MORPHOLOGICAL ANALYSIS OF BRAHMAPUTRA RIVER USING GIS AND SATELLITE DATA

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

WATER RESOURCES DEVELOPMENT

By

LAKSHMAN SINGH

WATER RESOURCES DEVELOPMENT TRAINING CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE -247 667 (INDIA)

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CANDIDATE' S DECLARATION

I do hereby certify that the work which is being presented in the dissertation entitled **"MORPHOLOGICAL ANALYSIS OF BRAHMAPUTRA RIVER USING GIS AND SATELLITE DATA"** in partial fulfillment of the requirements for the award of Degree of **Master of Technology** in ***Water Resources Development (Civil)*** submitted in the **Water Resource Development Training Center, Indian Institute of Technology, Roorkee,** is an authentic record of my own work carried out since July, 2002 to December, 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: - December , 2002.

L. Singh.

(LAKSHMAN SINGH)

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

19/12/02

(Dr. S.K. Ghosh.)
Associate Professor
Dept. of Civil Engg.
IIT, Roorkee – 247667 (India)

Dr. Nayan Sharma.
Professor
WRDTC
IIT, Roorkee-247667 (India).

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L. Singh.

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(LAKSHMAN SINGH)

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ABSTRACT

From very beginning, human beings have largely dependent on mighty rivers for their livelihood. Early civilizations were established and developed in and around the river valley. As the population is increasing, rivers have been playing a key role in development of a nation. Mighty rivers are used for various development activities such as irrigation, industrialization and hydropower in addition to transportation and other basic utilities. But unfortunately, some rivers have been migrating and ultimately wiping out agricultural lands and cities in their path. The migration of channel boundary characteristics are in such a way that it includes typically any change in river plan form, channel geometry with context to X-section and drainage pattern. Thus to study the channel boundary characteristics will help to understand the river morphology both in time and space

Brahmaputra River is one of the greatest rivers in the world ranking fifth in terms of drainage area. It has also a very high sediment discharge ranking third in world. In the past it has registered phenomenal changes over period of time. So that is why it has been preferred for this study.

In the past such river migration were understood by conventional surveying or analytical approaches, which were very tidious, slow and time intensive. With the advent of Remote Sensing technology it has become easy to acquire this information. The remote sensing technology plays a very important role in monitoring the channel pattern characteristics. Applications of this technology have resulted in timely availability of repetitive and reliable information necessary for the resource management. Similarly geographic information system is available as a powerful tool for manipulating the huge amount of data. In this dissertation, an attempt is made to understand the channel boundary migration and land form changes over different time and space. The Morphological parameters such as Sinuosity, Braiding Index, Braid Channel Ratio and Plan form Index have been computed. It shows that degree of braiding is increasing with time.

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INTRODUCTION

1.1 GENERAL

Satellite imagery and Aerial photographs permit a quick study of river morphology, stream network analysis involving the mapping, measurement and classification of active drainage lines complexities in stream patterns and location of associated features like ponds have been assessed satisfactorily using imagery. Especially, the study of satellite imagery can be used for the evaluation of changes in river channel characteristics and detection of river piray. Repetitive coverage of satellite imagery can help to find out the shift in river bank line. This would enable us to predict future changes and would assist in taking Proper River tracing measures. Satellite imagery has also been found useful in detection and reconstruction of old courses of rivers.

1.2 STUDY AREA

The study area is Brahmaputra River in Assam, which is flowing east to west. It is located approximately between geocoordinates 26^0 N to 28^0 N latitude and 89.5^0 E to 95.6^0 E longitude. It flows through Kobo, Dibrugharh, Jorhat, Sibsagar, Guwahati, Goalpara and Dhubri in Assam.

There are four distinct seasons prevalent in the study area viz. winter, summer, monsoon and post- monsoon. The rainfall distribution varies in different part of study area. The most disturbing feature of rainfall pattern in study area is that winter is very dry due to absence of rain, while excessive rain during the monsoon months causes floods, water logging and erosion in several areas of Assam.

Out of total geographical area of Assam only 15222 sq km (19.4%) area is covered by hills and rest area is distributed in valley and plains.

1.3. SCOPE OF STUDY

Assam is facing sever problem of flooding and bank erosion from Brahmaputra river due to its rapidly shifting nature. Huge funds are being spent every year for protection works at various locations along the river Brahmaputra. Suffering caused by the floods of river led to the establishment of Brahmaputra Flood Control Department by the Government of Assam and Brahmaputra board by the Government of India for preparation and exception of a strategic overall plan for water management including master plan for training the Brahmaputra river based on a through understanding of all aspects of the river.

The morphological study of river may be helpful in such type of planing of engineering activities such as road networks, site location of bridges, hydraulic structures like barrages, sluices and river Training structures.

A study on the Brahmaputra river has been carried out by WAPCOS through a team of engineers like Sri S .Y Chattel, Prof. R.J. Garde, Sri N.K. Sharma and others to identify the basic morphological parameters of the river Brahmaputra in Assam. The study emphasized on shoal formation in the riverbed, river meandering, bed movement, river behavior under special condition and other hydrological aspects of the river.

Other notable studies have been carried out by Kallita (1993), Hussain (1992), Murthy (1989) on the morphological study of the river Brahmaputra and use of remote sensing data at different stretches of river.

Ishar (1990) has carried out studies related to know the width-widening rate of Brahmaputra River in Assam from year 1914 to year 1988. He found that river width increased from 6.48 km to 8.718 km.

Singh (2001) studied the morphological features of Brahmaputra River on the basis of data available for the year 1997 and 2000 using remote sensing.

The morphological study on this river for the duration 1990 to 2000 yet not has been done. This study will be very helpful while making a planing of river control scheme for Assam. Keeping this view in mind this dissertation study has been carried out.

1.4 OBJECTIVE

Recent development in remote sensing provides an opportunity to know river morphology with the help of satellite data. This dissertation explores into an important area of river morphology in relation to time and space using inputs from satellite data and hydrographic data and maps. The satellite imageries covering the Indian portion of Brahmaputra river for years 1990, 1997 and 2000 are available. The main objectives of dissertation are: -

- To study the channel boundary characteristics
- Appraisal of fluvial landform changes.
- Analysis of various morphological patterns with respect to time and space.

This will be helpful for planners, designers while planing, the river training and other hydraulic structures in Brahmaputra River

REVIEW OF LITERATURE

2.1 RIVER MORPHOLOGY

River Morphology is a science concerning shape of river. The study of alluvial river attempts to explain and describe the typical features of the river. These features are appeared as a result of complex dynamics of flow over a moving bed. Channel morphology changes with time and is affected by water and sediment discharge including sediment characteristics, composition of bed and bank materials, and vegetation. Channels change in different ways through the process of erosion and deposition. Almost in all cases, river bed profiles are irregular in shape and size. For representing these profiles, mathematical functions are generally used in the Conventional methods. But the representation is difficult when the river is having variables and complex patterns. The complexity in representing this information made somewhat easier and quick, by use of remote sensing and GIS techniques in this area.

A through understanding of the Morphology of alluvial streams requires actual knowledge of their Plan form. The Plan form of alluvial streams can be classified into the following three categories:

(a) **Braided stream:** A braided stream can be defined as one, which flows in two or more channels around alluvial islands. Leopold and Wolman (1957) stated that braided pattern in alluvial stream develops after local deposition of coarse material which cannot be transported under local conditions existing within the reach. This coarse material becomes the nucleus for a bar formation and subsequently grows into an island made up of coarse, as well as, fine material. The formation of bar deflects the main stream towards the banks and may cause erosion. Hydraulic characteristics of braided stream are steeper slope, wider and shallow channels with high rate of sediment load.

(b) Meandering streams: A Sinuous channel is called meandering stream. It consists of regular or irregular pattern of loops and a distinct sinuous plan form. A meandering river has a single channel while a braided river has a number of channels.

(c) Straight stream: A stream in this classification refers to one that does not have a distinct meandering pattern. It is extremely difficult to find straight reach of stream over large lengths. Straight reach implies neither constant depth across the channel nor a straight Thalweg. Even though the channel is straight, the line of maximum depth commonly known as thalweg moves from one bank to another bank.

2.2 CHARACTERISTICS OF BRAIDED STREAMS

Braided streams occur in high-energy environments of large and variable discharges, heavy sediment load and steeper gradients with erodible banks. Braided streams are characterized by wide and shallow cross - sections with random bar formations creating flow divisions. Flume experiments by Leopold and Wolman (1957) suggest that a bar of coarse sand diverts flow to cause channel widening and positive feedback, which then accentuates bar development, resulting in braided channel pattern. Sediment transport takes over the bar surface while incision in the lateral channels lowers the water surface to expose the bar which then becomes dissected. The complex of islands is stabilized by vegetation in natural streams and experiences further high stage sedimentation (Richards, 1982).

The distributory channels formed by braiding are less hydraulically efficient than a parent single. Braided reaches are characterized by steeper slopes for maintenance of stream power necessary for sediment transport. Braided reaches show greater complexity, that is, more bars and distributaries in the highest environments (Howard, 1970). This observation confirms that the braided channel pattern is optimal for the dissipation of excess energy in high energy streams, since the enhanced total flow resistance of the multithread channel results in rapid energy loss (Richards, 1982)

2.3 MEANDERING PARAMETER (Sinuosity)

Leopold and Wolman (1957) have defined sinuosity of a stream as the thalweg length to the valley length. They have arbitrarily classified streams with sinuosity greater than 1.5 as meandering streams. Friend and Sinha (1993) defined meandering parameter (Sinuosity) as modified Sinuosity parameter, and presented as

$P = L_{cmax} / L_R$ Where

P = Modified Sinuosity Parameter

L_{cmax} = mid channel of the widest channel

Where there is more than one channel.

L_R = over all length of the –belt reach measured along a straight line.

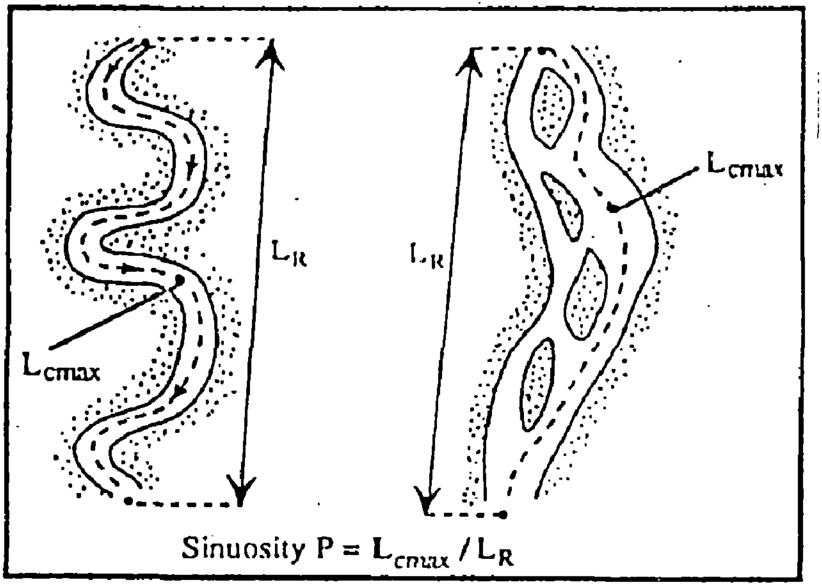


Fig 2.1: Schematic diagram representing the computation of Sinuosity for single channel and multi channel rivers.

2.4 BRAIDING PARAMETERS

2.4.1 Braiding Index (BI): -

For measuring channel multiplicity, Brice (1964) has introduced a braiding index parameter, which is defined as follows:

$BI = 2^* (\Sigma L_i)/L_r$ where

ΣL_i = the length of all islands or bars in the reach

L_r = the length of the reach measured midway between the banks of the channel belt

Brice(1964) rationalized this parameter as a measure of the total amount of bank length, where most island significantly have a greater length than width, so that the total bank length will be approximated by doubling the island or bar length. Its higher value shows the higher degree of braiding.

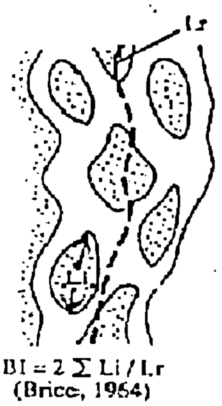


Fig. 2.2: Schematic diagram representing the computation of the Braiding Index of Brice(1964)

2.4.2 Braid Channel Ratio (BCR)

Friend and Sinha (1993) have proposed braid channel ratio (B) to define the braiding parameter of a braided river. It has also used the idea of total sinuosity developed by Richards (1982) to measure braiding in gravel Bed River. Braided channel ratio can be computed by

$B = L_{ctot} / L_{cmax}$, where

L_{ctot}= Sum of total channel lengths of all segments of primary channels

L_{cmax}= the mid channel length of the widest channel through the reach.

It measures the tendency of a channel belt to develop multiple channels in any reach.

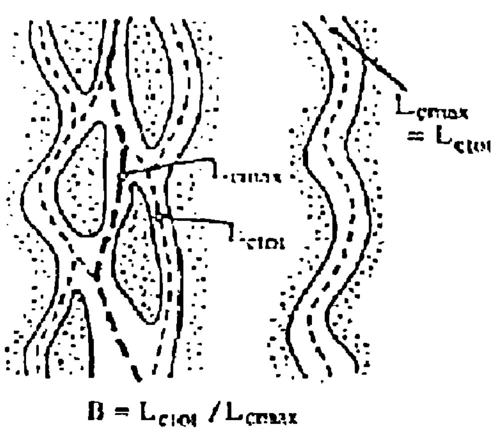


Fig. 2.3: Schematic diagram representing the computation of the Braid Channel Ratio Sinha(1993)

2.4.3 Plan form Index (PFI)

The braiding indicators, explained above, are inadequate in so far as these are not related to hydraulic efficiencies and submerged sub-channel configurations of the stream which are seen to be closely related to evolution of braiding phenomena.

Sharma (1995) formulated a new braiding index to describe braiding phenomenon and fluvial landform pattern in quantitative terms on a more logical basis. He mentioned that the braided channels are hydraulically less efficient. Also the formation of braids bars play an important role in the modification of the energy losses due to friction. With a view to incorporate the effect of the above hydraulic variables the proposed new index is as follows:

PFI = T/B *100/N, where

T = flow top width

B = over all river width

N = No of braided channel

It is expressed in percentage which shows the fluvial land form deposition with respect to a given water level and its lower value indicate higher degree of braiding. Fig 2.4 shows the plan form index.

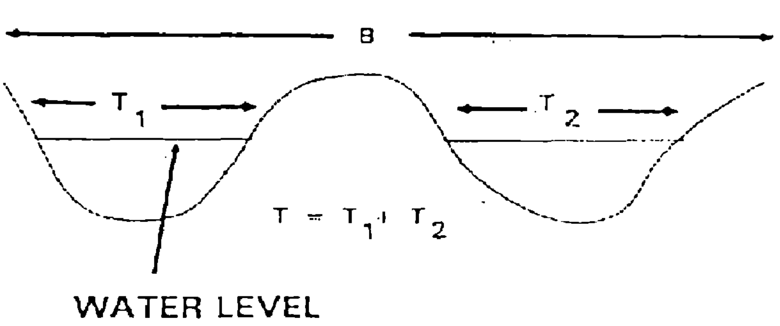


Fig. 2.4: Plan form index.

REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

3.1 CONVENTIONAL METHODS

In river engineering, there is a general and difficult task of river regime or alluvial channel to predict the Morphological Parameters. To understand these Parameters, there is an analytical approach, which employs the use of equations such as sediment transport, flow resistance and bank stability. Extremal hypothesis is another approach which describes on the basis of assumption that a channel acquires equilibrium or stability when specified function of some of variables has an extreme (maximum / minimum) subject to given constraints.

3.2 MODERN TECHNIQUE

In order to study the river plan form and morphological changes of a river, information at a regular interval of time for whole length of the river may be required. Ground based observations and other methods may not be sufficient to model the plan form and morphological changes. These may be uneconomical and time consuming if these methods have to be adopted on a repetitive basis. With advancement of remote sensing Ariel photographs and satellite imageries are available with GIS as an analysis tool, thus it is possible to acquire information related to river morphology.

3.3 REMOTE SENSING

Remote sensing is a science and art of obtaining information about an object , area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation. (Lillesand and Kaifer, 1982).

Photographic interpretation involves the study of photographic images, while remote sensing which is relatively a new technique, includes not only the analysis of photographs but also the use of data gathered from a wide range of remote sensing sensors and scanners on board the satellite. Remote sensing images, obtained from orbiting satellites are capable of providing quantitative as well as qualitative information about objects.

Remote sensing activity started in the decade of fifties. The usefulness of images for mapping and other applications increased in 1960,with the launching of the first US meteorological satellite TIROS-1. The launching of the first Earth Resources Technology Satellite ERTS (later renamed as LANDSAT) by USA in July 1972 marked the beginning of space development activities, including the use of remote sensing images for various natural resources applications.

3.4 REMOTE SENSING DATA

There are two types of remote sensing data used for various applications:-

3.4.1 Aerial Remote Sensing Data

The platform used for this data is normally an aircraft, and data products are black & white and coloured photographs.

3.4.2 Satellite Remote Sensing Data

The platform used for this data is a satellite, and the data products are black & white images, false colour composites (FCCs) , computer compatible tapes (CCTs) , compact disc (CDs), etc.

3.4.3 Application of Remote Sensing Data

Remote sensing data provide a permanent record of topographical features of the area. The profusion of information contained in a photograph is much greater than that afforded by any other cartographic device. The camera or sensor often reveals the ground information that would have been ordinarily missed by a human eye.

Developments in space technology have greatly enhanced the capabilities of resources, survey and mapping. Remote sensing has found many applications in the study of earth's resources, mainly because of its synoptic and repetitive coverage to gather real time information.

Data acquired by remote sensing has come to be accepted as a useful source for mapping and making inventories of natural resources. This data has been used in the field of forest mapping, snow hydrology, reservoir sedimentation, flood estimation, river morphology, watershed conservation, soil mapping, land / land cover mapping, crop yield forecasting etc.

