ABSTRACT

FLUVIO-MORPHOLOGICAL IMPACT OF PAGLADIYA-MORAPAGLADIYA RIVERS ON RURAL SETTLEMENTS

By

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SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENT OF THE
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INTRODUCTION:

There exists a close association of man with the rivers since early times. Therefore, one of the most conspicuous attributes of human settlements is man's affinity for riverine locations. From time immemorable, man has been attracted to riverine areas. There are good number of reasons for the strong attraction to riverine plains to man. The floodplain, from the geomorphic point of view, is the most dynamic topographic surface.

Although a floodplain is advantageous in many respects for human settlements, it can be a mixed blessing when the river overflows its banks causing a heavy toll of public life, property and displacement of settlements. During the flood bank erosion and channel migration pattern change the geomorphic features in a floodplain which indirectly affects human activities as well as settlement distribution pattern in different ways. It is obvious that the increasing population with economic activities have accelerated pressure on the floodplains. As a result, more and more areas under floodplain are converted to human settlements and this upsets the ecological balance. Due to heavy destruction of natural habitation by man for settlement and agriculture serious consequences of flood, erosion, channel change and other related problems are wrought on the riverine plain.

THE PROBLEM:

In Assam throughout the course of the river Brahmaputra there are innumerable tributaries coming out of the northern and north-eastern hill ranges. The Pagladiya, Morapagladiya and Burhadiya rivers are the principal north bank tributaries of the Brahmaputra system. These three rivers have formed a drainage complex since their sub-streams are interlinked throughout the courses from foothills to active floodplain zone covering most part of the Nalbari district. Since the great earthquake of 1950 the fury of flood has been increasing as the earthquake had changed the topography of the area with the other parts of Assam. Due to changes in the course of the Pagladiya and Morapagladiya rivers the whole district has become flood prone. Shifting of channel with excessive sediment load and devastating flood cause heavy Damage to human life, property, settlements and land resources in the nearby villages.

Pagladiya river especially possesses some unique features having short courses without a permanent bank line due to frequent shifting of the channels. The general tendency of channel shifting is mainly towards east. The other rivers of the area like- Morapagladiya and Burhadiya also tend to change their courses during the monsoon season. Occurrence of flood of these rivers is a rule rather than exception due to heavy rainfall during monsoon months.

The study of the impact of channel shifting and flood on rural settlements is very much useful and relevant in fluvial geomorphology. Therefore, a detail study on the displacement of settlements in the Pagladiya-Morapagladiya drainage complex is very important considering rainfall, frequency and intensity of floods which are directly responsible for drainage channel changes.

OBJECTIVES OF THE STUDY:

The study is intended to examine the impact of fluvio-morphological actions such as bank erosion, channel changes and flood inundation on rural settlements in respect of their displacement pattern.

The principal objectives are:

i) to study the process of channel migration in the Pagladiya-Morapagladiya drainage complex;

ii) to asses the displacement pattern of human settlement in different geomorphic units arising out of changes in channel courses; and

iii) to analyse the spatio-temporal features of settlement displacement with respect to changing pattern of rainfall, channel migration, flood frequency and intensity and geomorphic features over time.

RESEARCH QUESTIONS:

To arrive at the objectives the following questions are formulated:

i) What is the impact of 1897 and 1950 earthquakes on the channel changes of the Pagladiya- Morapagladiya drainage complex?

ii) What are the cause-effect relationship among the variables- rainfall, floods and micro-geomorphic changes and settlement over time?

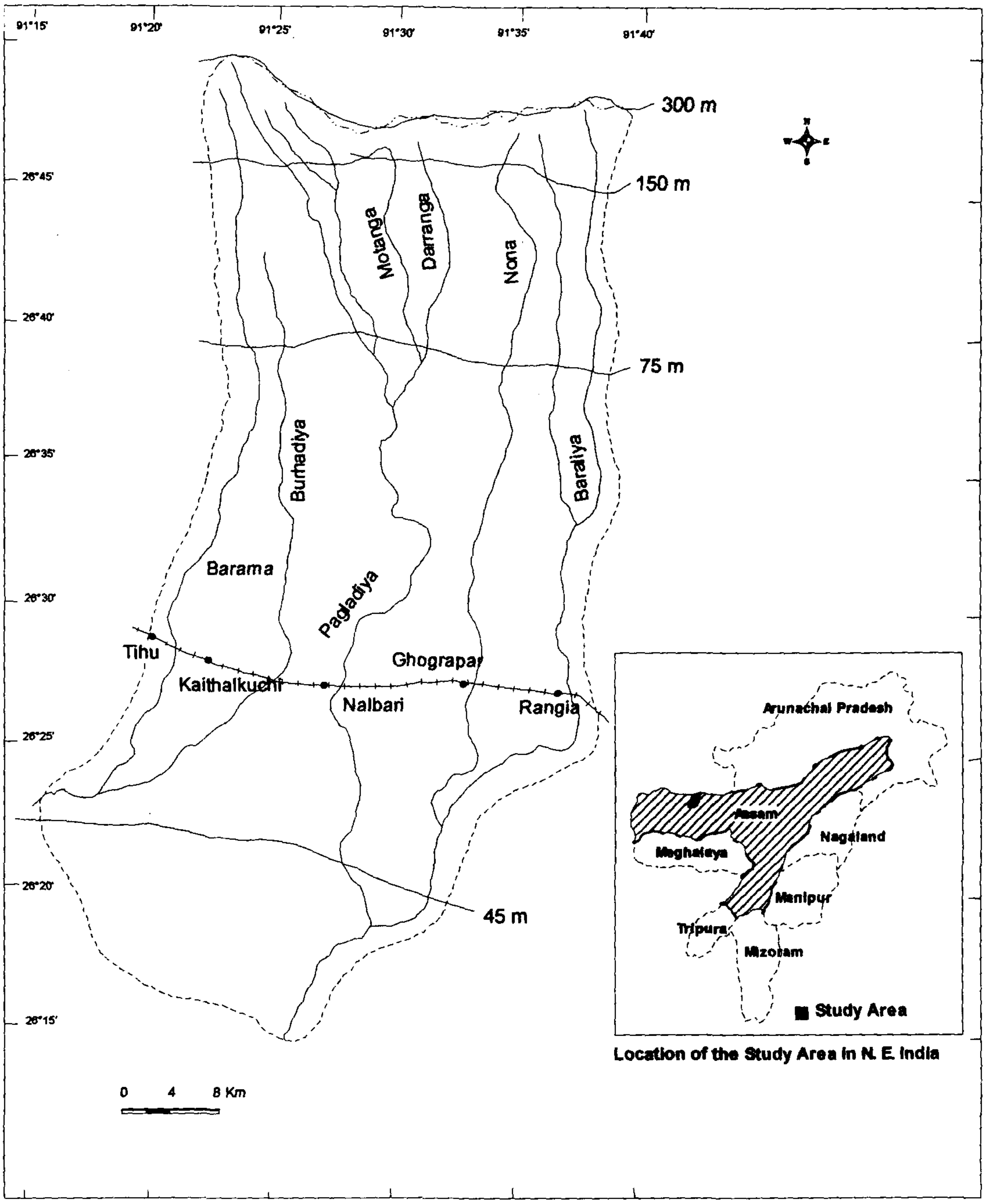
iii) If the changes in channel courses have displaced a number of villages in the past, what is the trend of development of villages in future?

THE STUDY AREA:

The latitudinal and longitudinal extent of the Pagladiya-Morapagladiya drainage complex falls between 26°14'N to 26°50'N and 91°15'E to 91°39'E and covers an area of 1,758.89 sq. km. The Pagladiya river springs out from the southern slope of Bhutan-Himalaya. The river debouches into the Nalbari district traversing a length of 177.80 km to meet the Brahmaputra river. The study area is also criss-crossed with the tributaries like- Morapagladiya and Burhadiya, infact which form the great Pagladiya- Morapagladiya drainage complex.

METHODOLOGY:

Morphometric techniques are used for understanding the basins' general configuration and drainage network. Channel characteristics in terms of pattern of channel changes, bank erosion and flood have been taken as the basis for understanding the nature of shifting of the river courses over time and have been related to displacement of settlements under the same period of time. Other quantitative methods like hydrographs, flood frequency curves, drainage density, drainage frequency, stream ordering, bifurcation ratio and other relevant techniques are used to understand the behaviour of channel. Both Hydraulic Sinuousity Index and Topographical Sinuousity Index have been calculated for understanding the meandering nature of the two concerned rivers. Rainfall, flood and discharge relationship of extreme events have been considered to explain how and to what extent displacement of settled families take place. Frequent visits to the areas affected by floods have been done to understand the nature of fluvial activity.



The Study Area: Pagladiya – Morapagladiya Drainage Complex

To understand the drainage systems channel positions of Pagladiya-Morapagladiya drainage complex at earlier times, few old maps of viz., A. Robinson (1841), H. L. Thaillies (1875), Surveyor General of India, Calcutta; map of 1893 based on the District Gazetteers of 1905 reproduced by Geological Survey of India and of 1897 based on Oldham's report of great earthquake were consulted and represented on maps.

To study the temporal variation of channel migration of the Pagladiya river, the method of comparison of various maps and satellite imageries of appropriate scale is used. For the present study, the topographical maps surveyed in 1911-`12 and 1967-`68 and landsat imageries of 1989-`90 are the main data base. The study period covers a span of 80 years from 1911-`12 to 1989-`90. Superimposed maps of (i) 1911-`12 to 1967-`68, (ii) 1967-`68 to 1986-`87, (iii) 1911-`12 to 1986-`87 and (iv) 1911-`12 to 1967-`68 and 1986-`87 are drawn and the general nature of channel changes of the Pagladiya river is analysed.

To analyse the distributional aspects of rural settlements dispersion relevant techniques were used for understanding the relationship between derived geomorphic variables like distance from river and size of settlements, rainfall and floods etc. and their effect on distribution of settlements. Chi-square test was calculated for understanding the pattern of variation of settlements which proved to be very useful for this work. Settlement dispersion analysis (Rn value) was done to understand how the villages are dispersed in the area of study.

The final stage consists of the preparation of the dissertation on the basis of the data collected and analysis of the quantitative data on which the results are based.

Data Base:

a) The necessary materials for the study are collected from the sources like-memoirs and records of Geological Survey of India, toposheets of Survey of India at 1:50,000 scale and remote sensing images. For the spatio-temporal study of the channel changes topographical maps surveyed in 1911-'12 and 1967-'68 and Landsat imageries of 1986-'87 are used. To study the nature of bank line migration for the period 1971-1997 a large scale super-imposed map is also used. The secondary data are collected from census reports, district gazetteers, maps, statistical handbooks, and reports of various government departments.

b) Primary data has been collected from 75 sample villages. For this purpose three categories of social groups, viz., tribes, non-tribes and immigrants settled in different ecological units are considered. The settlement characteristics and their response to channel changes, bank erosion and flood are also considered with emphasis on displaced villages.

