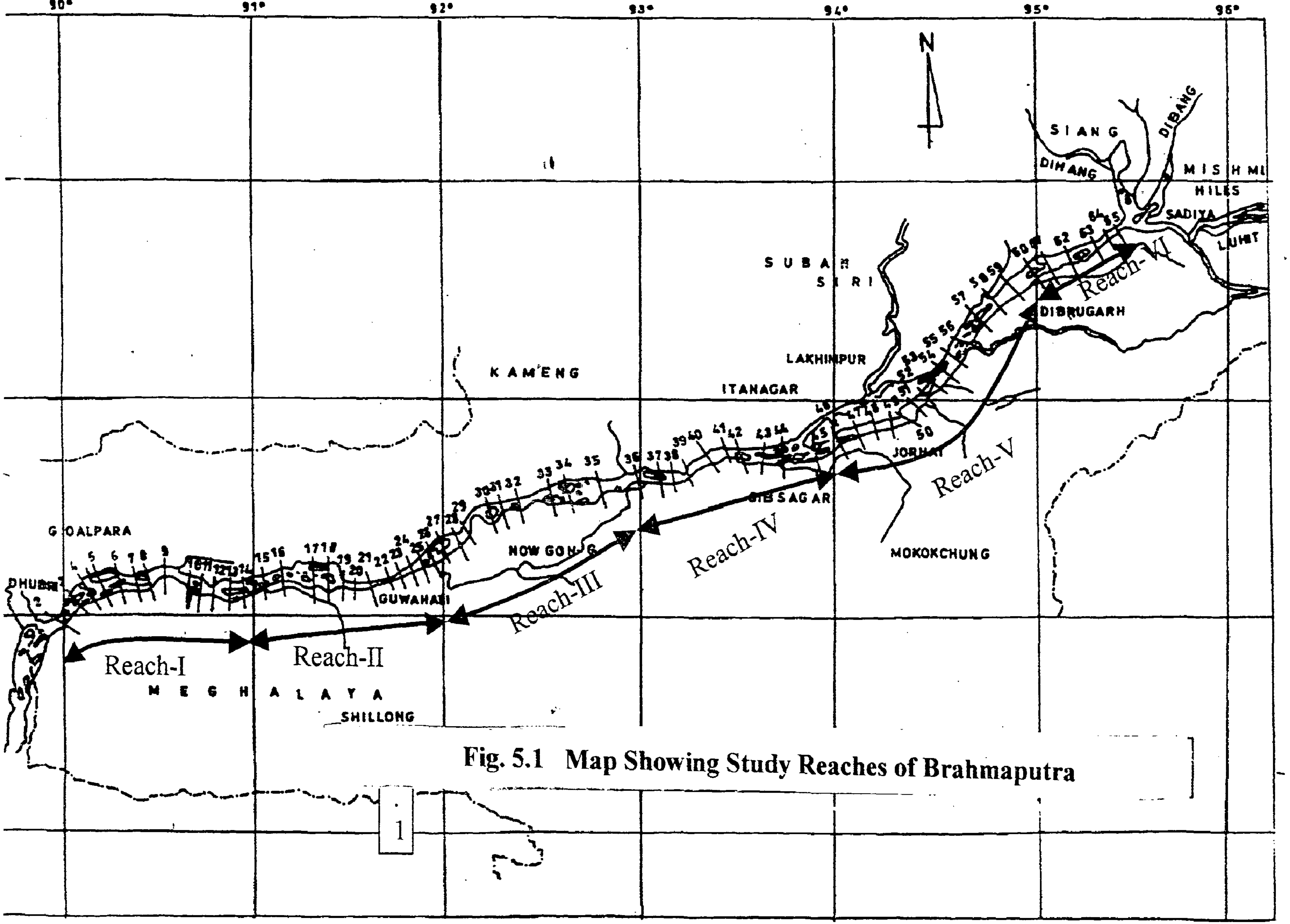

Fig. 5.1 Map Showing Study Reaches of Brahmaputra

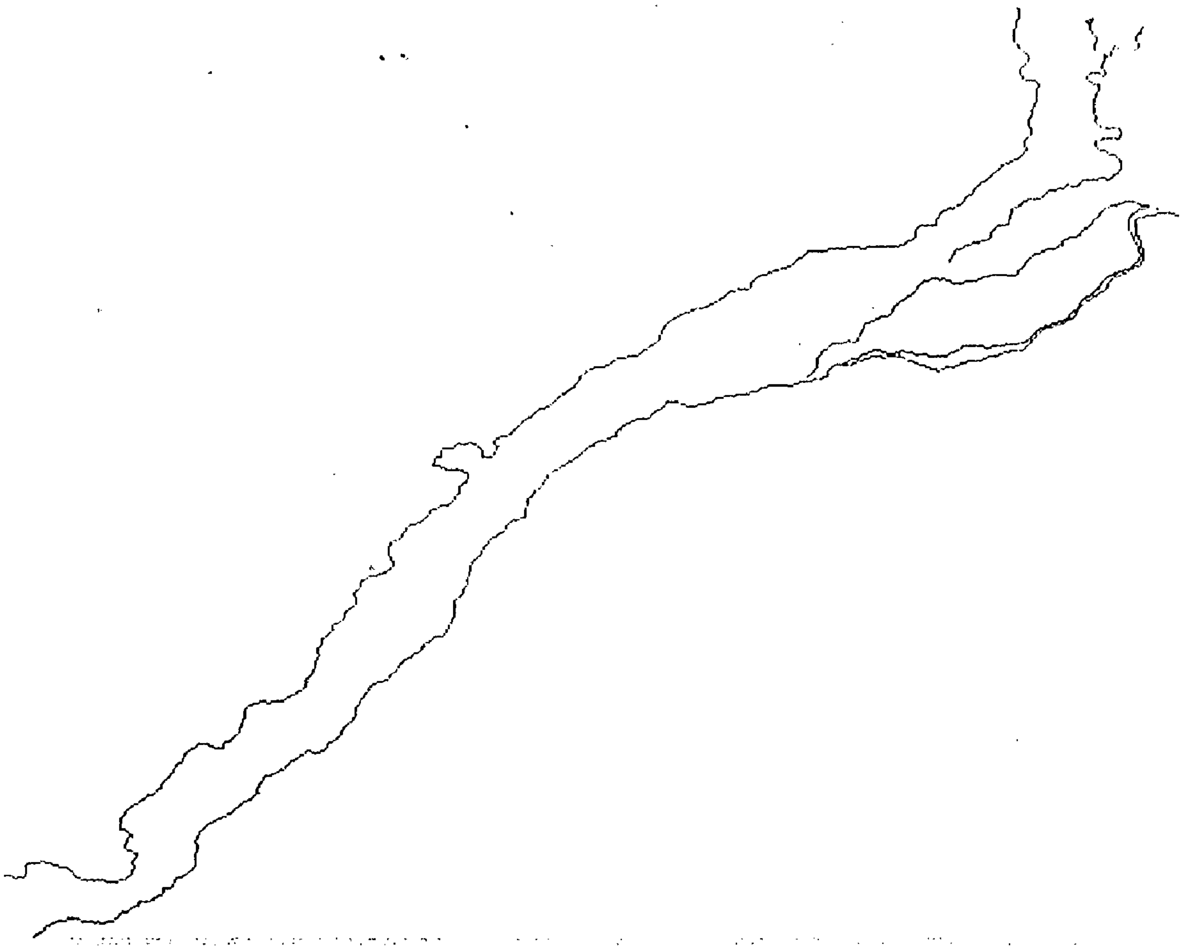

FIG.5.2 DIGITIZED MAP OF 1997 SATELLITE IMAGERIES OF BRAHMAPUTRA RIVER

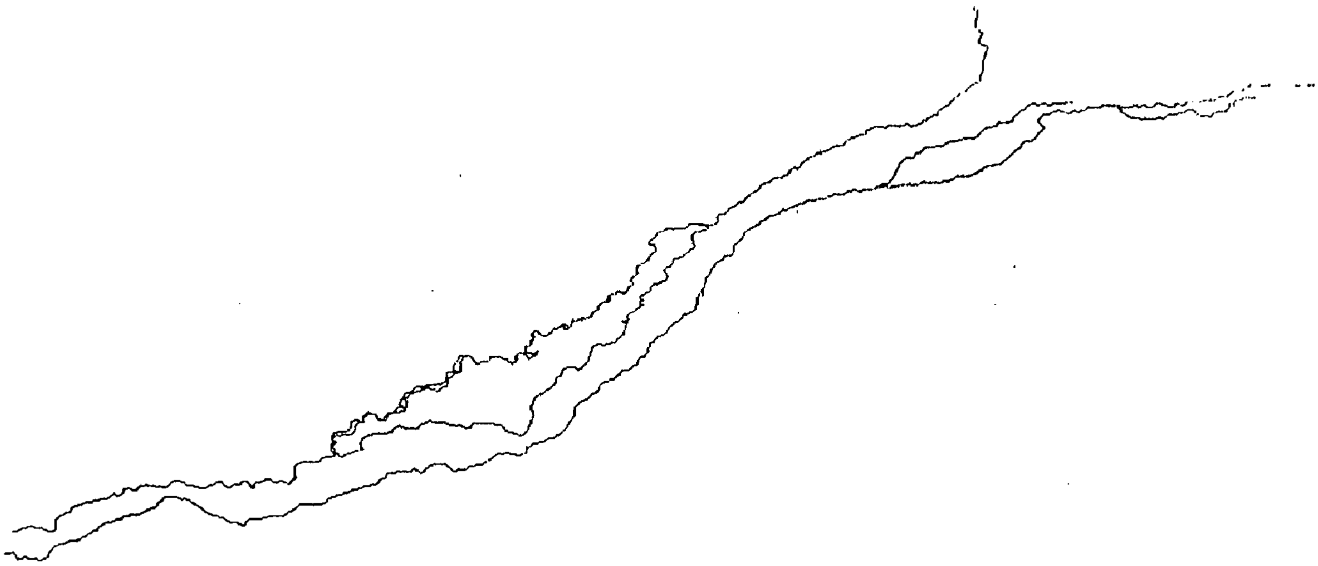

FIG.5.3DIGITIZED MAP OF 2000 SATELLITE IMAGERIES OF BRAHMAPUTRA RIVER

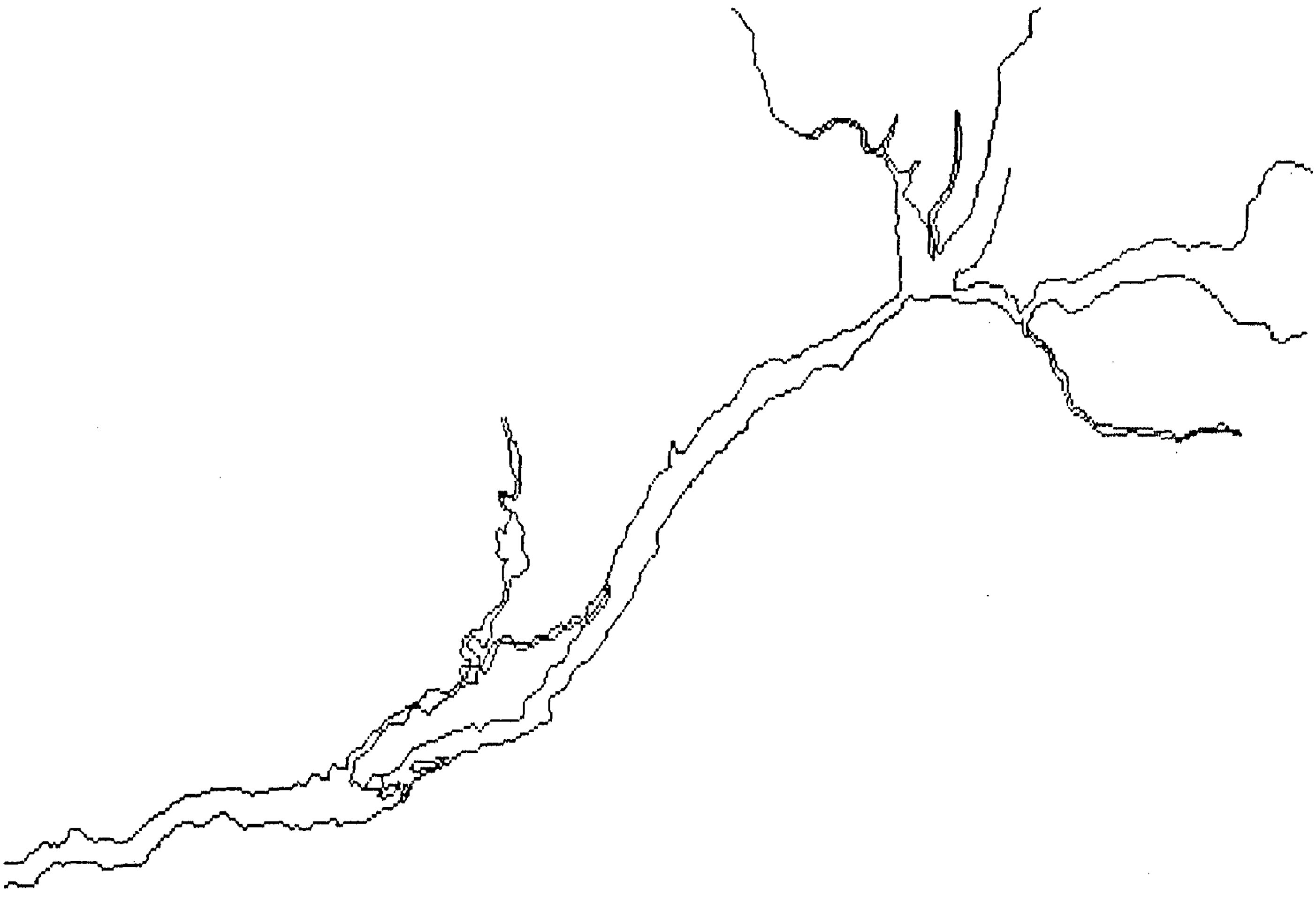

FIG.5.4 DIGITIZED MAP OF HYDROGRAPHIC SURVEY MAP OF BRAHMAPUTRA RIVER

Table 5.2 : Off-sets of River Bank Lines from Base Line (26^0 Latitude Line)

Distance on Base Line in K.M.	Off-sets of LB of Sat-IMG (2000) in km	Off-sets of RB of Sat-IMG (2000) in km	Off-sets of LB of Sur-Map in km	Off-sets of RB of Sur-Map in km	Off-sets of LB of sat Img. 1997	Off-sets of RB of sat Img. 1997
0		4.63		6.86		
2		5.12	-2.78	10.72		
4	-3.43	6.31	-0.93	14.1		
6	-1.69	7.13	1.14	15.78		
8	-1.74	8.54	4.95	17.8		
10	-1.9	10.23	6.42	19.32		
12	-0.82	12.63	6.86	20.63		
14	4.95	14.2	6.86	22.21		
16	5.55	15.35	7.46	22.1		
18	6.1	14.2	8.98	22.26	Satellite Image Not Available	
20	7.4	15.4	9.58	22.91		
22	7.84	15.73	10.12	24.06		
24	9.09	17.25	11.16	24.87		
26	9.69	18.4	11.65	25.2		
28	10.23	20.35	12.68	23.89		
30	10.12	22.46	13.3	22.51		
32	11.25	22.68	13.51	21.68		
34	13.08	23.03	13.3	21.51		
36	13.82	22.16	13.38	21.03		
38	13.25	23.16	13.47	21.81		
40	13.82	24.81	13.64	22.99		
42	14.29	24.81	13.64	23.03		
44	15.29	25.77	13.77	23.12		
46	15.08	26.98	13.95	23.42		
48	16.64	27.81	15.25	24.68		
50	21.2	28.37	19.29	25.77		
52	22.2	29.07	20.94	25.98		Satellite Image Not Available
54	22.64	28.11	21.9	25.81		
56	22.99	25.33	22.16	25.68		
58	23.03	25.29	21.55	25.37		
60	21.51	25.94	20.86	25.42		
62	21.2	25.98	20.16	23.59		
64	20.38	26.94	19.25	23.07		
66	18.94	26.85	18.25	22.16		
68	18.77	26.94	15.47	21.9		
70	15.08	27.55	13.38	21.77		
72	14.56	26.9	12.21	21.59		
74	13.6	27.46	11.82	20.86		
76	13.9	28.76	11.6	19.34		
78	14.21	28.59	11.91	17.03		
80	13.82	28.33	12.56	16.16		
82	13.25	28.33	12.3	17.21		
84	12.04	26.16	10.86	18.47		
86	11.25	25.07	9.39	20.25		
88	10.78	24.98	9.17	19.94		

Distance on Base Line in K.M.	Off-sets of LB of Sat-IMG (2000) in km	Off-sets of RB of Sat-IMG (2000) in km	Off-sets of LB of Sur-Map in km	Off-sets of RB of Sur-Map in km	Off-sets of LB of sat Img. 1997	Off-sets of RB of sat Img. 1997
90	10.56	25.07	8.08	18.51	Satellite Image Not Available	Satellite Image Not Available
92	11.17	26.07	8.43	18.34		
94	11.82	26.37	9.47	18.86		
96	12.86	25.9	10.86	19.37		
98	13.56	25.77	11.82	20.86		
100	14.99	26.07	11.95	21.68		
102	16.64	28.24	12.12	21.94		
104	18.16	27.76	13.64	21.33		
106	17.25	27.5	15.21	20.94		
108	18.38	27.76	16.21	21.86		
110	20.12	27.24	16.99	23.33		
112	20.25	27.33	17.55	24.29		
114	19.9	27.46	18.16	25.16		
116	19.38	28.11	18.37	25.16		
118	18.55	28.94	18.94	25.11		
120	16.38	29.33	18.99	24.77		
122	14.86	29.24	18.86	25.81		
124	14.21	29.81	18.51	27.83		
126	13.17	29.44	17.81	28.53		
128	11.81	29.63	16.93	27.65		
130	11.96	29.7	16.46	28.27		
132	12.11	29.59	15.98	28.75		
134	11.74	30.21	16.82	28.93		
136	12.11	30.5	17.08	28.09		
138	12.14	29.92	16.2	27.25		
140	12.84	30.21	14.23	26.99		
142	14.3	29.74	14.08	28.05		
144	15.03	28.02	15.76	28.64		
146	14.01	20.59	17.08	28.02		
148	13.75	18.98	17.26	20.15		
150	13.9	19.17	16.5	18.8		
152	14.12	19.13	15.76	18.91		
154	15.33	19.06	15.4	18.51		
156	16.28	18.69	15.51	18.51		
158	16.46	20.34	15.62	18.65		
160	16.61	22.6	15.8	22.9		
162	17.19	23.44	16.31	24.43		
164	19.06	21.36	17.04	23.01		
166	19.53	20.74	17.81	21.25		
168	19.79	20.77	18.29	20.01		
170	19.75	20.92	18.58	20.19		
172	19.9	22.42	19.02	20.92		
174	21.73	25.16	19.57	21.84		
176	22.79	25.86	20.34	22.71		
178	23.15	26.63	21.18	23.77		
180	23.63	26.88	22.24	24.87		
182	23.92	26.92	23.37	25.9		

Distance on Base Line in K.M.	Off-sets of LB of Sat-IMG (2000) in km	Off-sets of RB of Sat-IMG (2000) in km	Off-sets of LB of Sur-Map in km	Off-sets of RB of Sur-Map in km	Off-sets of LB of sat Img. 1997	Off-sets of RB of sat Img. 1997
184	24.29	29.55	24.29	27.07	Satellite Image Not Available	Satellite Image Not Available
186	24.87	29.37	24.87	30.54		
188	26.3	29.19	25.31	32.11		
190	29.22	31.56	25.53	33.94		
192	30.21	33.25	25.82	35.88		
194	31.16	33.8	26.81	38.7		
196	31.38	35.92	28.35	40.05		
198	32	36.87	29.99	41.26		
200	34.27	42.03	31.35	42.21		
202	34.27	45.02	32.74	42.43		
204	34.32	46.23	34.32	42.57		
206	36.25	47.99	35.95	42.83		
208	35.7	47.95	37.23	43.12		
210	36.36	48.02	38.66	43.82		
212	39.14	49.89	40.75	47.22		
214	40.12	55.27	42.28	52.38		
216	42.76	53.29	43.71	56.18		
218	44.59	52.63	53.22	56.4		
220	46.27	54.24	50.73	56.73		
222	46.19	54.35	50.61	56.75		
224	48.4	57.03	47.67	57.47		
226	48.95	57.06	47.84	57.44		
228	49.8	57.59	50.27	57.5		
230	53.69	57.79	53.34	57.91		
232	53.96	59.14	55.54	58.55		
234	53.69	61.86	55.86	59.81		
236	53.87	63.29	54.98	60.13		
238	54.4	64.32	54.51	60.28		
240	54.46	64.29	54.75	60.42		
242	56.62	65.08	55.98	60.86		
244	57.79	68.06	58.23	61.51		
246	58.46	68.53	59.46	62.18		
248	58.93	69.4	60.03	63.51		
250	59.39	70.68	58.8	64.97		
252	60.81	70.64	57.52	65.97		
254	61.36	71.42	57.33	66.39		
256	61.17	71.87	57.56	67.35		
258	58.75	71.92	57.79	68.44		
260	58.71	72.06	58.29	69.36		
262	59.8	73.11	58.52	70.27		
264	60.76	73.47	58.43	70.59		
266	60.35	72.38	58.11	69.95		
268	61.59	72.6	57.38	70.27		
270	63.51	72.56	56.97	70.87		
272	63	73.47	57.65	70.73		
274	63.87	73.56	57.65	70.55		
276	64.47	73.61	56.51	70.46		

Distance on Base Line in K.M.	Off-sets of LB of Sat-IMG (2000) in km	Off-sets of RB of Sat-IMG (2000) in km	Off-sets of LB of Sur-Map in km	Off-sets of RB of Sur-Map in km	Off-sets of LB of sat Img. 1997	Off-sets of RB of sat Img. 1997
278	64.37	71.28	57.56	69.22		
280	63.89	71.26	61.2	68.97		
282	65.38	71.32	63.46	69.08	Satellite Image Not Available	
284	65.61	71.42	63.96	69.04		
286	65.65	71.32	64.19	68.99		
288	67.94	70.96	63.64	69.54		
290	67.94	72.28	63.6	70.87		
292	68.95	72.56	65.24	72.56		
294	70.32	72.88	66.93	73.34		
296	72.42	73.47	68.31	72.97		
298	71.51	75.26	68.72	73.06		
300	71.32	75.07	68.67	74.2		
302	70.04	74.62	68.9	76.77		
304	68.86	73.7	69.08	76.54		
306	67.56	73.63	69.06	75.06		
308	65.93	74.2	68.81	74.07		
310	66.19	75.18	68.23	74.31		
312	66.05	74.95	67.82	74.18		
314	66.19	74.31	67.73	74.09		
316	68.95	73.89	68.29	73.89		
318	69.09	76.03	68.22	73.94		Satellite Image Not Available
320	70.83	76.68	68.4	75.01		
322	71.2	79.3	68.44	76.68		
324	73.05	81.19	70.11	78.21		
326	74.29	83.08	72	79.26		
328	76.03	83.69	74.03	80.42		
330	79.9	84.6	75.41	81.44		
332	77.66	84.78	77.08	82.93		
334	78.64	86.38	77.74	83.66		
336	79.08	85.95	78.28	84.2		
338	79.81	87.54	77.77	84.53		
340	80.75	87.29	77.48	84.78		
342	82.89	87.29	78.54	85.51		
344	83.84	87.69	79.81	85.76		
346	84.06	88.78	80.75	86.2		
348	83.62	88.05	79.59	86.2		
350	82.2	87.22	78.14	86.02		
352	81.08	86.67	77.05	85.47		
354	79.19	87.14	77.08	84.78		
356	78.61	88.38	77.16	84.75		
358	77.7	87.25	77.7	85.15		
360	76.52	87.88	78.15	85.41		
362	76.04	88.83	78.25	85.78		
364	77.61	87.09	77.61	86.1		
366	77.53	88.54	77.03	86.01		
368	78.34	89.21	77.26	86.97		
370	78.48	88.45	76.94	86.82		

Distance on Base Line in K.M.	Off-sets of LB of Sat-IMG (2000) in km	Off-sets of RB of Sat-IMG (2000) in km	Off-sets of LB of Sur-Map in km	Off-sets of RB of Sur-Map in km	Off-sets of LB of sat Img. 1997	Off-sets of RB of sat Img. 1997
372	78.63	88.74	77.41	89.06		
374	80.11	88.89	77.93	89.15		
376	81.83	94.27	78.28	88.34		
378	81.95	94.66	79.15	90.74		
380	81.7	94.48	77.23	90.56		
382	82.53	95.68	78.64	90.27		
384	84.2	95.74	78.39	86.78		
386	84.82	95.83	78.43	86.5		
388	85.71	97.02	78.31	86.48	Satellite Image Not Available	
390	86.39	97.74	78.99	88.48		
392	87.43	102.37	80.53	88.98		
394	88.03	102.87	81.26	88.98		Satellite Image Not Available
396	89.61	102.92	81.9	89.75		
398	91.29	103.46	82.8	91.29		
400	91.61	104.92	83.98	93.61		
402	91.57	104.33	87.8	95.02		
404	92.38	104.37	88.8	95.61		
406	92.19	105.93	89.58	96.39		
408	93.61	106.1	89.98	96.5		
410	93.95	105.98	90.59	97.06		
412	93.21	105.31	91.69	97.99		
414	92.95	104.98	93.17	98.54		
416	92.36	104.5	93.95	98.95		
418	93.03	105.63	94.01	99.56		
420	93.65	105.67	94.31	99.92	97.37	106.97
422	95.02	105.6	95.55	99.27	98.22	109.06
424	96.53	105.01	95.74	100.51	99.86	109.06
426	96.92	103.58	95.68	101.23	100.83	108.54
428	96.59	102.6	95.61	101.29	101.03	106.71
430	96.59	102.4	96.39	101.23	100.64	106.51
432	99.46	106.65	97.05	100.97	100.9	106.12
434	100.25	114.09	97.83	105.21	102.34	107.69
436	101.1	115.49	98.61	106.51	103.58	118.37
438	101.88	118.37	99.46	107.69	104.75	120.26
440	103.84	121.37	100.12	109.26	106.78	123.72
442	111.8	121.79	106.84	113.7	114.81	125.45
444	111.87	121.76	106.91	113.76	115.07	125.35
446	113.57	124.93	108.15	115.07	116.24	126.43
448	114.78	128.26	111.35	118.76	117.78	131.59
450	117.84	128.39	113.24	121.24	121.24	132.31
452	118.5	128.98	111.06	122.22	122.22	132.17
454	121.04	132.37	115.75	124.5	124.18	133.55
456	121.34	137.66	117.68	126.1	124.93	137.66
458	124.11	139.42	120.65	128.62	126.13	142.3
460	128.58	144.68	123.49	137.46	128.91	145.53
462	130.61	146.47	125.45	140.92	133.09	149.48
464	132.01	147.26	127.9	143.41	134.82	150.49