3.5 REMOTE SENSING COMPONENTS

Remote sensing works with the help of a sensor which records reflected electromagnetic energy from the objects to be characterized. Various objects are identified with the help of variation in the reflected electromagnetic energy. A remote sensing system may have the following components: -

- i Source of electromagnetic energy
- ii Medium (atmosphere) which interacts with this energy
- iii Ground objects
- iv Sensor to detect and record the changes in electromagnetic energy.

3.6 REMOTE SENSING SATELLITE

Remote sensing was started with the launching of the first earth resources technology satellite (ERTS), now known as LANDSAT-1, BY Americans in year 1972. Since then, with the advancement in sensor technology, a number of remote sensing ERTS have been launched, they are: -

LANDSAT series 1,2,3,4,5,6 and 7. French satellite SPOT 1,2 and 3, Indian polar satellites Bhasker 1&2, IRS 1A /1B /1C /1D, IRS-P2 /P3 /P4 and Indian meteorological and communication satellites INSAT 1A /1B / 1C / 1D & 2A /2B /2C /2D / 2E

India started the use of remote sensing techniques with the launch of Bhasker 1 &2 in 1979 &1981 respectively. In 1989, the first Indian remote sensing (IRS) Satellite was launched under the Indian Space Program. Indian Remote Sensing Satellites in the IRS series, designated as IRS 1A, IRS 1B, IRS P2, IRS 1C, IRS P3, IRS 1D and IRS P4 were launched during the year 1989, 1991, 1994, 1995, 1996, 1998 and 1999 respectively.

The National Remote Sensing Agency (NRSA) Hyderabad, under the Department of space (India), is mainly responsible for acquisition, processing and dissemination of satellite data. The Space Application Centre (SAC), Ahmedabad, India and the Indian Space Research organization (ISRO), Banglore, are mainly responsible for the design and launching of sensors and platforms, including satellite launch vehicles.

The data from Indian remote sensing satellites is received in the form of digital signals at Sadhnagar ground receiving station, Hyderabad. This data is corrected, pre-processed and analyzed on computers and is converted into different forms such as films , paper prints , FCc , CCTs , CDs etc and is supplied to the users for various application.

3.7 SENSOR SYSTEM IN IRS SERIES

The salient features and the utilities of different sensors employed in IRS series are given in Table no: 3.1

Table 3.1 Sensor system in IRS series

Satellite	Launch	Sensor system	Spatial resolution	Repeat coverage
IRS 1A	1989	LISS –1 LISS -II	72.5 m 36.25 m	22 days
IRS 1B	1991	LISS –1 LISS -II	72.5 m 36.25 m	22 days
IRS P_2	1994	LISS -II	32*37 m	24 days
IRS 1C	1995	LISS -III	23.5 m	24 days
IRS P_3	1996	MOS –A MOS –B MOS –C	2.5*2.5 m 720*580 m 1*.7 km	----------- -----------
IRS 1D	1997	LISS -III	23.5 m	24 days
IRS P_4	1999	Ocean color	12 bits	--------

3.8 STAGES INVOLVED IN REMOTE SENSING TECHNIQUE

The remote sensing technique is used to collect, analyze and convert remotely sensed data into useful information in order to assist in inventory, mapping and monitoring the earth resources. The basic stages involved in this process are data collection, data analysis and data representation.

3.8.1 Data Collection

It involves energy sources, propagation of energy through the atmosphere, energy interactions with earth surface features, airborne or spaceborne sensors to record reflected or radiation energy from features and data products in pictorial, graphical or numerical form.

3.8.2 Data Analysis

It involves examining the data and. deduces its significance. This may be performed by one of the following methods: -

- Visual interpretation
- Digital interpretation
- Hybrid method

Visual interpretation is manual analysis of an image by a skilled or trained analyst based on the elements of photo interpretation where as digital interpretation is done by a computer. Hybrid method is a mixed form of above two methods of data analysis. Since visual and digital methods are complementary in nature, consideration must be given to obtain best results by combination.

3.8.3 Data Representation

It is done in graphical, tabular or numerical forms depending upon the purpose for which the end result is needed.

3.8.4 Image Processing Systems

After the spatial data is received, it needs a system to manipulation, this system is known as image processing. Thus remote sensing and image processing are two powerful tools for many research and applications areas.

Image processing applications software normally resides as an executable command module on the hard disk of a system. This software is usually interactive, prompting the user for specified inputs. This characteristic of software is essential and helpful to the users. There are so many softwares available for image processing. If the data to be analyzed is enormous, digital interpretation techniques may prove to be faster. Some of the images processing software are given below: -

- Comtal image processing system
- Integrated Land And Water Information System (ILWIS)
- Intergraph MGE
- International Imaging System (I^2S)
- Earth Resource Data Analysis System (ERDAS)

ERDAS is advancing one and it is being used for image processing in this dissertation.

3.9 GEOGRAPHIC INFORMATION SYSTEM (GIS)

Remote sensing generally requires other kinds of ancillary data to achieve both its greatest value and highest levels of accuracy as a data and information production technology. GIS is defined as a system of computer hardware, designed to allow users to collect, manage, analyze and retrieve large volumes of spatially referenced data and associated attributes collected from a variety of sources (Aronoff, 1991).

Spatial data analysis is a multidisplinary, activity concerning hydrology, water resources, geography, urban planning and earth sciences. Spatial data sets are frequently heterogeneous, having data on soils, water rainfall, infiltration, landuse, topography, forestry, administrative boundaries, population, etc., and often are available at different scales in different coordinates systems, at various levels of accuracy and Arial coverages for solving a variety of problems. These data sets may be derived from text, maps, charts, and ground information, organizations, aerial photographs and satellite imagery. The management and analysis of such large volumes of spatial data requires a computer-based system called Geographic Information System (GIS), which can be used for solving complex geographical and hydrological problems (Garg, 1991).

GIS is rapidly becoming a useful tool for management of resources. Effective utilization of large spatial data volumes is dependent upon the existence of an efficient geographic handling and processing system that transforms this data into usable information. GIS permits the integration of data sets acquired from library, laboratory and fieldwork. Remote sensing data provides timely data for a variety of applications and it can handle the huge amount of data. Remote sensing together with GIS, is the most efficient way for natural resources. For mapping and monitoring the channel pattern changes, and associated geomorphological characteristics of sorrounding area, satellite remote sensing techniques can be effectively utilized with GIS.

3.9.1 Components of GIS

A working GIS integrates five key components; hardware, software, data, people, and methods.

(I) Hardware

Hardware is the computer on which a GIS operates. Today GIS software runs on a wide range of hardware types, from centralized computer servers to desktop computers used in standalone or networked configurations.

(II) Software

GIS software provides the functions and tools needed to store, analyze and display geographic information Key software components are:

- Tools for the input and manipulation of geographic information.
- A data base management system (DBMS)

- Tools that support geographic query, analysis, and visualization.
- A graphical user interface (GUI) for easy access to tools

(III) Data

Data is the most important component of GIS. Geographic data and related tabular data can be collected in house or purchased from a commercial data provider. A GIS will integrate spatial data with other data resources and can even use a DBMS, used by most organizations to organize and maintain their data, to manage spatial data.

(IV) People

GIS technology is of limited value without the people who manage the system and develop plans for applying it to real world problems. GIS users range from technical specialists who design and maintain the system to those who used it to help them perform their everyday work.

(V) Methods

A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

3.9.2 Data Structures

Data structures are classified into two classes. These are: -

Vector data structures: - Vector representation of an object is an attempt to resent the object as exactly as possible. The objects of interest are extracted using digitizers and other devices. The coordinate space is assumed to be continuous, not quantized as with the raster space, allowing all positions, lengths and dimensions to be defined precisely. Besides the assumption of mathematically exact coordinates, vector methods of data storage; use implicit relations that allow the complex data to be stored in a minimum space. The accuracy of the output depends on the skill of the operator and quality of the associated systems. The vector based GIS capture the data in vector form, analyze the data in vector form and produce output in either vector or raster format. Some of the vector based GIS are ARCVIEW, ARC INFO by ESRI and MGE by Intergraph.

Raster data structures:- The simplest raster data structures consist of an array of a grid cells (pixels). A row and column number references each grid cell and it contains a number representing the type or the value of the attribute being mapped. In raster structure, a single grid cell indicates a point where as a line is represented by number of neighboring cells strung out in a given direction and an area by an agglomeration of neighboring cells. More space is required while storing the data. However the overlay is simpler and accurate as the data is available in grid form. This form is computationally efficient and fast, and is most suitable for further processing and overlaying of data.

3.9.3 GIS Tasks

General purposes GISs essentially perform six processes or tasks.

(i) Input

Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. The process of converting data from paper maps into computer files is called digitizing.

Modern GIS can technology can automate this process fully for large projects using scanning technology. Today many types of geographic data already exits in GIS compatible formats. These data can be obtained from data suppliers and loaded directly into a GIS.

(ii) Manipulation

It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with the system. Geographic information is available at different scales. Before this information can be integrated, it must be transformed to the same scale. GIS technology offers many tools for manipulating spatial data and for weeding out unnecessary data.

(iii) Management

For small GIS projects it may be sufficient to store geographic information as simple files. However, when data volumes become large and the number of data users becomes more than a few, it is often best to use a data base management system (DBMS) to help store, and manage data .A DBMS is nothing more than computer software for managing a database.

(iv) Query and analysis

GIS provides both simple point and click query capabilities and sophisticated analysis tools to provide timely information to managers and analysts alike. GIS technology really comes into own when used to analyze geographic data to look for patterns and trends and to undertake, what if' scenarios. Modern GISs have many powerful analytical tools.

(v) Overlay analysis

The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay can integrate data on different layers.

(vi) Visualization

For many types of geographic operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. GIS provides new and exciting tools to extend the art and science of cartography. Map displays can be integrated with reports, photographic images and other output such as multimedia.

3.9.4 GIS Packages

There are several GIS packages, some of them are:

- ARCINFO
- ARCVIEW
- ERDAS IMAGINE
- ERMAPPER
- IDRISI
- MAPINFO
- ILWIS
- GEODEX

3.9.5 ERDAS IMAGINE

This system is a PC based system having image processing and basic GIS utililities The ERDAS software contains a variety of modules that can be used independently, or combined. ERDAS programs within each module are accessible through of menus. This is useful to toggle the overlay

Application used included:

- Image processing
- Image manipulation
- Image classification
- Image overlaying and merging
- Image display
- Visualization of Satellite imagery
- Analysis of imagery

DETAILS OF STUDY AREA AND DATA USED

4.1 GENERAL

The river Brahmaputra is one of the largest rivers is the world. It originates at an altitude of 5300m in Kailash mountain range about 63 kms southeast of Mansarover lake in Tibet (China). It enters in India near tuning in Arunachal pradesh. After travelling for a distance of 278 km, it meets with two rivers Dibang and Lohit in Assam near Kobo. Below this confluence point, the river is known by the name of Brahmaputra. It passes through Assam into Bangladesh and at last it meets with Ganga near Goalundo in Bangladesh before joining the Bay of Bengal. In Tibet it is known by the name of Sangpoo, in Arunachal pradesh by Siang or Dibang in Assam by Brahmaputra & in Bangladesh by the name "Jamuna", "Padma", & "Meghana". Its total length is 2897 kms comprising of 1625 kms in Tibet, 918 kms in India and 354 kms in Bangladesh. It has 640 kms length only in Assam.

The Brahmaputra basin is confined by the great Himalayan ranges in the North and Northeast, Naga-Patkai hills in the East and Mikir hills and Sillong plateau in the South. The Assam valley is the eastern continuation of the Indo-Gangetic plains of the Indian subcontinent valley is very narrow in the east gradually expands to the west nearly 80 kms. and width, covering a spatial area of about 562704 sq. kms. In this valley, the river itself occupies a width of 6 to 12 km in most places. The catchment area of river extends from parts of Tibet, Nepal, Bangladesh, Northeast India & Bhutan.

Before entering India, the river flows in a series of big cascades as it rounds the Namcha-Barma peak. In the length of about 640 kms. in Assam valley, the river is flowing almost East-West. The river forms almost trough receiving the flows of its tributaries both from North and South. It is also a most braided river in the world. Its width at Pandu near Guwahati is just 1.2 km and few kms. distance to this points, its width is as large as 23 kms. There are three permanent stations namely Bessamara, Silghat and Pandu where gauge discharge & sediment is measured for Brahmaputra River.

Salient features of Brahmaputra river are summarized as given below: -

1. Total length from its source to the outfall in the Bay of Bengal	= 2897 kms.
a. Tibet	= 1625 kms.
b. India	= 918 kms.
(i) Arunachal pradesh	= 278 kms.
(ii) Assam	= 640 kms.
c. Bangladesh	= 354 kms
2. Total catchment area	=580,000 sq km
a. Tibet and Nepal	= 293,000 sq km
b. India	=195,000 sq km
c. Bhutan	= 45,00
d. Bangladesh	=47,000 sq km
3. Gradients	
a. Tibet	= 1: 385
b. Arunachal pradesh	=1: 515
c. Assam (Kobo to Dhubri)	= 1:6990
d. Bangladesh	= 1:22,150
4. Discharge	
a. Maximum observed discharge at Pandu near Guwahati (23/08/1962)	= 72,974 cum.
b .Minimum observed discharge at Pandu (20/02/1968)	= 1757 cum.

c. Average dry season discharge (October to march) at Pandu = 4420 cum.

5. Sediment discharge at Pandu = 757.23

6. Rainfall

The average annual rainfall in Brahmaputra basin varies between 2130 mm in Kamrup district in Assam to 4140 mm in Tirap district in Arunachal pradesh.

7. It has largest river Island (Majuli Island near Guwahati) in world.

4.2 TRIBUTARIES OF BRAHMAPUTRA RIVER

Previously, Brahmaputra River was formed by joining two river Dibang and Lohit near Kobo but at present, rivers Dibang and Lohit are joining Dihang through another channel near Dibru. It has developed due to river avulsion phenomena. Now Dibru is receiving major part of discharge of Lohit similarly Brahmaputra river is fed by 49 no. of tributaries in Assam in which 37 no. of tributaries are from north bank and 12 no. from south bank.

Subnsiri, Jia Bharti, Dhansari, Puthimari, Pagladiya, Manas, Champabati and Sankosh are major tributaries of North bank. Similarly Bhuri Dihang, Disang, Dikhu, Dhansiri and Koppili are major river feed the Brahmaputra river from southern bank.

The main North and South tributaries of Brahmaputra River in Assam valley along with their chainages are listed below in tabular form.

TABLE: - 4.1 North Bank Tributaries

S.No.	North bank tributaries	Chainages in km
1	Simen	580
2	Jiyadhol	540
3	Subausin	430
4	Burai	392
5	Bargang	382
6	Jiya Bharati	338

7	Gabharu	300
8	Belsiri	280
9	Dhausiri	270
10	Noa Nadi	230
11	Nanai Nadi	215
12	Bar Nadi	205
13	Puthimari	172
14	Pagladiya	170
15	Beki	115
16	Manas	85
17	Chaupamati	63
18	Gurang	43
19	Tipkai	40
20	Sankosh	00

Table : 4.2 South Bank Tributaries

S.No.	South bank tributaries	Chainages in km
1	Dibru	592
2	Burhi Dihing	540
3	Disang	515
4	Dikhu	505
5	Jhanzi	495
6	Dhansari	420
7	Kopoli	220
8	Kulsi	140
9	Dcosila	130
10	Dudhani	108
11	Krishani	107
12	Jinari	100
13	Jinjiram	00

It has some important tributaries coming through north of West Bengal such as Tista, Jaldhaka, Torsa, Kaljani and Raidak. Besides these tributaries stated above, there are many minor streams, which drain directly or indirectly into the Brahmaputra river.

Brahmaputra basin has some certain significant features, which characterize the North bank and South bank tributaries. North bank has heavier rainfall with less stable hills. So they are more liable to soil erosion and land slide. These North bank tributaries carry larger silt. The Brahmaputra River is closer to the hills on the south as if it has been pushed southwards over geological period by the heavier silt carrying North bank tributaries. The features of north and south bank tributaries are as follows: -

The north bank tributaries:

1. Slopes are very step and channels are shallow braided for a considerable distance from foot of the hill.
2. Tributaries have boulder, pebble and coarse sandy beds and carry a heavy silt change.
3. Generally they have flashy flood.

South bank tributaries:

1. They have generally flatter grades and deep meandering channel almost from the foot of hills.
2. They have fine alluvial soils in bed and bank.
3. They have comparatively low silt change.

4.3 DATA USED

The following Satellite Data made available by NRSA Hyderabad and Brahmaputra board, Assam are used for this work:

IRS- 1A, LISS-1, Band-4, Path/ row 13/48 imageries dated 11 Jan 1990.

IRS- 1A, LISS-1, Band-4, Path/ row 14/48 imageries dated 11 Jan 1990

IRS- 1A, LISS-1, Band-4, Path/ row 14/49 imageries dated 8 Dec 1990

IRS- 1A, LISS-1, Band-4, Path/ row 18/49 imageries dated 16 Jan 1990

IRS- 1A, LISS-1, Band-4, Path/ row 15/49 imageries dated 5 May 1990

IRS- 1A, LISS-1, Band-4, Path/ row 16/49 imageries dated 10 Dec 1990

IRS- 1A, LISS-1, Band-4, Path/ row 17/49 imageries dated 6 Dec 1990

IRS-1C, LISS-111, band-4, Path/ row - 110/53 imageries dated 5 Mar 1997

IRS-1C, LISS-111, band-4, Path/ row - 112/53 imageries dated 2 Jan 1997

IRS-1C, LISS-111, band-4, Path/ row - 113/52 imageries dated 24 Feb 1997

IRS-1C, LISS-111, band-4, Path/ row - 113/53 imageries dated 24 Feb 1997

IRS- 1C, LISS- 111, band-4, Path/ row –109/53 imageries dated 13 Feb 2000

IRS- 1C, LISS- 111, band-4, Path/ row - 110/53 imageries dated 25 Jan 2000

IRS- 1C, LISS- 111, band-4, Path/ row - 111/53 imageries dated 23 Feb 2000

IRS- 1C, LISS- 111, band-4, Path/ row - 112/53 imageries dated 11 Jan 2000

IRS- 1C, LISS- 111, band-4, Path/ row - 113/53 imageries dated 28 Mar 2000

IRS- 1C, LISS- 111, band-4, Path/ row - 113/52 imageries dated 28 Mar 2000

Hydrographic survey map prepared by Brahmaputra Board in year 1986.