Relevant maps and diagrams have been prepared on the basis of the above exercises. To explain the different findings maps have been superimposed and diagrams comparing two or more variable have also been presented.

ORGANISATION OF CHAPTERS

The whole work is organized in seven chapters. The chapters can be described in a nutshell in the following lines

The first chapter is devoted to introduction of the problem and basis of sequence of the study.

Chapter II deals with the geomorphic characteristics of the study area with a brief description of its physiography, geology, climate, soil, vegetation with an overview of the Pagladiya nad Morapagladiya rivers.

Chapter III is devoted to river channel changes and factors. Salient features of channel changes, bank line migration, bank erosion and flood are discussed here.

Chapter IV deals with the processes of settlement evolution from the perspective of historical and geomorphic characteristics favourable for human settlements in the study area.

Chapter V examines the changing pattern of settlements that takes place due to channel changes, bank erosion, flood hazard etc.

Chapter VI deals with fluvio-morphological changes of the study area and their impact of displacement of settlements.

The last chapter (i.e., Chapter VII) deals with the synthesis consisting of summary and conclusion of the study.

FINDINGS:

Considering the discussion and analysis of the facts it was found that the Pagladiya and Morapagladiya rivers and their tributaries have changed their courses in the past. The changes are going on and each year human settlements are affected, the degree of damage being unpredictable depending much on variations of climatic parameters. It is observed from the analysis of collected data that the frequent occurrence of flood in the study area can be attributed to: (i) climatic factor, (ii) physiographic factor, (iii) tectonic factor and (iv) anthropogenic factor. Based on these facts the main findings of the present work can be summed in the following lines:

(i) The two episodes of earth movements that took place in 1897 and 1950 have made significant impact on the surface configuration of the study area hence initiating several changes in the channels and their flow pattern.

(ii) Climatic parameters play a very important role in determining floods. Rainfall is the most important component and the above analysis proves that floods have corresponded well with the pattern of rainfall.

(iii) The floods initiate changes in channels and river courses causing heavy damage to life and property. The permanent scars of such phenomena were recorded by completely destroyed settlements. Some other settlements were partially affected only to expand towards safer and flood free direction.

(iv) Sediment deposition by the rivers every year initiates changes in the channels.

(v) Construction of bridges for transport linkages have been seen to cause restriction of flow of large volume of water during the summer season thereby submerging areas which rarely experienced flood.

(vi) The Pagladiya river shows an eastward shifting trend in the past 100 years or so. It may be conjectured that there is constant tectonic adjustments taking place over this region which needs more intensive studies.

(vii) New settlements have been observed to evolve on higher elevation like levees, embankments or roadsides (as roads are at higher elevations presently acting as embankments) and also nearby *beels* and marshy areas. The trend of new settlements being located near transport lines is obvious since people are preferring to be free from floods as well as availing easy transport facilities

Keeping in mind the above findings few suggestions can be forwarded for better management of the study area and similar situations in the region during the summer season when recurrent floods occur. These suggestions may help the different agencies and administrative organizations by reducing losses rather than aiming relief only. The following points attempts to sum up the suggestions.

(i) There is a great need to understand the earth movements and subsequent surface adjustments occurring in the area. The area and the region as a whole being classed under Zone V for earthquake vulnerability as well as facing recurring floods has problems to be addressed to.

(ii) Natural changes like earthquakes, excessive rainfall, storms etc., are not within human controls and hence there is a need to take adequate precautionary measures to prevent or at least mitigate losses. It is therefore proposed that the should be a 'line of vulnerability' which would address the yearly flood problem in order to reduce loss of life and property. It is also suggested that any settlement that fall within the line may be treated as susceptible to floods. Hence appropriate precautionary measures could be taken up for such locations. This 'line of vulnerability' could be drawn as follows:

   a. For the Foothill Zone : 0.75 km from the current year bank line as the channel and course changes in this zone have not been observed to cross 0.50 km in the period of investigation
   b. For the Middle Built-up Plain : 1.25 km from the current year bank line as the river in this part starts to meander.
   c. For the Active Flood Plain : 3.0 km from the current year bank line since the river in this part is sluggish and had been observed to change its course to a maximum of 2.5 km in 1984.

(iii) Alternative long term measures, viz., " living with the flood" as suggested by the National Commission on Flood should be adopted in the most chronically flood effected areas of lower Pagladiya basin. Raised platforms should be constructed in this area for common use as shelter during the flood so that relief and evacuation becomes easier.

(iv) Not to disturb the wet lands (*beels* and marshy lands) which are natural absorbents of major floods by reclamation and encroachment.

(v) To protect river banks and embankments locally available tall grasses and reeds should be planted along the sides. Planting of bananas have also proved to be helpful in maintaining stable river banks and also provide livelihood to villagers. This can be a community effort.

(vi) The proposed Multi-purpose Dam Project to be constructed at Thalkuchi, 26 Km north of Nalbari town predominantly inhabited by the Bodo tribe is a major threat to displace more than 50,000 people from 38 villages in and around the project site. This may create socio-economic as well as resettlement problems for the indigenous inhabitants who have been residing in this area for 50 to 100 years., It is important to give due consideration to proper rehabilitation, resettlement and after affect of the dam should be contemplated.

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I, **Shri Surajit Barman** hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

This is being submitted to the North-Eastern Hill University for the degree of Doctor of Philosophy in **Geography.**

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Surajit Barman

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Chapter - I

INTRODUCTION

There exists a close association of man with the river since the early times. Therefore, one of the most conspicuous attributes of human settlements is man's affinity for riverine locations. From the time immemorial, man has been attracted to riverine areas. Even today a sizeable proportion of the world's population lives in such areas. White (1958) observes that about 12 percent of total population in the USA lives in the floodplains which are subject to periodic inundation. Similar is the case for Canada (Sewell, 1965). In India also the largest section of people live in the floodplains. There are a good number of reasons for the strong attraction of riverine plains to man. The river, being an open system, has manifold direct and indirect influences on human settlement. River valleys as well as floodplains have rich deposits of alluvial soil suitable for agriculture, flat plains for easy construction of houses, factories, roads and railways and free movement for man and materials. Besides, rivers provide navigational facilities, water for drinking purpose and industrial use, various aquatic resources including fish and avenues for recreation and game. History provides many examples of development of great human civilization mainly along the bottom lands of world's major rivers, such as the Indus, the Nile, the Tigris and Euphrates, and the Yangtze.

The floodplain, from the geomorphic point of view, is the most dynamic topographic surface. It is a strip of relatively low and flat land bordering a stream which is overflowed at the time of high water (Wolman, *et al.*, 1957). Hydrologically, it is the area inundated by flood events of particular magnitude and frequency (Kates and White, 1961). It is composed of alluvial deposits of varied thickness laid down by flood waters in areas beyond the natural levees. Thus the floodplain is subject to frequent inundation by flood and is, therefore, generally hazard prone in its natural state.

Although a flood plain is advantageous in many respects for human settlements, it can be a mixed blessing when the river overflows its banks causing a heavy toll of public life, property and displacement of settlements. During floods, bank erosion and channel migration pattern change the geomorphic features in a flood plain which indirectly affects human activities as well as settlement distribution pattern in different ways.

There are records of heavy floods in different parts of the world, such as in the USA, China, Pakistan, Korea etc. In India also heavy floods occur every year in many of her rivers including Ganges, Brahmaputra, Krishna, Godavari, Mahanadi etc. causing heavy loss of property, life and displacement of settlements through severe bank erosion, channel change and bank line migration. Thousands of people are left homeless and their sources of food and livelihood are damaged. In the case of Assam, it becomes a chronic malaise. Every year several waves of floods occur in Assam which has strong influence on the pattern and density of settlements. It is generally found that in the flood prone riverine areas settlement is mainly dependent on the nature, magnitude, extent and frequency of floods as well as fluvial action on geomorphic changes through bank erosion and channel changes.

It is a common experience that despite all efforts trying to cope with the problems created by fluvial actions of rivers, every year the amount of losses and ravages have gone up at an accelerated rate in many parts of the world. The main cause behind this is the increasing economic activities with the rising population pressure on the floodplain. More and more areas under floodplain are converted to human settlement and this upsets the ecological balance. Due to haphazard and heavy destruction of natural conditions by man for settlement and agriculture serious consequences of flood, erosion, channel change and other related problems are wrought on the riverine plain. Therefore, without proper adjustment with nature, man living in the riverine floodplain cannot avert the loss of life and property. It is rightly said that 'man's affinity for flood plains clearly exposes him to the risk of flooding which would in any case have taken place' (Patra, 1984).

Settlements are the basic units of human territorial occupancy from where culture spreads spatio-temporally to influence the sphere of human life. They help in the growth and development of a region and its overall spatial organisation. The socio-economic and cultural advancement of a society or of a region basically depends upon the way these units are organised to emanate development impulses. This in fact, calls for the study of various aspects of settlements, such as their spatial dimension, site, situation, size, type and pattern and the causal factors like physical setting, transport system, service facilities, economic situation etc. It is seen that in the less advanced countries where science and technology is yet to reach the grass-root level of development, ecological factors play a significant role in the distributional characteristics of settlement. In such areas, settlement distribution pattern has been determined mainly by relief, drainage and water-bodies and flood hazards, availability of cultivable lands and other cultural and economic factors. At present the changing politico-cultural factors along with the advancement of science and technology play a vital role in the spatial variation of settlements and their distribution.

Physiographically, the Brahmaputra valley along the east-west axis (north bank) has four distinct physiographic units, viz., the northern foot-hills, the north and south bank plains, the floodplain and *char* lands, and the southern foot-hills. The active flood plain is made up of the recent alluvial sediments carried by the Brahmaputra and its tributaries from the surrounding high lands. The flood plain of Brahmaputra including the *char* (river sand bar) lands inside the river is irregular in its transverse extension due to the occurrence of occasional hillocks and incipient levees on both the banks of the Brahmaputra. In the north bank, numerous swamps and *beels* (wetlands) bear the characteristic features of a flood plain. This zone is of immense significance as population is dense, fertile agricultural fields with good transport network.

1.1 THE PROBLEM:

In Assam throughout the course of the river Brahmaputra there are innumerable tributaries coming out of the northern and north-eastern hill ranges. In the Nalbari district the main tributaries of the Brahmaputra river are Baraliya, Puthimari, Nona, Pagladiya, Burhadiya and Morapagladiya. Their general tendency of flow is from north-east to south-west. These areas along with the other flood plain areas of the state have been invariably inundated by floods of Brahmaputra and its tributaries in almost every year. Although, written records of floods in the district do not date back beyond 13^{th} century, the pedologic and landform characteristics of the area are clearly indicative of large scale actions of recurring and occasional flooding in the historical past. Sometimes floods attain such a magnitude that they appear to be greatly hazardous to a major section of settlers in the flood plain. The Brahmaputra river is said to possess a highly dynamic fluvial environment (Richardson and Thorne, 2001) and there is no doubt the entire system is so and these conditions prompts for a lot of changes causing inevitable problems for human settlements in this region.