Distance on Base Line in K.M.	Off-sets of LB of Sat-IMG (2000) in km	Off-sets of RB of Sat-IMG (2000) in km	Off-sets of LB of Sur-Map in km	Off-sets of RB of Sur-Map in km	Off-sets of LB of sat Img. 1997	Off-sets of RB of sat Img. 1997
466	134.75	153.53	130.64	148.01	137.1	155.75
468	136.06	154.77	134.56	149.97	138.93	157.9
470	138.02	156.46	136.84	152.77	140.89	159.66
472	148.91	162.02	145.73	156.86	142.88	161.43
474	148.97	163.67	145.16	158.11	148.34	166.44
476	152.39	166.55	147.74	161.48	154.64	167.59
478	153.72	167.49	150.64	161.97	156.39	170.46
480	154.85	168.95	152.23	162.16	157.98	171.51
482	159.08	170.72	154.43	163.99	161.79	173.6
484	162.39	172.63	156.91	166.89	164.8	174.77
486	163.41	173.96	158.5	168.79	166.49	176.26
488	165.21	176.29	160.72	170.44	168.19	179.11
490	166.47	177.7	161.87	171.27	169.76	180.41
492	167.67	178.17	163.15	172.68	170.65	181.62
494	168.82	180.62	164.74	173.68	172.74	181.98
496	169.81	181.04	166.62	175.77	173.31	183.29
498	170.7	184.02	167.38	178.9	175.09	186.84
500	170.88	184.99	170.52	180.86	175.06	188.33
502	171.66	185.95	172.01	182.17	174.97	189.2
504	172.56	187.37	173.43	183.36	176.1	190.28
506	172.88	188.1	174.91	183.86	176.42	191.7
508	173.69	190.02	175.43	183.39	176.89	192.16
510	173.92	190.77	175.78	183.28	177.7	194.08
512	173.92	192.11	176.77	183.86	177.82	194.84
514	174.45	193.27	177.29	185.02	178.34	196.46
516	175.1	193.09	179.44	185.83	178.86	197.1
518	177.58	193.97	181.36	186.82	183.86	197.57
520	182.17	193.73	181.53	187.52	184.32	197.69
522	184.21	193.68	181.88	188.86	187.29	197.92
524	185.31	194.08	181.77	189.55	188.04	197.86
526	186.85	195.04	181.56	190.1	190.04	198
528	187.55	197.02	183.01	191.22	192.25	200.68
530	188.07	199.16	185.86	190.8	193.24	201.14
532	189.23	200.68	187.6	191.85	192.77	203.46
534	189.7	203.17	189.17	193.36	193.07	205.38
536	190.17	205.35	191.12	195.04	193.66	207.68
538	190.18	206.45	191.78	195.85	193.74	209.14
540	192.22	210.52	193.16	197.23	194.03	210.81

* Minus Value of Offsets Indicates that the Bank Line is South of the Base Line

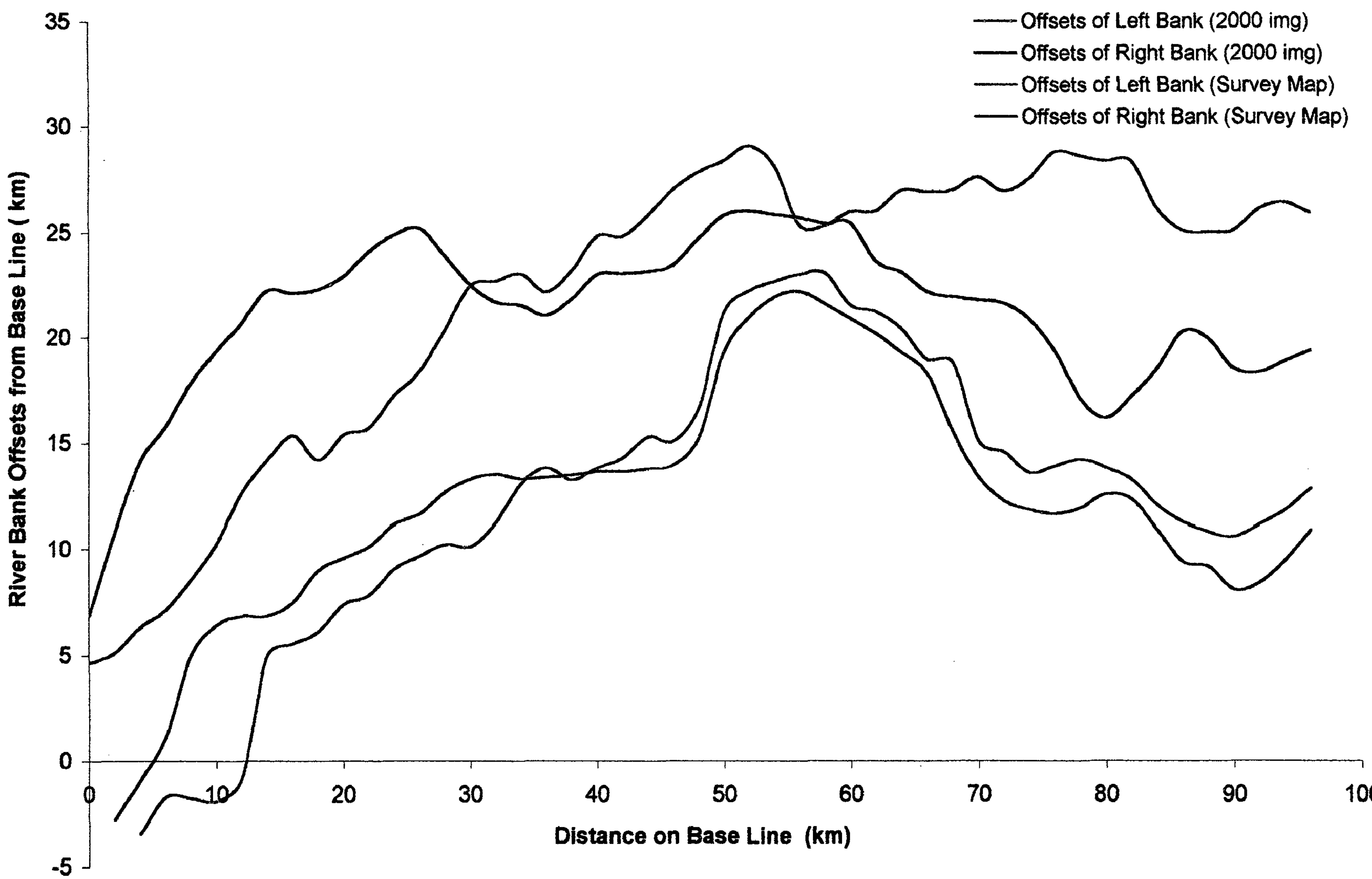

Fig. 5.5 River Bank Offsets Curve (0-100 km)

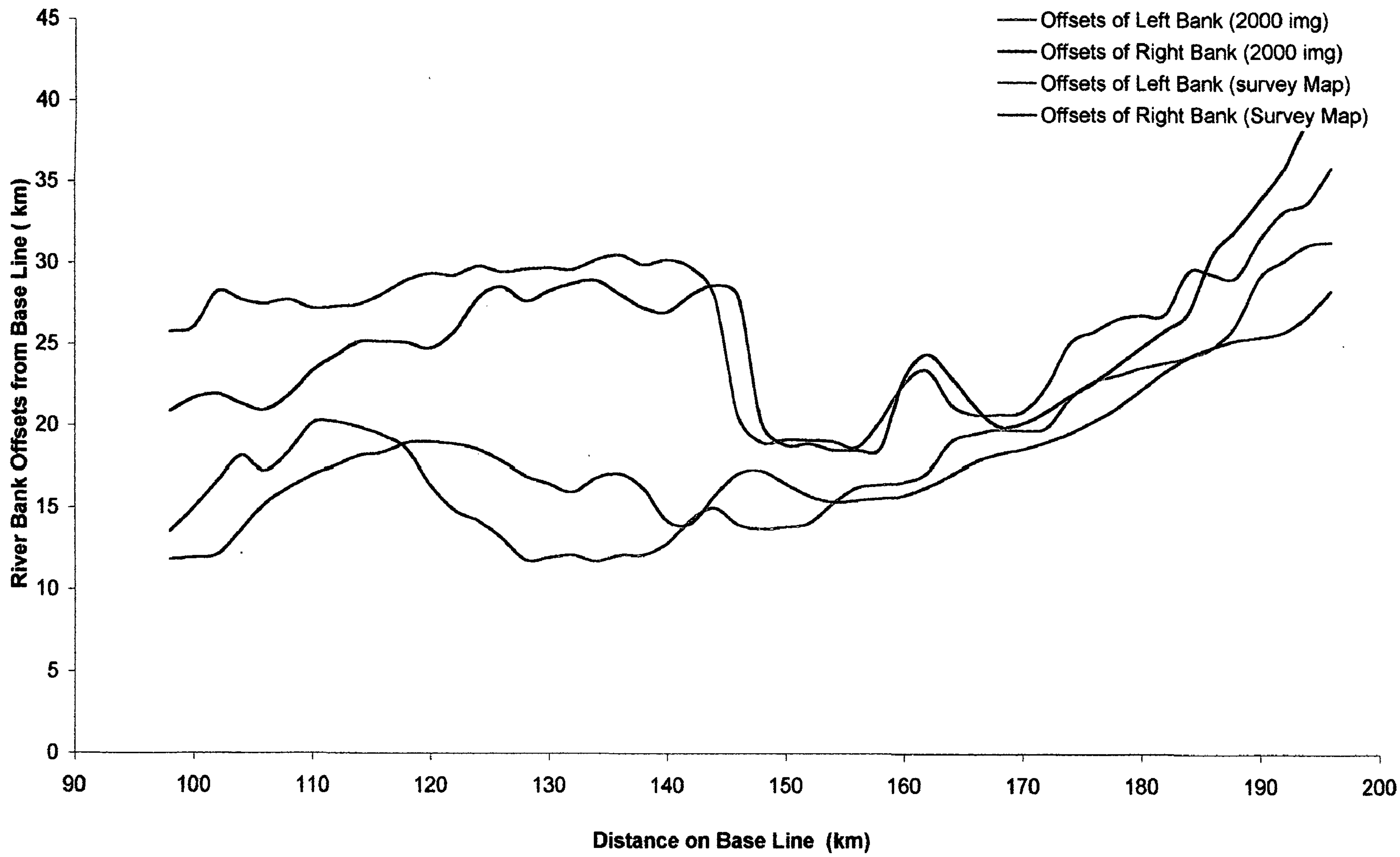

Fig. 5.6 River Bank Offsets Curve (100-200 km)

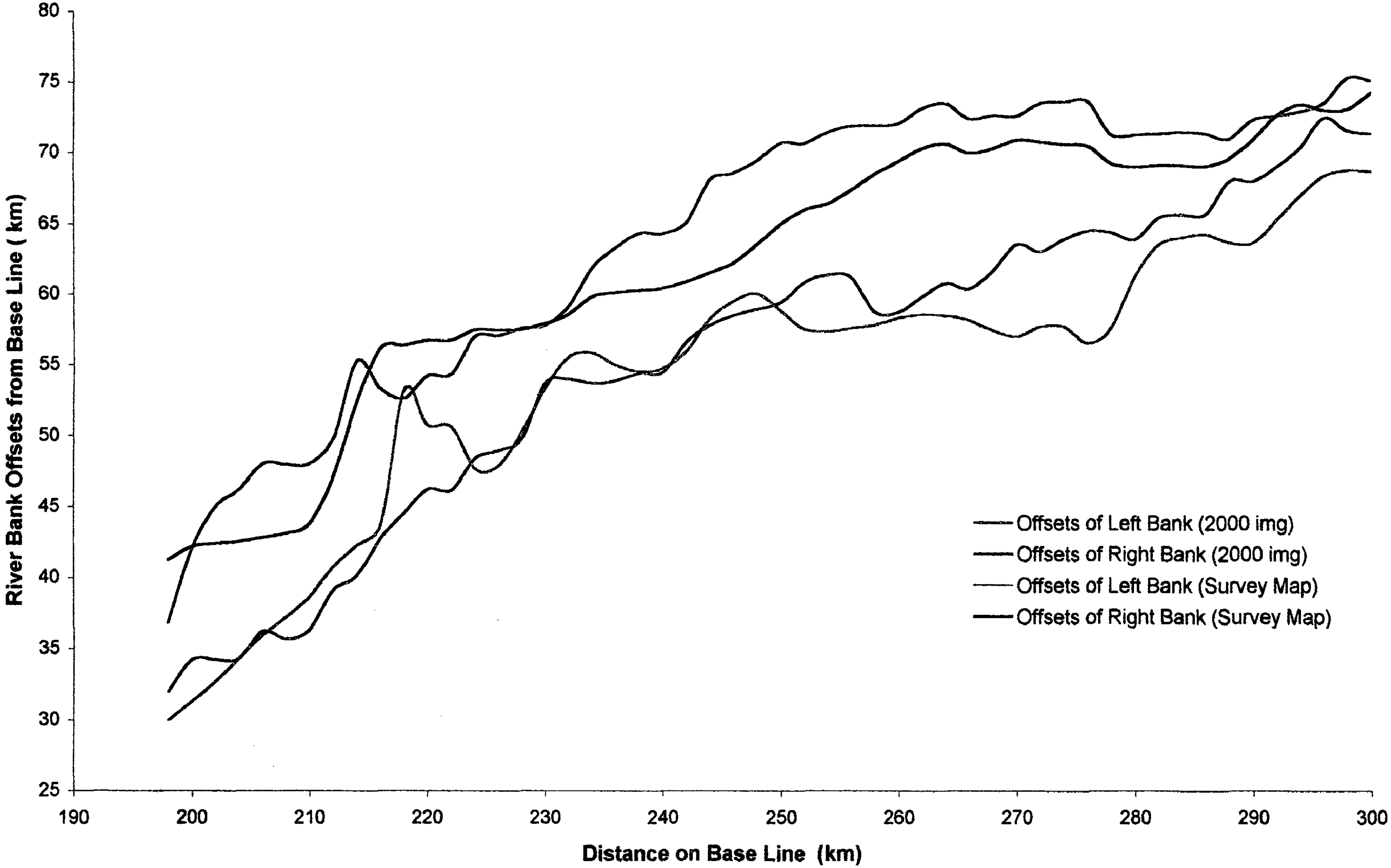

Fig. 5.7 River Bank Offsets Curve (200-300 km)

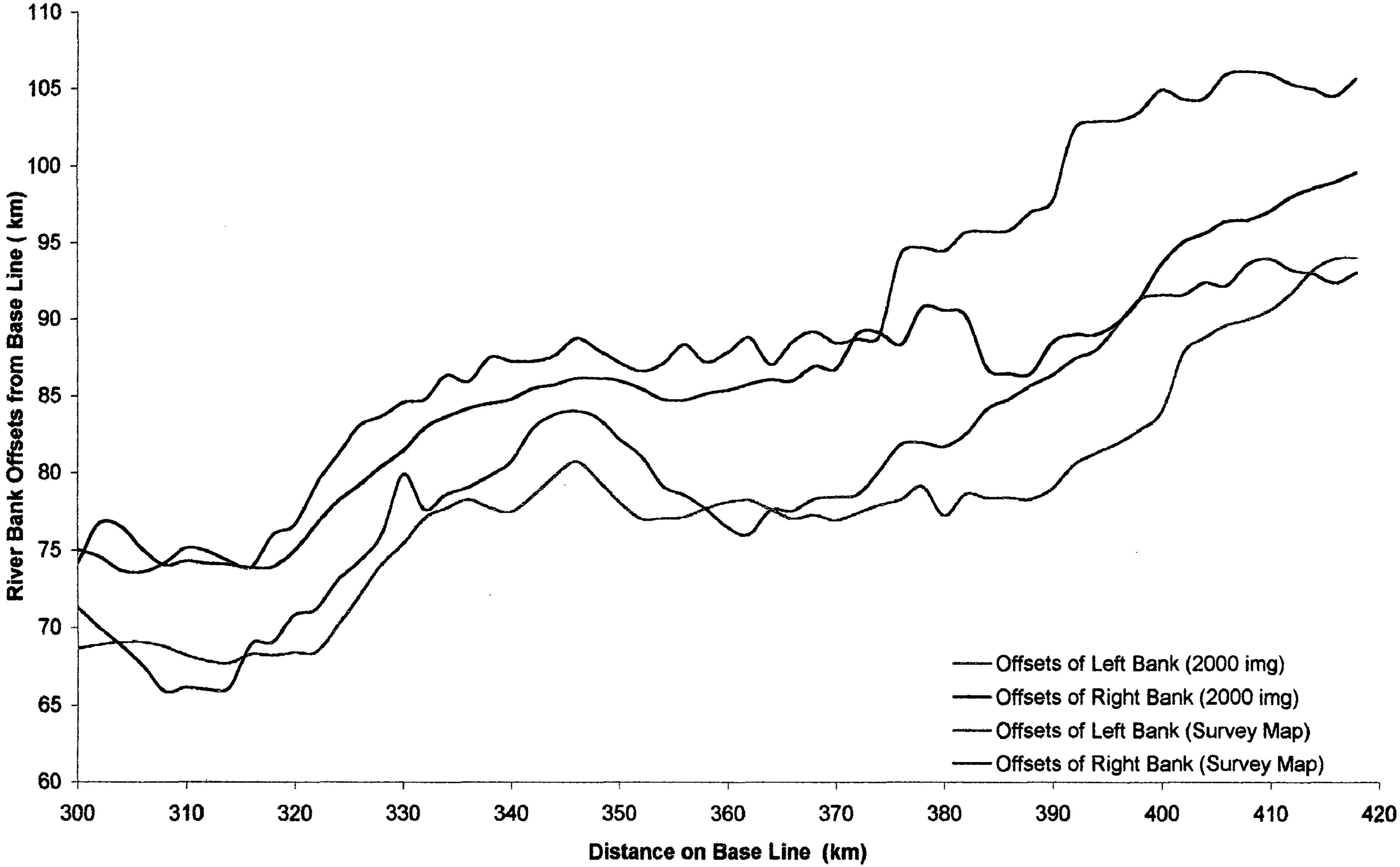

Fig. 5.8 River Bank Offsets Curve (300-420 km)

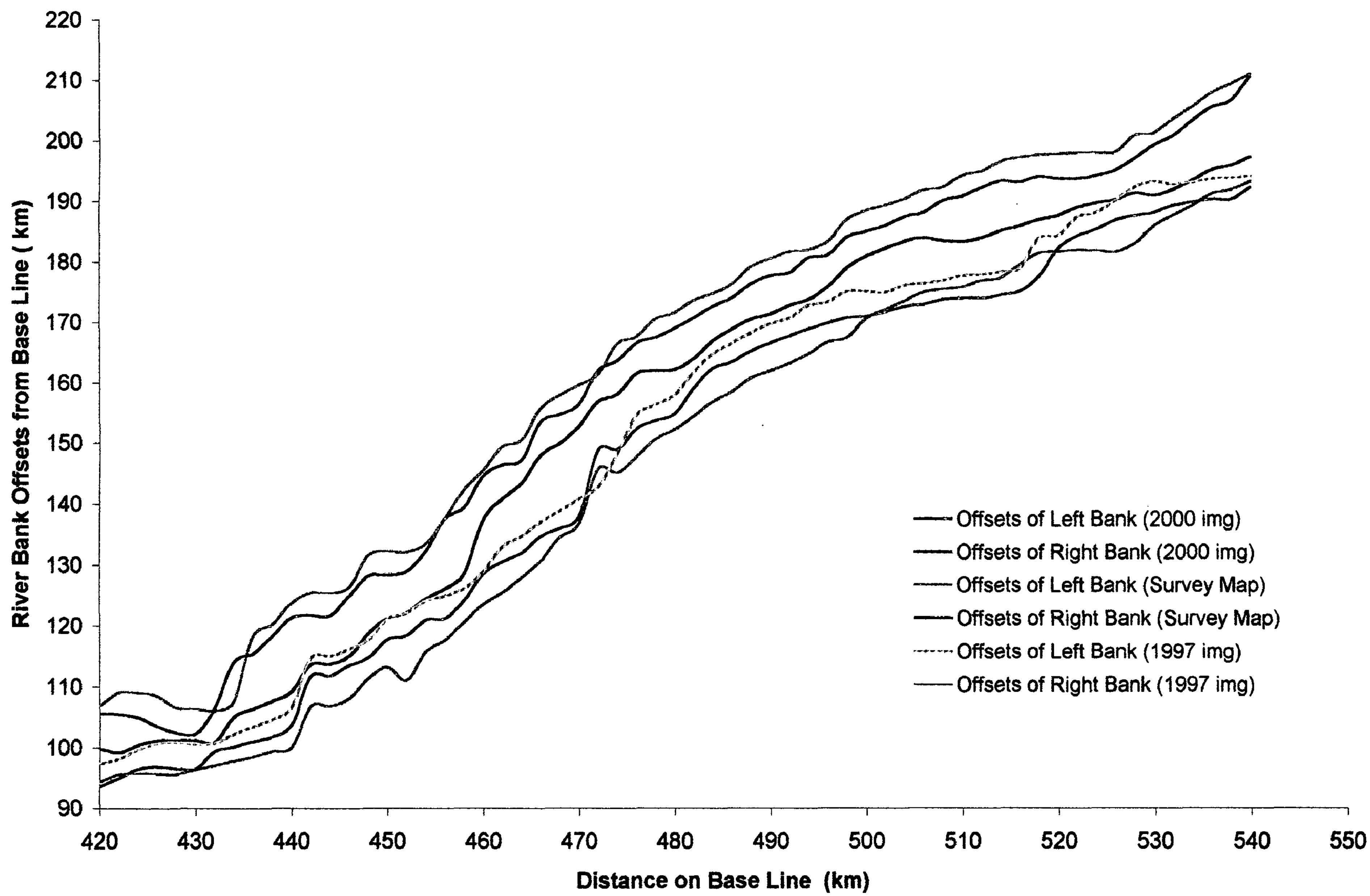

Fig. 5.9 River Bank Offsets Curve (420-540 km)

Table 5.3: Difference of Off-Sets Between Two Banks

Distance on Base Line in K.M.	Satellite Imagery (2000) in km	Survey Maps 1986 in km	Satellite Imagery (1997) in km
0			
2		13.5	
4	9.74	15.03	
6	8.82	14.64	
8	10.28	12.85	Satellite Image Not Available
10	12.13	12.9	
12	13.45	13.77	
14	9.25	15.35	
16	9.8	14.64	
18	8.1	13.28	
20	8	13.33	
22	7.89	13.94	
24	8.16	13.71	
26	8.71	13.55	
28	10.12	11.21	
30	12.34	9.21	
32	11.43	8.17	
34	9.95	8.21	
36	8.34	7.65	
38	9.91	8.34	
40	10.99	9.35	
42	10.52	9.39	
44	10.48	9.35	
46	11.9	9.47	Satellite Image Not Available
48	11.17	9.43	
50	7.17	6.48	
52	6.87	5.04	
54	5.47	3.91	
56	2.34	3.52	
58	2.26	3.82	
60	4.43	4.56	
62	4.78	3.43	
64	6.56	3.82	
66	7.91	3.91	
68	8.17	6.43	
70	12.47	8.39	
72	12.34	9.38	
74	13.86	9.04	
76	14.86	7.74	
78	14.38	5.12	
80	14.51	3.6	
82	15.08	4.91	
84	14.12	7.61	
86	13.82	10.86	
88	14.2	10.77	

Distance on Base Line in K.M.	Satellite Imagery (2000) in km	Survey Maps 1986 in km	Satellite Imagery (1997) in km
90	14.51	10.43	
92	14.9	9.91	
94	14.55	9.39	Satellite Image Not Available
96	13.04	8.51	
98	12.21	9.04	
100	11.08	9.73	
102	11.6	9.82	
104	9.6	7.69	
106	10.25	5.73	
108	9.38	5.65	
110	7.12	6.34	
112	7.08	6.74	
114	7.56	7	
116	8.73	6.79	
118	10.39	6.17	
120	12.95	5.78	
122	14.38	6.95	
124	15.6	9.32	
126	16.27	10.72	
128	17.82	10.72	
130	17.74	11.81	
132	17.48	12.77	
134	18.47	12.11	
136	18.39	11.01	Satellite Image Not Available
138	17.78	11.05	
140	17.37	12.76	
142	15.44	13.97	
144	12.99	12.88	
146	6.58	10.94	
148	5.23	2.89	
150	5.27	2.3	
152	5.01	3.15	
154	3.73	3.11	
156	2.41	3	
158	3.88	3.03	
160	5.99	7.1	
162	6.25	8.12	
164	2.3	5.97	
166	1.21	3.44	
168	0.98	1.72	
170	1.17	1.61	
172	2.52	1.9	
174	3.43	2.27	
176	3.07	2.37	
178	3.48	2.59	
180	3.25	2.63	
182	3	2.53	