METHODOLOGY

A flow chart showing the methodology adopted is shown in fig 5.1. The procedure with available data is performed as follows:

With the given data following procedure has been adopted: -

5.1 DECODING

It is the process of data importing. The IRS data have BIL format. The IRS data is loaded in hard disk and is imported with generic type file media in CD-ROM G. Then using row / col and band these data are converted in image format. These are processed on EREDAS IMAGINE package. Now image can be visualized in viewer in raster layer.

In the case of 97 and 2000 year imageries data, file header bytes is used as 540 as it gives the single clear image. But in 90-year data, it is attached with another image. So by trial & error, providing 0 file header bytes, another attached image is removed.

5.2 REGISTRATION

The data available are without geographic coordinates and at different scales. Thus registration is required so that the image remains fixed with one origin defined on a designed plane. The following processes are used for registration while working with ERDAS IMAGINE.

5.2.1 Warping

It is a process by which an image is registered to a design file or to another image. In this process, geographic coordinates from one image are assigned to other image.

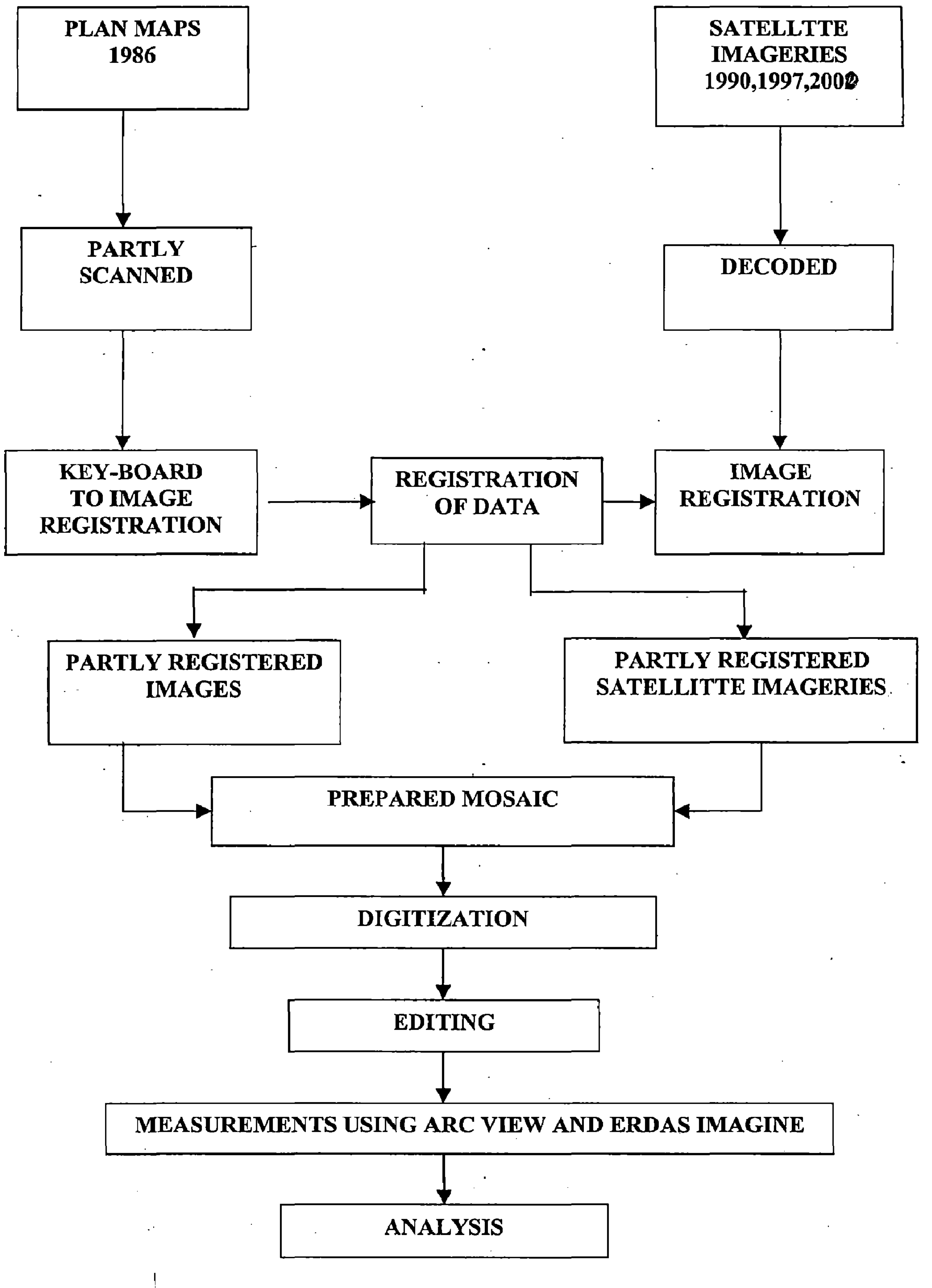


Fig.No. 5.1 : FLOW-CHART

These process use control points to calculate mathematical model to alter the image to best fit the coordinates.

In the case of Brahmaputra river valley imageries available, it is very difficult to trace the ground control points on it, considering this fact, geographic coordinates are provided to the image through the key board. The bridge location points observed on 2000- year imagery also have been considered while performing the registration of the image.

5.2.2 Resampling

Resampling is the process by which image values for the pixels on a new grid are interpolated from the values of the source pixels. In the most cases, the results of this procedure are that the output pixel values are determined by processing one or more input pixel values. Resampling is required when warping an image using any non-linear transformation model.

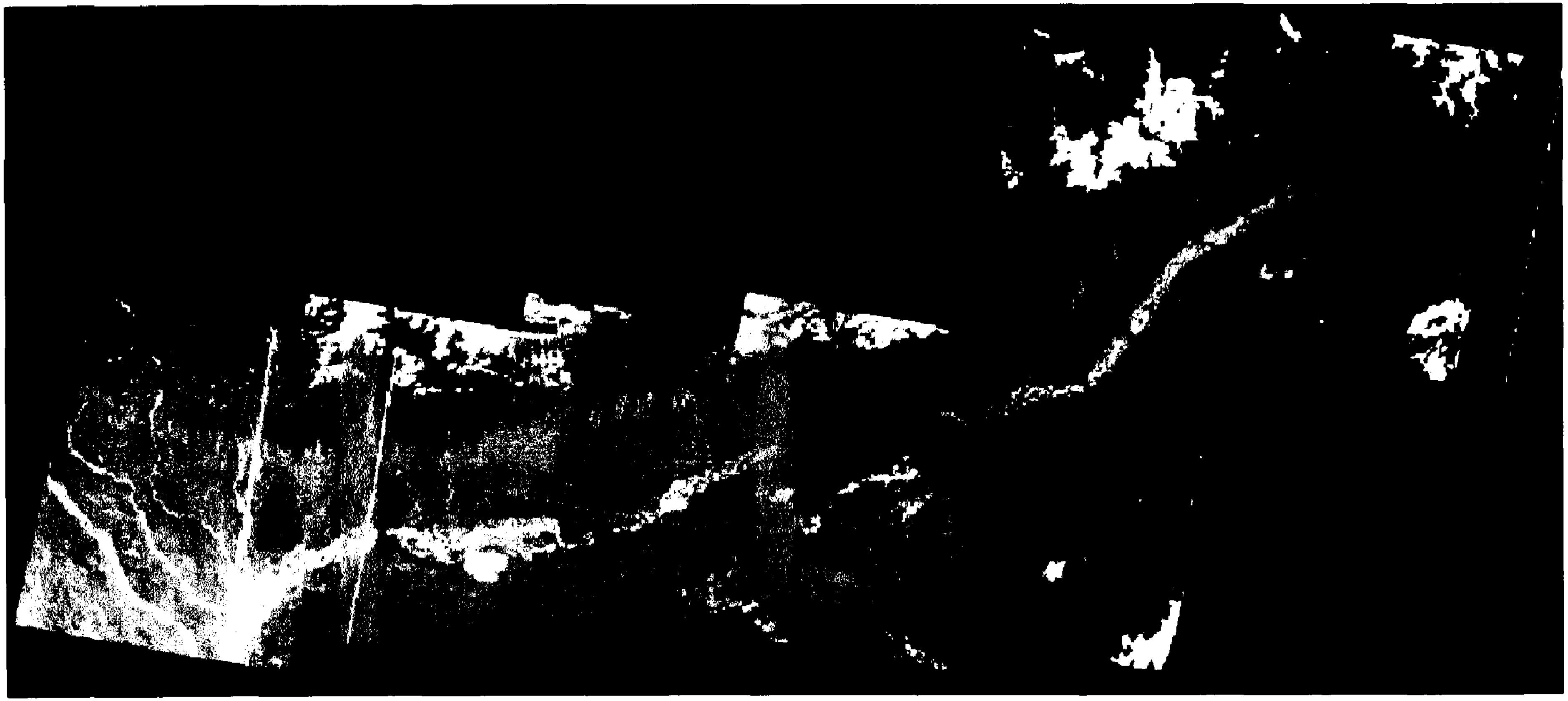
5.2.3 Registering an Image

It allows us to align the image geometrically with another image or to reference it to a standard map projection. The image to map option to register an image to map coordinates is used and image to image option to register an image to another image is used. These options appear on the geometric menu.

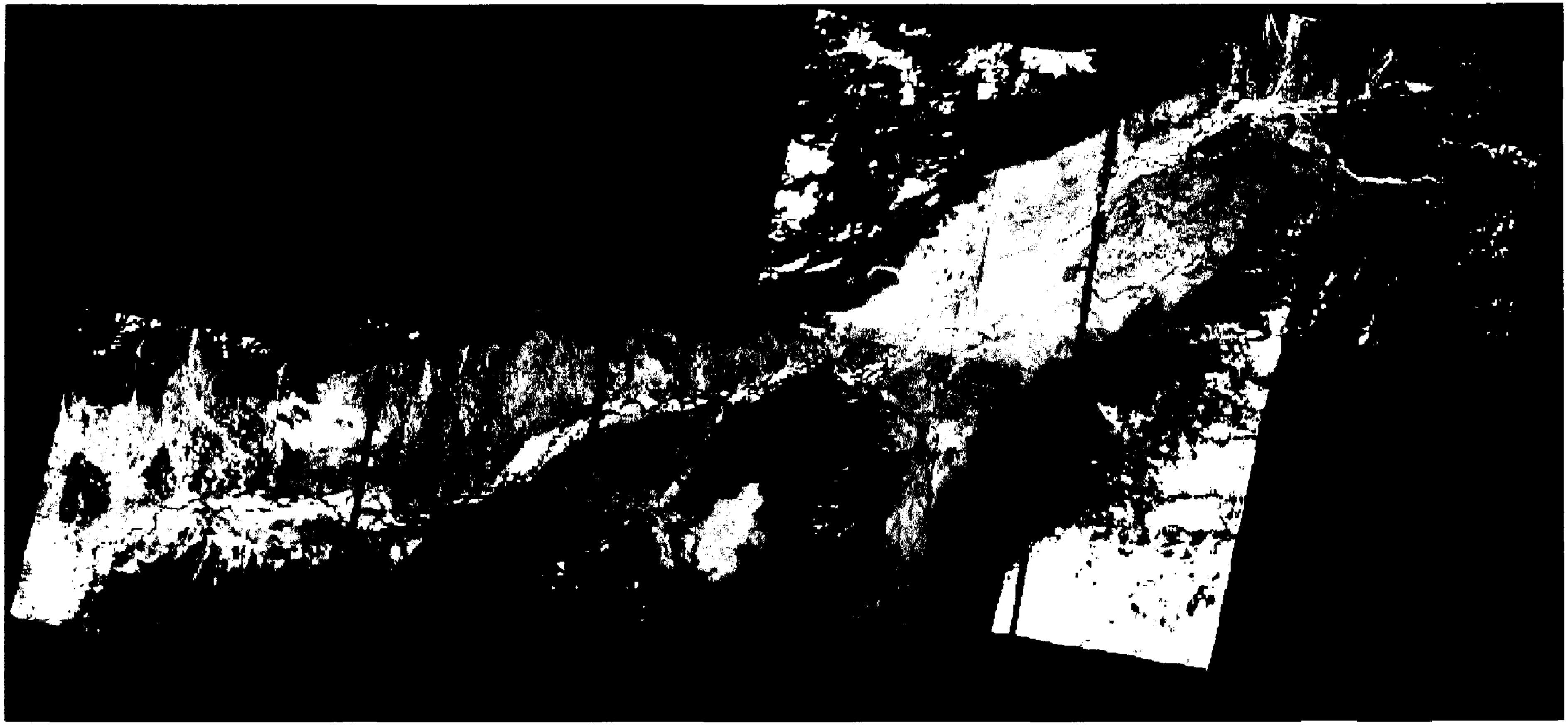
The image to be warped is referred to as the input image (active image), while the image to which the input image is being warped is referred to as the control.

5.3 MOSAIC

Mosaicing is the process of joining georeferenced images or a set of images. The input images must all contain map and projection information although they need not to



Mosaic of Satellite Imageries of year 1990



MOSAIC OF SATELLITE IMAGERIES OF YEAR 2000 be in the same projection or have the same cell sizes. All input images must have same number of layers. Mosaics are done with the help of mosaic tool using compute active area and add and image matching options.

5.4 DIGITIZATION

Digitization is the process of converting raster data into vector. It is the process which electronically converts the features on the maps and drawings into a GIS / Arc view theme. In this work screen digitization is being performed. After digitization editing is done in vector layer. Digitization is done in different layer, i.e. Channel boundary, flow pattern and braiding layer.

All these works are being performed in GIS tool on ERDAS IMAGINE package. ERDAS software: This system is a PC based system having image processing and basic GIS utilities The ERDAS software contains a variety of modules that can be used independently, or combined. ERDAS programs within each module are accessible through of menus. This is useful to toggle the overlay

5.5 COMPUTATION OF CHANNEL BOUNDARY AND OTHER MORPHOLOGICAL PARAMETERS

5.5.1 Migration of Channel Boundary

After editing, a base line is taken as 26^0 N latitude line on 1986 –year hydrographic map as well as this base line is used as reference line on migration channel boundary pattern map and plan form map. First ARC- coverage file is converted into shape file. The digitized map of year 1990 and year 2000 imageries are overlaid on digitized map of 1986-year survey map on ARCVIEW package. With reference to baseline located on 1986-year survey map, the offsets of bank lines and other parameters has been computed.

5.5.2 Meandering and Braiding Parameters

From digitized maps for different layers, number and length of channels, length of islands and other parameters are noted down using ERDAS software. On the basis of these parameters, Meandering and various Braiding Indices are computed as discussed in chapter 2.

5.6 MIGRATION SIGN CONVENTION

Offsets are measured from base line. While comparing the boundary migration for two years (both left & right boundary) -ve sign indicates boundary migration towards south and +ve sign indicates boundary migration towards north. For left bank, +ve migration shows deposition while -ve migration shows erosion whereas for right bank, -ve migration shows deposition and +ve migration shows erosion.

ANALYSIS OF RESULTS AND DISCUSSION

6.1 GENERAL

The whole length of Brahmaputra River in Assam from chainage 17.34 km. to 640 km. is divided into 7 reaches in order to carry out the morphological analysis. These reaches are as shown below in Table no. 6.1.

Table No: 6.1 Description Of Different Reaches

S.N	Reach no	X -section no		Distance in km.
		From	To	
1	1	2	10	65.28
2	2	10	20	89.76
3	3	20	30	79.57
4	4	30	40	120.88
5	5	40	50	107.6
6	6	50	60	98.44
7	7	60	65	51.00

For above defined reaches, river bank line migration during the year 1990 & 2000 and 1997 & 2000 have been computed. Other morphological parameters such as Sinuosity, Braiding index, Braid channel ratio and Plan-form index are also calculated for the years 1990, 1997 and 2000 for each reach. Fig. 6.1 shows the various x-sections and reaches of river Brahmaputra.

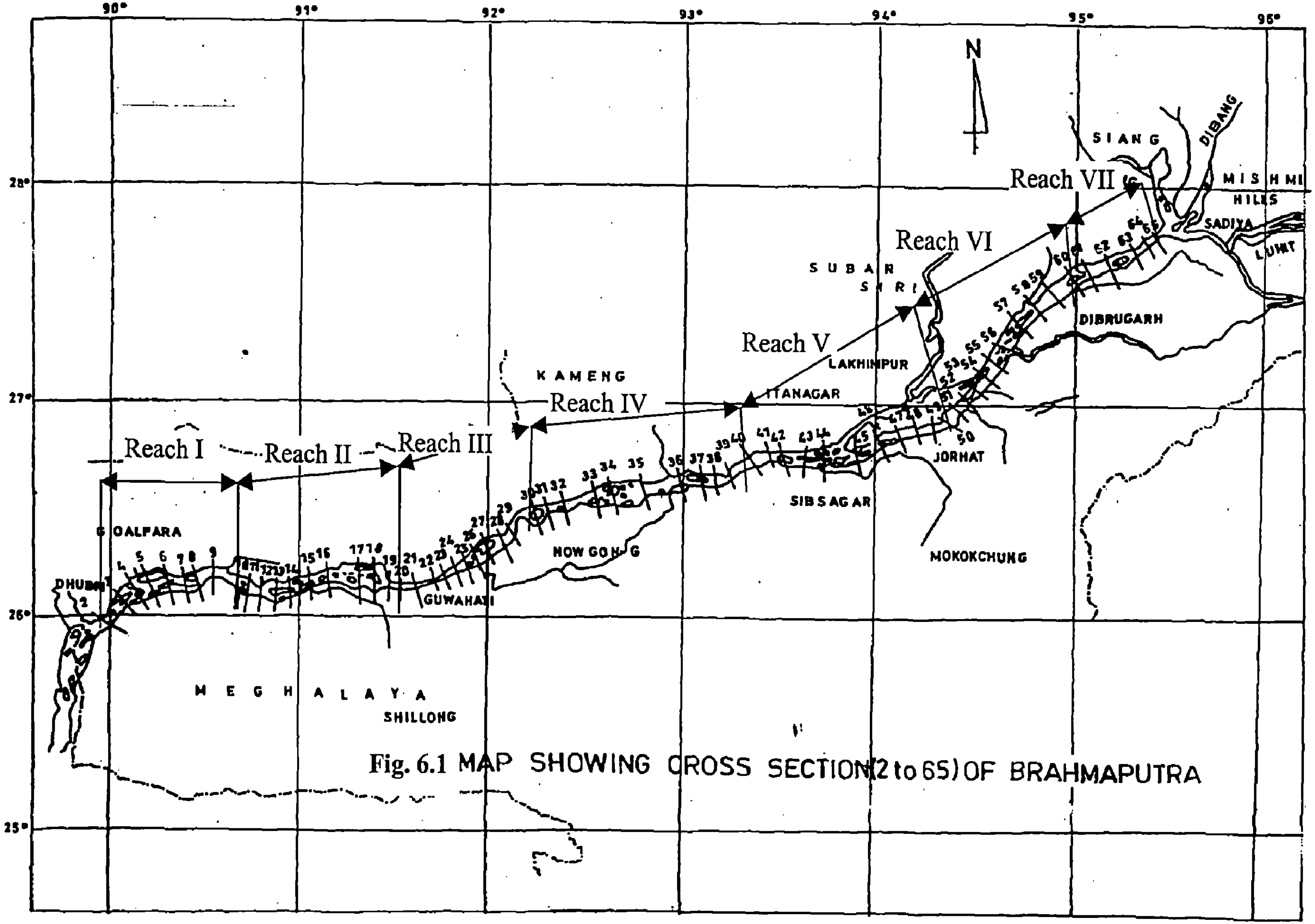


Fig. 6.1 MAP SHOWING CROSS SECTION(2 to 65) OF BRAHMAPUTRA

6.2 PLAN-FORM ANALYSIS

The plan-form analysis has been carry out for the whole stretch of river Brahmaputra from X-section no. 2 to X – section no. 65. The measurement records for offsets, channel width and bank line migration are shown in Table no. 6.2, 6.3 and Table no. 6.4. Plan-form of river during the years 1990, 1997 and 2000 are shown in fig no. 6.2, fig no. 6.3 and fig no. 6.4.