The Pagladiya, Burhadiya and Morapagladiya rivers are the principal north bank (sub-Himalayan) tributaries of the Brahmaputra system. These three rivers have formed a drainage complex since their sub-streams are interlinked throughout the courses right from the foot-hills to active flood plain zone. Floods have been occurring in the district perhaps, since the days of existence of these rivers. In the recent past the fury of floods has been increasing after the great earthquakes of 1897 and 1950. These earthquakes changed the topography of this area along with the other parts of Assam inducing shifting of channels of the Pagladiya, Burhadiya and Morapagladiya rivers. These changes with excessive sediment load and devastating flood cause heavy damage to human life, property, settlements and land resources.

Pagladiya river especially possesses some unique features of having short courses without a defined bank line due to frequent shifting of the channels. The general tendency of channel shifting of this river is mainly towards east. The Burhadiya and Morapagladiya rivers also change their courses during the monsoon season. Occurrence of annual floods of these rivers is also a rule rather than exception. Rainfall, both volume and intensity, is the most important climatic factor governing floods. Almost every monsoon season Pagladiya, Burhadiya and Morapagladiya rivers collect large amount of head water which reaches the plains suddenly only to overflow the valley channels.

Although, by and large, the area under the sub-basins of Pagladiya, Burhadiya and Morapagladiya is affected by flood and flood related factors, yet the middle and lowermost parts are most seriously affected by flood along with bank erosion, sand deposition and channel changes. Of course, near the confluence of Pagladiya river with the mighty Brahmaputra combined effects of both the rivers are observed. Therefore, the problem is more acute in the lower most part of the Pagladiya basin.

Under such conditions, the study of the impact of channel shifting on rural settlements is very much relevant. Therefore, a detailed study on the displacement of settlements in the Pagladiya-Morapagladiya drainage complex is very much important considering rainfall, frequency and intensity of floods which are directly responsible for frequent channel changes. This will be very much helpful for planning purposes.

1.2 SURVEY OF LITERATURE:

Survey of literature for supporting the topic of research is an essential component of the study. It is very much needed for sound understanding of the research problem.

A good number of scientific researches on subjects like fluvial geomorphology and hydrology relating to the problems of river basin – its planning and management, flood hazard, human response to flood, protection measures taken against flood, floodplain management and human occupancy have been carried out so far in different parts of the world, especially in the USA and UK. The gradual improvement in theoretical approaches and methodological techniques has attracted many physical geographers to the study of fluvial processes. As a result, many research works on these lines have been published in recent times.

In the field of settlement geography, considering the morphological, structural and functional variations in a given ecology as well as the difference in the methodological approach of both the branches (viz.,- rural and urban) have drawn attention of geographers who have analysed the various facts and elements and developed distinct concepts.

1.2.1 Literature in International Scenario:

A variety of methods are now available for studying the problems of river basins as suggested in the works of Hoyet and Lengbein (1955), Dury (1961), Leopold *et al.* (1964), Chorley (1969), Nelson and Chambers (1969), Harvey (1969), Coates (1971), Strahler (1971), Sparks (1972), Cooke and Doornkamp (1974), White (1974), Gregory (1977), Ward (1978), Richards (1982) etc.

Throughout the history floods have been a major area of man's interaction with his riverine environment. Some evidences of use of flood water for irrigation have been found in the Nile valley of Egypt, Hwangho of China, Tigris and Euphrates of the Middle-East and the Indus of India and Pakistan. Such historical studies are found in the works of Parsons and Bowen (1966), Biswas (1970), and Smith (1971). Other works on floods and floodplain settlements carried out with historical perspective include those of Hartshorne (1939), Willey (1953), Forbes (1965), Lambert and Millard (1969). Smith (1969) considered drainage basin as an appropriate areal extent for assessing human activities over time.

The studies of Jarvis (1942), Wisler, *et al.* (1949), Chow (1956), Wolman, *et al.* (1957), Schumm and Lichly (1963), Miller (1966), Bue (1967), Simons (1969), Dury (1969) and Mc Phurson (1969) are worth mentioning. Hydrological aspects related to flood, floodplain formation, channel flow and floodplain characteristics were analysed in their studies.

Sewell (1969) and Beckinsale (1969) studied the various aspects of human response to floods and river regimes respectively. Sewell in his paper discussed the causes that attracted people to the floodplains despite losses incurred due to floods in the USA and Canada.

In recent years many scholars have devoted themselves to the study of problems like floods and termed these as natural hazards. Such studies include subjects like human adjustment to floods, mitigation of losses caused by floods and human perception of floods etc. In this regard, noted works include those of Kates (1963, 1965 and 1971), Kates and White (1964), Burton (1969), Ruhe (1971), Abramov (1982) and Gerasimov (1983).

In the 'Commission of Man and Environment' of the International Geographical Union (IGU) held in New Delhi in 1968 under the leadership of Gilbert White(1974) of Chicago University, a decision was taken to start integrated research programmes through active participation of scholars and a new research dimension at global, national and regional levels was evolved. In North America, the Centre for Flood Hazard Studies moved subsequently from Chicago to Toronto, Colorado and Clark University (Gold, 1980; White, 1974). New areas like flood hazard, human response to flood and hazard mitigation were covered by White (1970, 1973 and 1974), Beyer (1974), Erickson (1974), Harding and Parks (1974), Oliver (1975) and Montez (1982).

A large number of scholars also studied the problem of floodplain management. In this connection the works of Colman (1953), Murphy (1958), Kates (1962), White (1963), Sewell (1965), Issac (1967), Bue (1967), Goddard (1969), Burton (1969), and Rosewell (1972) are worth mentioning. In the areas of flood hazard perception and planning, the works of Moline (1974), Harding and Parks (1974) are noteworthy. As regards river basin planning, the works of Lightfoot (1951) and Saha and Barrow (1981) may be mentioned. The classic work of Wei-Huang (1978) on the Yellow river in China related to flood and its control is also worth mentioning here. In recent years studies on bank erosion, channel migration and associated consequences were carried out by Environment Agency (1999), Duan (2001), Couper *et al.* (2002), Darby and Delbeno (2002), Derby *et al.* (2002), Simon and Thomas (2002), Simon *et al.* (2002), Wright *et al.* (2002). Cheng (2002), Huang and Nanson (2002) and Yen (2002) devoted to the study of sediment transport by rivers. The work of Katul *et al.* (2002) on river and flood plain hydraulics is also worth mentioning.

A large number of scholars engaged themselves on the study of hydromorphological features formed by sedimentation. In this regard Clark *et al.* (1997), Dey (2003), Daniels (2003), Ferguson (2003), Peckham (2003), Belestrini, Cazzola and Buffagni (2004), Bogen (2004) are noteworthy. Besides, channel microforms in anastomosing system were studied by Ryszard *et al.* (2003).

On the other hand, general interest in the study of rural settlements goes back to 1921 when Blache, Aurousseau, Alhman, Demangeon, Brunhes and others were laying the foundation of settlement geography. The real interest was seen in the study of rural settlements at the time of establishment of the 'Commission on Types of Rural Habitation' under the auspices of International Geographical Union which published its first report in 1928. Although the study of rural settlements has immense significance, very little work has been done in the highly urbanised western world. Aurosseau (1920), Bowman (1926), Dickinson (1949), Blache (1952), Chisholm (1962), Demangeon (1962), Jordan (1966), Baker (1969), Eidt (1974), Stone (1975) Koloszar (1975), Gwen (1976), Frolov (1983) and Alayeb (1986) are some of the outstanding contributors in the field of rural settlement geography. All the scholars studied different aspects of rural settlements from philosophical and theoretical perspectives to socio-economic development of inhabitants.

1.2.2 Literature pertaining to India:

In India relatively few scholars have so far contributed to the study of river basin geomorphology, hydrology and problems relating to floods. These works are confined mainly to the recent years. Mention may be made of the works by Tamaskar (1959), Kumra (1968), Mukhopadhyay (1968), Bhattacharyya (1973), Ramchandran and Thakur (1974), Sharma (1976), Kayastha and Yadava (1977), Subramaniam *et al.* (1978), Sen (1979), Das (1982), Gupta (1982), Prasad (1982), Verma and Roy (1982), Pal and Bagchi (1983), Benerji (1987), Basu and Santra (1988), Biswas (1988), Goswami (1988, 1989). Kale, Ely, Enzel and Baker (1994), Mahindra and Prakash (1994), Hofler (1995), Kale, Baker and Mishra (1996), Singh (1996), Kale, Hira and Baker (1997) and Singh and Durbey (2000).

In the field of river hydrology, particularly river size, type and their behaviour were studied by Goswami (1985), Gupta (1988), Singh (1996) and Katul *et al.* (2002). The works of Jorgensen *et al.* (1994), Singh (1996), Sukla *et al.* (1999) and Richardson and Thorne (2001) are some of the outstanding contributions related to braided channel patterns of Ganga and Brahmaputra rivers. Kale *et al.* (1994), Deodhar and Kale (1999) analysed the river channel changes of Himalayan rivers. The dynamic nature of alluvial channels is reflected by frequent channel changes, changes in bank-line, sinuosity and size of channel bars in the studies made by Rajaguru *et al.* (1995), Deodhar and Kale (1999). Flood morphology with respect to hydro-meteorology and effects of floods has been summarised by Gupta (1988) and Kale (1998). Singh and Dubey (2000) examined the man-impacted gully basins in the alluvial riverine environment.

In the case of settlement geography in India, the credit goes to Prof. E. Ahmad, Prof. R. L. Singh, Prof. Pithwala, and Bushman etc. Ahmad (1952) deserves special mention for his work on rural settlements in Uttar Pradesh. Misra (1965) identified types of rural settlements of Himachal Pradesh. Dixit (1969) examined the evolution of rural settlements in the Dun Valley of Uttar Pradesh. As regards of evolutionary studies, Singh (1955) traced the evolution of rural settlements in the Middle Ganga valley through various periods of history. An attempt was made by Singh and Singh (1976) to assess the impact of morphometric characteristics of landforms on evolution and distribution of rural settlements in the Palamau uplands. Singh (1977) also dealt with the evolution of rural settlements conditioned by the geographical factors and historical processes involved in the occupation and colonization of the Patna region.

In recent years a number of geographers have evinced keen interest in the morphology of tribal and caste settlements. Mention may be made of papers on Bhils by Srivastava (1946), Hindu Jats by Mukerji (1957, 1959), Gujars, Jats and Kanets by Grover (1985) etc. Verma (1957) dealt with geomorphology and human settlements of Ranchi Plateau. Rai (1980) made an attempt to study effect of geomorphology on human life in Sonar-Bearma basin. Bhattacharyya and Das (1973) also dealt with different geomorphological aspects of Kaliaghat river basin which is worth mentioning. The works of Sharma (1986) is a pioneering study of culture-ecological processes of rural settlements of Solan district in lower Himalaya inhabitated by different cultural groups.