Distance on Base Line in K.M.	Satellite Imagery (2000) in km	Survey Maps 1986 in km	Satellite Imagery (1997) in km
184	5.26	2.78	Satellite Image Not Available
186	4.5	5.67	
188	2.89	6.8	
190	2.34	8.41	
192	3.04	10.06	
194	2.64	11.89	
196	4.54	11.7	
198	4.87	11.27	
200	7.76	10.86	
202	10.75	9.69	
204	11.91	8.25	
206	11.74	6.88	
208	12.25	5.89	
210	11.66	5.16	
212	10.75	6.47	
214	15.15	10.1	
216	10.53	12.47	
218	8.04	3.18	
220	7.97	6	
222	8.16	6.14	
224	8.63	9.8	
226	8.11	9.6	
228	7.79	7.23	
230	4.1	4.57	
232	5.18	3.01	
234	8.17	3.95	
236	9.42	5.15	Satellite Image Not Available
238	9.92	5.77	
240	9.83	5.67	
242	8.46	4.88	
244	10.27	3.28	
246	10.07	2.72	
248	10.47	3.48	
250	11.29	6.17	
252	9.83	8.45	
254	10.06	9.06	
256	10.7	9.79	
258	13.17	10.65	
260	13.35	11.07	
262	13.31	11.75	
264	12.71	12.16	
266	12.03	11.84	
268	11.01	12.89	
270	9.05	13.9	
272	10.47	13.08	
274	9.69	12.9	
276	9.14	13.95	

Distance on Base Line in K.M.	Satellite Imagery (2000) in km	Survey Maps 1986 in km	Satellite Imagery (1997) in km
278	6.91	11.66	
280	7.37	7.77	
282	5.94	5.62	
284	5.81	5.08	Satellite Image Not Available
286	5.67	4.8	
288	3.02	5.9	
290	4.34	7.27	
292	3.61	7.32	
294	2.56	6.41	
296	1.05	4.66	
298	3.75	4.34	
300	3.75	5.53	
302	4.58	7.87	
304	4.84	7.46	
306	6.07	6	
308	8.27	5.26	
310	8.99	6.08	
312	8.9	6.36	
314	8.12	6.36	
316	4.94	5.6	
318	6.94	5.72	
320	5.85	6.61	
322	8.1	8.24	
324	8.14	8.1	
326	8.79	7.26	
328	7.66	6.39	Satellite Image Not Available
330	4.7	6.03	
332	7.12	5.85	
334	7.74	5.92	
336	6.87	5.92	
338	7.73	6.76	
340	6.54	7.3	
342	4.4	6.97	
344	3.85	5.95	
346	4.72	5.45	
348	4.43	6.61	
350	5.02	7.88	
352	5.59	8.42	
354	7.95	7.7	
356	9.77	7.59	
358	9.55	7.45	
360	11.36	7.26	
362	12.79	7.53	
364	9.48	8.49	
366	11.01	8.98	
368	10.87	9.71	
370	9.97	9.88	

Distance on Base Line in K.M.	Satellite Imagery (2000) in km	Survey Maps 1986 in km	Satellite Imagery (1997) in km
372	10.11	11.65	
374	8.78	11.22	Satellite Image Not Available
376	12.44	10.06	
378	12.71	11.59	
380	12.78	13.33	
382	13.15	11.63	
384	11.54	8.39	
386	11.01	8.07	
388	11.31	8.17	
390	11.35	9.49	
392	14.94	8.45	
394	14.84	7.72	
396	13.31	7.85	
398	12.17	8.49	
400	13.31	9.63	
402	12.76	7.22	
404	11.99	6.81	
406	13.74	6.81	
408	12.49	6.52	
410	12.03	6.47	
412	12.1	6.3	
414	12.03	5.37	
416	12.14	5	
418	12.6	5.55	
420	12.02	5.61	9.6
422	10.58	3.72	10.84
424	8.48	4.77	9.2
426	6.66	5.55	7.71
428	6.01	5.68	5.68
430	5.81	4.84	5.87
432	7.19	3.92	5.22
434	13.84	7.38	5.35
436	14.39	7.9	14.79
438	16.49	8.23	15.51
440	17.53	9.14	16.94
442	9.99	6.86	10.64
444	9.89	6.85	10.28
446	11.36	6.92	10.19
448	13.48	7.41	13.81
450	10.55	8	11.07
452	10.48	11.16	9.95
454	11.33	8.75	9.37
456	16.32	8.42	12.73
458	15.31	7.97	16.17
460	16.1	13.97	16.62
462	15.86	15.47	16.39
464	15.25	15.51	15.67

Distance on Base Line in K.M.	Satellite Imagery (2000) in km	Survey Maps 1986 in km	Satellite Imagery (1997) in km
466	18.78	17.37	18.65
468	18.71	15.41	18.97
470	18.44	15.93	18.77
472	13.11	11.13	18.55
474	14.7	12.95	18.1
476	14.16	13.74	12.95
478	13.77	11.33	14.07
480	14.1	9.93	13.53
482	11.64	9.56	11.81
484	10.24	9.98	9.97
486	10.55	10.29	9.77
488	11.08	9.72	10.92
490	11.23	9.4	10.65
492	10.5	9.53	10.97
494	11.8	8.94	9.24
496	11.23	9.15	9.98
498	13.32	11.52	11.75
500	14.11	10.34	13.27
502	14.29	10.16	14.23
504	14.81	9.93	14.18
506	15.22	8.95	15.28
508	16.33	7.96	15.27
510	16.85	7.5	16.38
512	18.19	7.09	17.02
514	18.82	7.73	18.12
516	17.99	6.39	18.24
518	16.39	5.46	13.71
520	11.56	5.99	13.37
522	9.47	6.98	10.63
524	8.77	7.78	9.82
526	8.19	8.54	7.96
528	9.47	8.21	8.43
530	11.09	4.94	7.9
532	11.45	4.25	10.69
534	13.47	4.19	12.31
536	15.18	3.92	14.02
538	16.27	4.07	15.4
540	18.3	4.07	16.78

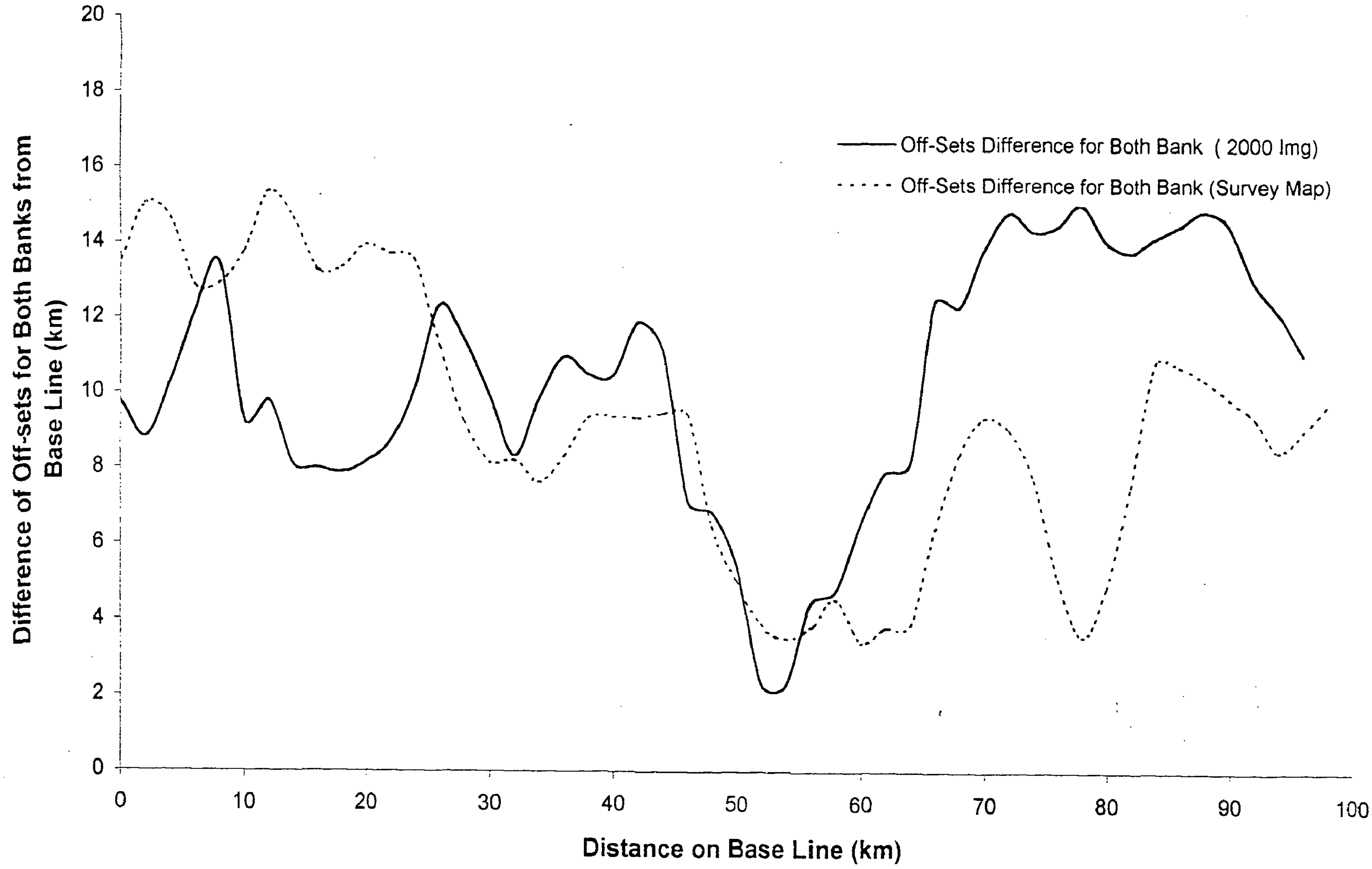

Fig. 510 Distance Between Two Banks on North South Line (0-100 km)

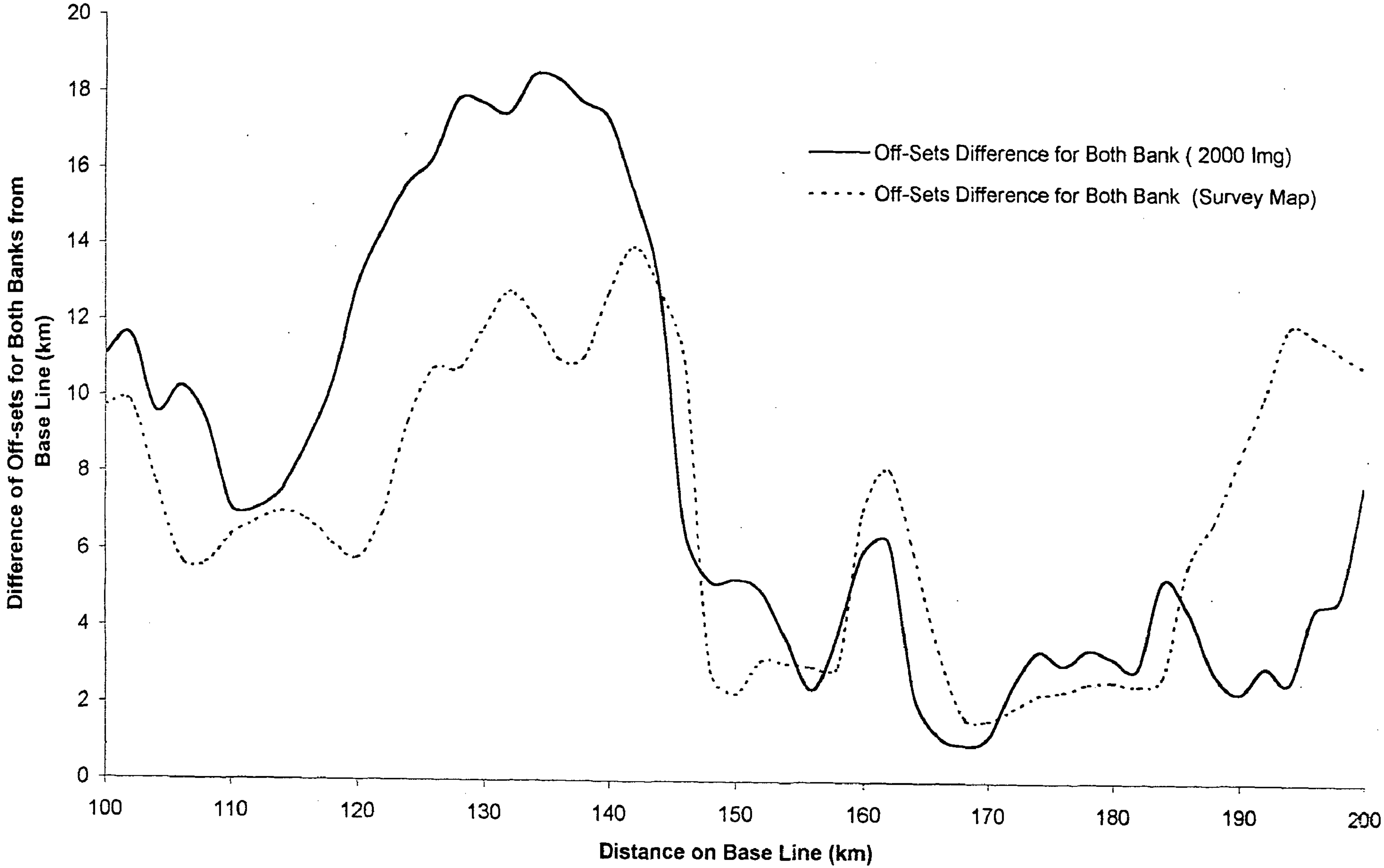

Fig. 5.11 Distance Between Two Banks on North South Line (100-200 km)

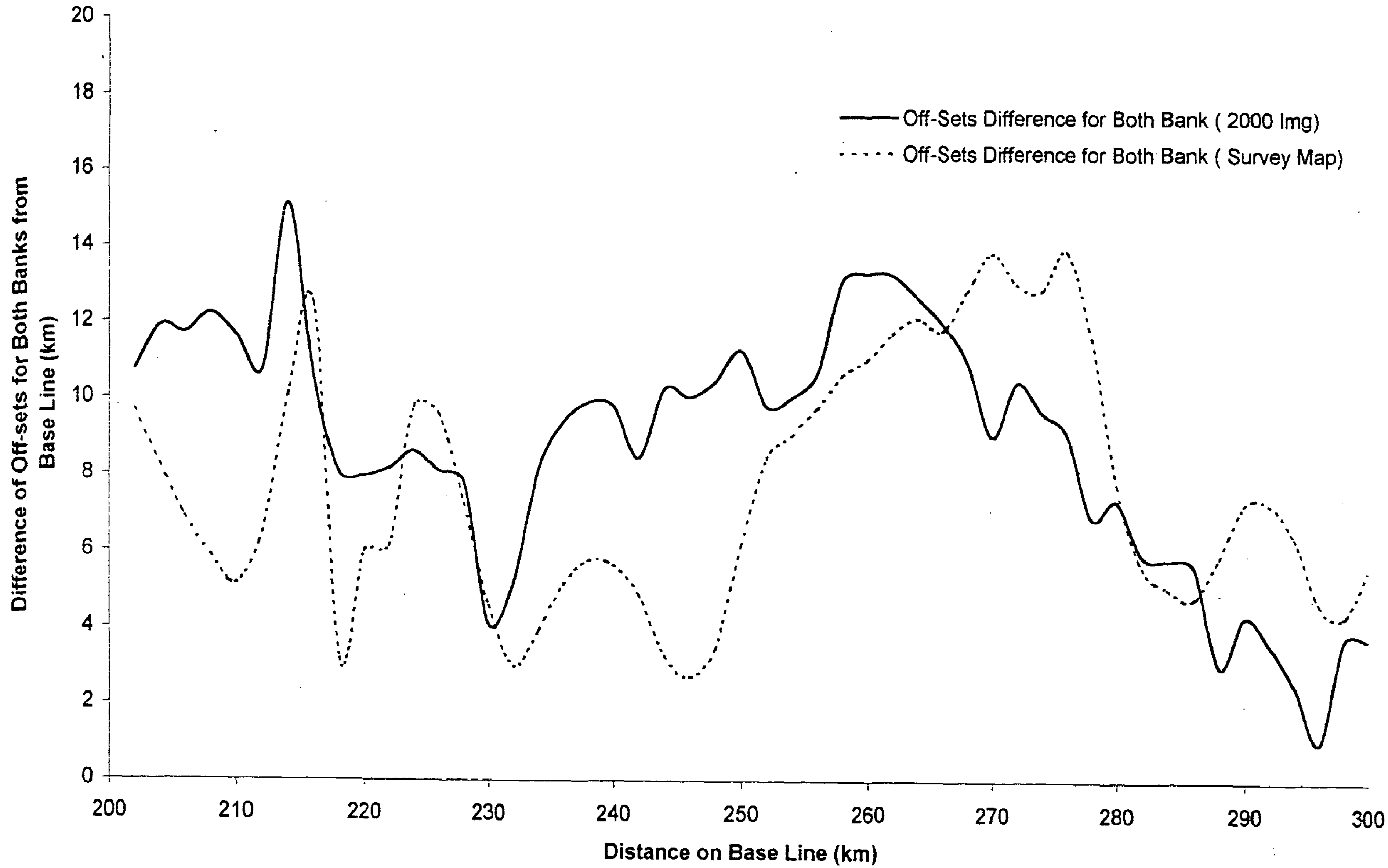

Fig. 5.12 Distance Between Two Banks on North South Line (200-300 km)

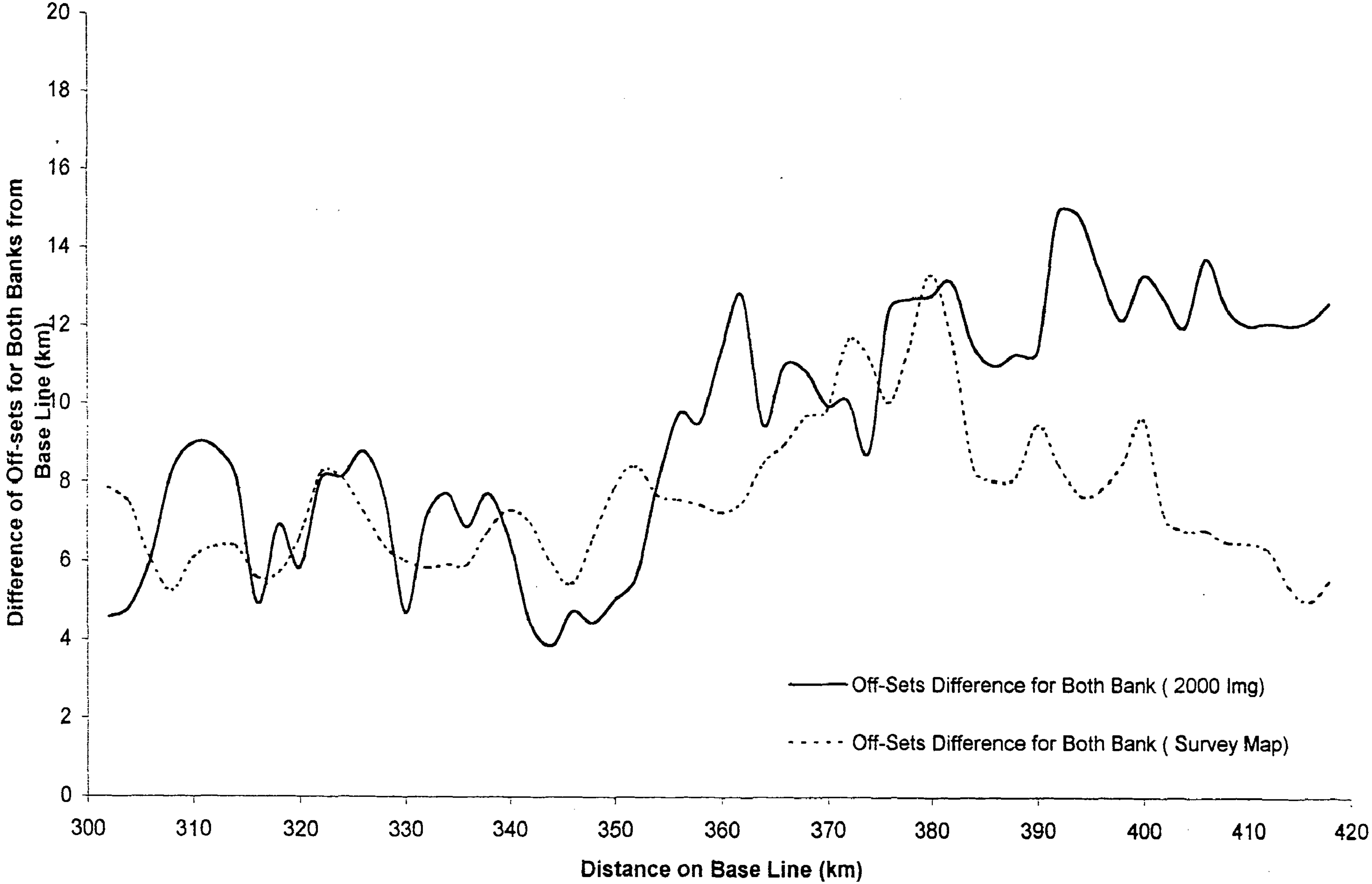

Fig . 5.13 Distance Between Two Banks on North South Line (300-420 km)

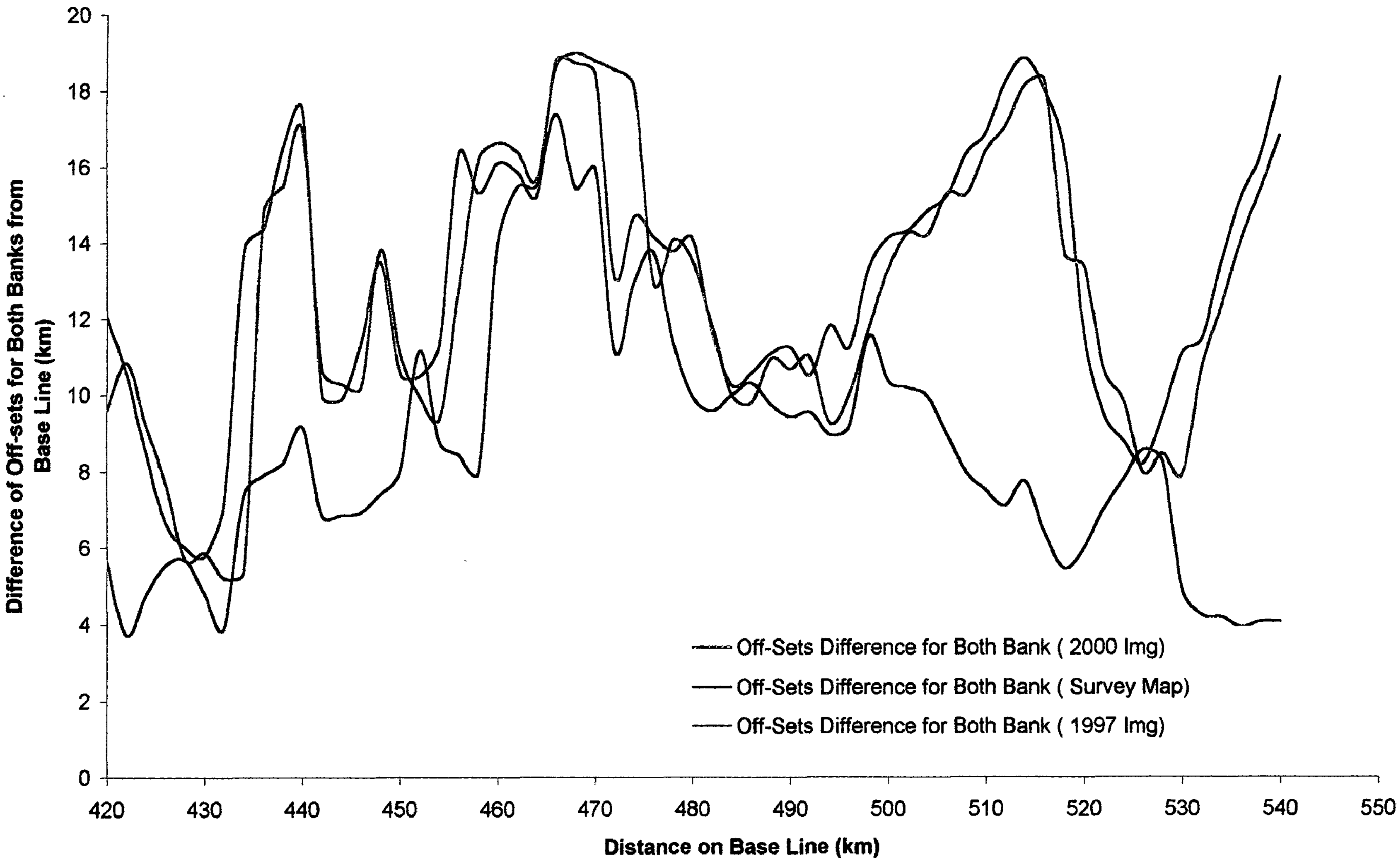

Fig. 5. 14 Distance Between Two Banks on North South Line (420-540 km)