The position of left and right bank during the years 1990, 1997 and 2000 for X-section no. 2 to X-section no. 40 and X-section no. 40 to X-section no. 65 have been shown in fig no.6.5, fig no. 6.6, fig no. 6.7 and fig no.6.8 respectively. Similarly migration of left and right bank for the years 1990 and 2000 and 1997 and 2000 have been presented in fig no.6.9 and fig no. 6.10. The width of the river during the periods 1990, 1997 and 2000 are shown in fig 6.11. The detailed analysis of plan-form is performed per reach as below: -

6.2.1. Reach – 1

During the year 1990 and 2000, there is a mixed trend of erosion and deposition along the left bank. From the X-section no. 2 to X-section no.6, it shows deposition, while from X-section no.7 to X-section no.10, erosion is observed.

In the case of right bank, there is a trend of erosion between X-section no.2 to X-section no.4 and deposition in between X-section no.5 to X-section no.10. Along this reach, there is decrease in the width of the river.

6.2.2. Reach – 2

In this reach, left bank of river is migrated towards North. It shows that it has deposition tendency. In the case of right bank also, deposition is observed. Thus the

Table 6.2 Measurement of records of offsets for channel migration during different years

Calculation of Offsets

Baseline :- 26^0 N Lattitude

All measurements are in km

S.N	Along X-section	1986 Survey Map		1990 imagery		1997 Imagery		2000 Imagery	
		Left Bank	Right Bank	Left Bank	Right bank	Left Bank	Right Bank	Left Bank	Right Bank
1	2	-4.45	4.82	-13.21	2.6	No Computation Due to lack of satellite data	No Computation Due to lack of satellite data	-12.02	2.65
2	3	2.46	14.72	-2.99	4.79			-2.68	6.72
3	4	6.09	20.06	-0.86	11.34			4.65	12.29
4	5	9.46	22.46	6.59	14.33			7.22	14.01
5	6	12.27	21.91	10.13	20.34			10.34	19.26
6	7	12.55	21.46	13.58	22.33			12.56	21.25
7	8	13.27	23.01	13.58	28.56			14.32	24.92
8	9	19.9	24.83	21.88	29.64			20.8	22.64
9	10	14.17	20.92	21.01	26.4			14.47	19.72
10	11	10.78	19.63	14.77	27.26			18	22.96
11	12	10.57	15.85	13.26	28.56			20.37	24.26
12	13	7.54	18.44	11.95	26.08			17.13	19.72
13	14	9.92	18.76	10.34	25.1			18.44	20.27
14	15	14.56	21.03	14.66	27.58			22.32	25.55
15	16	17.79	24.79	19.82	27.26			21.56	27.59
16	17	14.98	27.18	12.27	28.77			12.72	27.5
17	18	12.93	27.18	11.53	28.99			12.61	30.62
18	19	15.41	18.87	14.77	28.99			15.41	25.98
19	20	13.9	17.47	13.35	18.74			13.9	17.89
20	21	16.89	17.89	15.94	17.85			16.17	18.76
21	22	18.21	19.29	19.29	20.58			19.19	20.37
22	23	19.95	23.07	19.29	21.01			19.4	22.2
23	24	22.64	26.42	22.62	25.76			22.32	25.34
24	25	24.36	31.46	23.92	26.52			23.83	26.63
25	26	26.69	36.41	25.97	30.93			24.71	28.33
26	27	29.65	40.85	29.32	32.71			27.18	30.64
27	28	26.69	42.83	33.68	41.22			24.71	28.5
28	29	39.05	49.24	35.56	40.82			35.79	44.14
29	30	47.42	57.04	44.86	48.35			43.33	49.96
30	31	47.47	57.22	47.89	56.26			35.79	44.14
31	32	52.46	57.91	53.23	61.37			43.33	50.08
32	33	54.5	59.73	60.44	69.97			43.36	49.96
33	34	57.19	69.26	64.38	71.37			49.27	56.32
34	35	60.18	69.84	63.22	69.76			54.95	61.77
35	36	68.69	73.52	69.03	72.52			66.72	72.11
36	37	67.57	73.52	68.34	72.3	65.59	71.08	64.72	71.25
37	38	67.84	73.23	69.27	78.24	67.49	71.02	71.25	74.38
38	39	70.08	75.79	75.73	83.85	69.67	79.16	73.81	78.35
39	40	77.21	84.59	79.65	86.65	76.44	84.31	80.91	87.43
40	41	80.91	85.74	83.02	88.34	80.64	84.71	83.74	88.36
41	42	78.06	85.45	77.69	84.13	80.64	84.37	85.45	87.43
42	43	78.06	86.01	78.53	83.58	77.26	79.96	75.79	83.45
43	44	78.06	88.57	75.73	82.73	76.25	83.36	76.93	82.61
44	45	80.2	95.1	78.53	86.94	90.14	93.53	83.74	93.69
45	46	86.59	94.39	87.09	101.97	91.49	93.87	91.55	97.58
46	47	91.19	97.58	93.8	103.47	90.47	95.56	91.55	96.87
47	48	94.39	98.64	94.54	103.47	89.12	96.57	92.25	96.16
48	49	95.46	100.43	97.52	104.58	92.08	97.92	92.25	93.33
49	50	98.29	107.17	103.1	105.71	99.11	109.29	96.16	105.74
50	51	99.72	110.71	103.47	113.51	102.51	111.83	98.29	110
51	52	108.23	124.2	104.95	116.12	107.58	116.48	105.13	117.55
52	53	114.45	125.97	110.91	117.99	112.66	123.69	115.17	124.2
53	54	119.32	132.63	115.06	127.77	117.33	125.80	125.08	128.19
54	55	124.2	140.61	119.72	130.33	126.54	138.72	125.08	137.96

55	56	131.52	149.87	123.65	143.28	129.72	143.48	128.9	148.82
56	57	136.24	158.77	134.26	152.84	138.72	153.54	140.93	156.16
57	58	154.07	168.21	148.59	161.34	150.90	164.15	154.58	164.54
58	59	161.39	172.93	160.44	172.35	160.83	171.42	161.39	169.77
59	60	169.77	177.64	168.94	179.14	166.12	172.08	167.36	176.84
60	61	175.02	179.22	170.79	184.95	168.78	171.42	168.71	178.88
61	62	180.1	188.01	173.72	181.57	173.40	180.69	176.89	185.61
62	63	186.03	191.95	185.61	193.84	184.07	189.96	185.61	195.14
63	64	191.29	197.21	188.79	199.14	187.30	199.23	188.79	200.69
64	65	196.55	199.17	189.57	204.65	189.30	199.89	193.54	204.68

Table 6.3 Measurememt Record of Channel Width of River Brahmputra
All Measurements in km

width of river during different periods

S. N	Cross-Section No.	Distance Along Cross-Section	Periods- year			
			1986	1990	1997	2000
1	2	17.34	9.27	15.81	No Computation Due to lack of satellite data	14.67
2	3	28.05	12.26	7.78		9.4
3	4	38.25	13.97	12.2		7.64
4	5	46.92	13	7.74		6.79
5	6	56.61	9.64	10.21		8.92
6	7	66.3	8.91	8.75		8.69
7	8	73.44	9.74	14.98		10.6
8	9	82.62	4.93	7.76		1.84
9	10	92.82	6.75	5.39		5.25
10	11	100.98	8.85	12.49		4.96
11	12	109.65	5.28	15.3		3.89
12	13	119.85	10.9	14.13		2.59
13	14	128.01	8.84	14.76		1.83
14	15	137.7	6.47	12.92		3.23
15	16	146.37	7	7.44		6.03
16	17	156.06	12.2	16.5		14.78
17	18	167.28	14.25	17.46		18.01
18	19	175.95	3.46	14.22		10.57
19	20	182.58	3.57	5.39		3.99
20	21	189.21	1	1.91		2.59
21	22	197.37	1.08	1.29		1.18
22	23	206.55	3.12	1.72		2.8
23	24	213.18	3.78	3.14		3.02
24	25	218.79	7.1	2.6		2.8
25	26	224.91	9.72	4.96		3.62
26	27	234.6	11.2	3.39		3.46
27	28	241.23	16.14	7.54		3.79
28	29	251.95	10.19	5.26		8.35
29	30	262.15	9.62	3.49		6.63
30	31	272.35	9.75	8.37		8.35
31	32	284.08	5.45	8.14		6.75
32	33	296.83	5.23	9.53		6.6
33	34	310.1	12.07	6.99		7.05
34	35	325.91	9.66	6.54		6.82
35	36	354.21	4.83	3.49		5.39
36	37	352.94	5.95	3.96	5.49	6.53
37	38	365.18	5.39	8.97	3.53	3.13
38	39	371.81	5.71	8.12	9.49	4.54
39	40	383.03	7.38	7	7.87	6.52
40	41	389.66	4.83	5.32	4.07	4.62
41	42	398.33	7.39	6.44	3.73	1.98
42	43	412.09	7.95	5.05	2.7	7.66
43	44	423.31	10.51	7	7.11	5.68

44	45	439.63	14.9	8.41	3.39	9.95
45	46	453.91	7.8	14.88	2.38	6.03
46	47	465.13	6.39	9.67	5.09	5.32
47	48	474.82	4.25	8.93	7.45	3.91
48	49	483.49	4.97	7.06	5.84	1.08
49	50	490.63	8.88	2.61	10.18	9.58
50	51	498.8	10.99	10.04	9.32	11.71
51	52	505.94	15.97	11.17	8.9	12.42
52	53	513.08	11.52	7.08	11.03	9.03
53	54	522.77	13.31	12.71	8.47	3.11
54	55	531.95	16.41	10.61	12.18	12.88
55	56	541.13	18.35	19.63	13.76	19.92
56	57	558.98	22.53	18.58	14.82	15.23
57	58	570.2	14.14	12.75	13.25	9.96
58	59	579.38	11.54	11.91	10.59	8.38
59	60	589.07	7.87	10.2	5.96	9.48
60	61	601.82	4.2	14.16	2.64	10.17
61	62	613.04	7.91	7.85	7.29	8.72
62	63	626.3	5.92	8.23	5.89	9.53
63	64	634.46	5.92	10.35	11.93	11.9
64	65	640.07	2.62	15.08	10.59	11.14

Table 6.4 Channel Migration of Brahmputra River during different Periods

Calculation of Bank Line Shifting

Baseline :- 26^0 N Lattitude

Migration (Km) during the periods

S.N	Along X-section	Diff of offsets for L/B of 2000&90-yr img	Diff of offsets for R/B of 2000&90-yr img	Diff. of offsets for L/B of 2000&97- image	Diff. Of offsets for R/B of 2000&97-yr image
1	2	1.19	0.05	No Computation Due to lack of satellite data	No Computation Due to lack of satellite data
2	3	0.31	1.93		
3	4	5.51	0.95		
4	5	0.63	-0.32		
5	6	0.21	-1.08		
6	7	-1.02	-1.08		
7	8	0.74	-3.64		
8	9	-1.08	-7		
9	10	-6.54	-6.68		
10	11	3.23	-4.3		
11	12	7.11	-4.3		
12	13	5.18	-6.36		
13	14	8.1	-4.83		
14	15	7.66	-2.03		
15	16	1.74	0.33		
16	17	0.45	-1.27		
17	18	1.08	-1.63		
18	19	0.64	-3.01		
19	20	0.55	-0.85		
20	21	0.23	0.91		
21	22	-0.1	-0.21		
22	23	0.11	1.19		
23	24	-0.3	-0.42		
24	25	-0.09	0.11		
25	26	-1.26	-2.6		
26	27	-2.14	-2.07		
27	28	-8.97	-12.72		
28	29	0.23	3.32		
29	30	-1.53	1.61		
30	31	-12.1	-12.12		
31	32	-9.9	-11.29		
32	33	-17.08	-20.01		
33	34	-15.11	-15.05		
34	35	-8.27	-7.99		
35	36	-2.31	-0.41		
36	37	-3.62	-1.05	-0.87	0.17
37	38	1.98	-3.86	3.76	3.36
38	39	-1.92	-5.5	4.14	-0.81
39	40	1.26	0.78	4.47	3.12
40	41	0.72	0.02	3.10	3.65
41	42	7.76	3.3	4.81	3.06
42	43	-2.74	-0.13	-1.47	3.49
43	44	1.2	-0.12	0.68	-0.75
44	45	5.21	6.75	-6.40	0.16
45	46	4.46	-4.39	0.06	3.71
46	47	-2.25	-6.6	1.08	1.31
47	48	-2.29	-7.31	3.13	-0.41
48	49	-5.27	-11.25	0.17	-4.59
49	50	-6.94	0.03	-2.95	-3.55
50	51	-5.18	-3.51	-4.22	-1.83

51	52	0.18	1.43	-2.45	1.07
52	53	4.26	6.21	2.51	0.51
53	54	10.02	0.42	7.75	2.39
54	55	5.36	7.63	-1.46	-0.76
55	56	5.25	5.54	-0.82	5.34
56	57	6.67	3.32	2.21	2.62
57	58	5.99	3.2	3.68	0.39
58	59	0.95	-2.58	0.56	-1.65
59	60	-1.58	-2.3	1.24	4.76
60	61	-2.08	-6.07	-0.07	7.46
61	62	3.17	4.04	3.49	4.92
62	63	0	1.3	1.54	5.18
63	64	0	1.55	1.49	1.46
64	65	3.97	0.03	4.24	4.79