1.2.3 Literature pertaining to North East India:

In North East India, although Assam has severe flood and erosion problems in many parts of the valley that have been creating havoc since long and affected human settlements not much serious research work on these subjects has been done. However, in recent years few scholars have studied the physical and ecological aspects of flood plains and their human occupance. Few relevant works in this regard include those of Sarma and Basu Mallick (1984), Goswami (1985, 1989), Taher (1974, 1988), Bora and Goswami (1988), Barman (1986), Bardoloi (1986) and Bora *et al.* (1994). The works of Bardoloi has much relevance in the context of present study. He examined the problems of human settlements and land use vis-à-vis the physical aspects of channel migration in the erosion prone Palasbari area on the south bank of the Brahmaputra river.

Reference may be made of Bhattacharyya (1974, 1980 and 1986). He analysed the regional pattern of settlement system in Brahmaputra valley and North East India and impact of topography on it. The works of Barthakur (1981, 1982), Patowari (1983) and Majumdar (1986) are also equally important. In their studies they analysed physiographic control on settlement, its pattern, location, site etc. Jafri (1978) attempted to highlight the spatio-temporal variations in the level of socio-cultural development of settlements in Khasi and Jaiñtia Hills. Patnaik (1979) studied the impact of geomorphological characteristics on agriculture in Shillong plateau. Panda and Rai (1981) analysed how various aspects of landforms are influencing the location and distribution of rural settlements in Khasi and Jaiñtia hills. Panda (1983) also elaborately studied the geomorphology of Khasi and Jaiñtia hills and its impact on locational aspects of rural settlements. An attempt was made by Barman (1990) to analyse the spatial characteristics of settlements in Nalbari district, Assam.

1.3 SIGNIFICANCE OF THE STUDY:

The Pagladiya-Morapagladiya drainage complex has a significant influence on the people settled in its flood plain. In an agrarian society attraction of the flood plain is due to presence of a number of facilities there, despite the usual prevalence of the threat from flood, bank erosion and channel shifting. This area has high agricultural productivity and is thickly populated. Due to great earthquake of 1897, several physiographic changes had taken place in this area. Many marshy lands, *beels* (wetlands) as well as river courses were formed or changed as a result of the earthquake in the area. The earthquake of 1950 has also affected the general configuration of the Pagladiya-Morapagladiya drainage complex at different sections. The rationale behind the selection of this area for present study is that it will address the burning issues of the state, viz., flood, erosion and channel changes which influence the distributional pattern of both population and settlements.

The area selected for investigation has not yet been thoroughly studied from the perspective of fluvial-geomorphology vis-à-vis the rural settlements. Studies relating to impact of river on man is reflected through settlements and human activities are of great interest and useful to administrators, social scientists, geographers, engineers and other field scientists. Keeping this view, an attempt has been made to examine and analyse the salient issues relating to man river relationship in the study area based on field surveys and personal observations. Attempt has also been made to focus on some socio-economic problems faced by the settlers of this area.

1.4 OBJECTIVES OF THE STUDY:

As the study area covers a large part of flood, erosion prone and water logged region, the study is intended to examine the impact of fluvio-morphological actions such as bank erosion, channel changes and flood inundation on rural settlements which are reflected by their displacement pattern.

The principal objectives of the present study are:

i. to study the process of channel migration in the Pagladiya-Morapagladiya drainage complex;
ii. to assess the displacement pattern of human settlement in different geomorphic units arising out of changes in channel courses; and
iii. to analyse the spatio-temporal features of settlement displacement with respect to changing pattern of rainfall, channel migration, flood frequency and intensity and geomorphic features over time.

1.5 RESEARCH QUESTIONS:

To arrive at the objectives with a close examination of the study area, the following questions can be formulated:

i. What is the impact of 1897 and 1950 earthquakes on the channel changes of the Pagladiya-Morapagladiya drainage complex?
ii. What are the cause-effect relationship among the variables - rainfall, floods and micro-geomorphic changes and settlement displacement over time?
iii. If the changes in channel courses have displaced a number of villages in the past, what is the trend of development of villages in future?

1.6 THE STUDY AREA:

The study area (Fig. 1.1) covers the 177.80 km long section of Pagladiya river of Nalbari district, which also includes Burahadiya and Morapagladiya rivers. All these rivers form a drainage complex. The latitudinal and longitudinal extent of the Pagladiya-Morapagladiya drainage complex falls between 26°15'N to 26°50'N and

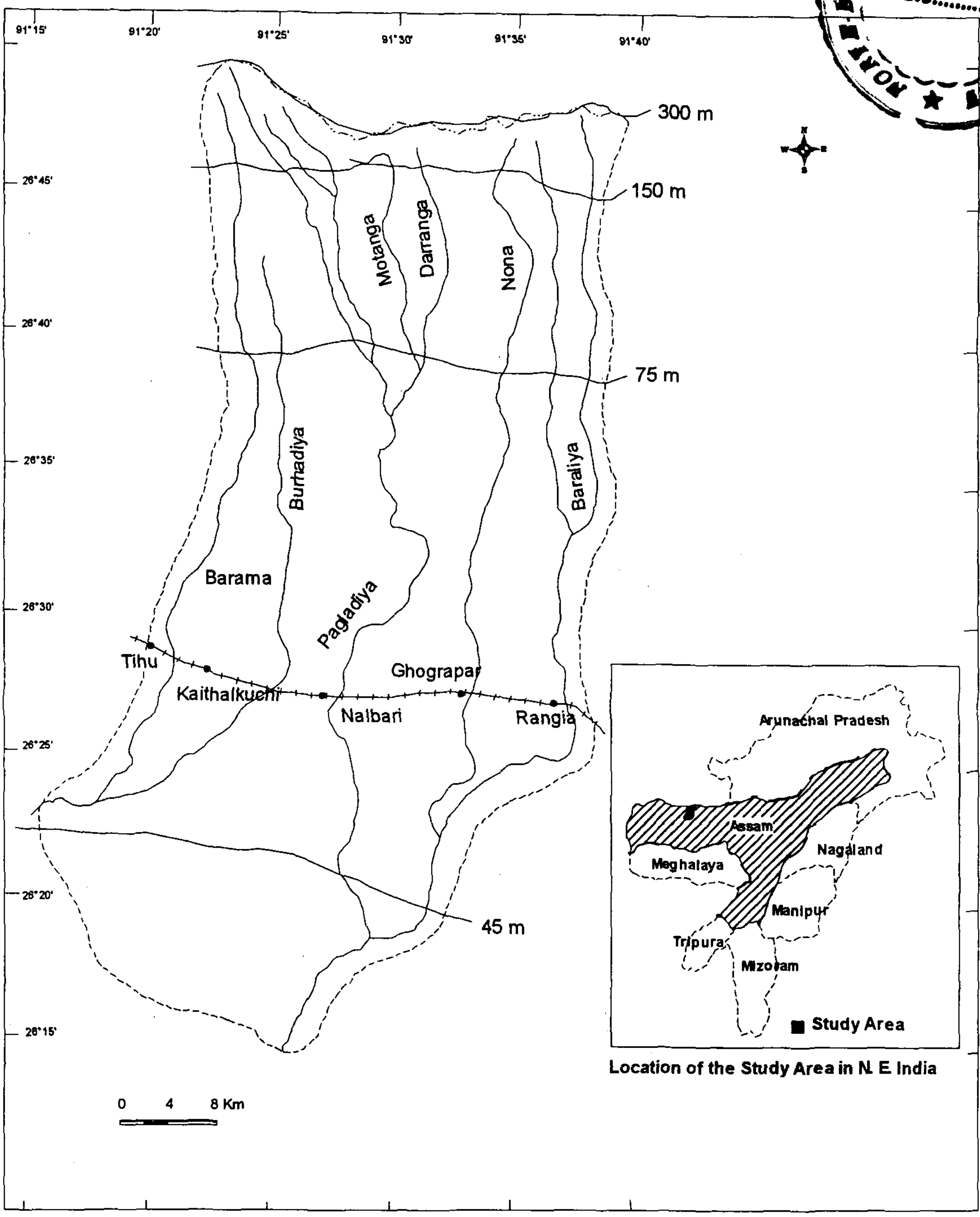

Fig. 1.1: The Study Area: Pagladiya – Morapagladiya Drainage Complex

91°15'E to 91°39'E and the catchment area of this drainage complex is about 1,758.89 sq. km. The Pagladiya river is the one of the main northern tributaries of Brahmaputra river which springs out from the southern slope of Bhutan-Himalaya. Darranga, Motanga, Nona and Baraliya are the main tributaries of Pagladiya river. The river debouches into the Nalbari district traversing a length of 177.80 km. to meet the river Brahmaputra. The study area is also criss-crossed with the tributaries, like Burhadiya and Morapagladiya, in fact which form the great Pagladiya-Morapagladiya drainage complex. In the west of the drainage complex, the boundary of the study area is demarcated by the catchments of Kaldiya and Morapagladiya; while in the east, it is demarcated by the catchments of Puthimari and Pagladiya.

Administratively the Pagladiya-Morapagladiya drainage complex is covered by 24 mouzas in 9 blocks under Nalbari and Kamrup districts. While some areas of Baska development block and Barkhetri development block in west and south-west respectively fall outside the drainage complex, some villages of Bangsor mouza under Rangia sub-division of Kamrup district fall within the drainage complex. Although the boundaries of the study area do not coincide with the administrative boundaries, it is bounded on the north by the international boundary between Bhutan and India. On the south the northern bank of Brahmaputra in Barkhetri development block limits the boundary of the drainage complex.

The area covers 701 villages with a population of 8,75,107 (2001) consisting of indigenous Assamese community belong to Hindu and Muslim religions; tribes belonging to Bodo, Rabha, Kachari etc. and Muslim immigrants with an average density of population 498 per sq. km. Out of total villages, 86 are mostly flood affected and situated in the active flood plain and lower part of the built-up plain.

1.7 METHODOLOGY AND DATA COLLECTION:

1.7.1 Methodology:

Physiographic units of the study area are identified and mapped using the methods available from existing literature (Das, 1970; Das, 1985; Taher, 1986 and NATMO, 1996). Morphometric techniques are used for understanding the basins' general configuration and drainage network. Channel characteristics in terms of pattern of channel changes, bank erosion and flood have been taken as the basis for understanding the nature of shifting of the river courses over time and have been related to displacement of settlements under the same period of time. Other quantitative methods like sinuosity index in terms of hydraulic and topographic indices, hydrographs, flood frequency curves, drainage density, drainage frequency, stream ordering, bifurcation ratio and other relevant techniques are used to understand the behaviour of channel. Rainfall, flood and discharge relationship of extreme events have been considered to explain how and to what extent displacement of settled families take place. Frequent visits to the areas affected by floods have been done to understand the nature of fluvial activity. Location of settlements and their displacement for different areas and time period are mapped. For this purpose mouzas are considered as the base for extracting data pertaining to Pagladiya-Morapagladiya basin area based on census data. 75 sample sites have been taken from the affected areas out of which 15 in the foothill zone, 40 in built-up plain and 20 in active flood plain.