Table 5.4: Bank Shifts in Different Periods Maps/Images

Distance on Base Line in K.M.	Difference of Offsets for L.B.(Survey and 2000 Img.)	Difference of Offsets for R.B. (Survey and 2000 Img.)	Difference of Offsets for L.B. (1997 Img. and 2000 Img.)	Difference of Offsets for R.B.(1997 Img. and 2000 Img.)
0	0	2.23		
2	-2.78	5.6		
4	2.5	7.79		
6	2.83	8.65		
8	6.69	9.26		
10	8.32	9.09		
12	7.68	8		
14	1.91	8.01		
16	1.91	6.75		
18	2.88	8.06		
20	2.18	7.51	Satellite Image Not Available	
22	2.28	8.33		
24	2.07	7.62		
26	1.96	6.8		
28	2.45	3.54		
30	3.18	0.05		
32	2.26	-1		
34	0.22	-1.52		
36	-0.44	-1.13		
38	0.22	-1.35		
40	-0.18	-1.82		
42	-0.65	-1.78		
44	-1.52	-2.65		
46	-1.13	-3.56		
48	-1.39	-3.13		
50	-1.91	-2.6		
52	-1.26	-3.09		Satellite Image Not Available
54	-0.74	-2.3		
56	-0.83	0.35		
58	-1.48	0.08		
60	-0.65	-0.52		
62	-1.04	-2.39		
64	-1.13	-3.87		
66	-0.69	-4.69		
68	-3.3	-5.04		
70	-1.7	-5.78		
72	-2.35	-5.31		
74	-1.78	-6.6		
76	-2.3	-9.42		
78	-2.3	-11.56		
80	-1.26	-12.17		
82	-0.95	-11.12		
84	-1.18	-7.69		
86	-1.86	-4.82		
88	-1.61	-5.04		

Distance on Base Line in K.M.	Difference of Offsets for L.B.(Survey and 2000 Img.)	Difference of Offsets for R.B. (Survey and 2000 Img.)	Difference of Offsets for L.B. (1997 Img. and 2000 Img.)	Difference of Offsets for R.B.(1997 Img. and 2000 Img.)
90	-2.48	-6.56		
92	-2.74	-7.73		
94	-2.35	-7.51		
96	-2	-6.53		
98	-1.74	-4.91		
100	-3.04	-4.39		
102	-4.52	-6.3		
104	-4.52	-6.43	Satellite Image Not Available	
106	-2.04	-6.56		
108	-2.17	-5.9		
110	-3.13	-3.91		
112	-2.7	-3.04		
114	-1.74	-2.3		
116	-1.01	-2.95		
118	0.39	-3.83		
120	2.61	-4.56		
122	4	-3.43		
124	4.3	-1.98		
126	4.64	-0.91		
128	5.12	-1.98		
130	4.5	-1.43		
132	3.87	-0.84		
134	5.08	-1.28		
136	4.97	-2.41		
138	4.06	-2.67		
140	1.39	-3.22		Satellite Image Not Available
142	-0.22	-1.69		
144	0.73	0.62		
146	3.07	7.43		
148	3.51	1.17		
150	2.6	-0.37		
152	1.64	-0.22		
154	0.07	-0.55		
156	-0.77	-0.18		
158	-0.84	-1.69		
160	-0.81	0.3		
162	-0.88	0.99		
164	-2.02	1.65		
166	-1.72	0.51		
168	-1.5	-0.76		
170	-1.17	-0.73		
172	-0.88	-1.5		
174	-2.16	-3.32		
176	-2.45	-3.15		
178	-1.97	-2.86		
180	-1.39	-2.01		
182	-0.55	-1.02		

Distance on Base Line in K.M.	Difference of Offsets for L.B.(Survey and 2000 Img.)	Difference of Offsets for R.B. (Survey and 2000 Img.)	Difference of Offsets for L.B. (1997 Img. and 2000 Img.)	Difference of Offsets for R.B.(1997 Img. and 2000 Img.)
184	0	-2.48		
186	0	1.17		
188	-0.99	2.92		
190	-3.69	2.38		
192	-4.39	2.63		
194	-4.35	4.9		
196	-3.03	4.13		
198	-2.01	4.39		
200	-2.92	0.18		
202	-1.53	-2.59		
204	0	-3.66		
206	-0.3	-5.16	Satellite Image Not Available	
208	1.53	-4.83		
210	2.3	-4.2		
212	1.61	-2.67		
214	2.16	-2.89		
216	0.95	2.89		
218	8.63	3.77		
220	4.46	2.49		
222	4.42	2.4		
224	-0.73	0.44		
226	-1.11	0.38		
228	0.47	-0.09		
230	-0.35	0.12		
232	1.58	-0.59		
234	2.17	-2.05		
236	1.11	-3.16		
238	0.11	-4.04		
240	0.29	-3.87		Satellite Image Not Available
242	-0.64	-4.22		
244	0.44	-6.55		
246	1	-6.35		
248	1.1	-5.89		
250	-0.59	-5.71		
252	-3.29	-4.67		
254	-4.03	-5.03		
256	-3.61	-4.52		
258	-0.96	-3.48		
260	-0.42	-2.7		
262	-1.28	-2.84		
264	-2.33	-2.88		
266	-2.24	-2.43		
268	-4.21	-2.33		
270	-6.54	-1.69		
272	-5.35	-2.74		
274	-6.22	-3.01		
276	-7.96	-3.15		

Distance on Base Line in K.M.	Difference of Offsets for L.B.(Survey and 2000 Img.)	Difference of Offsets for R.B. (Survey and 2000 Img.)	Difference of Offsets for L.B. (1997 Img. and 2000 Img.)	Difference of Offsets for R.B.(1997 Img. and 2000 Img.)
278	-6.81	-2.06		
280	-2.69	-2.29		
282	-1.92	-2.24		
284	-1.65	-2.38		
286	-1.46	-2.33		
288	-4.3	-1.42		
290	-4.34	-1.41		
292	-3.71	0		
294	-3.39	0.46		
296	-4.11	-0.5		
298	-2.79	-2.2		Satellite Image Not Available
300	-2.65	-0.87		
302	-1.14	2.15		
304	0.22	2.84		
306	1.5	1.43		
308	2.88	-0.13		
310	2.04	-0.87		
312	1.77	-0.77		
314	1.54	-0.22		
316	-0.66	0		
318	-0.87	-2.09		
320	-2.43	-1.67		
322	-2.76	-2.62		
324	-2.94	-2.98		
326	-2.29	-3.82		
328	-2	-3.27		
330	-4.49	-3.16		
332	-0.58	-1.85		
334	-0.9	-2.72		
336	-0.8	-1.75		
338	-2.04	-3.01		
340	-3.27	-2.51		
342	-4.35	-1.78		
344	-4.03	-1.93		
346	-3.31	-2.58	Satellite Image Not Available	
348	-4.03	-1.85		
350	-4.06	-1.2		
352	-4.03	-1.2		
354	-2.11	-2.36		
356	-1.45	-3.63		
358	0	-2.1		
360	1.63	-2.47		
362	2.21	-3.05		
364	0	-0.99		
366	-0.5	-2.53		
368	-1.08	-2.24		
370	-1.54	-1.63		

Distance on Base Line in K.M.	Difference of Offsets for L.B.(Survey and 2000 Img.)	Difference of Offsets for R.B. (Survey and 2000 Img.)	Difference of Offsets for L.B. (1997 Img. and 2000 Img.)	Difference of Offsets for R.B.(1997 Img. and 2000 Img.)
372	-1.22	0.32	Satellite Image Not Available	Satellite Image Not Available
374	-2.18	0.26		
376	-3.55	-5.93		
378	-2.8	-3.92		
380	-4.47	-3.92		
382	-3.89	-5.41		
384	-5.81	-8.96		
386	-6.39	-9.33		
388	-7.4	-10.54		
390	-7.4	-9.26		
392	-6.9	-13.39		
394	-6.77	-13.89		
396	-7.71	-13.17		
398	-8.49	-12.17		
400	-7.63	-11.31		
402	-3.77	-9.31		
404	-3.58	-8.76		
406	-2.61	-9.54		
408	-3.63	-9.6		
410	-3.36	-8.92		
412	-1.52	-7.32		
414	0.22	-6.44		
416	1.59	-5.55		
418	0.98	-6.07		
420	0.66	-5.75	3.72	1.3
422	0.53	-6.33	3.2	3.46
424	-0.79	-4.5	3.33	4.05
426	-1.24	-2.35	3.91	4.96
428	-0.98	-1.31	4.44	4.11
430	-0.2	-1.17	4.05	4.11
432	-2.41	-5.68	1.44	-0.53
434	-2.42	-8.88	2.09	-6.4
436	-2.49	-8.98	2.48	2.88
438	-2.42	-10.68	2.87	1.89
440	-3.72	-12.11	2.94	2.35
442	-4.96	-8.09	3.01	3.66
444	-4.96	-8	3.2	3.59
446	-5.42	-9.86	2.67	1.5
448	-3.43	-9.5	3	3.33
450	-4.6	-7.15	3.4	3.92
452	-7.44	-6.76	3.72	3.19
454	-5.29	-7.87	3.14	1.18
456	-3.66	-11.56	3.59	0
458	-3.46	-10.8	2.02	2.88
460	-5.09	-7.22	0.33	0.85
462	-5.16	-5.55	2.48	3.01
464	-4.11	-3.85	2.81	3.23

Distance on Base Line in K.M.	Difference of Offsets for L.B.(Survey and 2000 Img.)	Difference of Offsets for R.B. (Survey and 2000 Img.)	Difference of Offsets for L.B. (1997 Img. and 2000 Img.)	Difference of Offsets for R.B.(1997 Img. and 2000 Img.)
466	-4.11	-5.52	2.35	2.22
468	-1.5	-4.8	2.87	3.13
470	-1.18	-3.69	2.87	3.2
472	-3.18	-5.16	-6.03	-0.59
474	-3.81	-5.56	-0.63	2.77
476	-4.65	-5.07	2.25	1.04
478	-3.08	-5.52	2.67	2.97
480	-2.62	-6.79	3.13	2.56
482	-4.65	-6.73	2.71	2.88
484	-5.48	-5.74	2.41	2.14
486	-4.91	-5.17	3.08	2.3
488	-4.49	-5.85	2.98	2.82
490	-4.6	-6.43	3.29	2.71
492	-4.52	-5.49	2.98	3.45
494	-4.08	-6.94	3.92	1.36
496	-3.19	-5.27	3.5	2.25
498	-3.32	-5.12	4.39	2.82
500	-0.36	-4.13	4.18	3.34
502	0.35	-3.78	3.31	3.25
504	0.87	-4.01	3.54	2.91
506	2.03	-4.24	3.54	3.6
508	1.74	-6.63	3.2	2.14
510	1.86	-7.49	3.78	3.31
512	2.85	-8.25	3.9	2.73
514	2.84	-8.25	3.89	3.19
516	4.34	-7.26	3.76	4.01
518	3.78	-7.15	6.28	3.6
520	-0.64	-6.21	2.15	3.96
522	-2.33	-4.82	3.08	4.24
524	-3.54	-4.53	2.73	3.78
526	-5.29	-4.94	3.19	2.96
528	-4.54	-5.8	4.7	3.66
530	-2.21	-8.36	5.17	1.98
532	-1.63	-8.83	3.54	2.78
534	-0.53	-9.81	3.37	2.21
536	0.95	-10.31	3.49	2.33
538	1.6	-10.6	3.56	2.69
540	0.94	-13.29	1.81	0.29

Minus Value indicates that 2000 (img.) Bank is north of Survey Map Bank or 1997 Img. Map as the case may be and vice versa

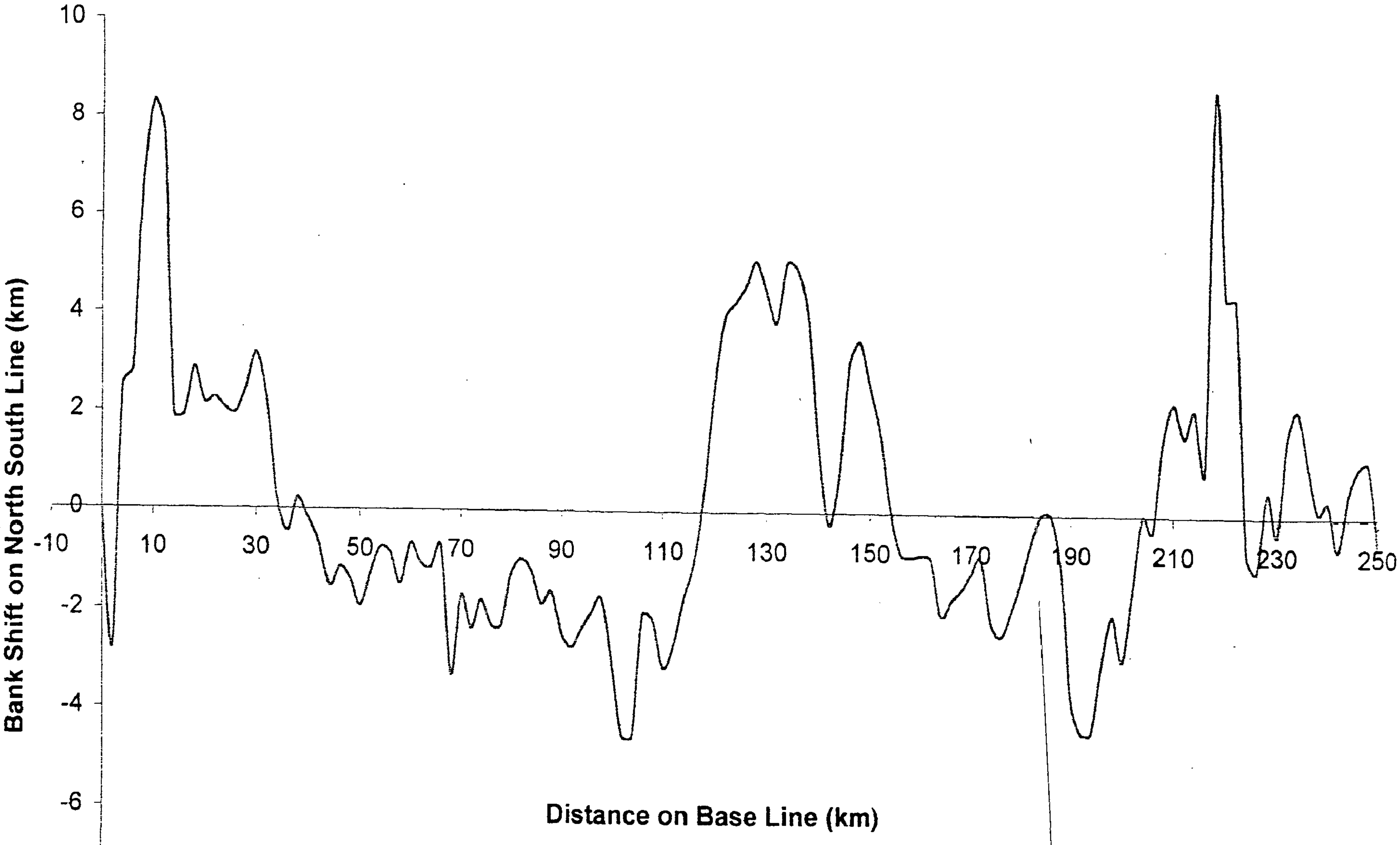

Fig. 5.15 Shift of Left Bank (2000 img) from Left Bank of Survey Map (0-250 km)

* Positive Value of Y Indicates that Left bank of (2000 img) has shifted in north from Left Bank of Survey Map and vice -versa

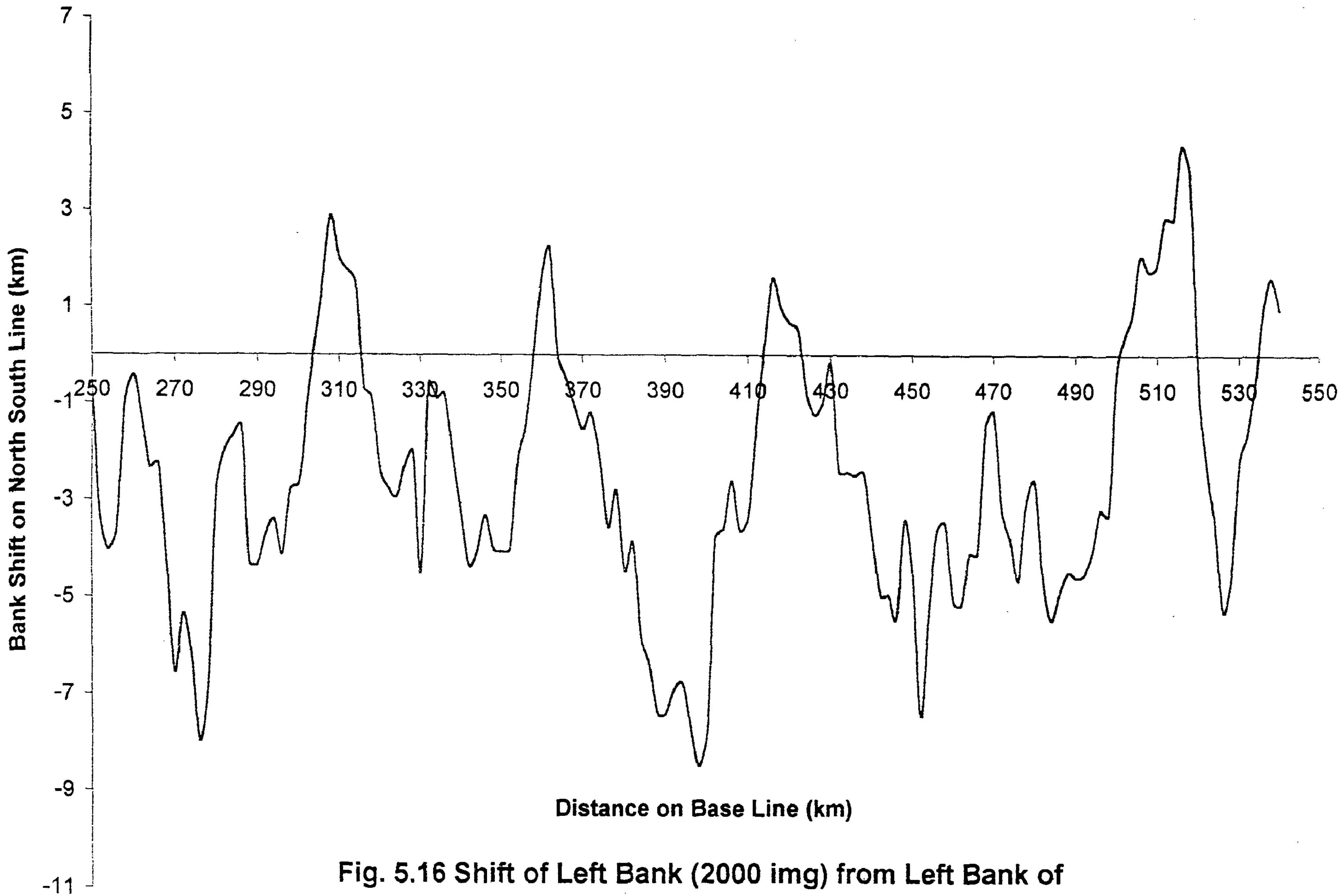

Fig. 5.16 Shift of Left Bank (2000 img) from Left Bank of Survey Map (250-540 km)

* Positive value of Y Indicates that Left Bank of (2000 img) has Shifted in north from Left Bank of Survey Map and vice -versa

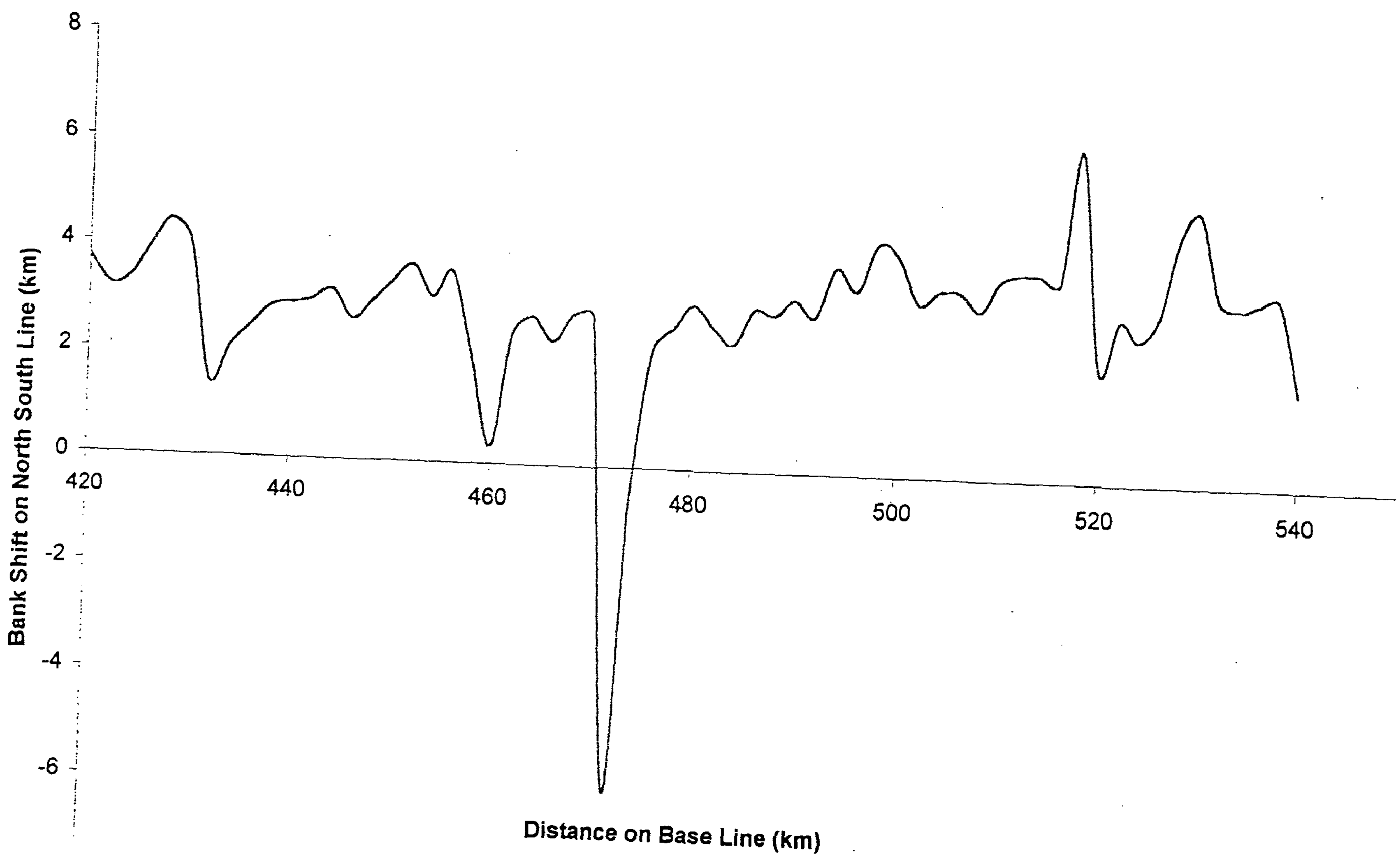

Fig. 5.17 Shift of Left Bank (2000 img) from Left Bank of (1997 img) (420-540 km)

* Positive value of Y Indicates that Left Bank of (2000 img) has shifted in South from Left Bank of (1997 img) and vice -versa

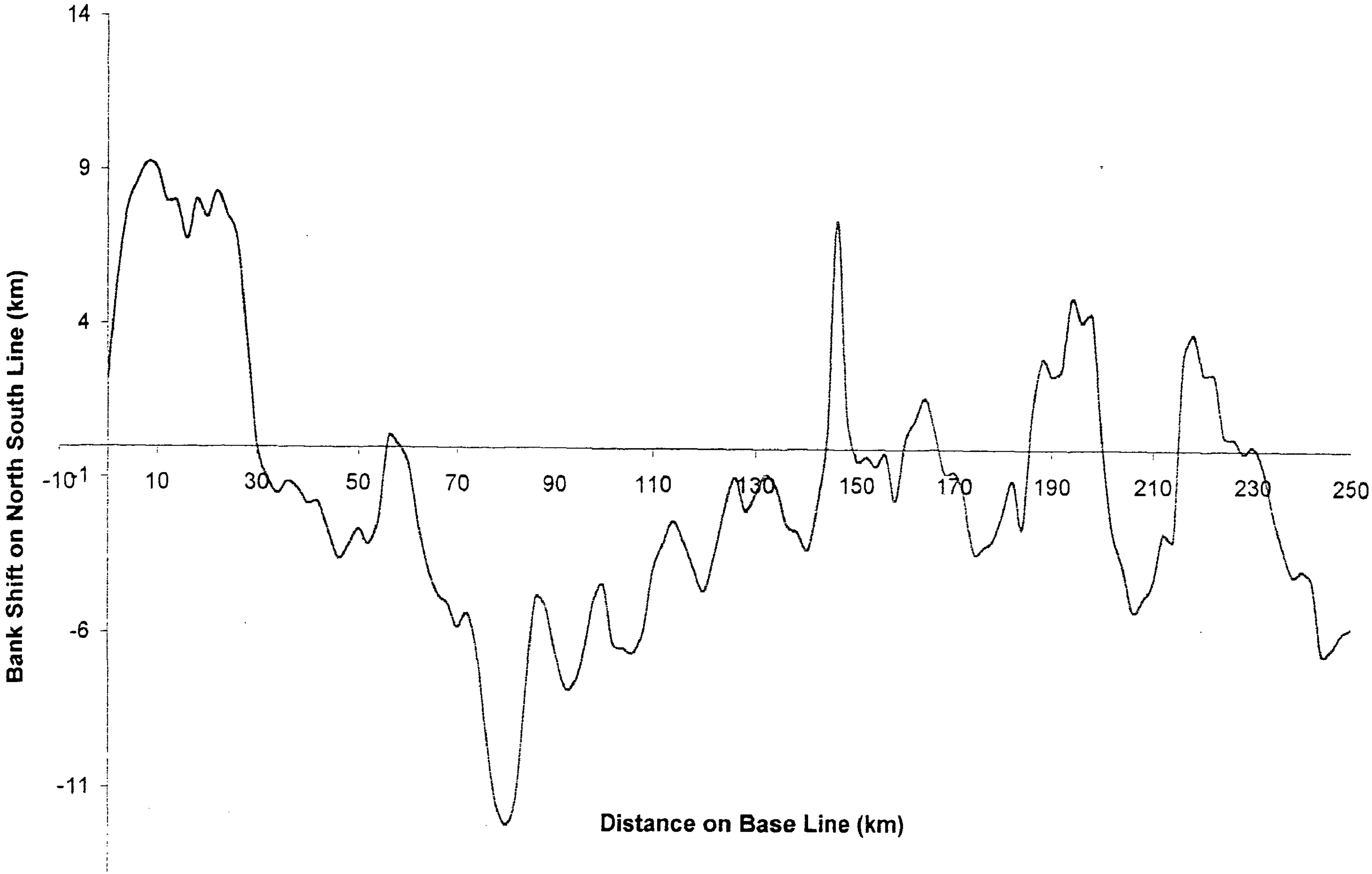

Fig. 5.18 Shift of Right Bank (2000 img) from Right Bank of Survey Map (0-250 km)