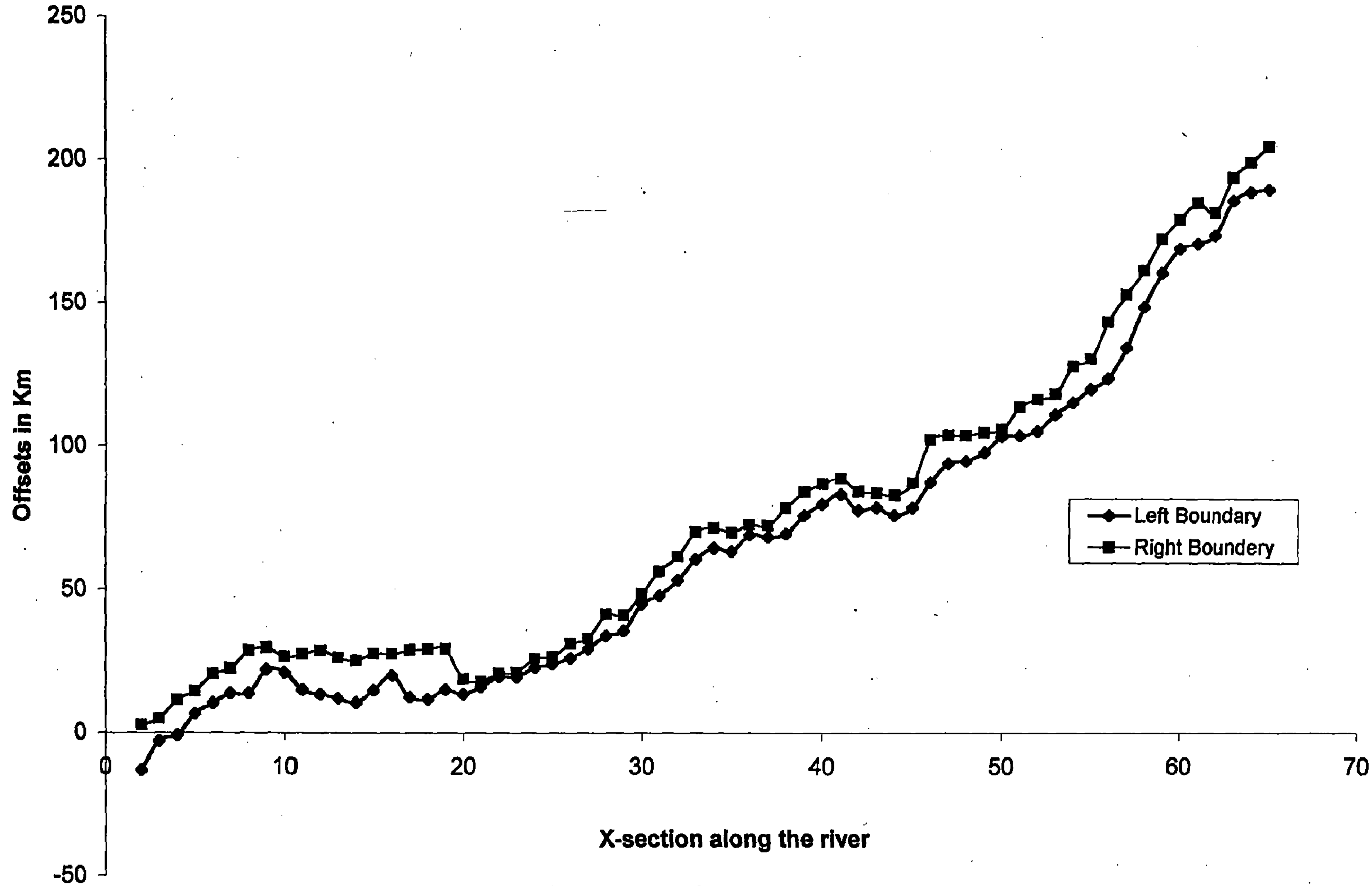


Fig. 6.2 Plan- form of River Brahmaputra year 1990

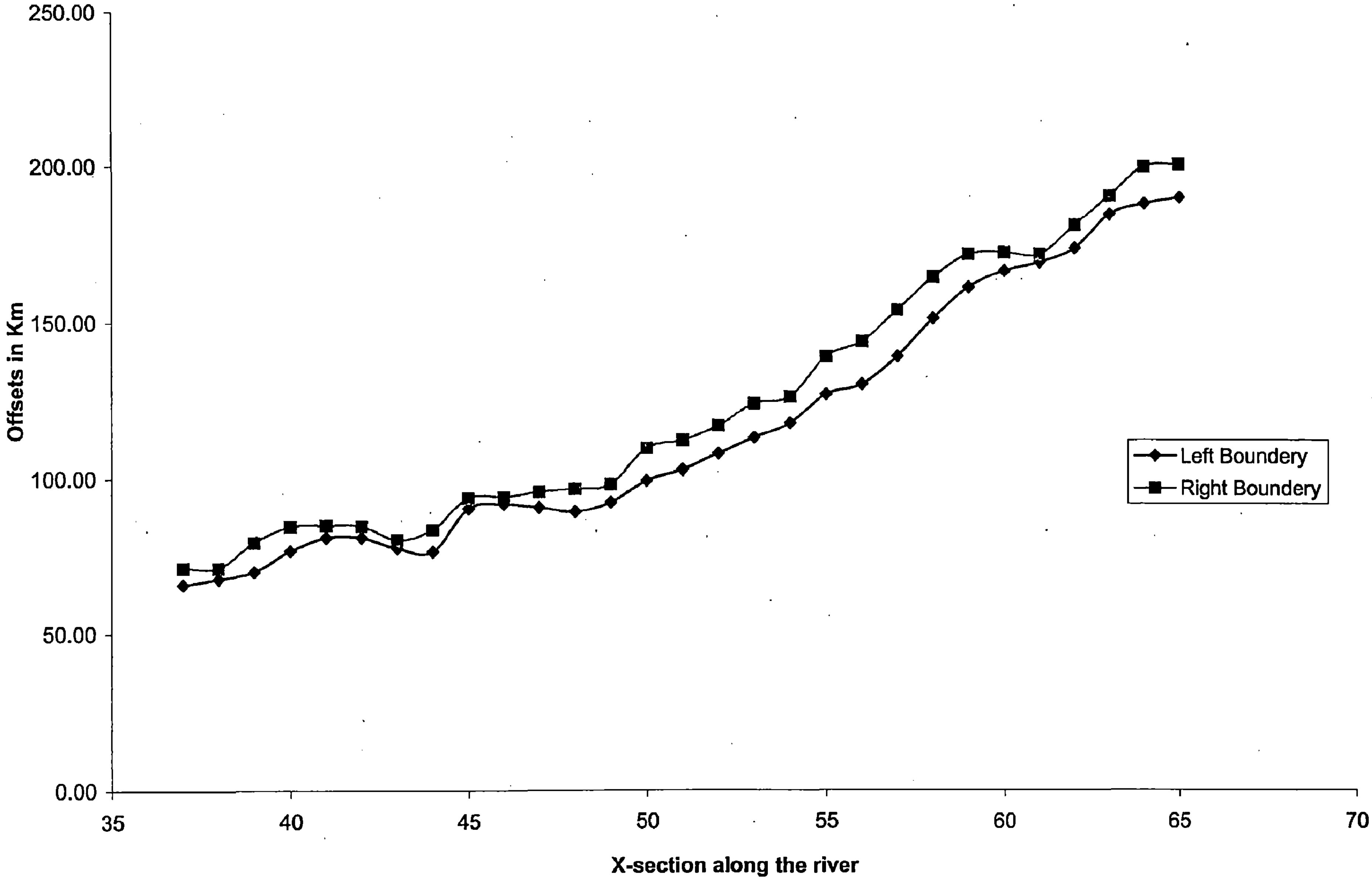


Fig. 6.3 Plan- form of River Brahmaputra year 1997

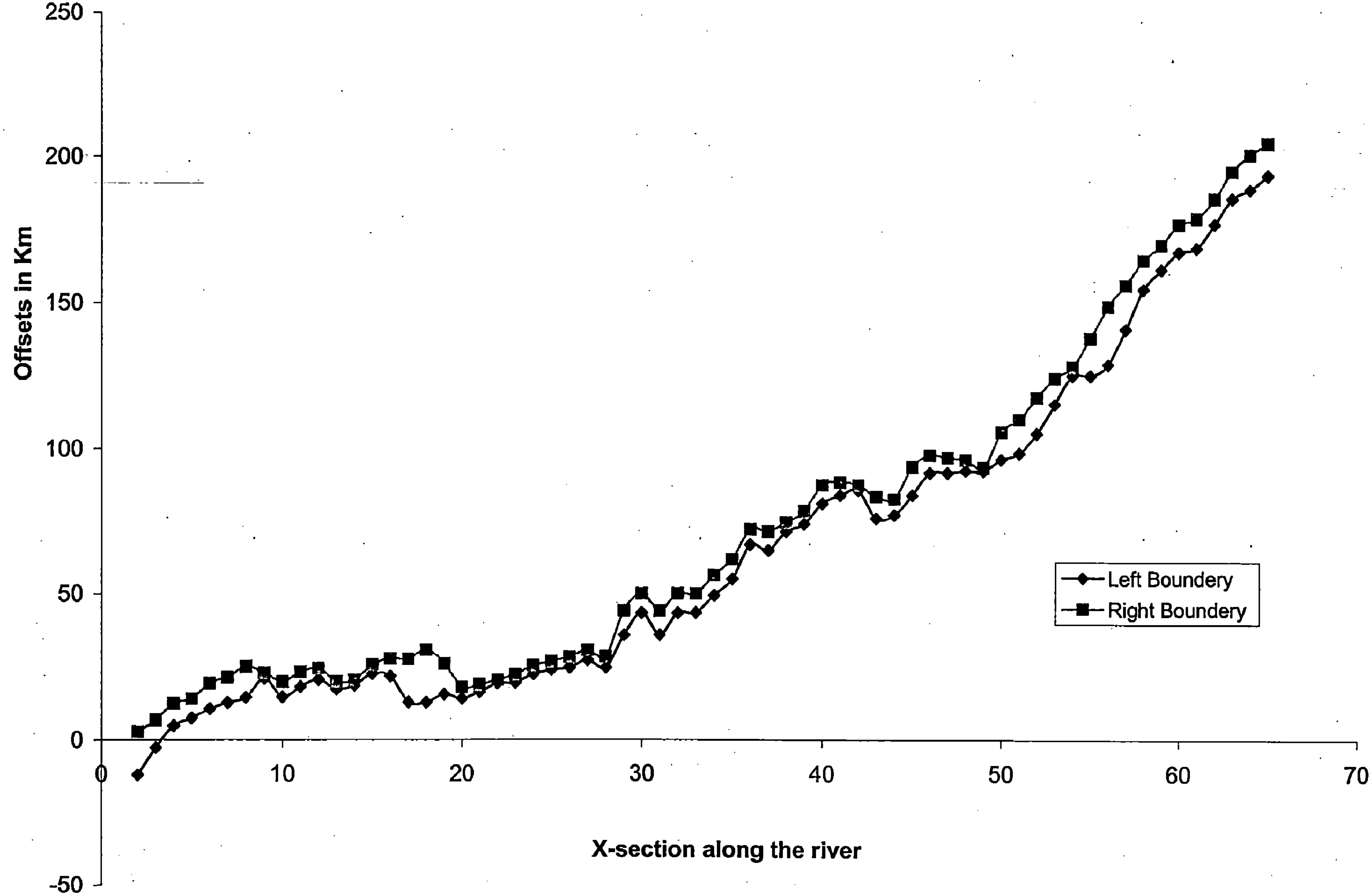


Fig. 6.4 Plan- form of River Brahmaputra year 2000 .