To understand the drainage systems channel positions of Pagladiya-Morapagladiya drainage complex at earlier times, few old maps of viz., A. Robinson (1841), H. L. Thaillies (1875), Surveyor General of India, Calcutta; map of 1893 based on the District Gazetteers of 1905 reproduced by Geological Survey of India and of

1897 based on Oldham's report of great earthquake (Oldham, 1899) were consulted and represented on maps.

To study the temporal variation of channel migration of the Pagladiya river, the method of comparison of various maps and satellite imageries of appropriate scale is used. For the present study, the topographical maps surveyed in 1911-`12 and 1967-`68 and landsat imageries of 1989-`90 are the main data base. The study period covers a span of 80 years from 1911-`12 to 1989-`90. Superimposed maps of (i) 1911-`12 to 1967-`68, (ii) 1967-`68 to 1986-`87, (iii) 1911-`12 to 1986-`87 and (iv) 1911-`12 to 1967-`68 and 1986-`87 are drawn and the general nature of channel changes of the Pagladiya river is analysed.

To analyse the distributional aspects of rural settlements in respect to settlement site, nature of settlement dispersion nearest neighbour analysis, chi-square test and relevant techniques are used. Correlation (r value) has been applied for understanding the relationship between derived geomorphic variables like distance from river and size of settlements, rainfall and floods etc. and their effect on distribution of settlements.

The final stage consists of the preparation of the dissertation on the basis of the data collected and analysis of the quantitative data on which the results are based.

1.7.2 Data Base:

As mentioned in the objectives, the present study aims at the understanding of the characteristics of fluvial landscape and its classification. The research work considers the main effects of fluvio-morphological characteristics of human settlements from different perspectives. This is carried out in the following manner:

a) The necessary materials for the study are collected from the sources like- memoirs and records of Geological Survey of India, toposheets published by Survey of India at 1:50,000 scale and remote sensing images. However, toposheets for Bhutan portion were not available. For the spatio-temporal study of the channel changes topographical maps of Survey of India nos. 78 N/6, 78 N/7, 78N/8, 78 N/10 and 78 N/11 surveyed in 1911-'12 and 1967-'68 and Landsat imageries of 1986-'87 are used. To study the nature of bank line migration for the period 1971-2000 a large scale super-imposed map of Pagladiya river prepared by Department of Embankment and Dam, Government of Assam is used. The secondary data are collected from census reports, district gazetteers, maps, statistical handbooks, and reports of various government departments like Brahmaputra Board, Brahmaputra Flood Control Commission, the Revenue Department, Block Offices, Economics and Statistics Department, Pagladiya Investigation Division etc. Besides for better understanding of the problem relevant geomorphological books, journals, papers, and various bulletins have been consulted. The data base mainly covered for the period 1971 to 2001.

b) Primary data has been collected from the field to update recent changes through direct field observation and sample survey of 75 villages. For this purpose questionnaire based interviews have been undertaken considering three categories of social groups- tribes, non-tribes and immigrants settled in different ecological units. The settlement characteristics and their response to channel changes are also considered with emphasis on displaced villages. There was a need to carry out primary data collection for Morapagladiya sub-system related to channel change, bank erosion and flood due to the lack of secondary data. Hence, a one time data only was available for this area and necessary comparison could not be made.

1.8 SCOPE AND LIMITATION:

Several constraints are faced by the researcher in doing this research work. In respect of primary data the limitation of time available for the study proves to be constraint. It is almost impossible for researcher to collect a large volume of primary data required for the study. The census data of 1981 are also not available as the census was not done for Assam in 1981. Even the census data does not cover certain aspects of the study. Besides, due to official restriction on the use of large scale topographical maps and recorded data of the area, the researcher faced difficulty in obtaining the necessary data for analysis and interpretation. The digital data for Pagladiya and Morapagladiya river is not available till date. Some amount of hydrological data of Pagladiya river is collected from the Gauge Station at North Trunk Road (NT Road) crossing. These data although not fully reliable are no doubt of immense use of the present work. However, as many as 75 villages out of 701 villages in different physiographic zones have been visited for collecting relevant information. In spite of these constraints an attempt has been made to investigate and analyse the fluvio-morphological impact of Pagladiya-Morapagladiya rivers on rural settlements and present with as much as sincerity as possible.

1.9 ORGANIZATION OF THE WORK:

The whole work is organized in seven chapters:

The first chapter is devoted to introduction of the problem and basis of sequence of the study.

Chapter II deals with the geomorphic characteristics of the study area with a brief description of its physiography, geology, climate, soil, vegetation with an overview of the rivers.

Chapter III is devoted to river channel changes and factors. Salient features of channel changes, bank line migration, bank erosion and flood are discussed here.

Chapter IV deals with the processes of settlement evolution from the perspective of historical and geomorphic characteristics favourable for human settlements in the study area.

Chapter V examines the changing pattern of settlements that takes place due to channel changes, bank erosion, flood hazard etc.

Chapter VI deals with fluvio-morphological changes of the study area and their impact of displacement of settlements.

The last chapter (i.e., Chapter VII) deals with the synthesis consisting of summary and conclusion of the study.

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Chapter - II

GEOMORPHIC CHARACTERISTICS OF THE STUDY AREA

The Pagladiya-Morapagladiya drainage complex within its watershed has physical, hydrological, socio-economic entities of its own, which bears a great significance to the study of geomorphological characteristics for formulation of strategies for socio-economic development and settlement planning etc. The physical base of the drainage complex between Bhutan Himalayas and the mighty Brahmaputra has been acting both as the material (i.e. compositional) and dynamic bases for development and modifications of landforms. The following few paragraphs, therefore, are devoted to the appraisal of the drainage complex.

2.1 GEOLOGY AND SEISMICITY:

The general stratigraphic formation of the Pagladiya-Morapagladiya drainage complex indicates the influence of the Siwalik upheavals that had occurred during Miocene to Tertiary period. The wide variations in stratigraphic, lithological and chronological orders have been grouped as Recent, Pleistocene and Pre-Cambrian or Archaean as noted in Table 2.1.

The Pre-Cambrian or Archaean gneissic complex is seen scattered in the northern boundary of Bhutan-foothill zone. Gneisses, granites, pegmatites and quartz are the characteristics lithology of this part of geological formation. The Pleistocene group is restricted to the areas of sediment concentration of older alluvium. Boulder, gravels, sands and alluvial clay conform to the lithological character of this group of geological formation. The older group of rocks in the study area is observed to occur up to the elevation of 91.5 m in the foothill zone.

Table 2.1: Geological formation of the Pagladiya-Morapagladiya drainage complex

Age group	Formation	Lithological Character	Regional Unit *
Pre-Cambrian or Archaean	Gneissic complex	Gneisses, granites, pegmatites and quartz, veins	Bhutan foothill
	Unconformity		
Pleistocene	Old alluvium	Boulders, gravels, sands and alluvium clay	Bhabar-Tarai zone
	Unconformity		
Recent	Newer alluvium	Shingles, sands, silts and alluvium clay	Built-up zone and chronically flood affected land

Source: ARSAC, Guwahati, 1990; * marked by the researcher.

Sediments of recent origin are observed in the built-up and chronically flood affected areas including areas in and around Nalbari, Barbhag and Barkhetri. The lithological characteristics have shown the contents of shingles, sands, silts and alluvial clay. This group consists of alluvium.

Tectonically the study region possesses significant geologic and lithologic development (Das, 1992). The tectonic forces and geological setting in the region further control the shape of the geomorphic features of the drainage complex.

During the middle of the Miocene period where the second upheaval of the Himalayas did occur, the part of the ridges between the Rajmahal hills in the west and the Garo hills in the east got depressed (Krishnan, 1940). Thus, two thrust movements, one from the north and the other from the east affected the Assam plateau (present Meghalaya plateau).

Geological history of the study region and its surroundings depicts that there have been formations of layers composed of alluvium of both older and newer origin. Boulders and clays were deposited on an east-west elongated shallow gap which is called as foredeep below the rising Himalayas (Pascoe, 1919). This foredeep later developed as the Brahmaputra valley as a result of continuous deposition of waste materials coming from the uplifted Himalayas in the north and the Assam plateau in the south. The thickness of the alluvium in the valley ranges between 91.5 m and 122 m (Pascoe, 1964).

A large portion of the study area covered by flood plain is made up of recently deposited alluvium carried by Brahmaputra and its tributaries, viz., Pagladiya, Morapagladiya, Burhadiya, Baraliya and Chaulkhowa etc. Mathur and Evans and the Geological Survey of India investigated the geological conditions in the Brahmaputra valley and suggested a classification of geological horizons. According to them the middle built-up plain (south of 60 m contour) and active flood plain fall under the stratigraphical and geomorphological unit known as 'Recent flood plain' and the geological unit called 'Nalbari Formation' (Barman, 1986).

The study area, like other parts of Assam lies in the most active seismic zone, therefore, the area is an earthquake prone area. The area has suffered from a number of moderate to severe earthquakes of magnitude ranging from 5 to above 8 in Richter scale. Earthquakes have been an influential factor in affecting landform and drainage network. The earliest recorded earthquake occurred in this region in 1663. Of course, there is a vivid description of 1696 earthquake in the Tungkhungia Buranji (Poddar, 1952). In recent times since 1920 more than 416 earthquakes of different magnitudes are recorded. The main causes of such frequent occurrence of earthquakes are presence of numerous faults, thrusts and other weak zones in the Assam valley and adjoining hilly areas. Amongst the recorded earthquakes of the region, the earthquakes of 1897 and 1950 are the most important ones. The magnitudes of these were 8.7 and 8.5 respectively on the Richter scale.