* Positive value of Y Indicates that Right Bank of (2000 img) has shifted in South frcm Right Bank of Survey Map and vice -versa

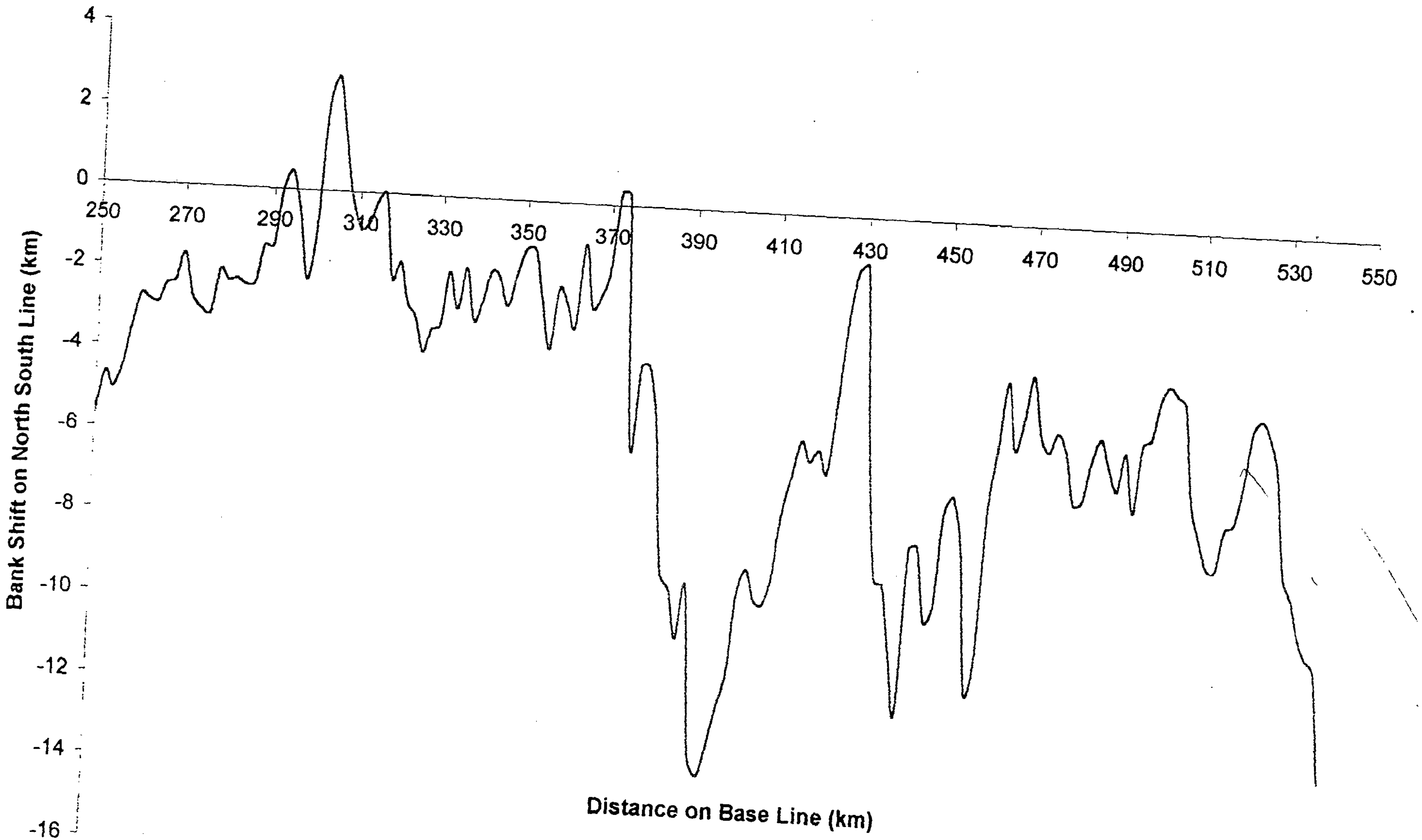

Fig. 5.19 Shift of Right Bank (2000 img) from Right Bank of Survey Map (250-540 km)

* Positive value of Y Indicates that Right Bank of (2000 img) has shifted in South from Right Bank of Survey Map and vice -versa

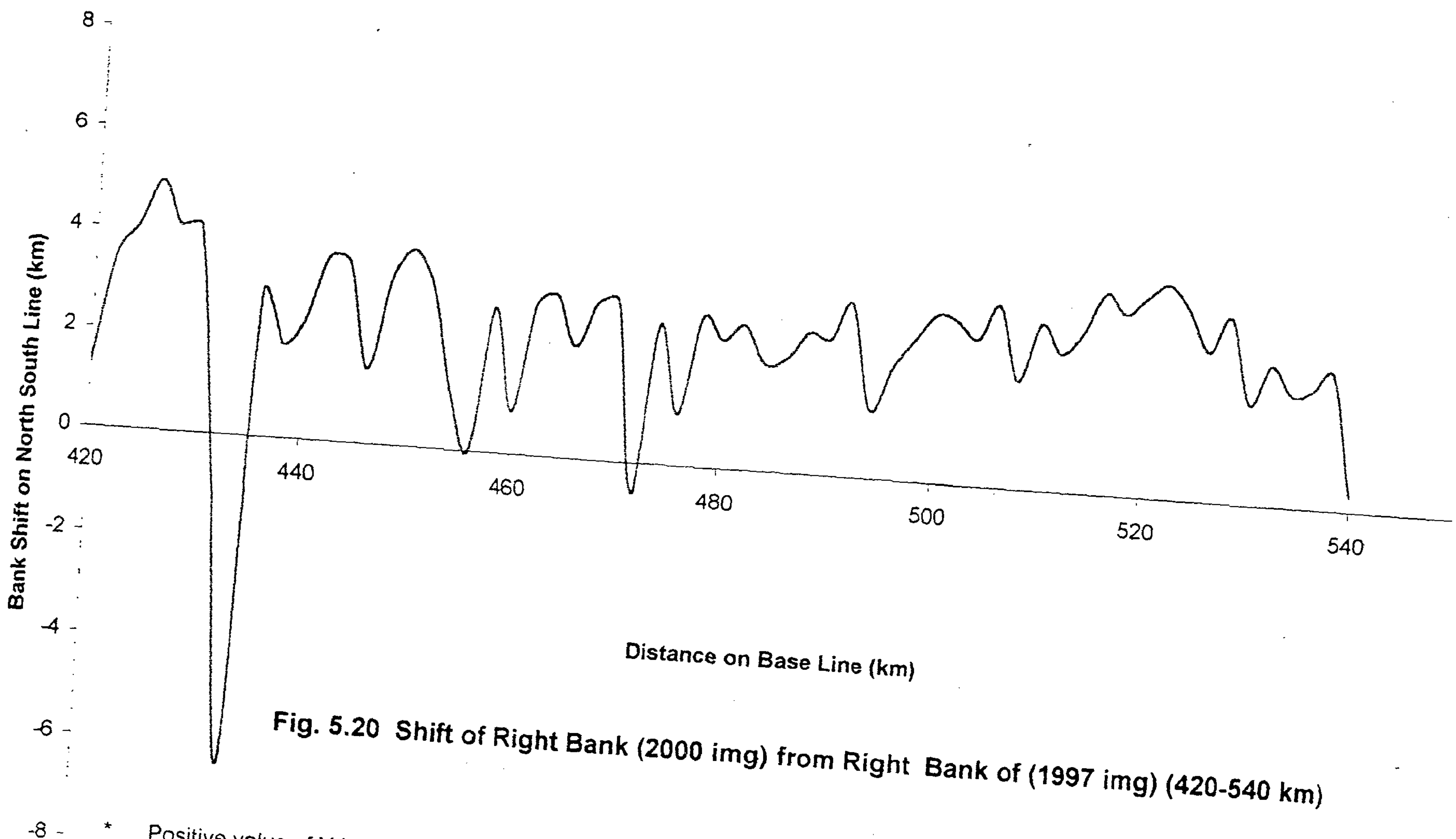

Fig. 5.20 Shift of Right Bank (2000 img) from Right Bank of (1997 img) (420-540 km)

* Positive value of Y Indicates that Right Bank of (2000 img) has shifted in South from Right Bank of (1997 img) and vice -versa

Table No. 5.5 Majuli Island Cross-section Position

Cross Section No.	*Chainage From Cross Section No.-1 in (km)*
1	0
2	3
3	6
4	9
5	12
6	15
7	18
8	21
9	24
10	27
11	30
12	33
13	36
14	37
15	40
16	43
17	44
18	45
19	46
20	47
21	48
22	49
23	50
24	51
25	52
26	53
27	54
28	55
29	56
30	57
31	58
32	59
33	60
34	61
35	66
36	71
37	75

Table No.: 5.6

Bed Levels at Different Cross-sections Before and after run of Model (Majuli Reach) of Brahmaputra

Distance from Left Bank (cm)	Cross Section No. 1		Cross Section No. 5		Cross Section No. 10		Cross Section No. 13		Cross Section No. 20		Cross Section No. 33		Cross Section No. 35		Cross Section No. 37	
	Before Run cm	After Run cm	Before Run cm	After Run cm	Before Run cm	After Run cm	Before Run cm	After Run cm	Before Run cm	After Run cm	Before Run cm	After Run cm	Before Run cm	After Run cm	Before Ru cm	After Run cm
10	39.1	38.4	41.7	41.5	44	43.6	42.4	42.4	43.3	43.4	47	46.6	46.1	46	46.5	45.4
30	39.1	38.1	41.5	41.4	43.9	43.5	42.1	42.1	43.4	43.4	42.9	41.1	46.4	46.4	45.5	45.7
50	38.6	37.3	41.3	41.3	43.7	43.5	41.1	40.5	42.2	43.4	43	41	46	45.9	39	45.2
70	39.1	37.8	41.2	41.4	40.2	38.2	40.2	40.3	40.4	39.2	43.1	42.8	39.4	39.5	39.5	38.9
90	39	34.4	35.4	37.4	40.8	35.6	37.4	38.8	36.6	39.6	43	43	39.5	39.9	44	44.1
110	35.8	35.3	39.8	38.1	41.7	41.1	41.2	40.1	39.5	39.5	39	40.8	43.6	43	45.2	44.9
130	34.8	36	39.8	40.3	41.7	39.4	41	41	43	39.9	43.1	42.8	43.1	42.2	40.1	43.2
150	37.8	35.8	40.5	38.4	36.5	37.8	40.7	37.8	40.2	40.6	43.1	42.6	40.1	39.1	45.5	44.7
170	33.8	35.7	37.1	37.5	41.7	37.8	42.1	36.3	43.1	42.9	39.9	39	43.6	43.3	42	45.4
190	37	36.4	40.3	38.4	43.1	42.9	42.6	41.9	43.4	44.8	45	41.9	40.5	38.5	41.5	41.7
210	39	35.4	43.3	36.2	43.5	43.6	42.9	42.3	44.9	43.7	45.5	44.8	43.1	41.3	47.4	45.3
230	39.7	39.1	43.3	42.9	43.6	43.9	43	42.5	40.8	41.2	45.5	44.8	45.2	44.4	48	47.8
250	40.1	39.5	43.5	43.9	44.5	44.1	43.2	43.2	42	46.2	46	45.8	46.2	46.6	47	48.7