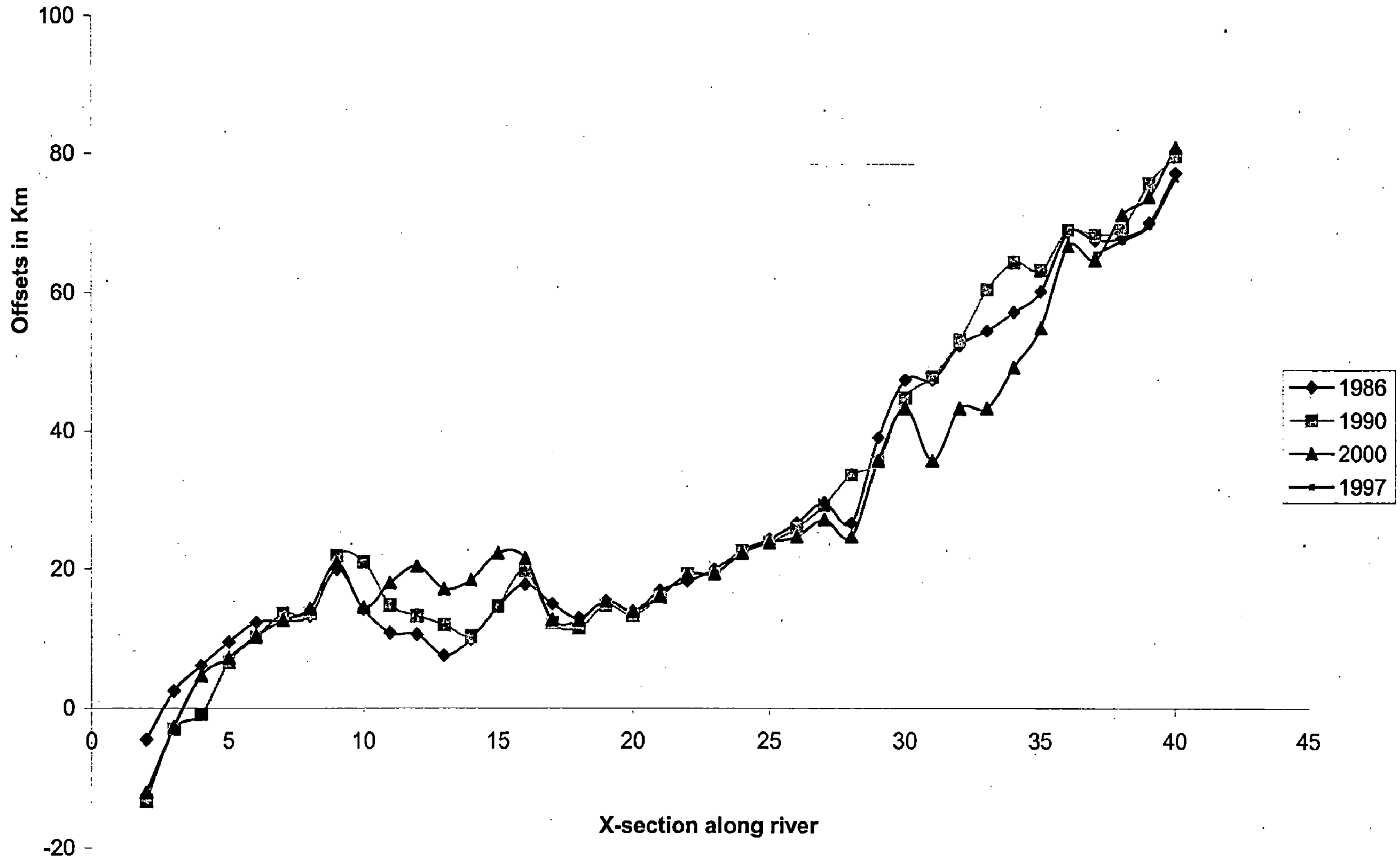


Fig. 6.5 Position of Left Boundary of River

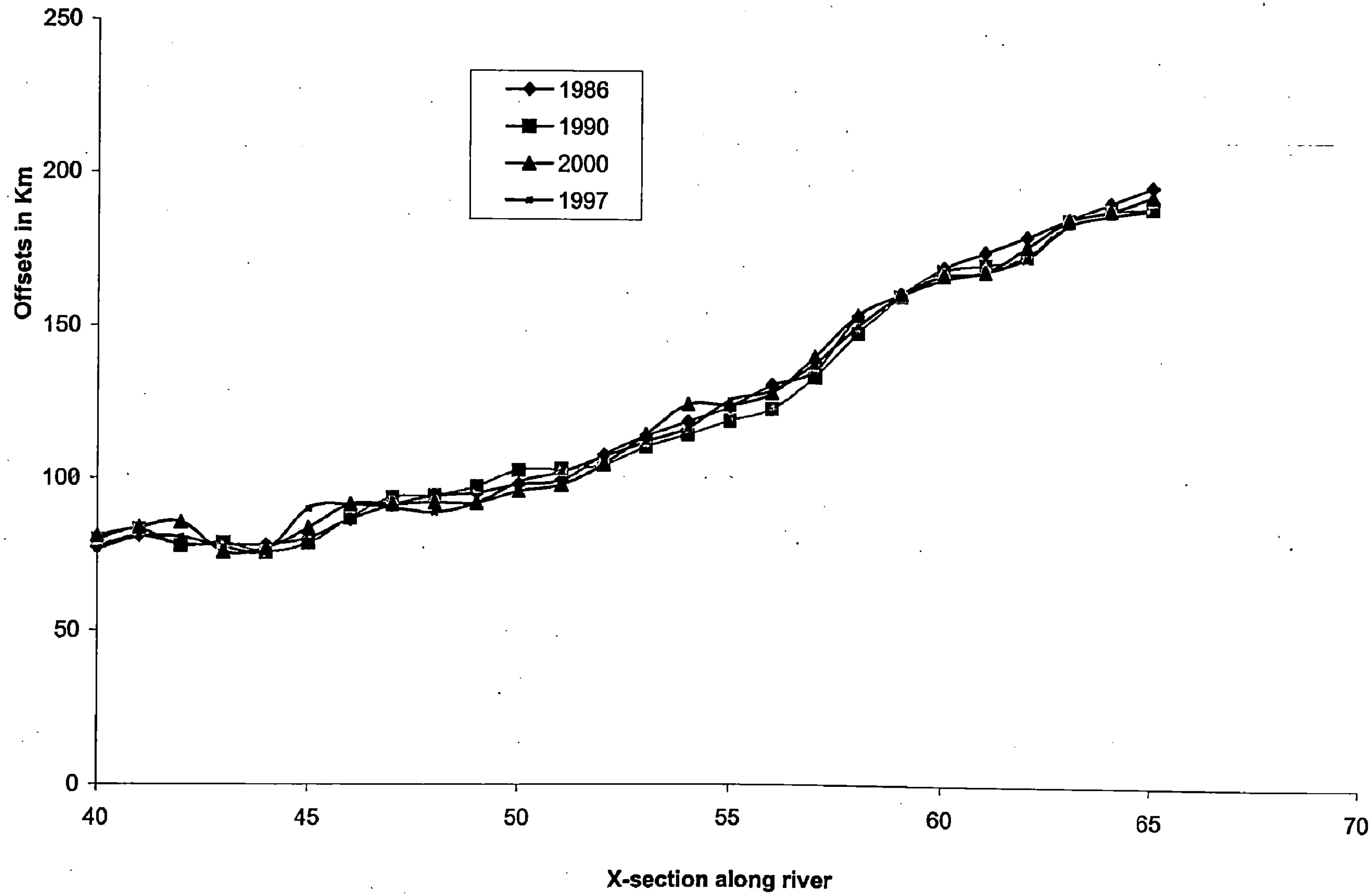


Fig. 6.6 Postion of Left Boundary of River

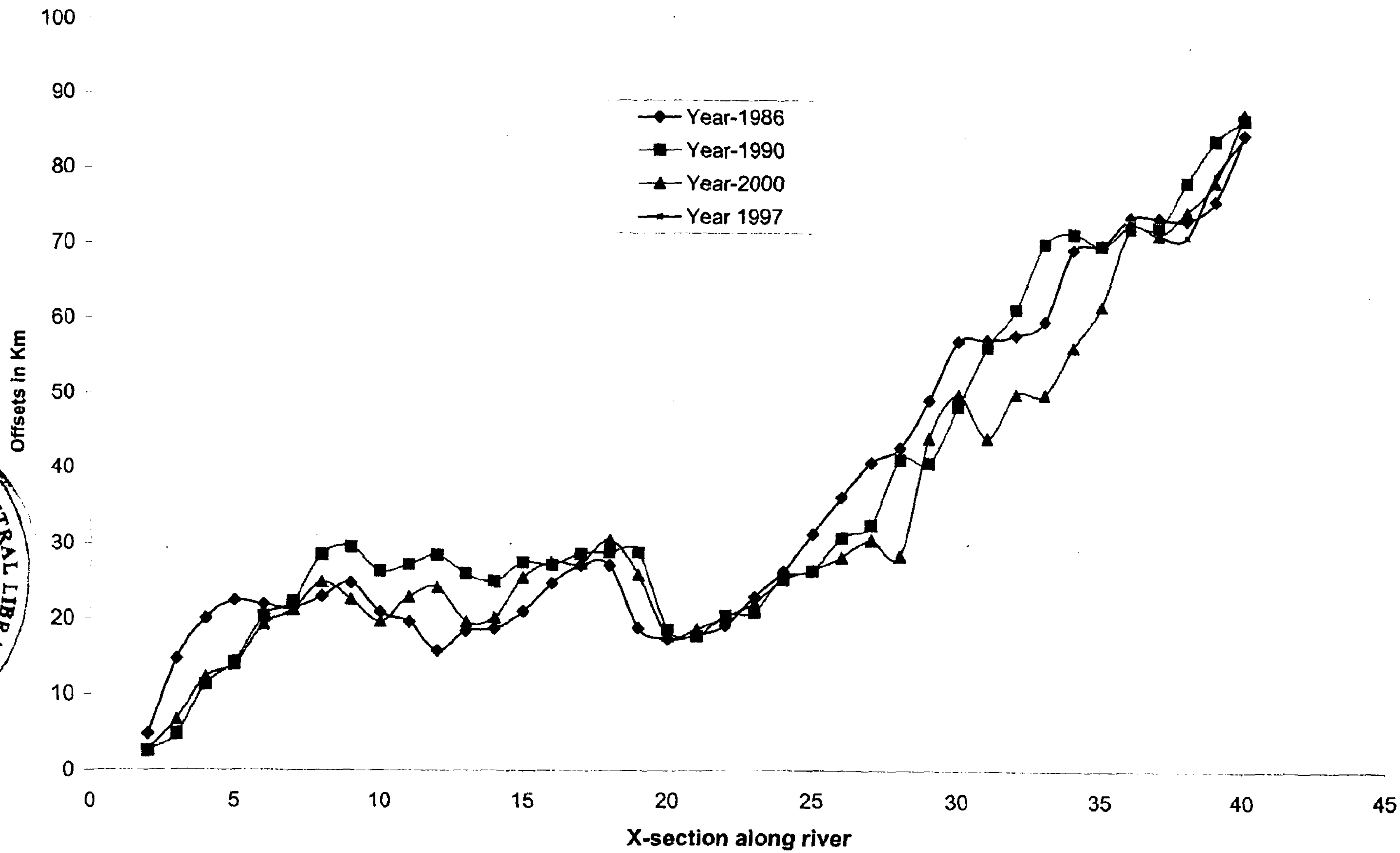


Fig. 6.7 Postion of Right Boundary of River

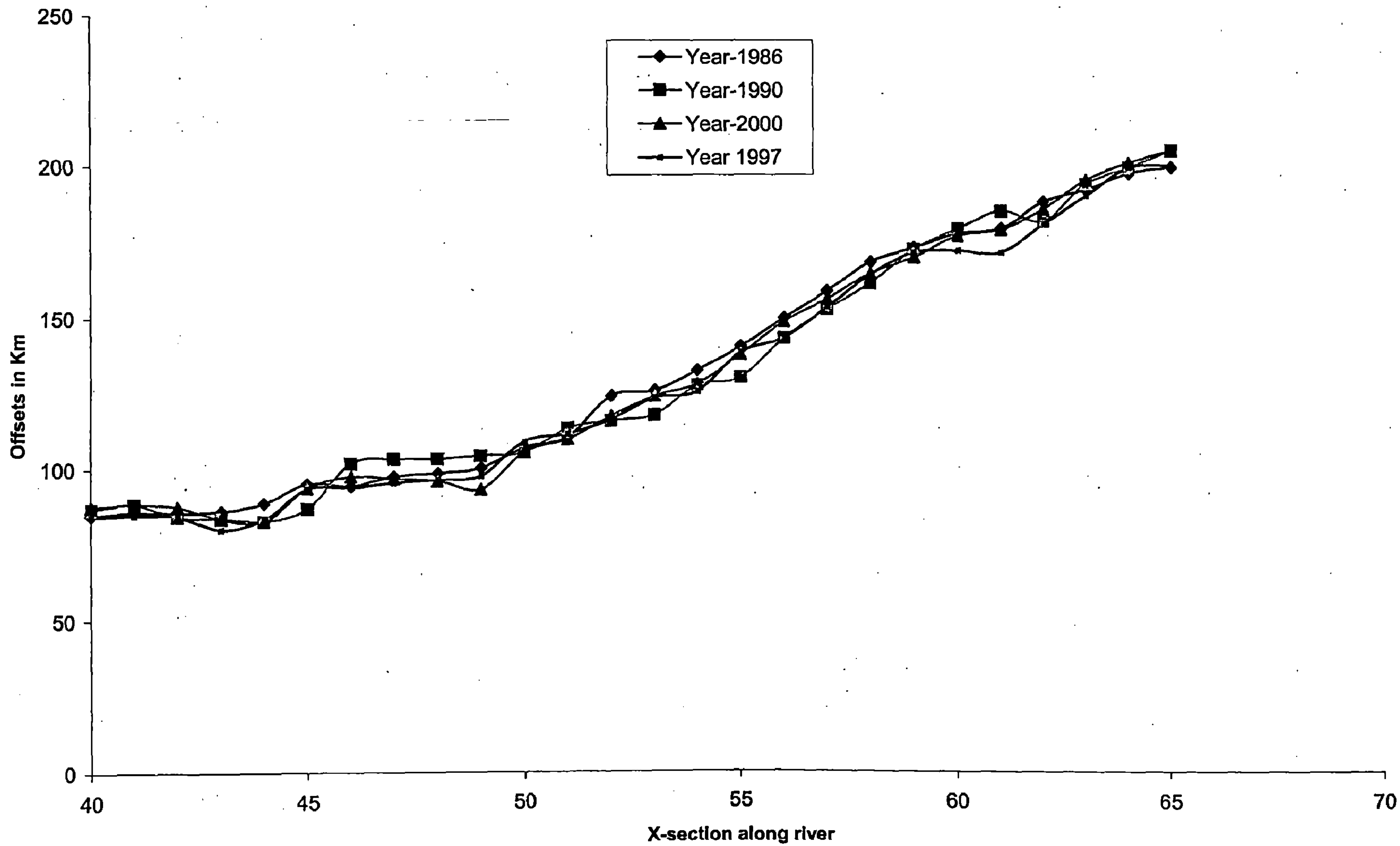


Fig. 6.8 Postion of Right Boundary of River

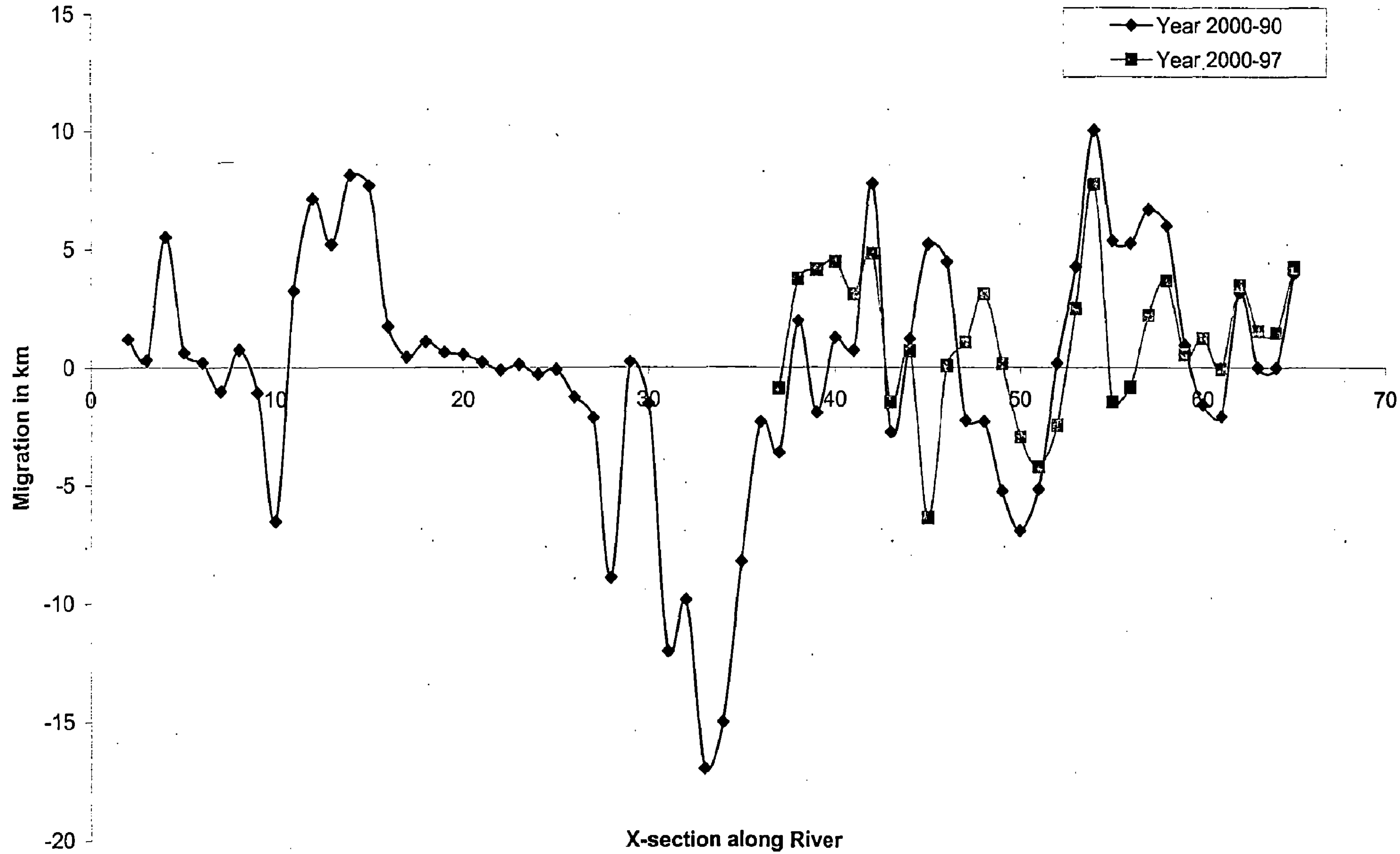


Fig. 6.9 Left bank migration

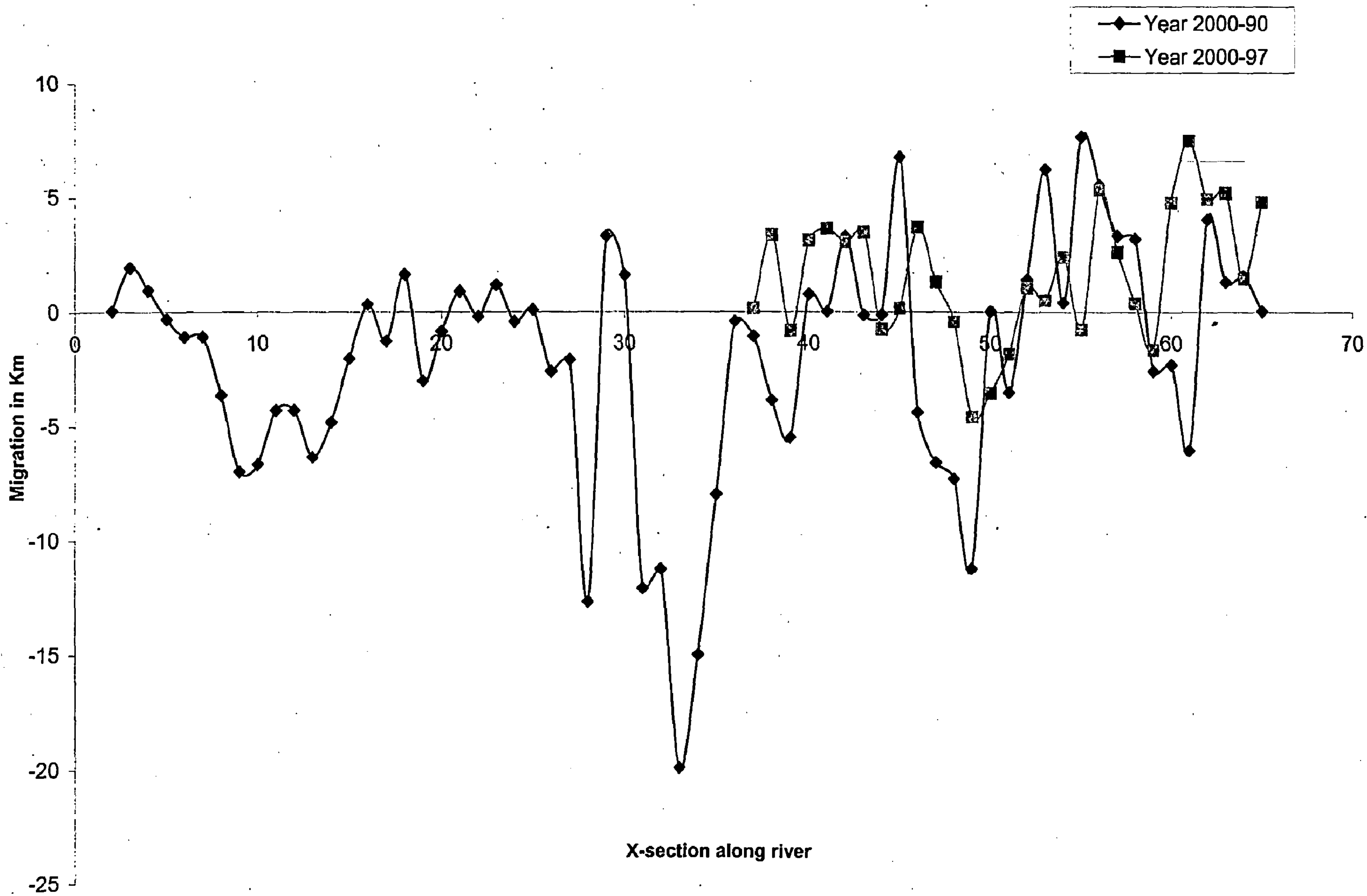


Fig. 6.10 Right bank migration

whole reach having the length of 89.76 kms is influenced by deposition. River is changing its course towards North over this reach. However the width of the river is decreased.

6.2.3. Reach – 3

This reach has a length of 79.5 km. For the left bank, over 9 kms length, there is deposition. The remaining 70 kms length channel bank is affected by erosion tendency and it is migrating towards South. In the case of right bank, mixed trend of deposition and erosion has been observed. Maximum deposition occurs in between chainage 224.91 kms to chainage 251.95 kms i.e., from X-section no 26 to X-section no 29. River width also is varying. It varies at different X-sections of this reach. However river width does not change significantly.

6.2.4. Reach – 4

In this reach, all X-sections on left bank except at X-section no.37 and 40, shows trend of erosion and are migrating towards South. In the case of right bank, there is deposition tendency and it is migrating towards South. Thus left bank shows erosion while right bank shows deposition for the whole reach. River width is decreasing between X-section no.31 to X-section no.33 and where as it is increasing between X-section no.34 to X-section no 36.

6.2.5. Reach - 5

During the period 1990 and 2000, from X-section no.40 to X-section no.42 in (15 kms length), it shows deposition on left bank and erosion on right bank. Again the left bank shows deposition between X-section no.44 to X-section no.46 while it shows erosion between X-section no.47 to X-section no.50. The right bank shows deposition in between X-section no.46 to X-section no.49. The river width has increased only at X-section no.43, X-section no.45 and X-section no.50 and for remaining X-section, there is decrease in river width.

During the period 1997 and 2000, the left bank has deposition tendency between X-section no.40 to X-section no.42 and also between X-section no.46 to X-section no.49. Other remaining X-sections show erosion along this bank. Similarly right bank has erosion tendency in between X-section no.40 to X-section no.43 and X-section no.45 to X-section no.47. Deposition also takes place along right bank in between X-section no.48 to X-section no.50. River width varies at different X-sections.

6.2.6. Reach – 6

Deposition is observed along left bank during the period 1990 and 2000 while there is erosion on right bank.

During the period 1997 and 2000, X-section no.51 to X-section no.52 and X-section no.55 to X-section no.56, show tendency of deposition where as X-section no.53 to X-section no.54 and X-section no.57 to X-section no.60 show tendency of erosion along the left bank. On the right bank, X-section no.52 to X-section no.54 and X-section no.56 to X-section no.58 erosion.

For both the duration 1990 and 2000, 1997 and 2000, the river width is increased at X-section no.51 to X-section and X-section no.55 to X-section no.56 while it is decreased at X-section no.54, X-section no.58 to X-section no.59.

6.2.7. Reach – 7

During the period 1990 and 2000 left bank have mixed nature of both deposition and erosion while along right boundary there is erosion. During the period 1997 and 2000 there is deposition along left bank and erosion along right bank.

During the period 1990 to 2000, the width of the river has increased at some X-sections while it has decreased at others but during the period 1997 to 2000, the river width has increased. The deposition and erosion on the reach basis is given in Table no. 6.5 The minimum and maximum widths of river Brahmaputra have been summarized in Table no. 6.6.

Table no. 6.5 Summary of Plan form analysis on reach basis

Reach	During Periods	
	1990-2000	1997-2000
I	Deposition	-
II	Deposition	-
III	Erosion	-
IV	Deposition	-
V	Deposition	Deposition
VI	Deposition	Deposition
VII	Erosion	Erosion

Table no 6.6 The minimum and maximum width of river on Reach basis

Reach	Width km during the period		
	1990	1997	2000
I	5.34-15.81	-	1.84-14.67
II	5.39-17.46	-	1.83-18.01
III	1.29-8.37	-	1.18-8.35
IV	3.49-9.53	-	3.13-8.35
V	2.61-14.88	2.38-9.49	1.08-9.95
VI	7.08-19.63	8.46-14.82	3.11-11.92
VII	7.85-15.08	2.64-11.92	8.72-11.90

6.3. ANALYSIS OF MEANDERING AND BRAIDING PARAMETERS

The meandering and Braiding parameters have been analyzed for each reach. The satellite imagery map of year 1990, 1997 and 2000 have been digitized in different layers i.e., Bank line, Channel patterns and Islands. From these maps, the Meandering and Braiding parameters - Sinuosity (P), Braiding Index (BI), Braid Channel Ratio (B) and Plan form Index (PFI) are computed. The computations of these parameters are shown in Table No.6.7. A comparative assessment of these parameter as per reach basis for the years 1990, 1997 and 2000 for the years 1990, 1997 and 2000 is given in Table 6.8.

The variations of number of Channels, Islands, Sinuosity (P), Braiding Index (BI), Braid Channel Ratio (B) and Planform Index (PFI) are shown in fig.6.12 to fig. 6.17.