The earthquake of 1897 occurred on June 12 just after 5 pm. The epicenter was located partly on the Shillong plateau and partly in the plains of the Brahamaputra valley. It was felt over an area of 2,80,000 sq. km. Horizontal acceleration that reached at Gauhati was 2,600 mm/sec. According to Wadia (1966), this earthquake was felt over the area bounded by the isoseismic line of V or VI. The area under study was also heavily affected by this earthquake. The Oldham's report (1899 and reprint of 1981) gives a clear picture of the nature of this earthquake. This account was prepared by P.R.T. Gurdon, the then Deputy Commissioner of Kamrup on 26th November, 1897 and have been narrated as follows:

> "Through out the length and breadth of the sadar sub-division cracks were very numerous. The road from north Gauhati to Tamulpur, notably the portion between Kamalpur and Rangia and that between the 5th and 6th mile of the Rangia-Tamulpur via Barama and Nalbari, and the adjoining fields were fissured in several places. In many instances cattle are said to have lost their lives by falling into the cracks.
>
> As regards effusions of sand and water, it is reported that in nearly all the tahsils , the rice fields opened in fissures, and through these were ejected sand and water which sometimes rose to a height of from 3 to 4 feet (in rice fields of Nalbari)......................."
>
> River beds were raised and rendered shallow by sand emitted from the underground and by the upheaval of beds. Several rivers, formerly very deep had its bed silted up and could easily be forded. The beds of the Pagladiya, Dimila, Motanga, Baraliya, Chengnoi, Hazosota, Barnadi and many hill streams in Tamulpur have been considerably raised, and the water from them overflowing the banks inundated the whole country on both sides..............The beds of Chaulkhowa, Mora Manas, Kaldiya, Singra rivers were raised. The Nonai rose suddenly and flooded some villages near Nalbari......................."

The Pagladiya river mentioned in this report is probably the present Morapagladiya. Near Nalbari there was another river Noa nadi (Nanoi as mentioned above) which was flowing west of Nalbari (at present as a municipal drain which passes between the old Gurdon school and PWD Bungalow) has completely dried up after this earthquake. The bed of the Japarkuchi *beel* was also raised and drained out during the 1897 earthquake (Sarma, 1969; Sarma, 1989).

The focus of the earthquake was not far from Shillong, and in course of a few minutes all masonry buildings were over thrown. Great alteration was made in the level of the whole country. Extensive tract of land was subsided and became uncultivable and in many places roads, railways and embankments were utterly destroyed (Gait, 1963).

Another disastrous earthquake occurred on the 15th of August, 1950. The epicenter of this earthquake was located at 29° N and 97° E. The offshoots of the major tremors of this earthquake affected the study area. Landslips and rockfalls occurred along the foothills of the Eastern Himalayas due to earth movements. As a result the rivers carried large quantities of earth and sand as a consequence of which the beds of the rivers downstream have risen up. The beds of the Pagladiya and Nona rivers rose significantly ranging from 2 to 3 feet (Barman, 1986) and thus affected the whole drainage complex of Pagladiya and Morapagladiya. It also intensified the occurrence of flood annually in this region.

2.2 GEOMORPHIC AND LITHOSTRATIGRAPHIC UNITS:

Similar to the physiographic unit the area can be divided into three geomorphic units, viz., (i) Piedmont plain, (ii) Younger alluvial plain and (iii) Flood plain. The last two units come under the lithostratigraphic unit called 'Recent Alluvium' (Fig. 2.1).

(i) Piedmont Plain: The piedmont plain is the transitional zone between the hills on the north and alluvial built-up plains in the south. This plain is covered by shallow deposits of outwash materials from the northern Bhutan-Himalaya during the Pleistocene period. This may be sub-divided into two geomorphic units, (a) upper piedmont plain and (b) lower piedmont plain composed of alluvial lithostratigraphic unit.

(ii) Younger Alluvial Plain: Most of the lower half of the younger alluvial plain falls under the second physiographic unit of the study area. This unit consists of layers of gravels, sands, silts and clays of later cycle of fluvial regime. This area is characterized by channel fills and annual floods with gentle slope towards south. The flat alluvial plain is formed at a little higher elevation than the existing flood plain. It is a recharge zone and has a large number of cutoff meanders and ox-bow lakes. This zone is identified as suitable location of moderate to deep tube wells.

(iii) Flood Plain of Brahmaputra and its Tributaries: This unit almost corresponds to the active flood plain zone. It consists of unconsolidated materials like sands, silts and clays. It has a very low gradient towards Brahmaputra and is flooded seasonally when the rivers overflow their banks. Old meanders, natural levees, back swamps, *beels*, channel bars etc. are the geomorphic features found in the area. It is partially a recharge zone having shallow ground water table (ARSAC, 1990).

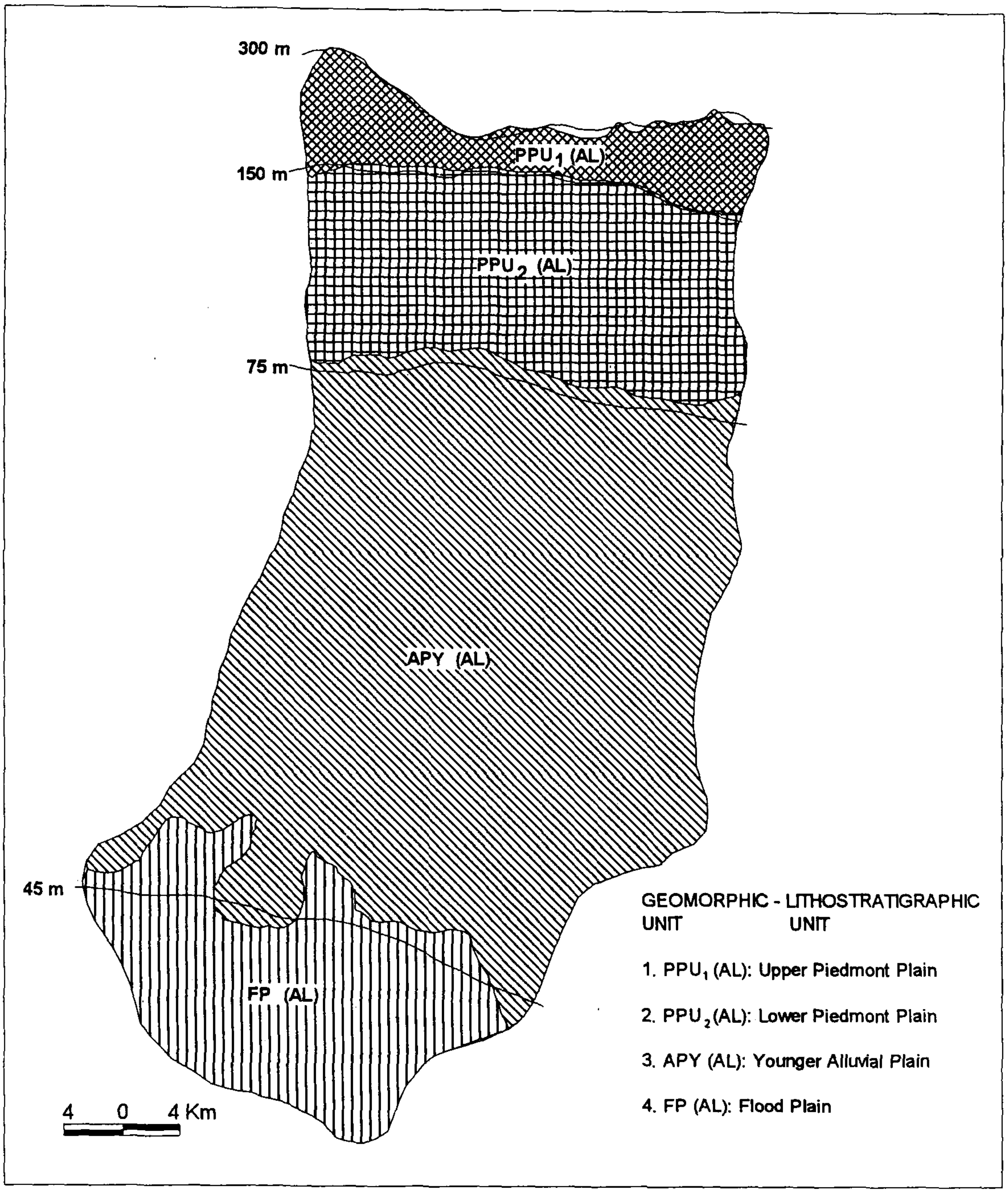

Fig. 2.1: Geomorphic and Lithostratigraphic Units

2.3. PHYSIOGRAPHY:

The study area is a part of the north bank plain of the Brahmaputra valley. This part is a reverine flat plain formed due to continuous fluvio-geomorphic actions of the Pagladiya, Morapagladiya, Burhadiya, Nona, Ghogra and Baraliya rivers. The Brahmaputra river is also responsible for the formation of the lower most part of the drainage complex. These tributaries have dissected the area and meet the Brahmaputra with sub-parallel courses along the active flood plain of the river forming beels and swamps here and there. The topography of the area was also modified by the great Assam earthquakes of 1897 and 1950. The general altitude above mean sea level of the region varies from 300 m in the north to 42 m near the bank of the river Brahmaputra in the south. The region has a very gentle southward gradient and a little east-west variation in topography. This is due to the tilt of the southern plain towards the west.

On the basis of the geomorphological features the region may be divided into three micro-physiographic zones (Das, 1985) and they are almost running parallely to the Brahmaputra river. The zones are: viz., (i) The Northern Foothill Zone, (ii) The Built-up Plain and (iii) The Active Flood Plain (Fig. 2.2).

(i) The Northern Foothill Zone: Along the Indo-Bhutan boundary, this zone is stretching with a width of 10-20 km. This zone may be sub-divided into a narrow Bhabar zone along the piedmont of the Lesser Himalayas and the flat Tarai belt south of the former spreading north of the middle plain bounded by 75 m contour.

The coalescence of alluvial cones at the piedmont of the Himalayas (Bhabar zone) gives rise to undulated topography where soils are composed of unassorted detritus. Due to the sudden fall of the streams from the high mountain to the plains, the water percolates down to the Bhabar and reappears a few kilometers down the stream at the southern limit of the Bhabar.

Towards the south of the Bhabar, there is a flat plain where water seeps out from Bhabar zone. This zone is known as Tarai, a plain of tall grass with unhealthy damp soil. The gradient of slope of this zone is slightly less than that of the Bhabar zone. It is interesting to note that the water seeps out here gives rise to many of small tributaries of the Brahmaputra. The foothill zone of the study region is the home of many reserve forests like – Batabari, Dihira, Subankhata and Darranga. Human settlement is very sparse in this part of the study area.