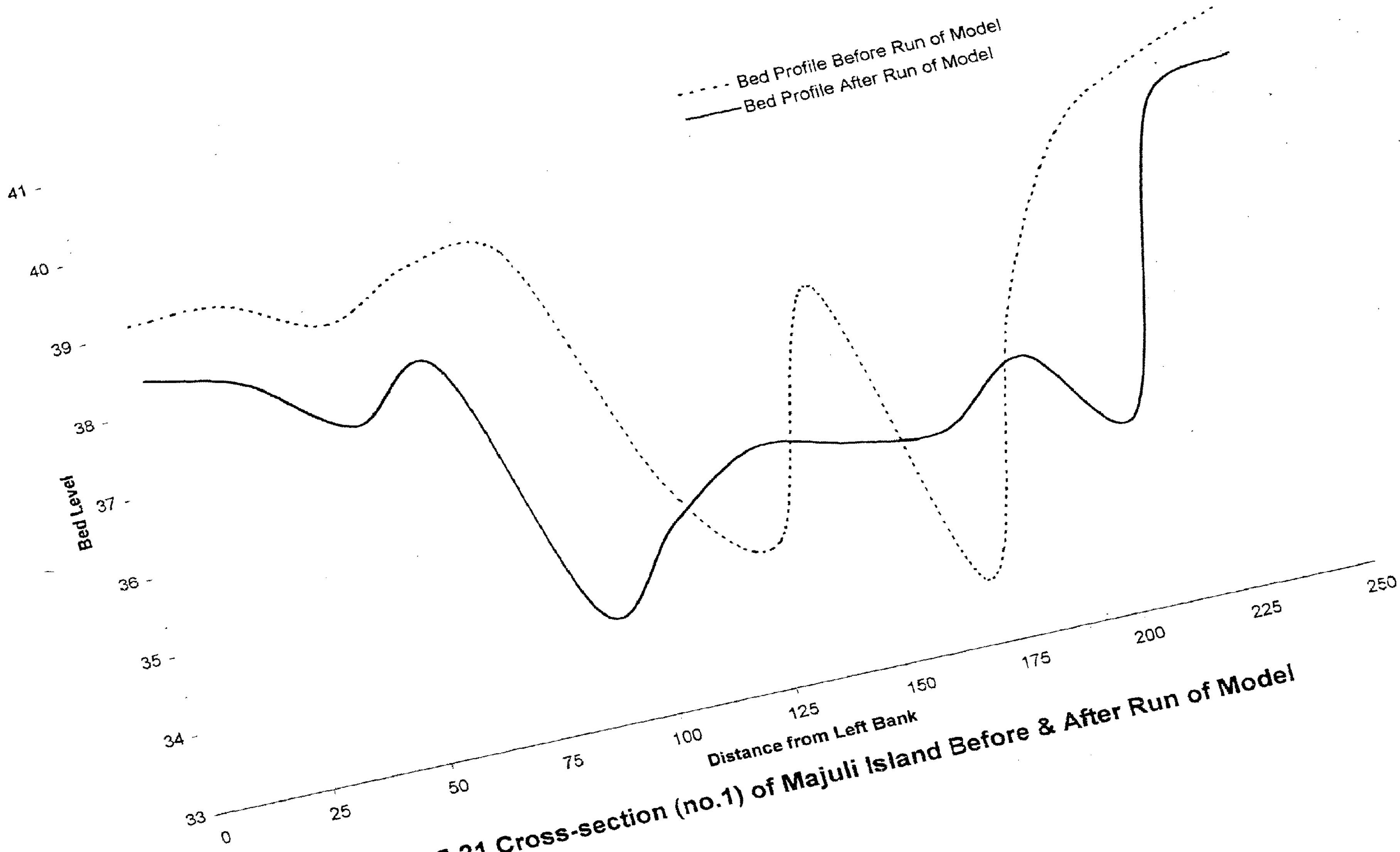

Fig. 5.21 Cross-section (no.1) of Majuli Island Before & After Run of Model

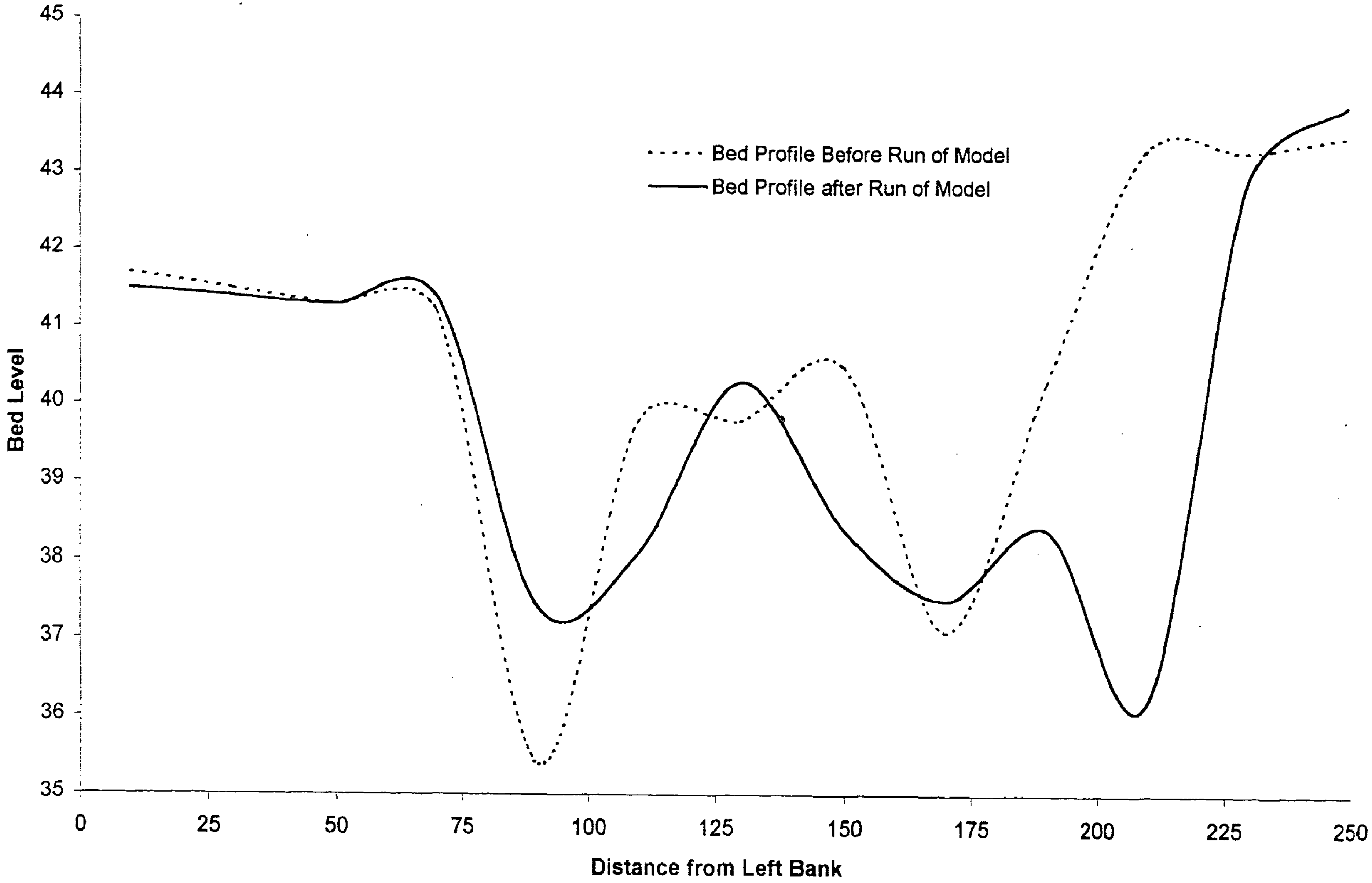

Fig. 5.22 Cross-section (no.5) of Majuli Island Before & After Run of Model

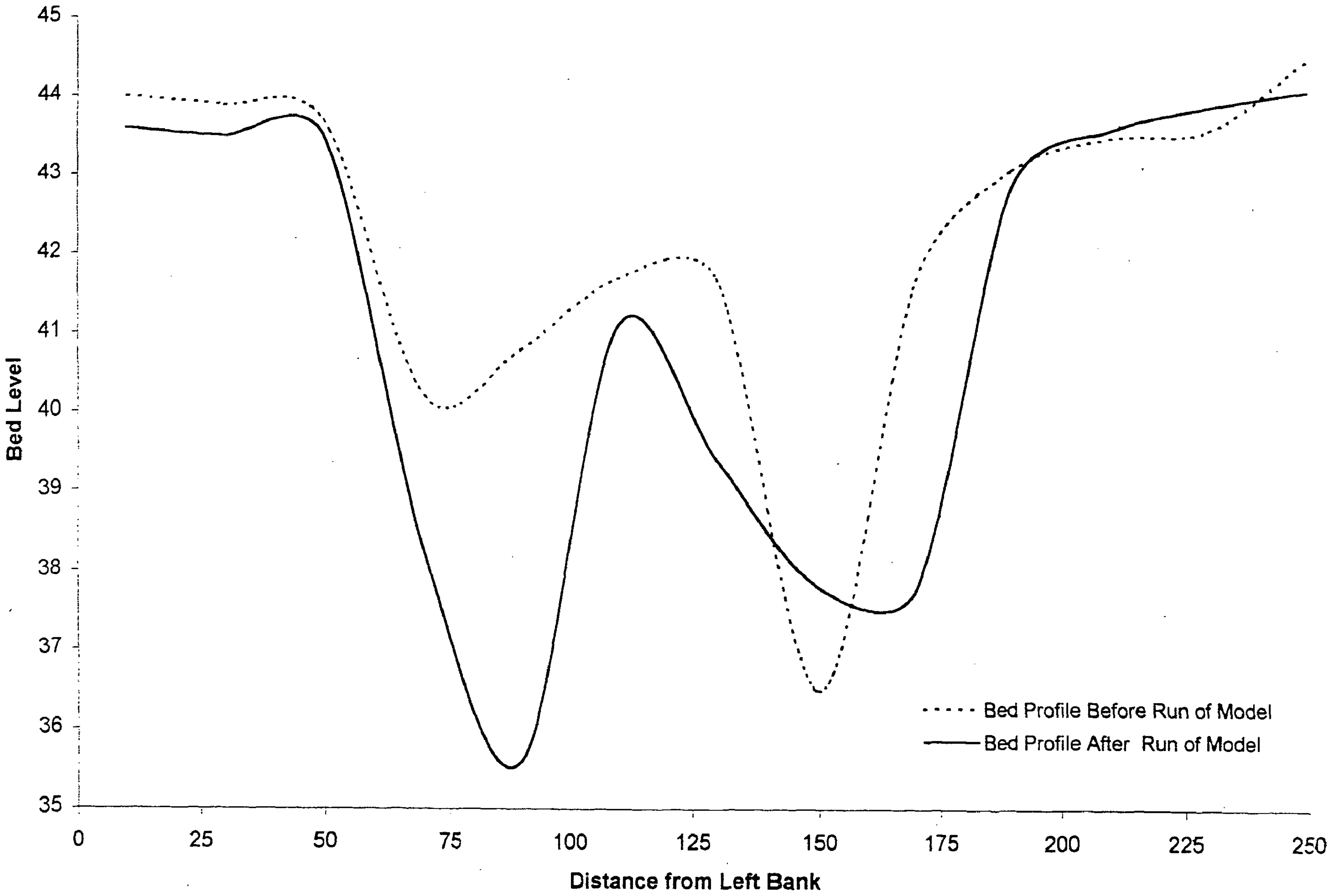

Fig. 5.23 Cross-section (no.10) of Majuli Island Before & After Run of Model

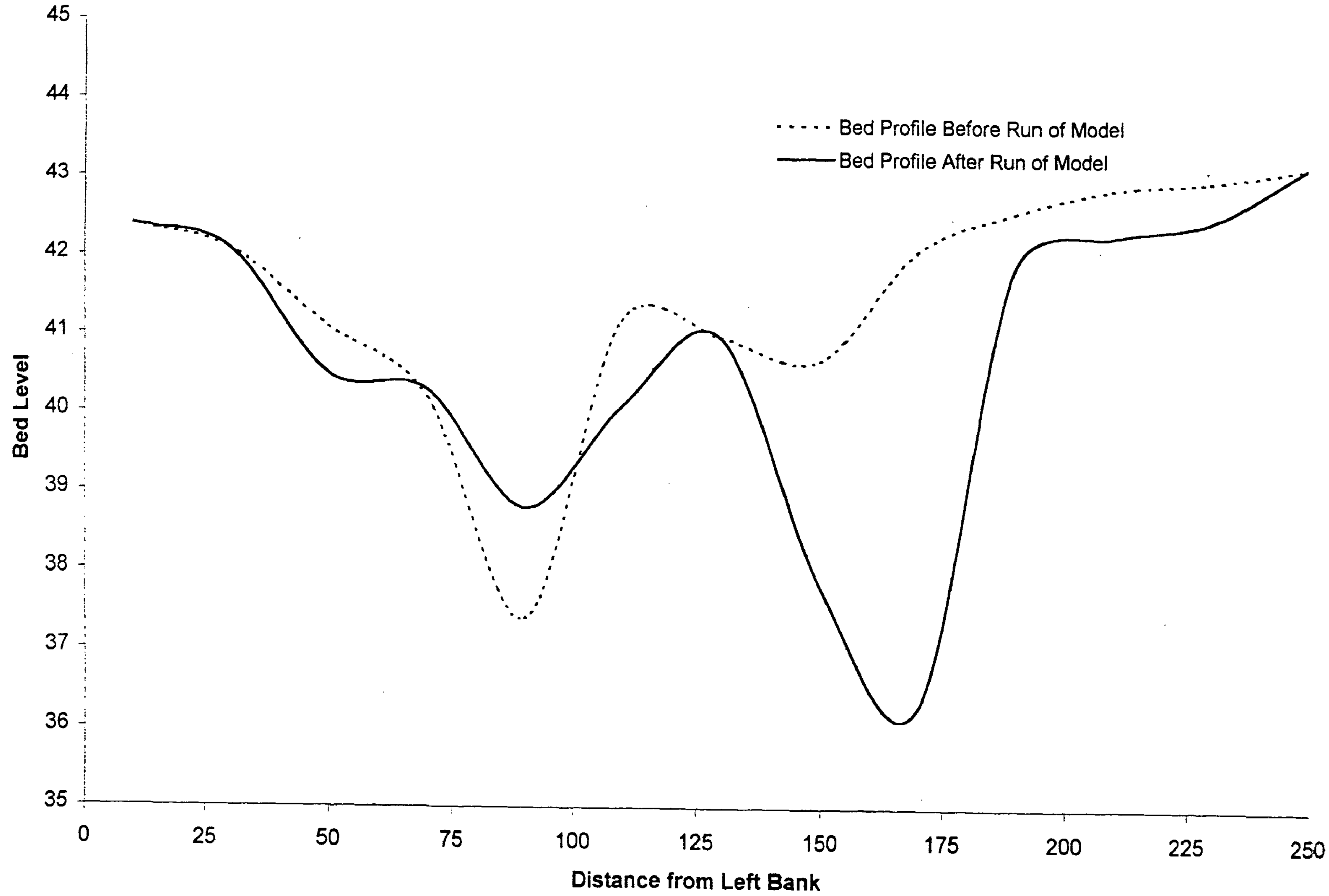

Fig. 5.24 Cross-section (no.13) of Majuli Island Before & After Run of Model

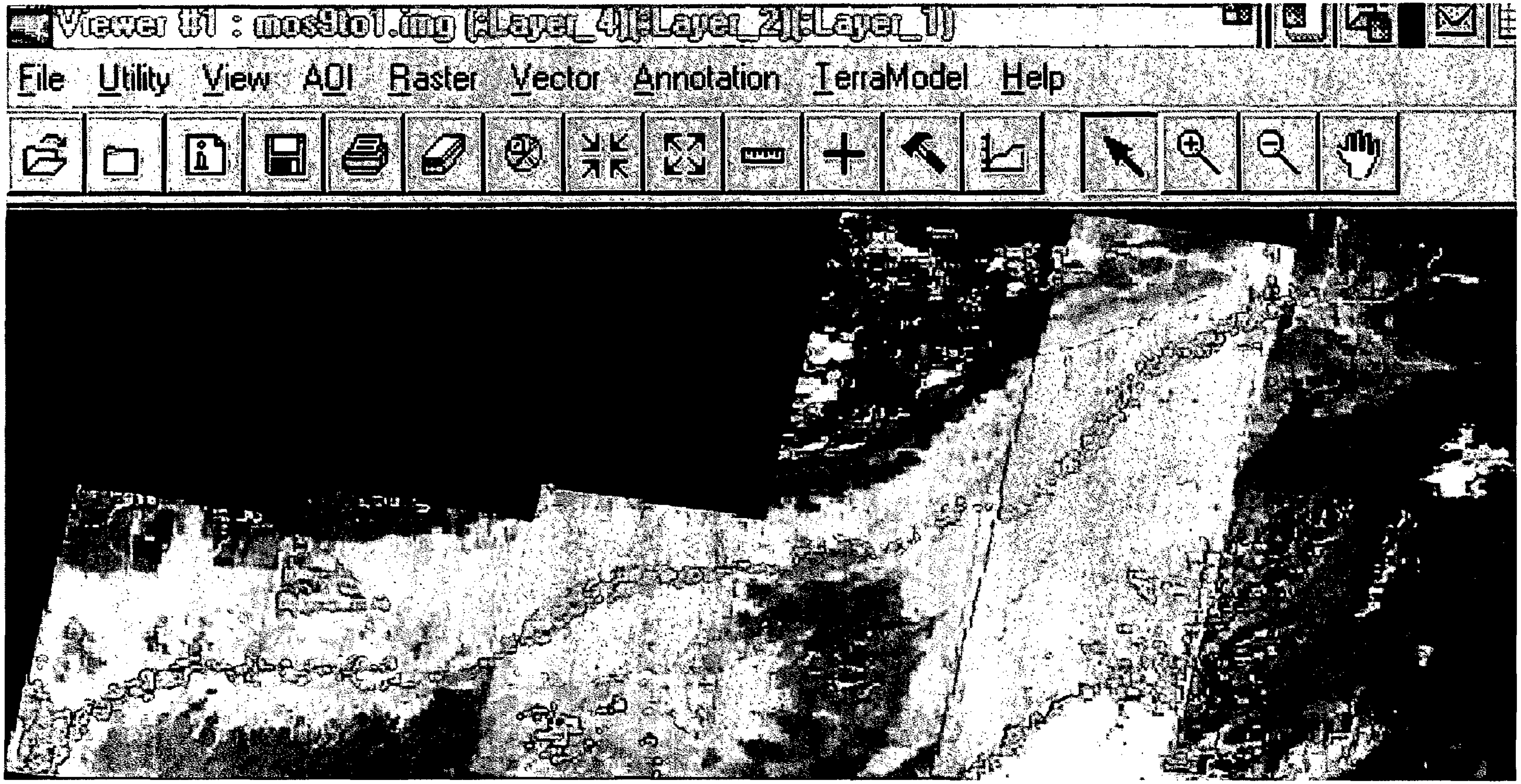

Fig.5.25 Mosaic of Satellite Imageries(9 Nos.) of 2000

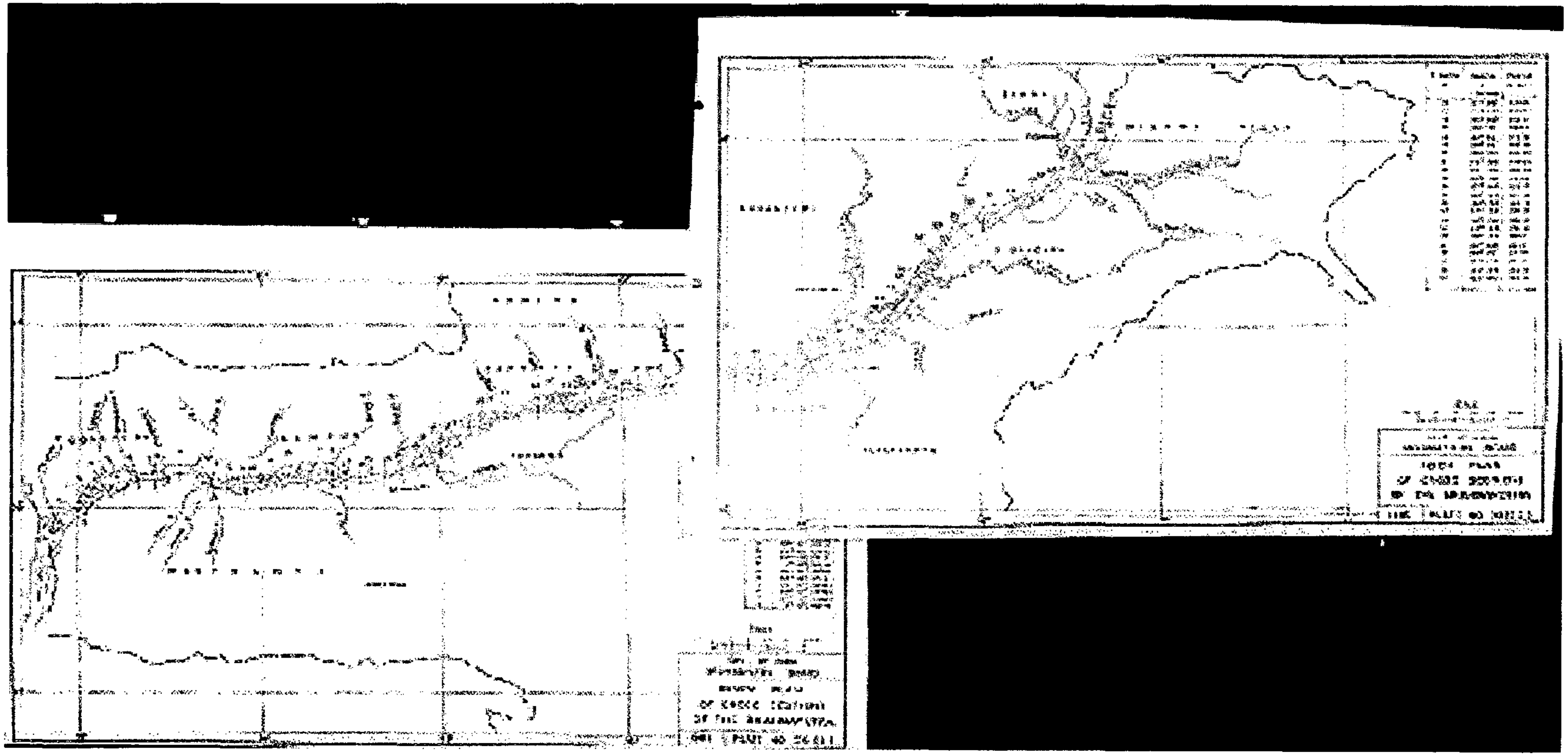

Fig.5.26 Mosaic of Hydrographic survey maps of River Brahmaputra

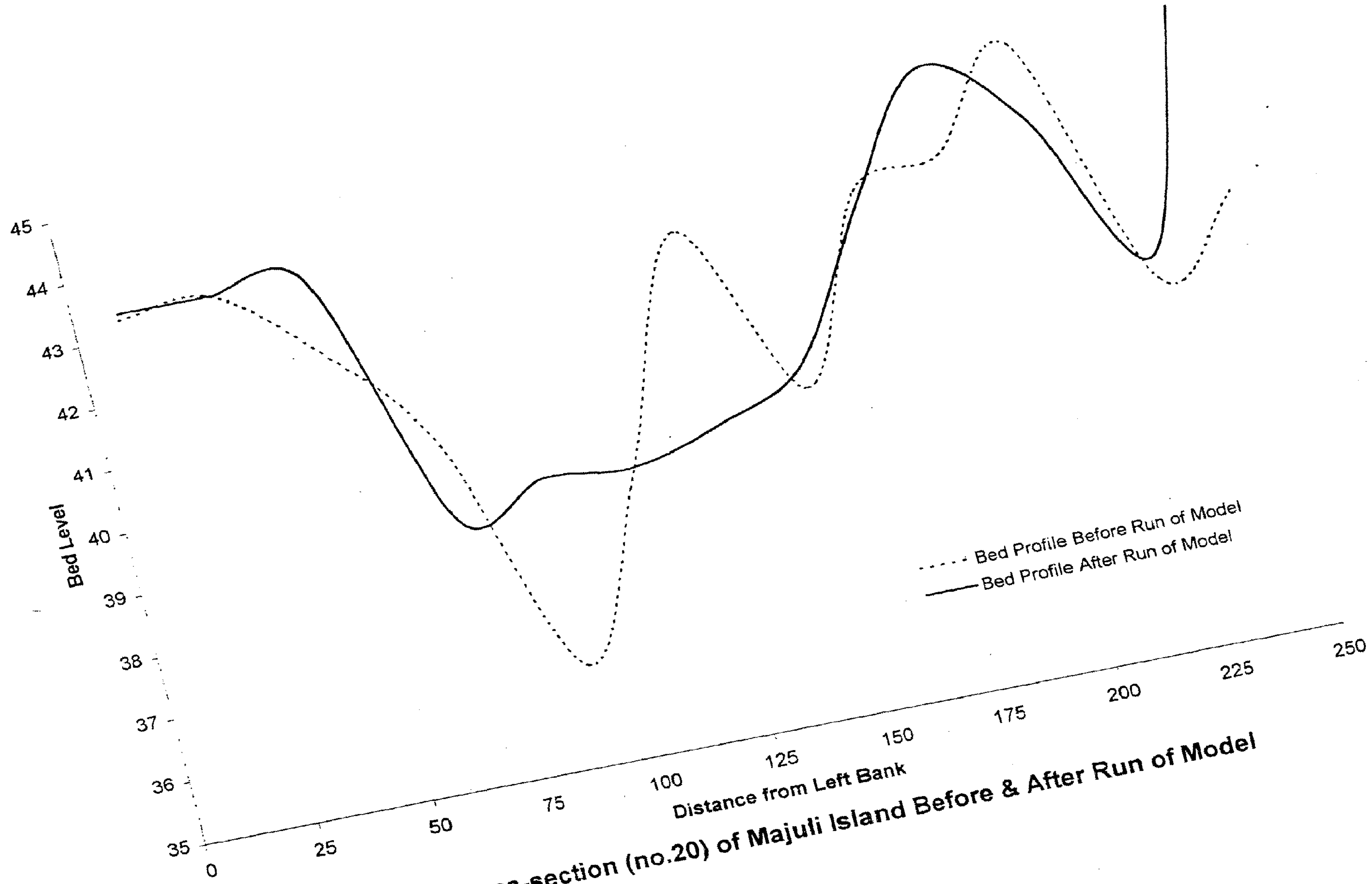

Fig. 5.27 Cross-section (no.20) of Majuli Island Before & After Run of Model

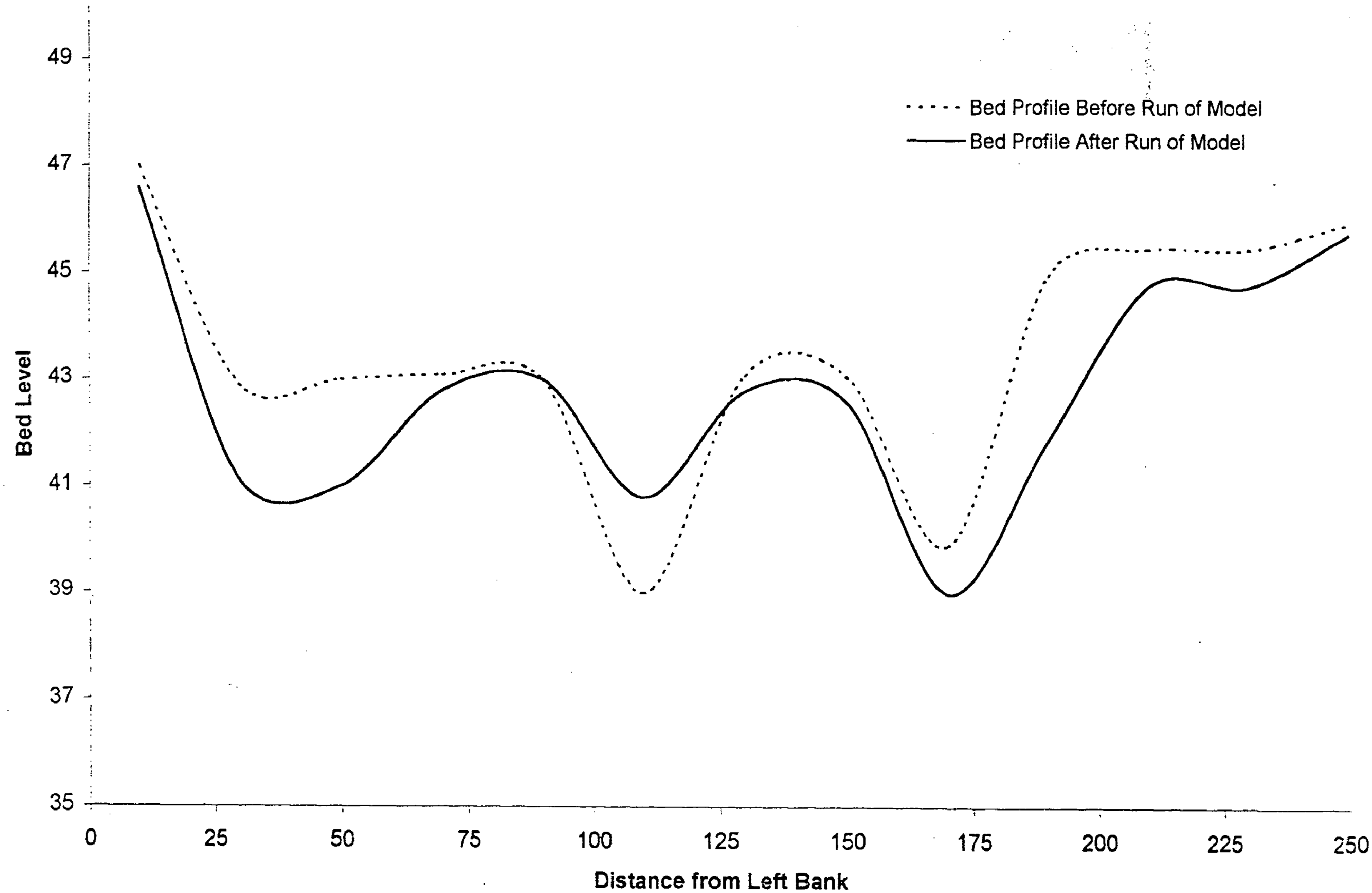

Fig. 5.28 Cross-section (no.33) of Majuli Island Before & After Run of Model

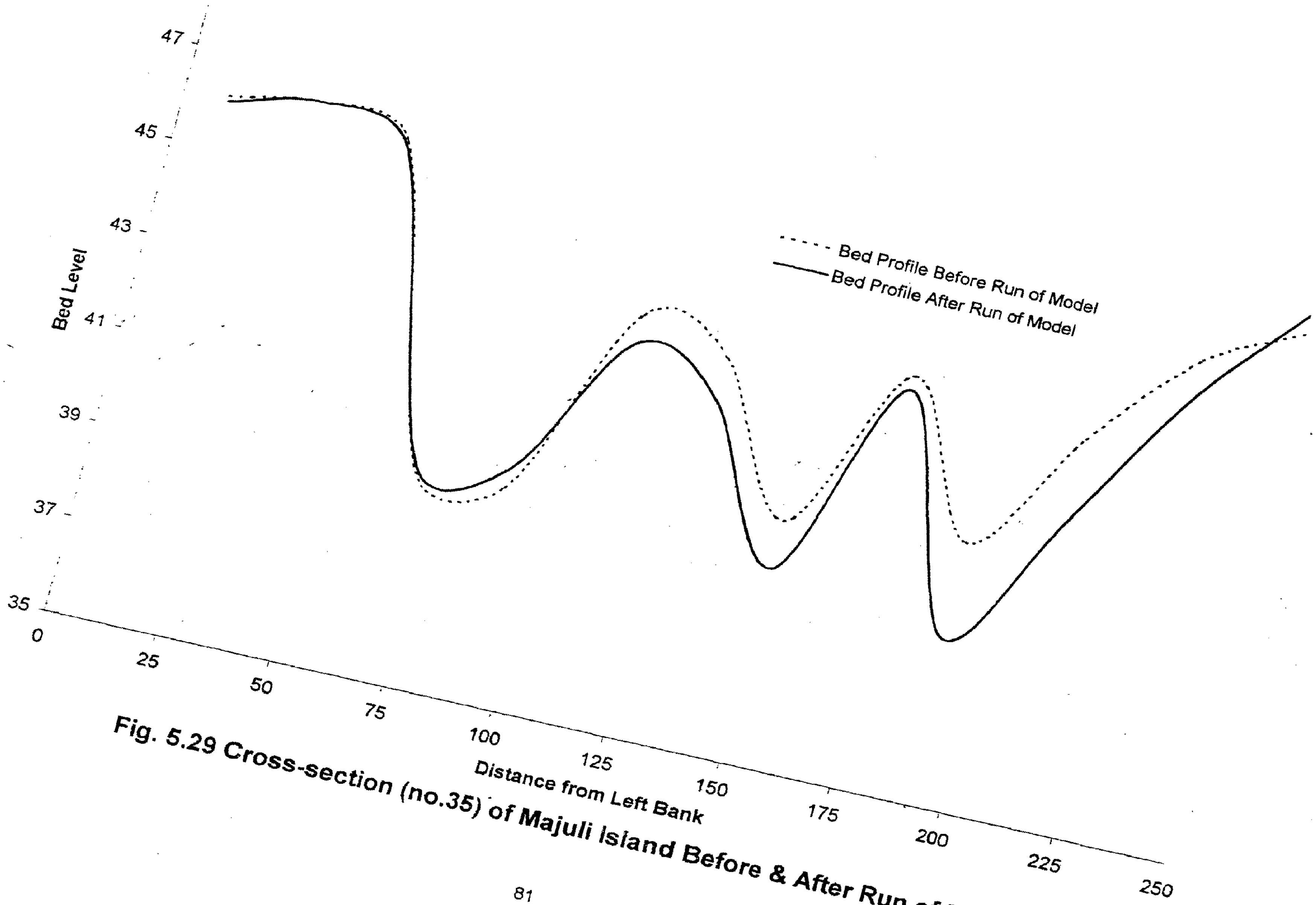

Fig. 5.29 Cross-section (no.35) of Majuli Island Before & After Run of Model

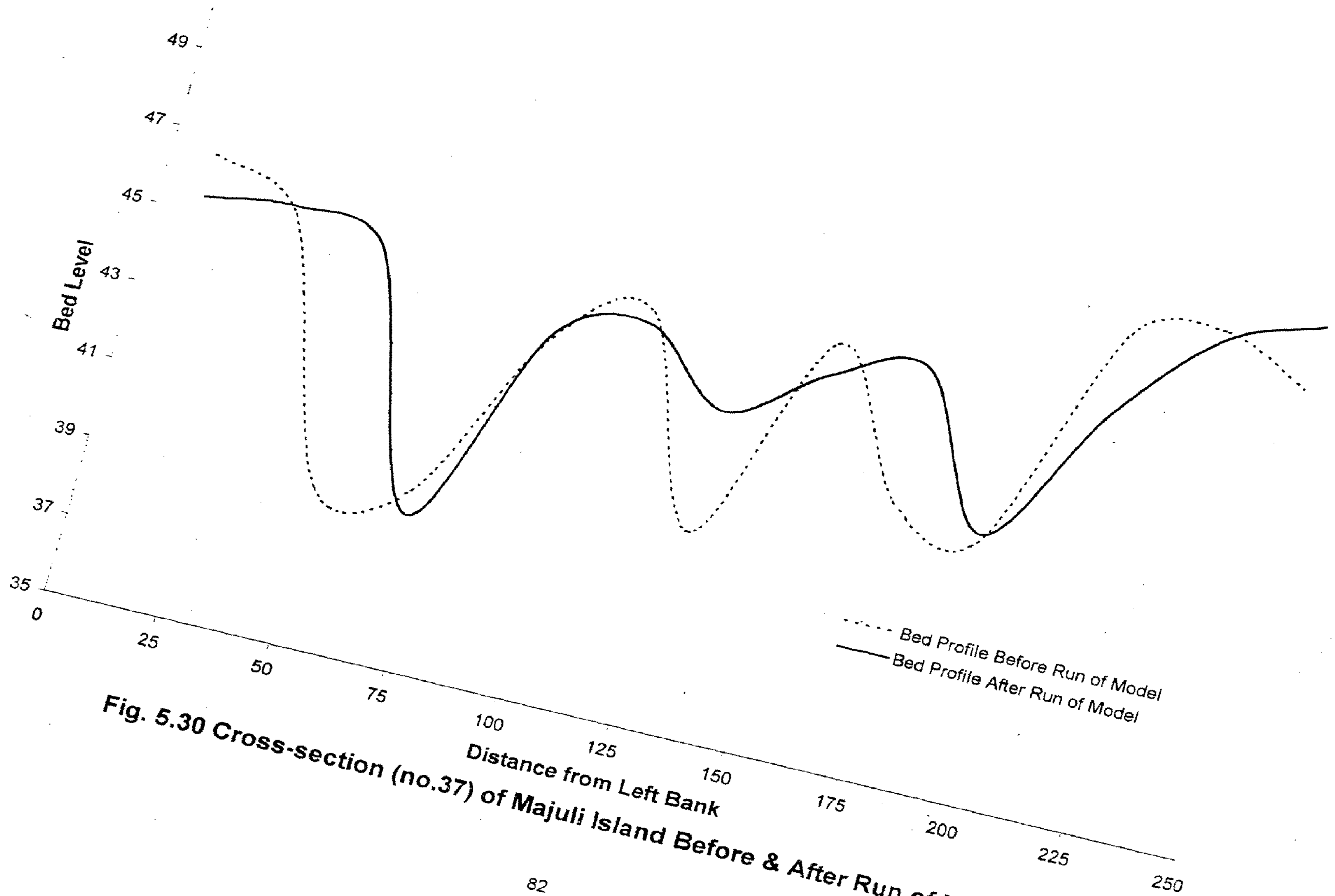

Fig. 5.30 Cross-section (no.37) of Majuli Island Before & After Run of Model

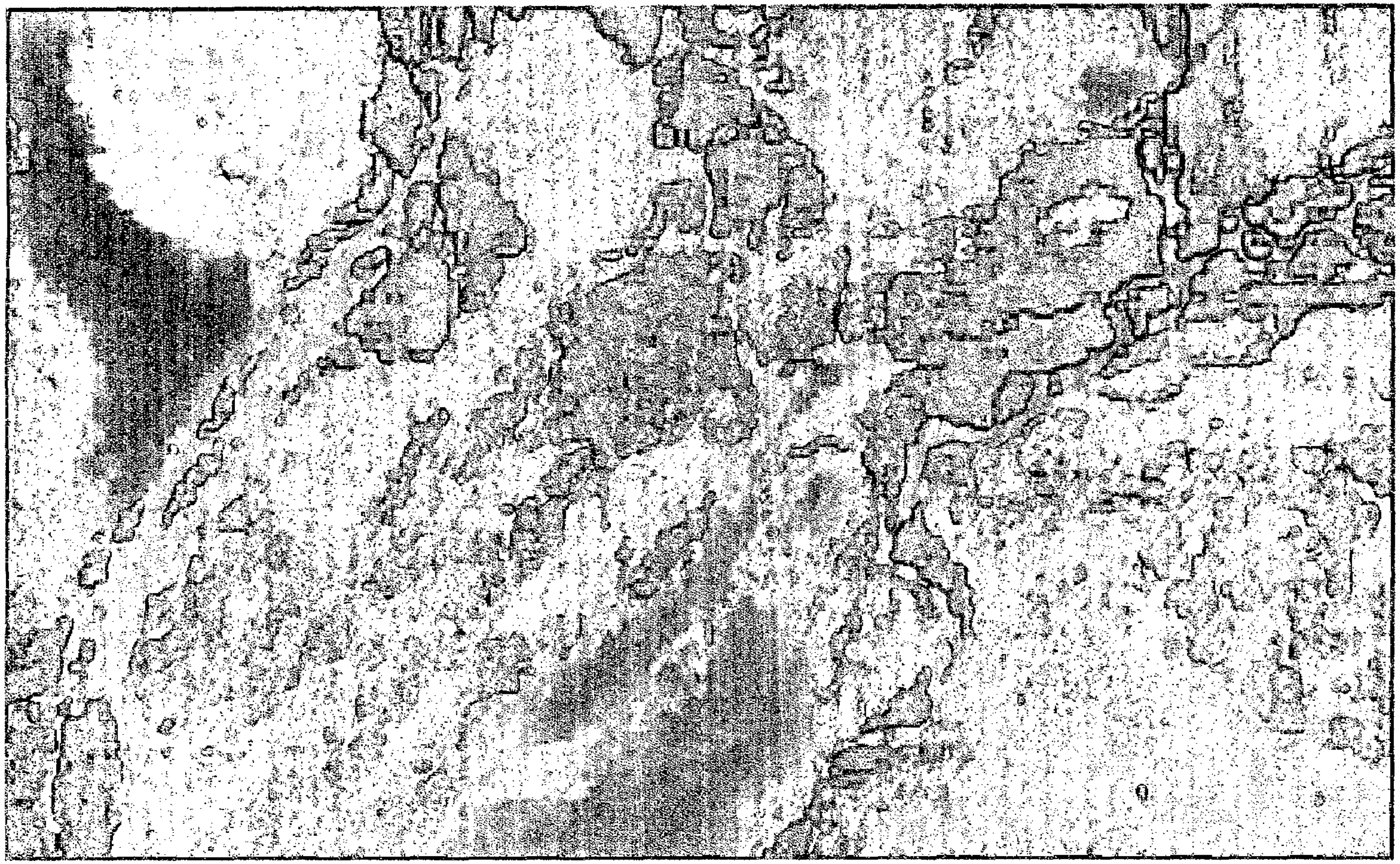

Fig-5.31 (Satellite Imagery of Confluence of Dihang Dibang and Luhit on 07-01-2001)

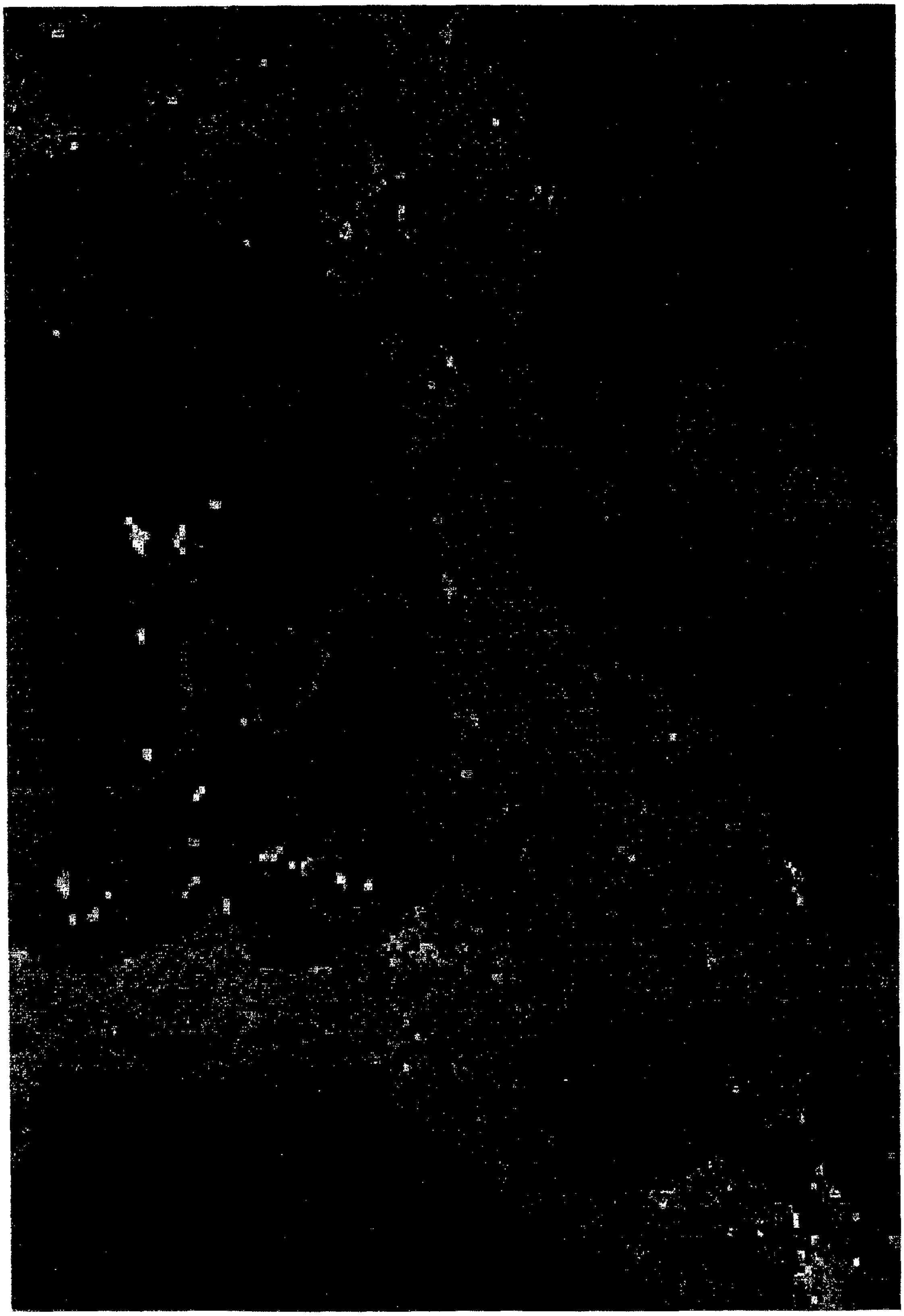

Fig No-5.32(Satellite Imagery of Confluence of Dihang Dibang and Luhit on 08-07-1994)

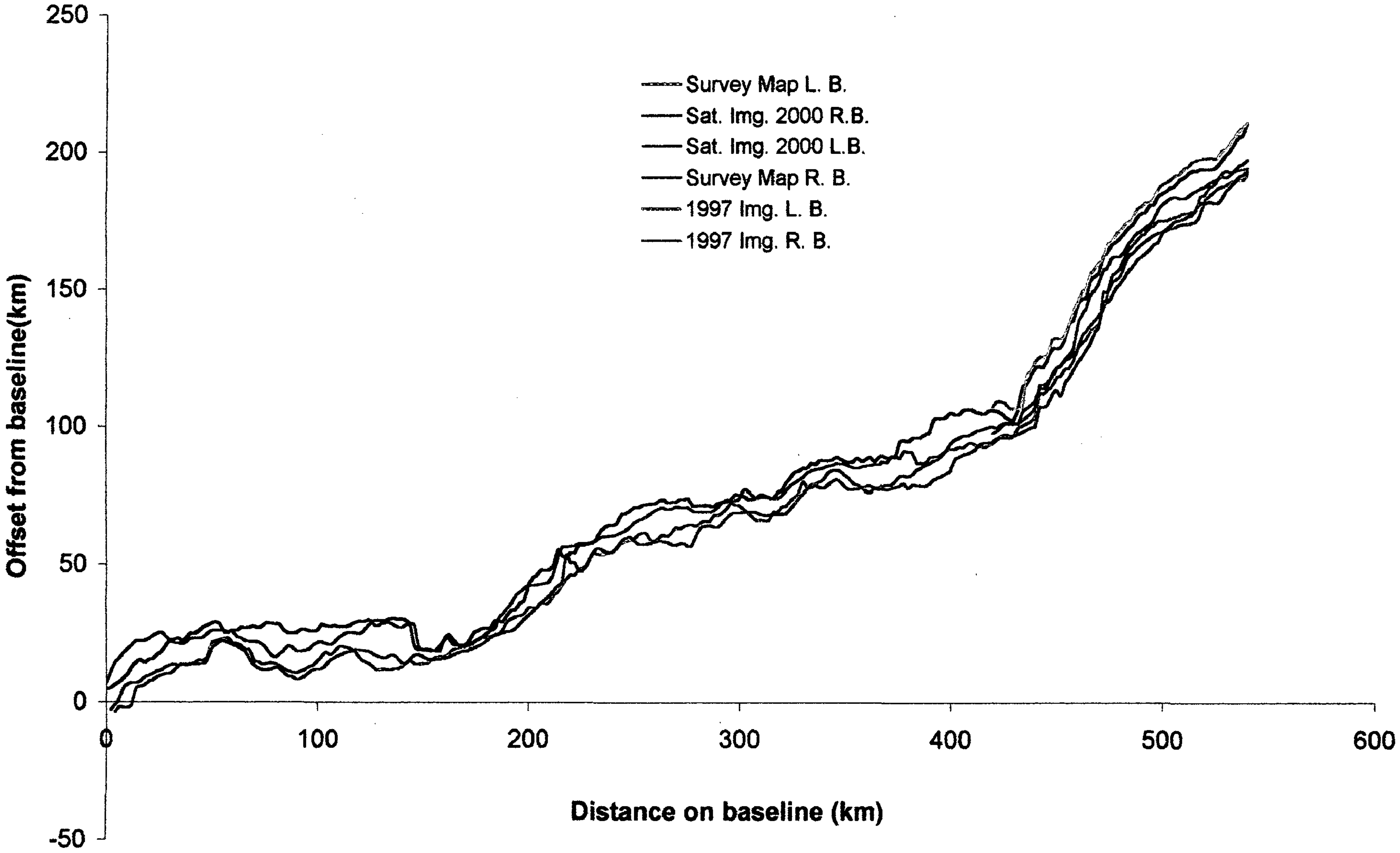

Fig. 5.31 Survey Map, 1997 (Img.) & 2000 (Img.) Bank Line Offsets Graph

DISCUSSION OF RESULTS AND CONCLUSION

6.1 GENERAL

For the reaches defined in Chapter-5, Table 5.4 shows shift of the bank lines between the years 1986-2000 & 1997-2000. Since the satellite imageries of 1997 were not available for the entire study area so in reach nos. I ,II, III & IV bank line shift has been shown only for 1986-2000.

Reach wise detailed study of plan form area is as follows

6.1.1 REACH -1 Dhubri-Goalpara-Barpeta:-

In this reach a mixed trend of scouring and deposition has taken place between 1986 to 2000. On the left bank side of river from 0(KM)(Dhubri) to 34 (KM) scouring has taken place. Then just for a small length (between 34 km to 37.5 km) there is nominal deposition and then from 37.5 to 40 km (on base line) neither silting nor scouring has taken place. From 40 KM to 55 KM the deposition is quite significant From 55 km to the end of this reach there is deposition as scouring has taken place on the opposite bank. In this reach on right bank there is deposition upto 30 km then for the next 26 km. scouring has taken place and just for a small length (56 km to 58 km) the bank line is almost intact. Beyond this there is a long zone of heavy scour from 58 km to 143 km.

6.1.2 REACH-II Barpeta-Guwahati-Mangaldai

This reach is marked with alternate scour and deposition on both banks. This reach is in famous for its high braiding index. On left bank from 100 km to 117 km there is deposition and on right bank in the same zone there is heavy scour. From km 117 to 141 there is scour on both banks but it is more pronounced on the right bank. Scour has still taken place between 141 to 154 on both banks but on right bank in this length, it is nominal and rather it is some what deposition between 143 to 148 km. Again on left bank scour has taken place between 148 km to 173.5 km. Between 173.5 to 176 km the zone has witnessed neither silting nor scouring. Between 176 to 184 km there is deposition and there is a brief length of (184 to 180 km) scour. This reach finishes with deposition on left bank. On right bank in 10 km length (148 to 158 km) there is nominal scour followed by partial scour and partial deposition for next 10 km (158 to 168 km). Between 168 to 174 section is almost balanced except for a traces of scour at a few points. After 174 km. there is scour upto 186 km and then deposition upto 200 km.

6.1.3 REACH-III Mangaldai-Silghat-Tezpur :-

This reach is marked with very frequent change of scour and deposition pattern on the left bank while on right bank in comparison to scour deposition is in insignificant. From 200 km to 206.5 km there is deposition and from 206.5 km to 223.5 km there is scour.From 223.5 to 227.5 km there is deposition. Form 227.5 to 229.5 km erosion has taken place then for about half km very nominal deposition is there. From 230 to 237.5 km there is scour. From 237.5 km to 241 km left bank has remained stable. From 241 to 244 km silt deposition has taken place. Again for 5 kms there is erosion on left bank followed by heavy deposition for next 11 km (from 249 to 260 km) Still heavy deposition is there upto 304 km.

On the right bank from 200 km to 212.5 km there is scour. From 212.5 to 226.75 km it is deposition followed by a point scour (between 0.25 km length)

From 228 km to 231 bank is balanced. Then for the next 60 km upto 292 there is lying a severely scoured zone. In the next three kms (292 to 295) deposition has taken place and next 5 km. of this zone has again witnessed scour.

6.1.4 REACH-IV Tezpur-Behali-Gohaigaon

In this reach on the left bank there is heavy deposition from kms 300 to 304 (on base line). From 304 km to 316 km. there is scour. Then there is a long reach of deposition upto 358 km. From 358 km to 363 km there is again erosion. From 363 km upto 413 km there is deposition and it appears that here bank line has shifted towards north.

On the right bank from 300 km to 307 km silting has taken place. From 307 to 372 km tremendous scouring has occurred. Then there is deposition in a path of 2 km. From 374 km to the 540 km. on base line there is throughout scour without any break.

6.1.5 REACHES-V Gohaigaon (Majuli)-Sibsagar-Dibrugarh

This reach is quite different from the last three reaches in river meandering sense and phenomena of scour and deposition. Here river is not straight but curved. In this reach it is also not flowing east to west rather northeast to southwest. The sinuosity in this reach is 1.37 while in the last three reaches it varies from 1.07 to 1.17 only. The world famous Majuli island lies in this reach.

On left bank after initial deposition of 13 km. (400 km to 413 km) there is scour for about 10 km (from 413 km to 423 km). From 423 to 500 km. there is only deposition and this in turn has created erosion on the entire reach length of the right bank.

6.1.6 REACH-VI Dibrugarh-Tinsukia-Pasighat.

Again this is a reach of high sinuosity (1.85). The bed slope is also steeper than the remaining four reaches. After mountainous phase of Arunachal Pradesh high hills., river comes here in alluvial plain starting from Pasighat. In this reach on both banks there is erosion except for 10 km on left bank (from 520 to 530 km) there is deposition. Actually river after traversing the high hills of Arunachal, it comes on a flatter ground and thus its width spreads both side which is the cause of scour.

6.2. RESULTS OF MODEL STUDIES OF MAJULI

The following observations were made with the model studies of Majuli island.

(1) At Discharge equivalent to 52000 cumec in prototype, the erosion on southern bank of Majuli between cross-sections no. 1 to 10 is quite serious.