Table : 6.7 Computation of Braiding and Meandering Parameters during 90, 97and 2000

Year 1990, All measurements are in metres

Reach	Length of Reach(L_R)	no of channels	no of Island	Lr	Lc max	Lc total	River Width B	T	Sum Li	P	BI	BCR	PFI %
I	65280	9	21	127243	90660	85540	10000	4000	77951	1.39	1.23	0.94	4.44
II	89760	11	16	81580	96882	123187	13000	2900	95104	1.08	2.33	1.27	2.03
III	79570	7	8	73974	76068	56407	3500	2000	47520	0.96	1.28	0.74	8.16
IV	120880	8	16	120315	129805	130810	7100	2500	88770	1.07	1.48	1.01	4.40
V	107600	8	21	115514	131370	98145	7500	4000	119845	1.22	2.07	0.75	6.67
VI	98440	11	23	111600	108493	126275	12400	3800	118050	1.10	2.12	1.16	2.79
VII	51000	5	7	50134	61500	23335	11000	1700	26410	1.21	1.05	0.38	3.09

Year 1997, All measurements are in metres

Reach	Length of Reach(L_R)	no of channels	no of Island	Lr	Lc max	Lc total	River Width B	T	Sum Li	P	BI	BCR	PFI %
I	65280												
II	89760												
III	79570												
IV	120880												
V	82100	19	20	82785	84889	123586	4000	2200	80231	1.03	1.94	1.46	2.89
VI	98440	44	69	102826	121853	277240	10800	3400	246200	1.19	4.79	2.28	0.72
VII	51000	29	26	59447	66570	103384	7600	2400	68853	1.12	2.32	1.55	1.09

Year 2000, All measurements are in metres

Reach	Length of Reach(L_R)	no of channels	no of Island	Lr	Lc max	Lc total	River Width B	T	Sum Li	P	BI	BCR	PFI %
I	65280	15	17	77040	88345	142525	9960	3500	137715	1.35	3.58	1.61	2.34
II	89760	25	41	81713	99507	202963	4620	3100	191092	1.11	4.68	2.04	2.68
III	79570	8	6	68048	69731	41665	5310	2600	28466	0.88	0.84	0.60	6.12
IV	120880	24	25	132380	148531	205136	5470	2500	145720	1.23	2.20	1.38	1.90
V	107600	20	19	111370	126159	190620	8050	3100	97855	1.17	1.76	1.51	1.93
VI	98440	40	41	101805	121454	300005	9530	4100	176243	1.23	3.46	2.47	1.08
VII	51000	12	19	49810	59400	135800	10031	3900	58700	1.16	2.36	2.29	3.24

Table 6.8 Summary of Various Morphological Parameters

Reach	Various Morphological Parameters During Different Years																		Assessment
	Number of Channels			Number of Islands			Sinuosity			Breading Index			Braid Channel Ratio			Plan Form Index %			
Year	1990	1997	2000	1990	1997	2000	1990	1997	2000	1990	1997	2000	1990	1997	2000	1990	1997	2000	
I	9		15	21		17	1.39	-	1.35	1.23		3.58	0.94	-	1.61	4.44	-	2.34	River is braided. It is unstable
II	11		25	16		41	1.08	-	1.11	2.33	-	4.68	1.27	-	2.04	2.03	-	2.68	High degree of Braiding. River is unstable
III	7		8	8		6	0.96	-	0.88	1.28	-	0.84	0.74	-	0.60	8.16	-	6.12	Lower degree of Braiding. It is unstable.
VI	8		24	16		25	1.07	-	1.23	1.48	-	2.20	1.01	-	1.38	4.40	-	1.90	High degree of Braiding. River is unstable.
V	8	19	20	21	20	19	1.22	1.03	1.17	2.07	1.94	1.76	0.75	1.46	1.51	6.67	2.89	1.93	High degree of Braiding. River is unstable.
VI	11	44	40	23	69	41	1.10	1.19	1.23	2.12	4.79	3.46	1.16	2.28	2.47	2.79	0.72	1.08	River is highly braided and unstable
VII	5	29	12	7	26	19	1.21	1.12	1.16	1.95	2.32	2.36	0.38	1.55	2.29	3.09	1.09	3.24	High degree of braiding. River is unstable

From above table it is clear that the river is not sinuous but it is braided and unstable at each reach. Reach 3 has lower degree of braiding in year 1990 as well as in year 2000. Reach 6 and 7 in year 1997 are highly braided and unstable. Similarly it can be observed that river has high degree of braiding characters in year 2000 than year 1990