(ii) The Middle Built-up Plain: Between the Tarai in the north bounded by 75 m contour and the floodplain in south bounded by 45 m contour there lies a comparatively high and extensive plain, spreading east-west parallel to the course of the river Brahmaputra. This plain is comparatively elevated than the flood plain in the south with an average slope of less than 1.0 to 0.8 m/km. Although dissected by a number of small and big streams, the topography of this zone is not so much undulating. Basically the plain has been formed by aggradation of sediments carried by the Pagladiya, Morapagladiya, Burhadiya, Nona, Baraliya etc. and the Brahamaputra river itself. The extensive plain is composed of new alluvium of recent origin. A good number of marshy lands, beels and cutoff meanders or ox-bow lakes are found in this zone. This area frequently suffers from devastating floods occurred due to the frequent breach of the embankments of the rivers. As the

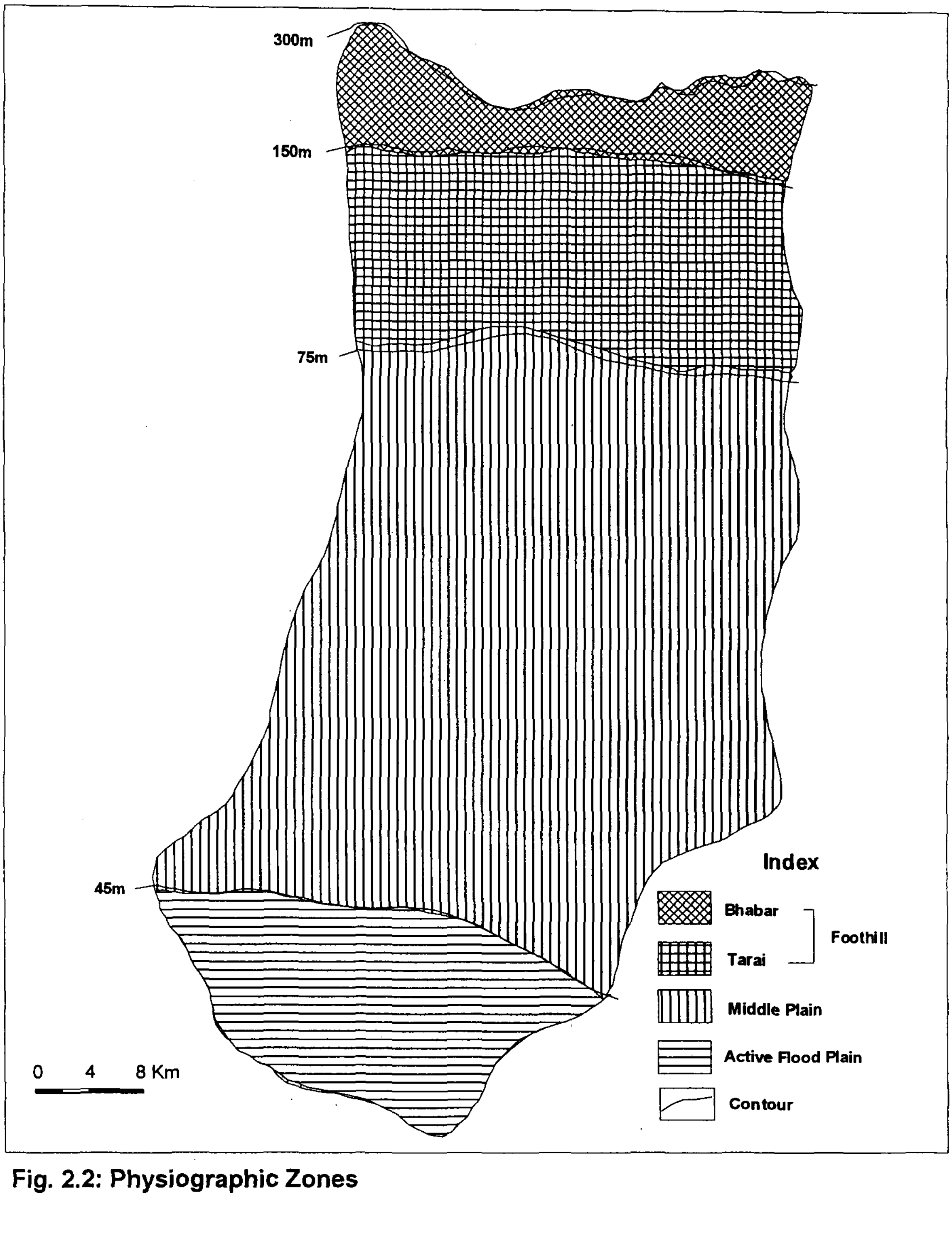

Fig. 2.2: Physiographic Zones

plain is made up of new alluvium, this is not only the most densely populated area but also supports rich rice fields of the study area.

(iii) The Active Flood Plain: It is the lowermost part of the Pagladiya-Morapagladiya drainage complex. It lies between 45 m contour in the north and the Brahmaputra river in the south. This region as a whole is very low lying having an average gradient of 0.5 m/km and it is flooded annually by the high flows of Pagladiya and the back water of the Brahmaputra. This area is composed of recently deposited alluvium and silts. Due to low altitude and flatness of the topography, the entire zone is characterized by the existence of numerous *beels* and waterlogged tracts.

This zone is favourable for buffalo grazing and most of the *bathans* (place for buffalo and cattle herding) of the study area are found here. In the recent years the size of the marshy and waterlogged areas is found to be gradually decreased as a result of reclamation and encroachment for cultivation and settlements.

2.3.1. Analysis of Slope:

Slopes are the major constituent element of all the geomorphic features. They have wide variations in regard of morphology, genesis and development. The primary slopes under differential conditions of structure, relief, rocks, climate, soil, vegetations and to a certain extent human interference have rendered or derived secondary slopes rather complex due to mainly exogenetic processes (Scheidagger, 1970). The slopes, thus, having wide variations in their morphology and development processes are yet to be fully understood. The analysis and mapping of slopes have, therefore, been some of the major tasks of the geomorphologists.

An attempt has been made here to evaluate the average slopes in the study region in respect of their representation through map, description and classification and to find out some probable causes of the pattern and differential development of slopes.

The present work is based on the morphometric data from topographical sheets (1:50,000) of the region. The average slope of the area has been calculated by the application of Wentworth's method (1930), but converted to suit metric toposheets. This method, though tedious but serves the interest of the researcher best. The modified formula writes as follows:

$$\tan\Theta = N.I./636.6$$

Where, N is the average number of contour crossings per km;
I is the contour interval and 636.6* is the constant value.

*(The constant number has been fully explained by Wentworth, and its origin form for the FPS measurement was 3,361. This was derived from the multiplication of 5,280 and 0.6366. The value 0.6366 is said to be the mean of all possible values of Sine Θ, where Θ is the angle between the grid lines and the contours. 5,280 stands for the number of feet per mile and this is replaced by 1,000 which is the number of metres per kilometre. This enables the user of Metric sheets to apply formula without much changes).

For the purpose of slope study, the entire region has been classified into two morphological units, viz., hills and plains. These are then grided and average slope is computed using the modified formula and computed values are then plotted on the grids of the map. Isopleths are drawn in order to find out spatial pattern of the average slopes.

The slope map (Fig. 2.3) reveals that while the slopes range between less than 5' and above 30', majority of the area (86 per cent) have average slopes of less than 30'. The northern foothill zone is characterized by slopes ranging between 30' and 3° and the Pagladiya-Morapagladiya plain have less than 30'. The minor variations of slope on

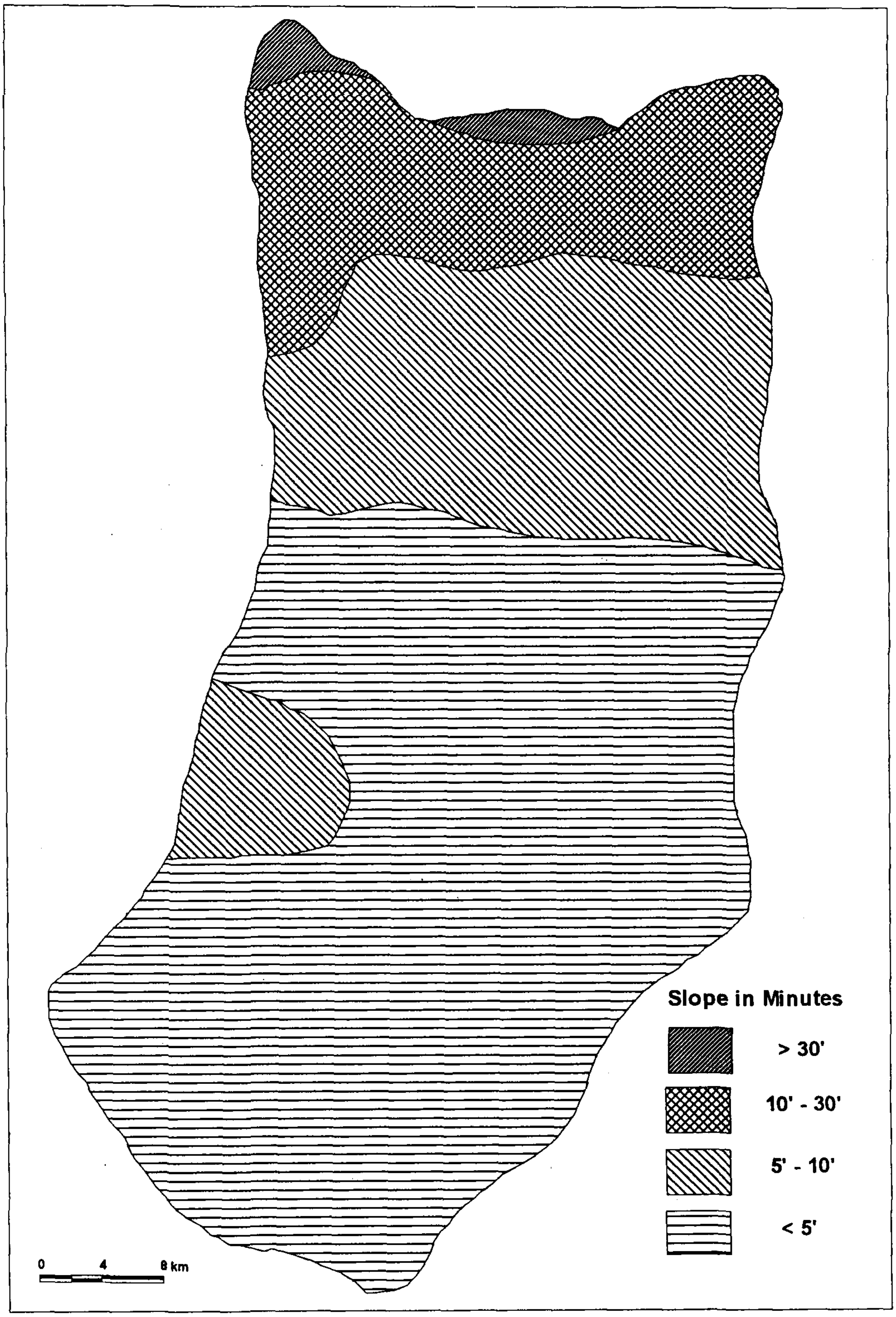

Fig. 2.3: Average Slope (Wentworth's Method)

different morphological units are mainly due to existing drainage pattern (Twidale, 1960). The spatial pattern of slopes in the region is closely linked with the direction of the master stream Brahmaputra and Pagladiya, Morapagladiya, Burhadiya, Nona and Baraliya rivers. The ruggedness of relief modified by drainage has given minor slopes amplitudes along east-west direction. The average slope on the middle built-up and active flood plain is characterized by the landform under equilibrium condition. This is perhaps due to the fact that the Pagladiya, Nona and other rivers have deposited silts and sands in their flood plain carried out from the foothills of Bhutan-Himalayas.