(2) At this discharge, the bank is vunerable

(3) At higher discharges, the bank near cross-section no. –1 (i.e. d/s end of Majuli) starts coming under sub-mergence.

(4) At discharge equivalent to 65000 cumec, erosion starts on more length of the bank and also tension cracks appear at several points of the bank. ?

(5) In Majuli reach of Brahmaputra, the velocity measured from ADV is always higher on northern bank than to that of southern bank and it is true for almost all discharges.

6.3 OBSERVATION AT CONFLUENCE OF DIBANG & LUHIT

The rivers Dibang & Luhit join the Dihang to form Brahmaputra river.

After the confluence of Dibang & Luhit the channel has carved out a separate course during the past 5 or 6 years making wider a fishing channel already existing and drying up the original course. From satellite imageries the following measurements were taken.

(1) Year 1994 (on 08.07.1994)

- (i) Just d/s of confluence point of Dibang & Luhit top width water way = 2.7 km
- (ii) Top width of fishing channel = 0.661 km
- (iii) 30 km. d/s of confluence of Luhit & Dhbang width of water way. = 9 Km.

(2) Year 2001 (On 07.01.2001)

- (i) Just d/s of confluence point of Dibang & Luhit top width water way = 0.978 km
- (ii) Top width of fishing channel = 0.541 km
- (iii) 30 km. d/s of confluence of Luhit & Dibang width of water way. = 1.05 Km.
- (iv) Though for better comparison, the imageries should of the same date of different years, still it is obvious that course has changed quite considerably.

6.4 CONCLUSION

On the basis of the present study on Morphological changes of river Brahmaputra, certain concrete conclusions can be drawn such as

(i) During the last 50 years or so, the river morphology has been subjected to a tremendous change.

(ii) During the major tract of its reaches under study erosion and scour is predominant over deposition. Generally scour is not on both sides at the same reach of the river. But it is not true for entire length. In some cases scour has taken place both sides simultaneously.

(iii) Contrary to the prevailing notion, deposition is also not less significant. Although scour and deposition both are opposite to each other and require opposite conditions for their taking place still both are taking place in the river. Its causes should be studied in detail. It appears that due to large scale deforestation and faulty management of the water shed area in the upper reaches, huge amount of silt is coming every year in this river and in flatter reaches it is being deposited and this forms the main cause of deposition. There is one report from local authorities that volume of debris is increasing every year in Brahmaputra which confirms rapid deforestation of the catchment area.

(iv) Still scour of the magnitude of several kilometers is the matter of prime concern and how to control this should be the subject of future study. Plan form changes can still be further studied to a still greater accuracy with the advent of more and more high resolution satellite imageries.

(v) On the confluence of Dihang Dibang & Luhit, the change in flow pattern is so paramount that it forms a case of river avulsion. More than 50% discharge appears to be diverted towards Dibru river.. It all has happened during the last 7 years i.e. between 1994 to 2001.

(vi) The scour on the southern bank of Majuli is no doubt extremely serious. Both short term and long term measures are essential to save the very existence of this island.

(vii) Model studies can be carried out in a betterway by making the model on ground.More data like stage-discharge curve etc. are required for precise study.

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APPENDIX –A

HYDRAULIC SCALE MODELLING OF MAJULI

Apart from study of plan form changes of river Brahmaputra in Assam between 1986 to 2000 one of the prime objective of this dissertation was to study the erosion mechanism taking place on the Majuli Island. So this phenomenon has also been studied by making a hydraulic model of this reach in river Engineering lab and allowing model discharge ranging from 0.516 LPS to 3.69 LPS which are equivalent to normal discharge of 10,200 cumec to Maximum flood discharge of 73000 cumec. The bed level was observed before and after running of model at selected points of each cross section adopted. The readings were tabulated.

How the model parameter has been fixed is being shown below:

Maximum flood discharge (Q) = 73000 cumec. (Field Data)

Mean Cross sectional area (A) = 30,000 m^2 (Calculated from Cross-section)

Velocity (prototype) $V_p = \frac{Q}{A} = \frac{73,000}{30,000} = 2.43$ mt/s

Width (prototype) B_p = 12 km = 12000 mt (field data)

Width Ratio $B_r = \frac{B_p}{B_m} = \left(\frac{12000}{2.6}\right) = 4615.38$

Say 4700

Available width in flume = 2.6 mt.

$$B_m = \left(\frac{12000}{4700}\right) = 2.55 \text{ mt.}$$

A = W x D

$$D_p = \frac{A}{W} = \frac{30000}{10000} = 3 \text{ mt.}$$

Where W = width of water way = 10 km

suppose

D_p = 10 mt., as (H.F.L. –B.L.) = 86.94-74.40 = 12.54 mt

Let us have our scale as follows.

Horizontal 1:5000

Vertical 1:100

Now

$$D_r = \frac{D_p}{D_m}$$

or $$D_m = \frac{D_p}{D_r} = \frac{10mt}{100} = \frac{10x100}{100} = 10\text{ cm}$$

$V_p = 2.43$ mt/s

$$V_r = \frac{V_p}{V_m} = D_r^{1/2}$$

or $$\frac{V_p}{V_m} = D_r^{1/2}$$

or $$\frac{2.43}{V_m} = (100)^{1/2}$$

$$V_m = \frac{2.43}{(100)^{1/2}} \text{ mt/sec}$$

$$= 24.3 \text{ cm/s}$$

Suppose n for Brahmaputra river at

Majuli = 0.035

Now $$n_r = \frac{n_p}{n_m} = \frac{(D_r)^{2/3}}{(L_r)^{1/2}} = \frac{100^{2/3}}{(5000)^{1/2}} = \frac{21.57}{70.71} = 0.304$$

$$n_r = \frac{n_p}{n_m}$$

so $$n_m = \frac{n_p}{n_r} = \frac{0.035}{0.304} = 0.1148$$

but n value for model should not be more than 0.065

So we change the scale as follows.

horizontal 1:5000

Vertical 1:200

Then $$D_m = \frac{D_p}{D_r} = \frac{10mt}{200} = 5\text{ cm}$$

Again $V_p = 2.43$ mt/s

$$V_r = \frac{V_p}{V_m} = D_r^{1/2}$$

or $\frac{2.43}{V_m} = (200)^{1/2}$

or $V_m = \frac{2.43}{(200)^{1/2}} = 01718\, mt/s$

$= 17.18$ cm/s

Now

$$N_r = \frac{n_p}{n_m} = \frac{(D_r)^{2/3}}{(L_r)^{1/2}} = \frac{(200)^{2/3}}{(5000)^{1/2}} = 0.483$$

So, $\frac{n_p}{n_m} = 0.483$

or $n_m = \frac{n_p}{n_r} = \frac{0.035}{0.483} = 0.0723$

which is still greater than 0.065

so we assume our scale as

Horizontal	1: 5000
Vertical	1:250

then $V_m = \frac{2.43}{(250)^{1/2}} = 15.36$ cm/s

and $\frac{n_p}{n_m} = \frac{(D_r)^{2/3}}{(L_r)^{1/2}} = \frac{(250)^{2/3}}{(5000)^{1/2}} = 0.561$

or $n_m = \frac{n_p}{0.561} = \frac{0.035}{0.561} = 0.0623$

which is less than 0.065

now

$$Q_r = \frac{Q_p}{Q_m} = L_r \; D_r^{3/2}$$

$$\frac{Q_p}{Q_m} = L_r D_r^{3/2} = 5000 \times (250)^{3/2}$$

$$Qm_1 = \frac{10,200}{5000 \times (250)^{3/2}} = 0.516 \text{ l/s}$$

$$Qm_2 = \frac{26000}{5000 \times (250)^{3/2}} = 1.315 \text{ l/s}$$

$$Qm_3 = \frac{52000}{5000 \times (250)^{3/2}} = 2.63 \text{ l/s}$$

$$Qm_4 = \frac{65000}{5000 \times (250)^{3/2}} = 3.28 \text{ l/s}$$

$$Qm_5 = \frac{73000}{5000 \times (250)^{3/2}} = 3.69 \text{ l/s}$$

Longitudinal slope

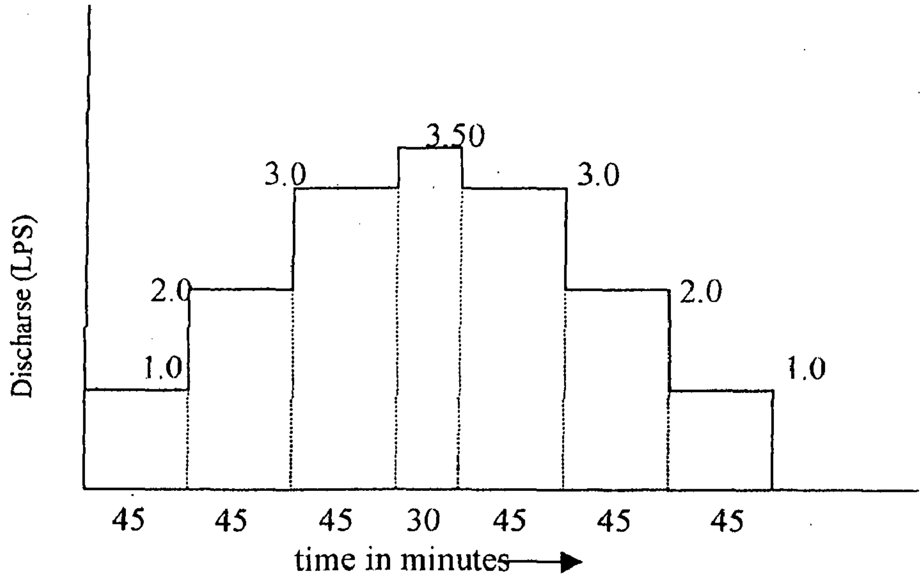
$$\frac{s_p}{s_m} = s_r = \frac{1}{V_E} = \frac{1}{5000/250} = \frac{1}{20}$$