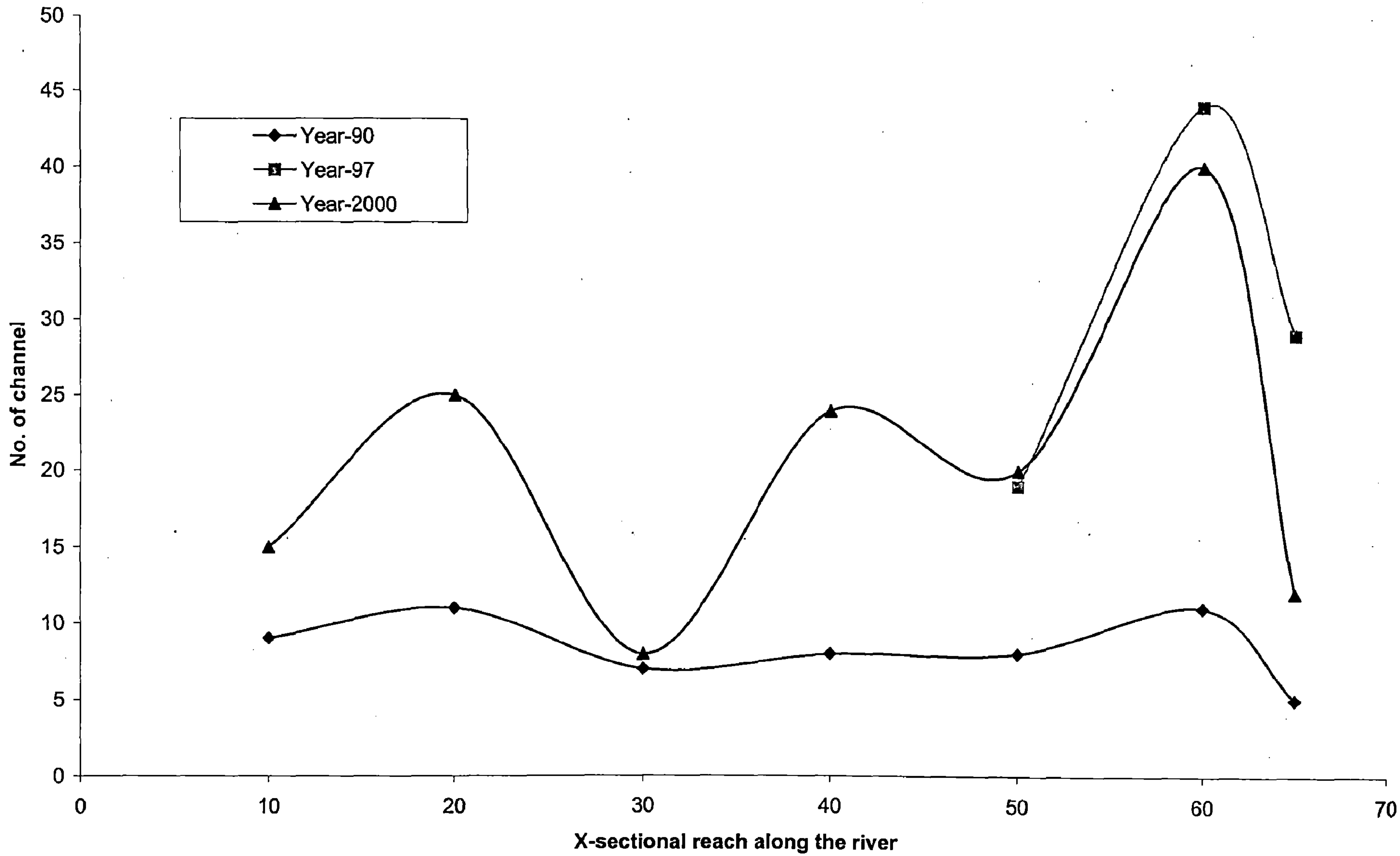


Fig. 6.12 Variation of number of channel of the river Brahmaputra

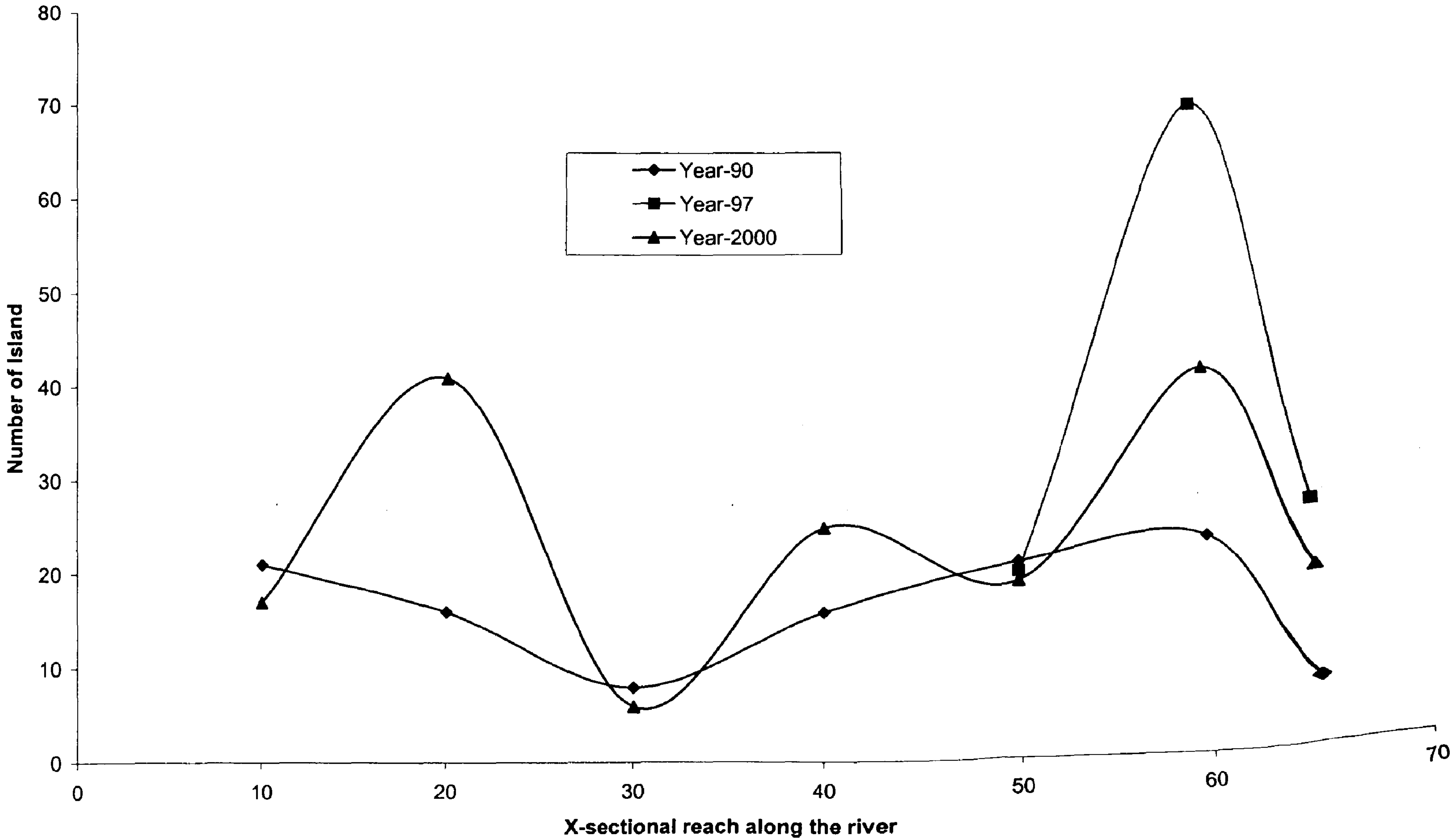


Fig. 6.13 Variation of Islands of the river Brahmaputra

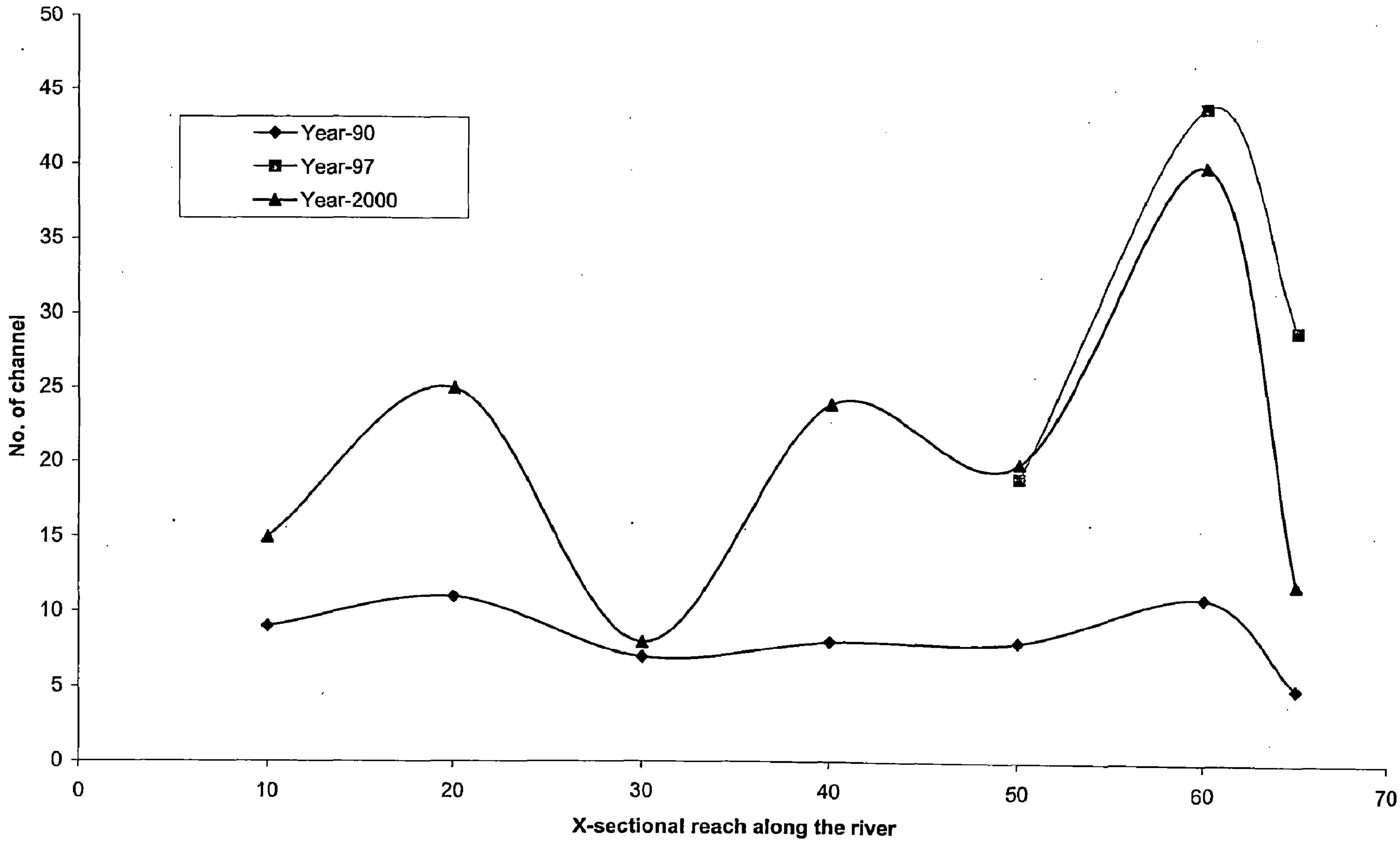


Fig. 6.12 Variation of number of channel of the river Brahmaputra

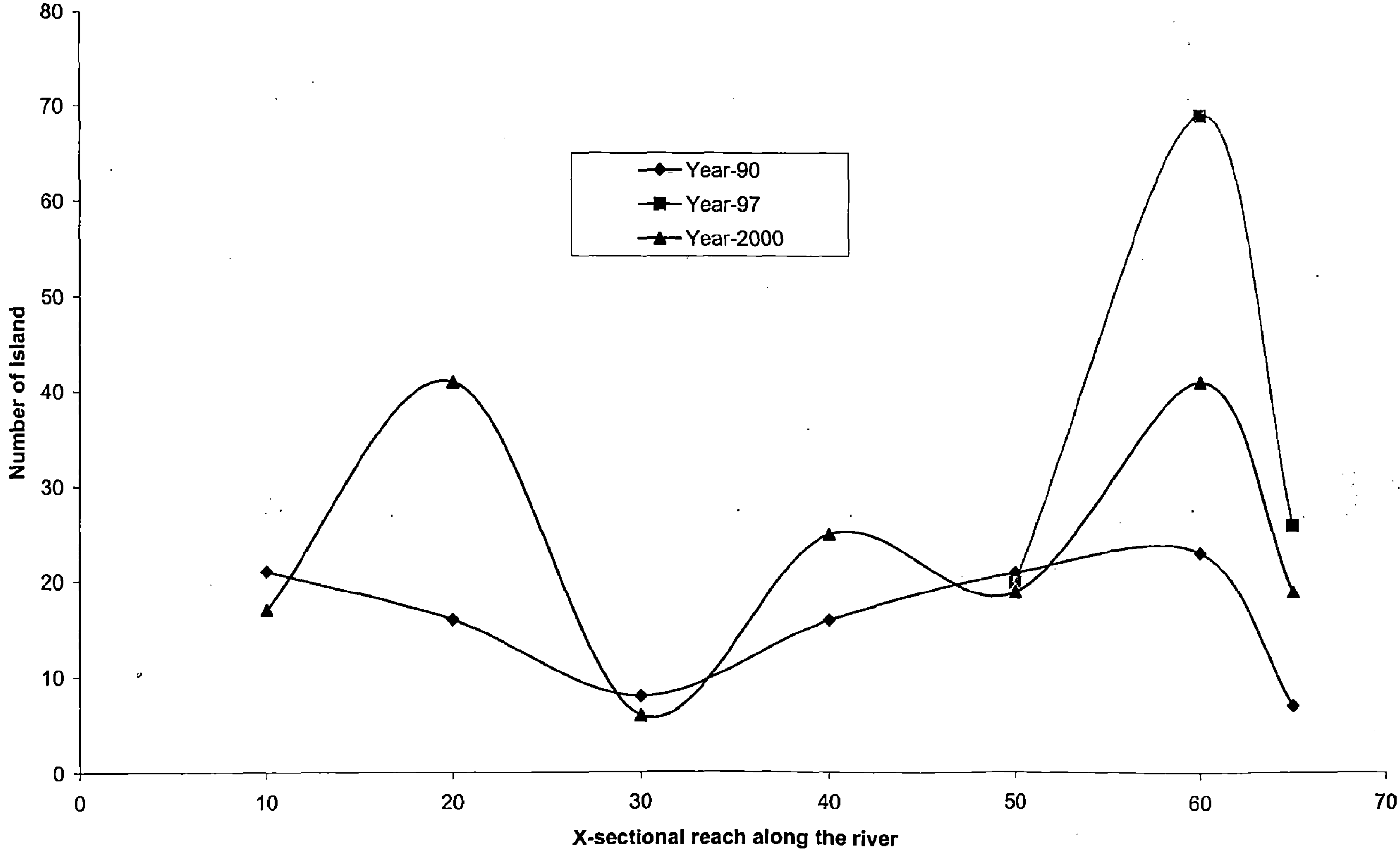


Fig. 6.13 Variation of Islands of the river Brahmaputra

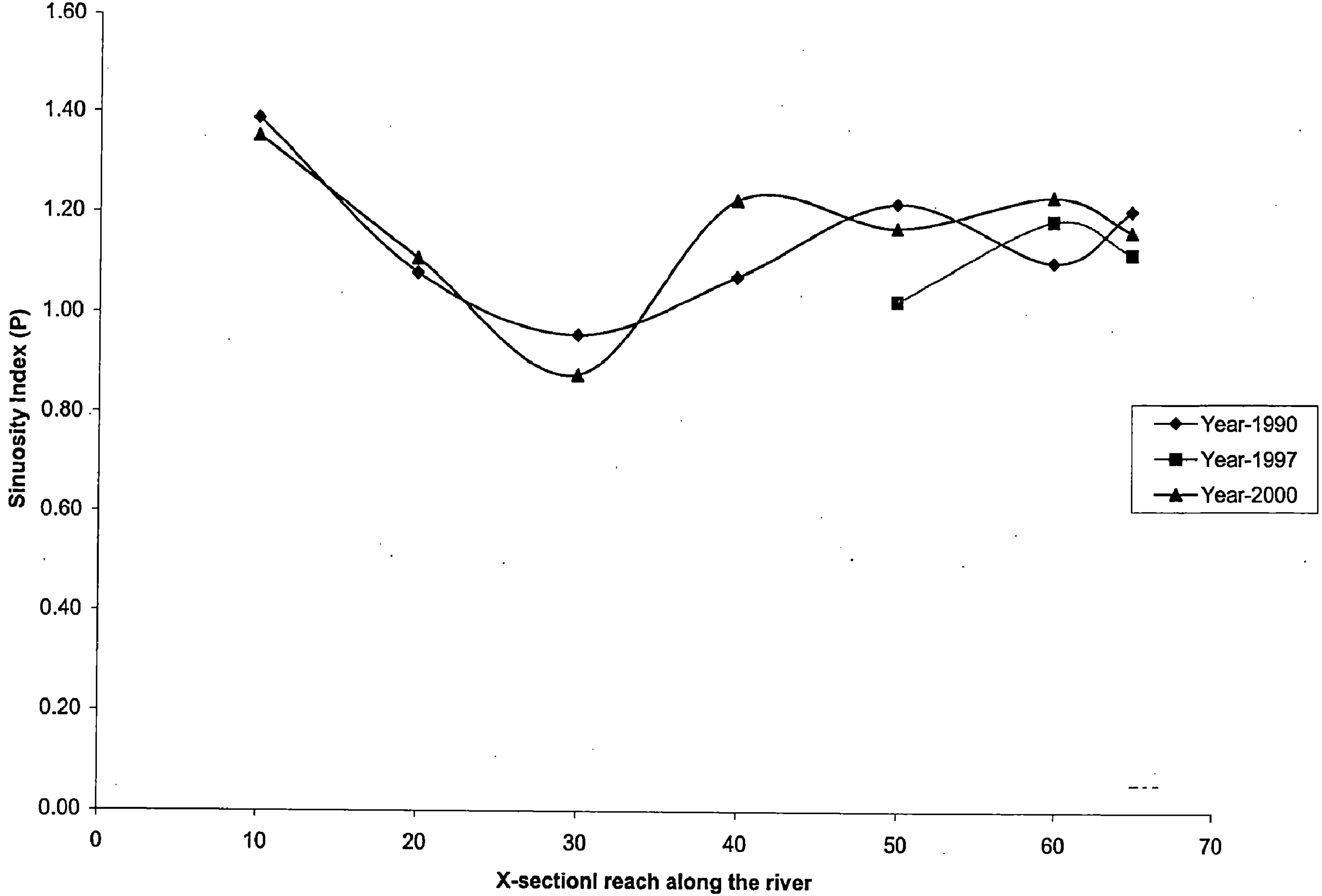


Fig. 6.14 Variation of Sinuosity Index (P) of River Brahmaputra

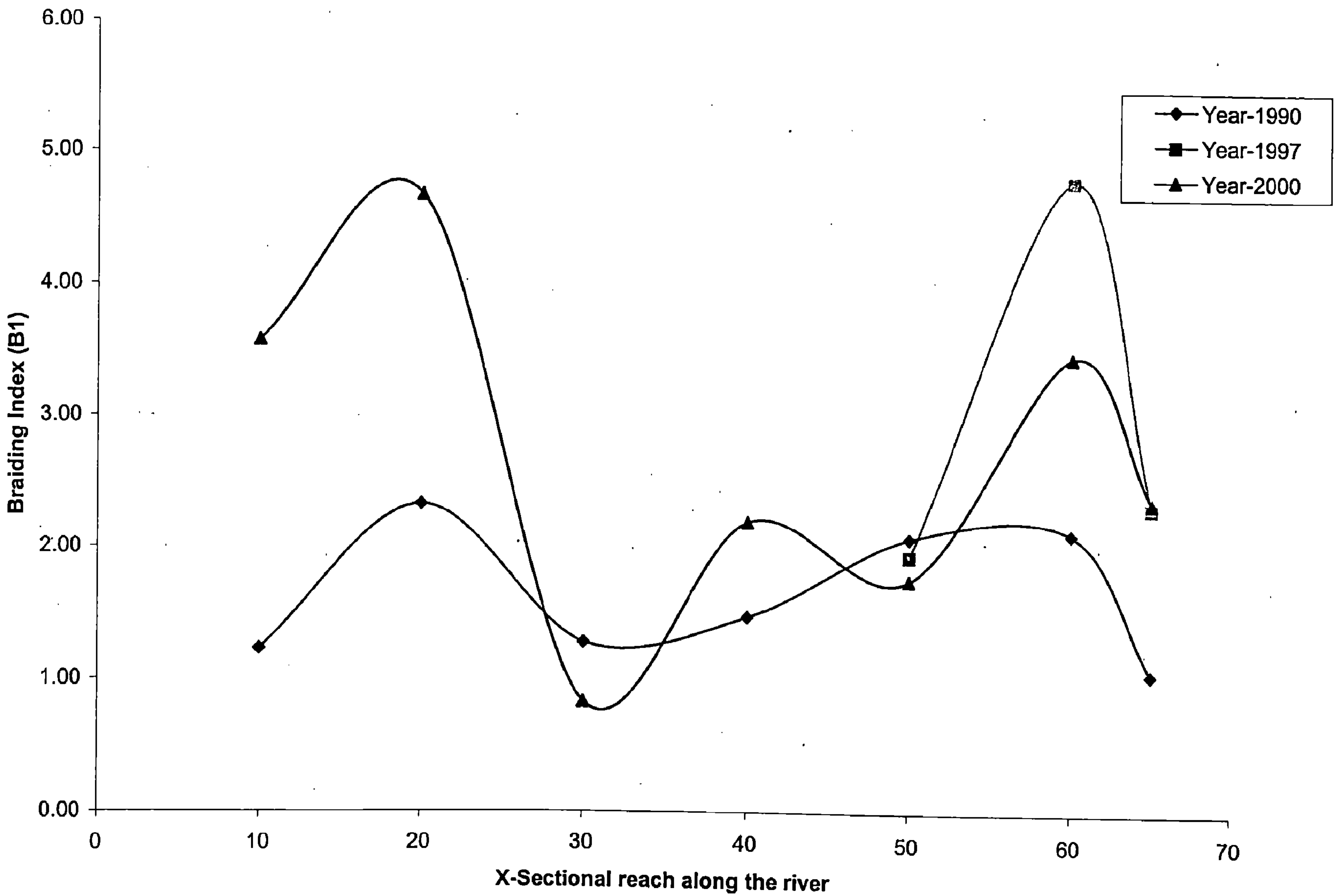


Fig. 6.15 Variation of Braiding Index (BI) of River Brahmaputra

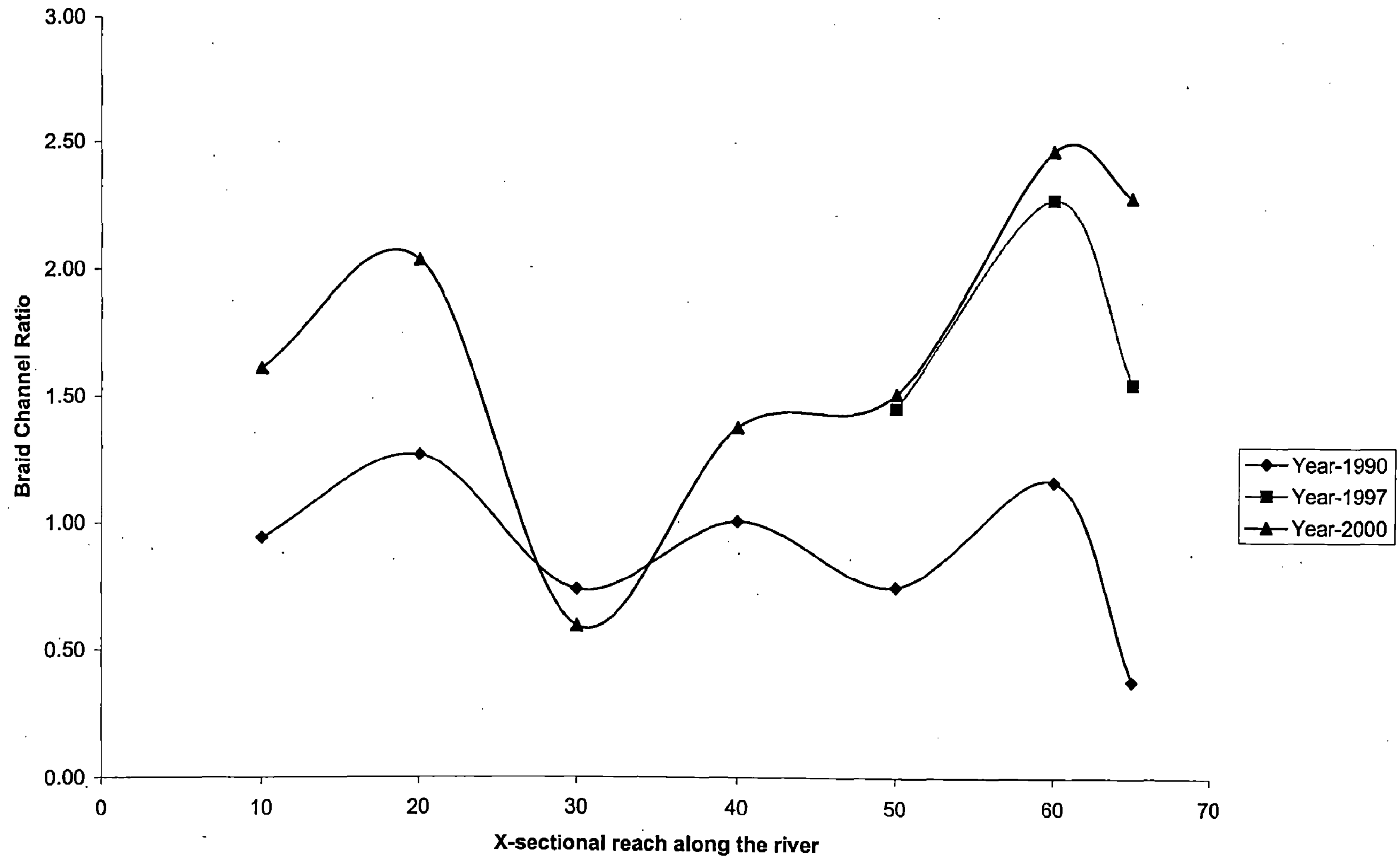


Fig. 6.16 Variation of Braid Channel Ratio (B) of River Brahmaputra

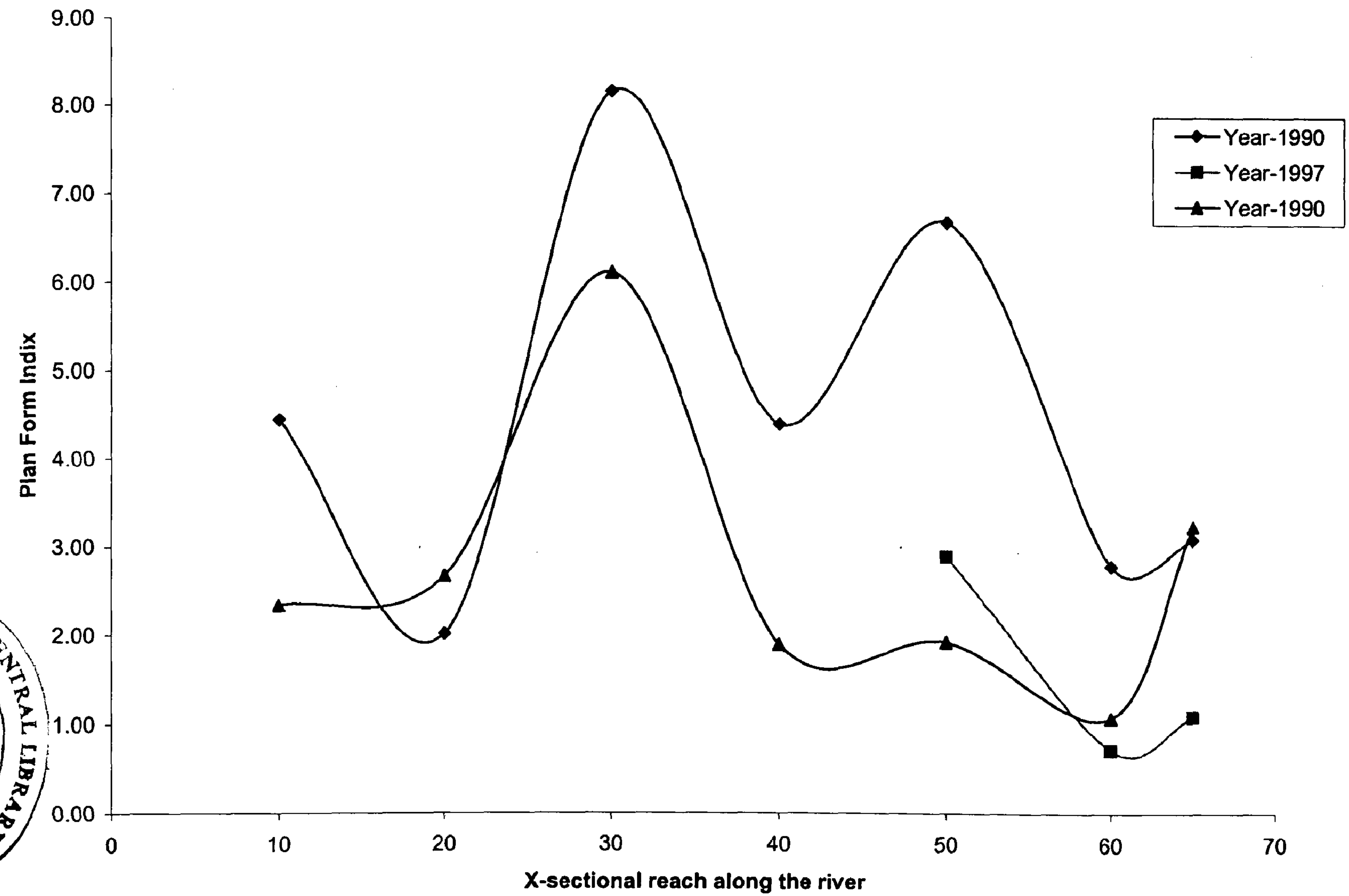


Fig. 6.17 Variation of Plan Form Index (PFI) of River Brahmaputra

CONCLUSION AND SCOPE FOR FUTURE WORK

7.1 CONCLUSIONS

The following conclusions are drawn from this study: -

1. Remote sensing is one of the efficient well-established, ideal data sets of GIS, as the repetitive coverage of data can help in understanding and analyzing dynamic phenomena with confidence and more accuracy.
2. On the basis of Plan-form study it can be concluded that river has a mixed trend of boundary migration towards North and South where ever is possible depending upon nature of river bank and flow pattern. However it is observed that the general tendency of river migration is towards South.
3. The meandering parameters indicate that the river does not show the Sinuous character. At every reach the river is showing braiding character. Braiding Index increases from 1990 to 2000, showing the higher degree of braiding in 2000.
4. The Plan-form Index is getting reduced by the year 2000. It also signifies the higher degree of braiding nature of river.

7.2 SCOPE FOR THE FURTHER WORK

1. The river morphology should be studied on the basis of long term and short term considering hydrographic data in addition to Satellite data.
2. Study should be extended for rainy- season and dry season. It can be beneficial while identifying the seasonal variations well as permanent variation for different morphological parameters.

3. The above-described Morphological parameters are not able to explain the braiding phenomena in terms of key variables like water level, hydraulic radius, and velocity. Also they do not account for under water braid bars and submerged channel configurations. Therefore mathematical modeling can also be used in addition to above described parameters to understand the morphological characteristics of the channel.

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