Since Bed slope of this reach is 0.00027 (from field data)

or $$S_m = \frac{0.00027}{S_r} = \frac{0.00027}{1/20}$$

$$= 0.00027 \times 20 = 0.0054$$

Running of Model



Time Scale

$$t_r = \frac{t_p}{t_m} = \frac{L_r}{(D_r)^{1/2}} = \frac{5000}{(250)^{1/2}} = 316.22$$

taking 2 months flood period in field (prototype)

$$t_r = \frac{t_p}{t_m} = 316$$

or $\frac{2.0 \times 30 \times 24}{t_m} = 316$

or $tm = \frac{2.0 \times 30 \times 24}{316} = 4.55 \text{ hrs}$

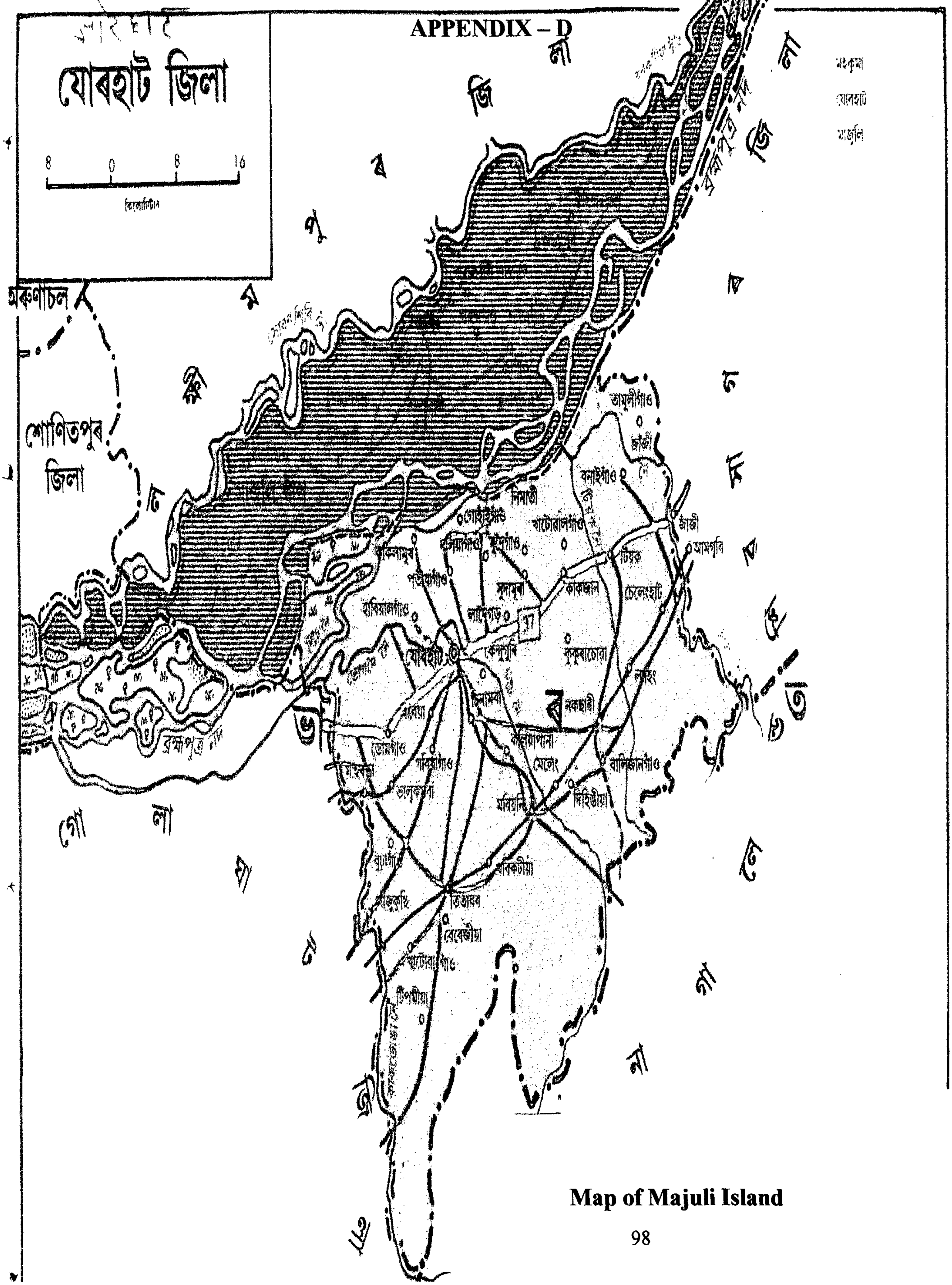
Let us run the model for 5 hours

APPENDIX-B

The Latitude/Longitude of some places useful in the study of River Morphology of Brahmaputra as per the Knowledge Series The Modern School Atlas is as below

Dhubri	90^0 0'E 26^0 0' N
Goalpara	88^0 36'E 36^0 12' N
Barpeta	91^0 06'E 26^0 18' N
Guwahati	91^0 42'E 26^0 12' N
Mangaldai	92^0 0'E 26^0 24' N
Tezpur	92^0 48'E 26^0 36' N
Silghat	92^0 09'E 26^0 05' N
Golaghat (Near Gohagaon)	93^0 54'E 26^0 30' N
Sibsagar	94^0 36'E 27^0 0' N
Dibrugarh	94^0 54'E 27^0 30' N
Tinsukia	95^0 84'E 27^0 05' N
Pasighat	95^0 18'E 28^0 06' N

APPENDIX – D



Map of Majuli Island

APPENDIX-B

The Latitude/Longitude of some places useful in the study of River Morphology of Brahmaputra as per the Knowledge Series The Modern School Atlas is as below

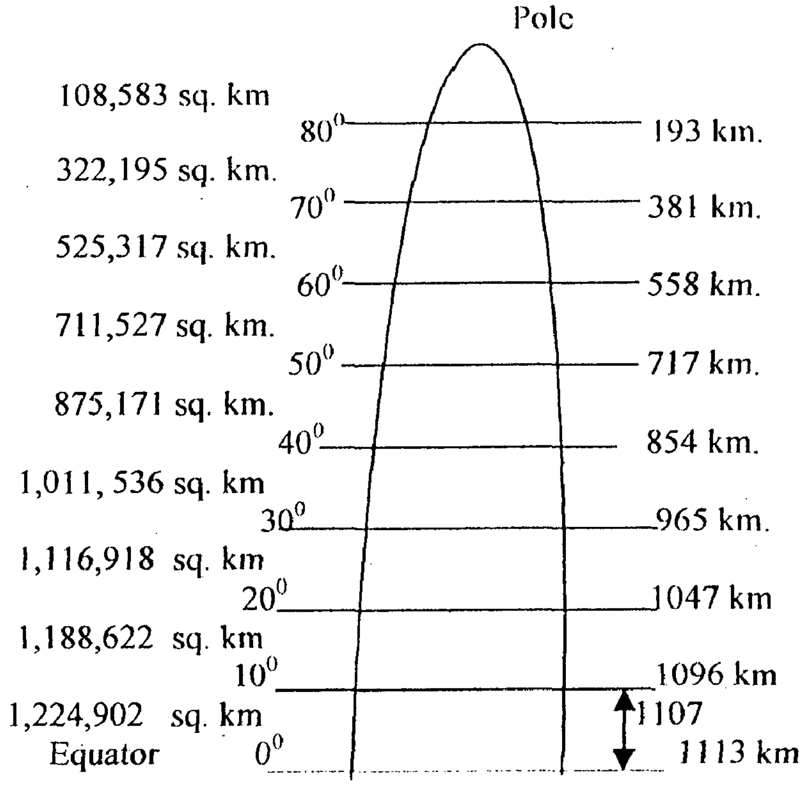
Dhubri	90^0 0'E 26^0 0' N
Goalpara	88^0 36'E 36^0 12' N
Barpeta	91^0 06'E 26^0 18' N
Guwahati	91^0 42'E 26^0 12' N
Mangaldai	92^0 0'E 26^0 24' N
Tezpur	92^0 48'E 26^0 36' N
Silghat	92^0 09'E 26^0 05' N
Golaghat (Near Gohagaon)	93^0 54'E 26^0 30' N
Sibsagar	94^0 36'E 27^0 0' N
Dibrugarh	94^0 54'E 27^0 30' N
Tinsukia	95^0 84'E 27^0 05' N
Pasighat	95^0 18'E 28^0 06' N

APPENDIX-C

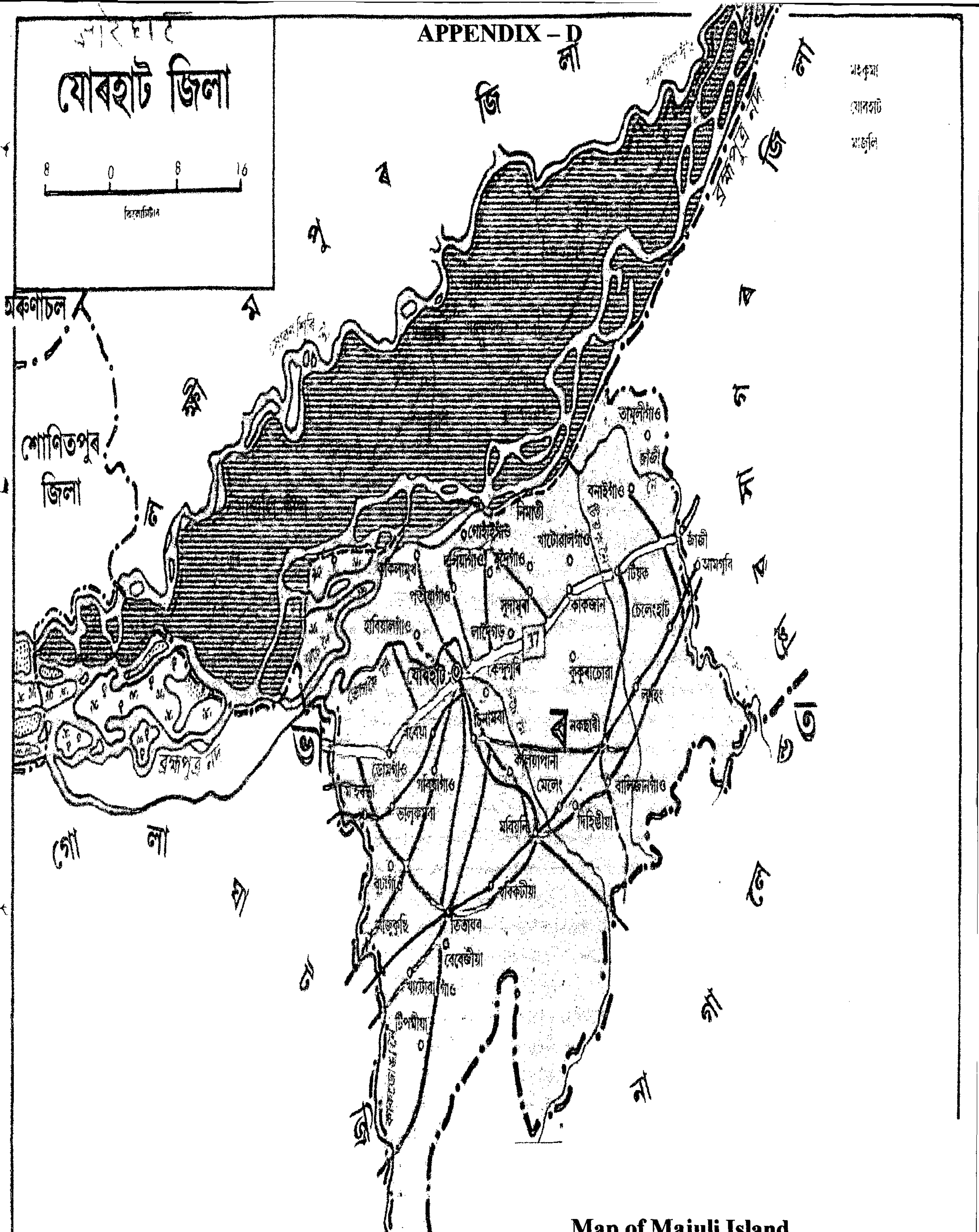
Distance and Area Variation on Different Parts of Earth

The area between 10 degrees of latitude and 10 degrees of longitude

The length of 10 degrees of longitude measured along line of latitude

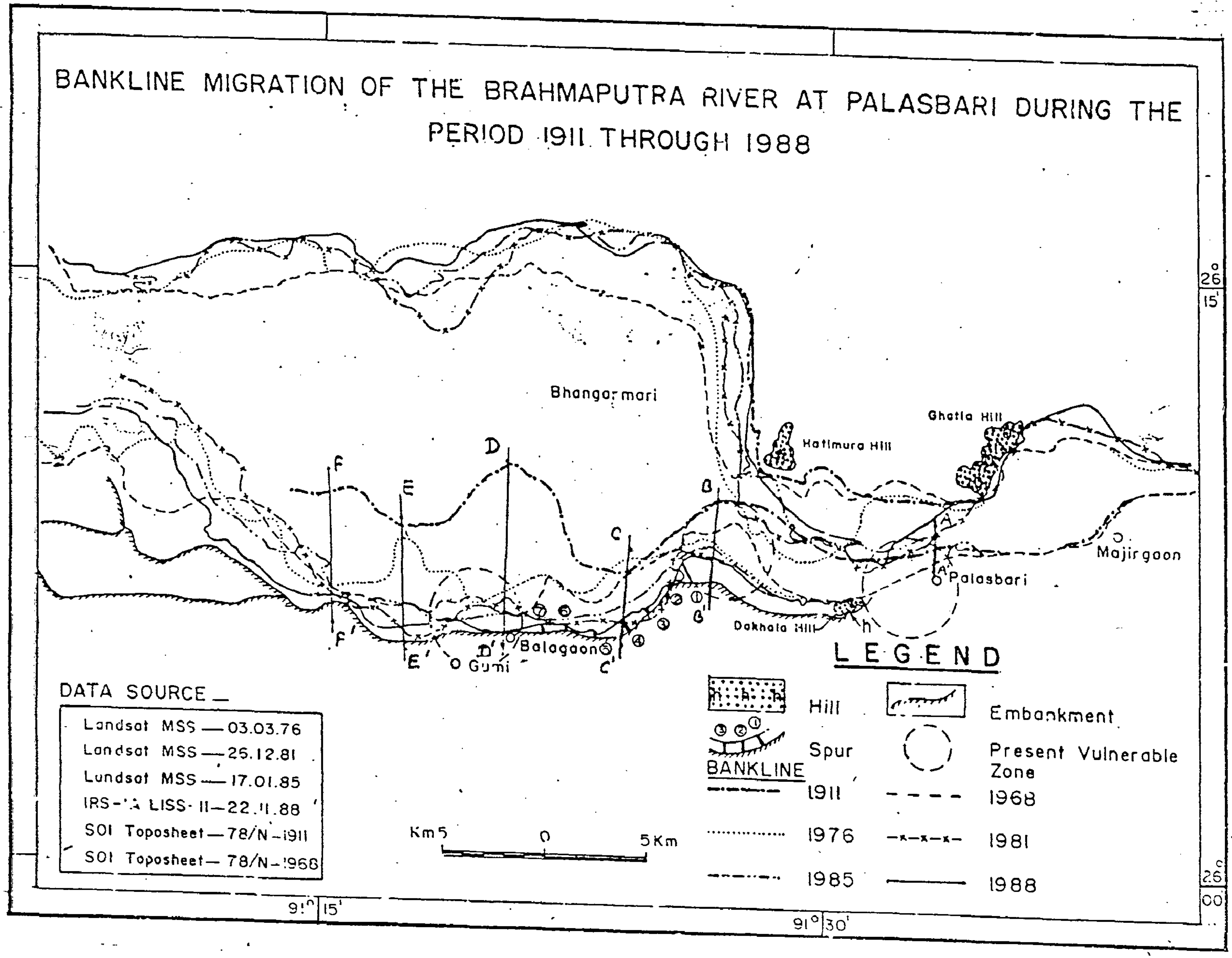


APPENDIX – D



Map of Majuli Island

APPENDIX –E


BANKLINE MIGRATION OF THE BRAHMAPUTRA RIVER AT PALASBARI DURING THE PERIOD 1911 THROUGH 1988
Bhangarmari
Hatimura Hill
Ghatla Hill
Majirgaon
Palasbari
Dakhala Hill
Balagaon
Gumi
DATA SOURCE _
Landsat MSS — 03.03.76
Landsat MSS — 25.12.81
Lundsat MSS — 17.01.85
SOI Toposheet — 78/N - 1911
SOI Toposheet — 78/N - 1968
Km 5
0
5 Km
LEGEND
Hill
Spur
BANKLINE
1911
1976
1985
Embankment
Present Vulnerable Zone
1968
1981
1988
91° 15'
91° 30'
26° 15'
25° 00

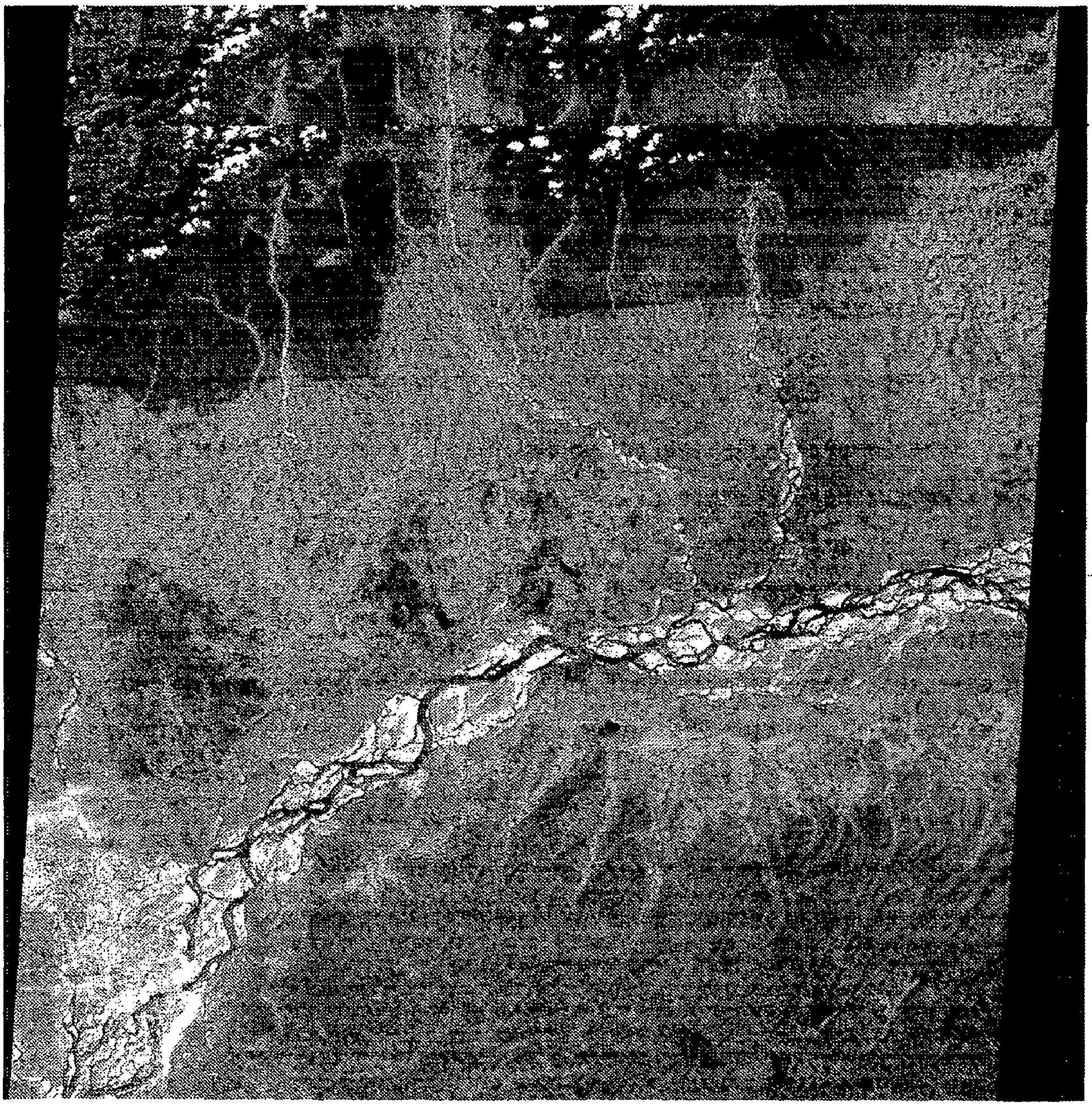


PLATE No. 1: IRS-IC, LISS-III BAND-4, ROW- 53, PATH-109, IMAGERY SHOWING PLAN- FORM OF RIVER BRAHMAPUTRA, DATE OF PASS 13-02-2000.

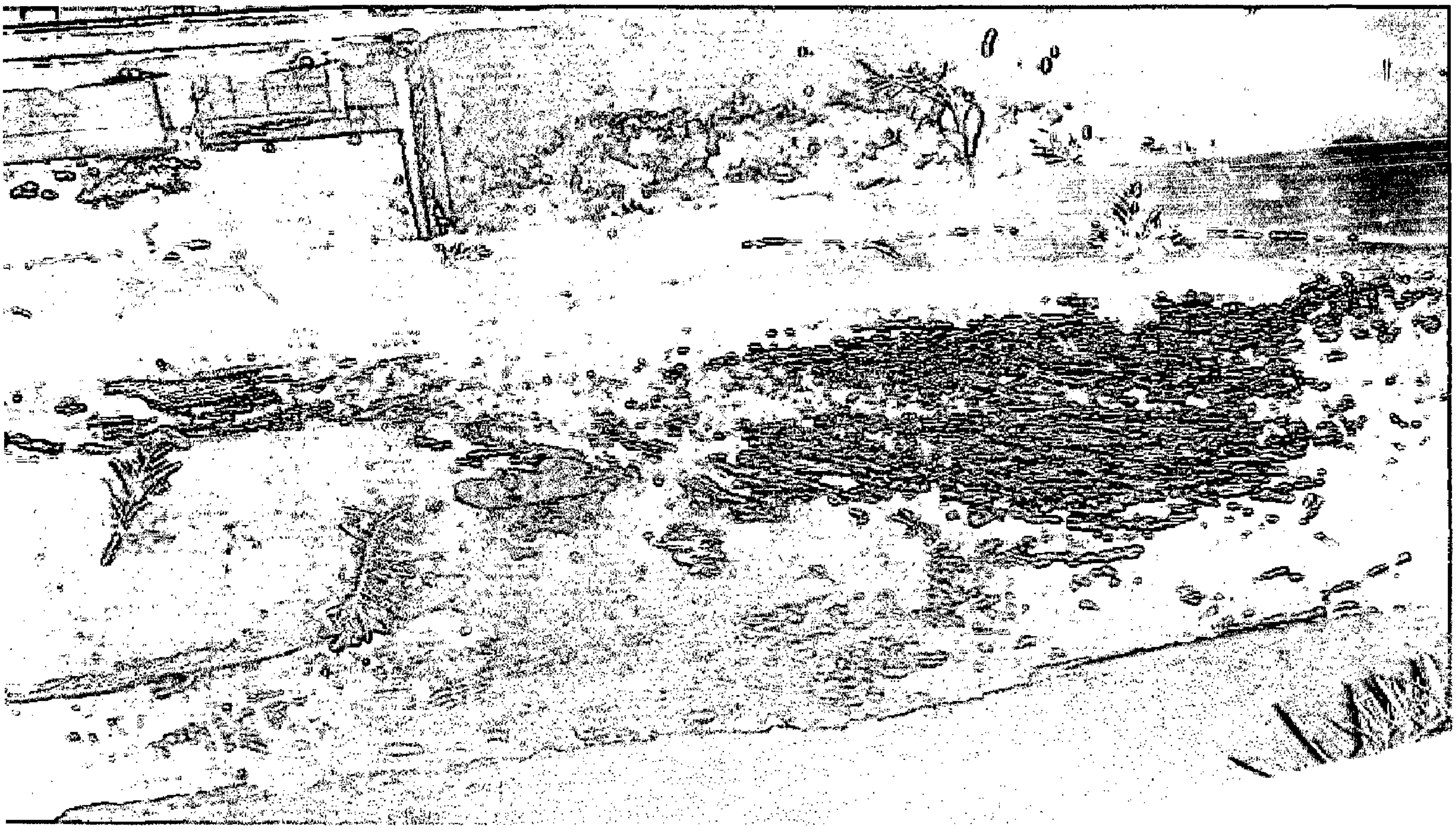


Plate No. 2 Model of Brahmaputra Majuli Reach