2.4 DRAINAGE AND WATER BODIES:

The study area is basically controlled and drained by two river systems, viz., Pagladiya and Manas (part). The river Brahmaputra has a remarkable influence in the lowermost part of the area. In accordance with the general south-westward slope of the western part of the study region, the tributaries such as Morapagladiya and Burhadiya flow to the river Manas. On the other hand, the tributaries of the eastern part of the drainage complex which form Pagladiya system including Pagladiya, Nona, Baraliya etc. flow directly from north to south to meet the Brahamaputra river (Fig. 2.4). Sources of these tributaries lie in the Bhutan Himalaya and, therefore, they carry huge amount of water and silts particularly during the summer. But most of the tributaries have lost their courses in the low-lying areas and marshes of the active flood plain zone. Because this zone is not well drained and greatly suffers from waterloggings during the summer.

Due to the seismic instability and fluvial reasons, the Pagladiya, Nona and Baraliya in the eastern part and Morapagladiya and Burhadiya in the western part of the study area take a sub-parallel course in their lower reaches before reaching the master

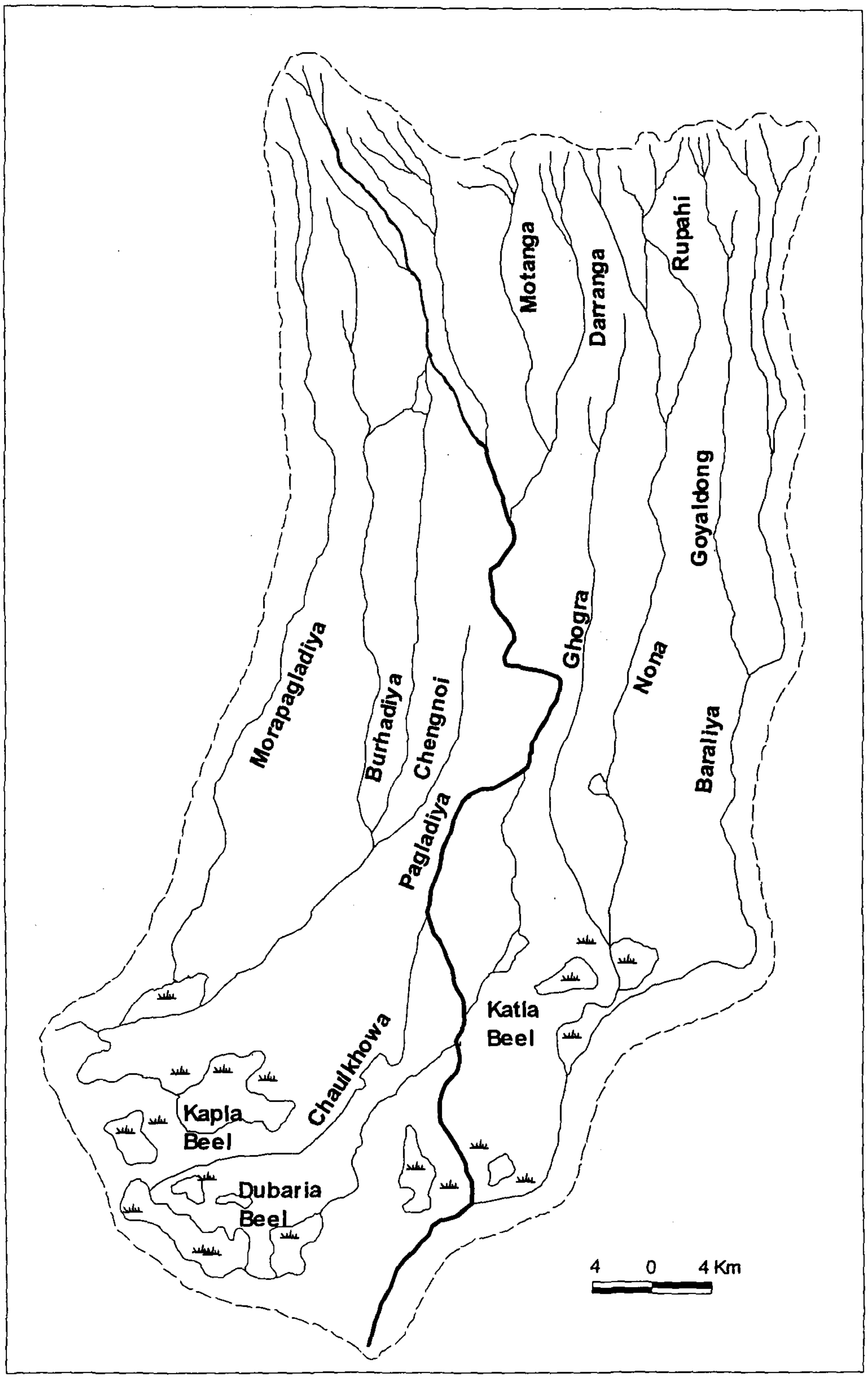

Fig. 2.4: Drainage and Water Bodies

stream Brahmaputra. On the other hand, the Brahmaputra has been shifting southward (Starkel *et al,* 1998). This is partly attributed to seismic instability of the Himalayas and partly the tremendous volume of deposition of detritus on the northern part of its bed by the more active Pagladiya river.

Another geomorphic phenomenon of the study region is the shifting nature of the river Pagladiya, Nona, Morapagladiya and other tributaries. Being obstructed by the natural levee of the Brahamaputra, the process of direct water discharge from the marshy and waterlogged areas is hindered. As a result, during the summer months particularly at the time of flood the tributaries are to carry huge volume of water and instead of flowing through the greatly meandering courses they naturally straighten their courses. This results in lateral shifting of the river courses. There are many instances of such shifts of channel which resulted in the creation of marshes, ox-bow lakes and other low-lying tracts in the southern most part of the study region. The important wetlands like- Kapla, Dubaria, Katla etc. are the natural fisheries of the study area.

2.5 THE PAGLADIYA – MORAPAGLADIYA DRAINAGE COMPLEX:

The Pagladiya and Morapagladiya are the important north bank tributaries of the Brahmaputra river. The Pagladiya river originating from the southern slope in the sub-Himalayan range of Bhutan (near Naningpho, 2,838m) flows towards south through a mountainous tract for 20 km upto Chowki. Then it leaves the hilly region and enters plains within Indian territory. It passes through the Bhabar-Tarai region of the Northern Foothill zone. The Bhabar zone along the piedmont of Lesser Himalaya with coalescence of alluvial cones gives rise to the formation of highlands, the soil of which is known as bhabar is composed of unassorted detritus. Towards the south of the bhabar there is a flat plain where water seeps out from the Bhabar zone is known as Tarai. The gradient of slope of this zone is slightly less than that of Bhabar zone. Then the river passes through the Middle Built-up plain and lower Active Flood Plain of Nalbari and Kamrup districts of Assam. Between the Tarai in the north and the flood plain in the south there lies a comparatively high and extensive plain, spreading east-west parallel to the course of the river Brahmaputra. The plain is comparatively elevated than the flood plain in the south. Although dissected by Pagladiya, Morapagladiya, Burhadiya and other small streams, the topography of this zone is not so much undulating. Both the depositional and erosional characteristics have been found to be prominent in the area.

On the south of the relatively high land zone, there lies an active flood plain of the Brahamaputra and its tributaries. Due to low altitude and flatness of the topography, this zone is characterized by the existence of numerous *beels* and waterlogged tracts. The genesis and growth of the *beels* and waterlogged areas are directly associated with the geo-physical conditions and tectonic evolution of the region, hydrologic and fluvio-geomorphic behaviour of the rivers and pattern of landuse and human occupance .This zone includes the most precarious flood prone areas of the study region.

The entire course of the Pagladiya river from source to confluence with Brahmaputra river is 196.80 km, out of which 19 km in hilly tracts of Bhutan and 177.80 km in Nalbari district of Assam. In the west of the study area Morapagladiya is another important tributary springs out from the southern slope of Bhutan-Himalaya at an elevation of 120 m. The upper part of the river up to Subankhata is known as Dirring. The Morapagladiya river is the original course of the Pagladiya river which was abandoned more than 160 years ago.

The study area is dissected by Pagladiya, Burhadiya and Morapagladiya rivers with numerous small tributaries, in fact which form the great Pagladiya-Morapagladiya drainage complex with an catchment area of 1,758.89 sq. km. Out of the total area, about 423 sq. km fall within the northern foothill zone. The middle built-up plain covers an area of 945 sq. km, whereas the lower active flood plain has an area of 391 sq km. In the plain the drainage complex has a general gradient of 1.5 to 1.0 m/km up to the built-up plain which reduces to 0.5 m at the confluence.

2.6 TRIBUTARIES OF PAGLADIYA AND MORAPAGLADIYA RIVERS:

The Pagladiya River has three main tributaries in the plain. They are: (i) Motanga, (ii) Baraliya and (iii) Nona.

The Motanga originates in the southern slope of the Bhutan-Himalayas and after traversing 48 km of its course joins the Pagladiya river near Uttarkuchi village in Nalbari district. The Baraliya originating near the Nagrijuli tea estate flows down through the foothill zone and passes with a meandering course in middle plain and joins Nona at 13 km of its course from Nagrijuli and both these rivers meet the Pagladiya river at Dosutimukh.

In the upper reach, the Nona is known as Nona-Motanga which is formed by two hilly streams, namely, Bojajuli and Memabari. The Motanga ultimately receives the Nona channel near Tamulpur and forms the Nona river.

The Pagladiya river system comprises the rivers Pubnoi, Pagla-Motanga, Darranga, Pagladiya, Jia-Baladi, Dimla (Rupahi), Nona-Motanga, Nona, Ghogra and Baraliya.

As the general course of the Pagladiya river is concerned, the river from its source in the hills flows southward upto Chowki and enters into the plain of Assam. At first the river turns towards the south-east direction and in between Bar Agra and Dosutimukh, it moves almost in the southward direction. After this part, as the river gradually approaches the Brahmaputra river especially from Bijulighat, it turns towards south-west and ultimately joins the master stream at 2 km downstream from Chotemari village.

On the other hand in accordance with the general south-westward slope of the western part of the study area. Morapagladiya and Burhadiya flow to river Manas. Burhadiya river originates from a marshy low lying tract at Bhalukdonga near Subankhata, where a tributary known as Lakhmi meets Burhadiya. It flows through Banekuchi crossing National Highway No.-31 (NH-31) and flows towards south up to Sahpur and then turns towards west. The Morapagladiya originates from the foothill zone near Dihira and stretches through Subankhata, Jopadong and crosses NH-31 through Barama and moves towards south. It merges with river Burhadiya near Barpit reserve at Bhojkuchi and flows westward. The Burhadiya ultimately joins with Manas river.

2.6.1 Morphometric Characteristics of Pagladiya and Morapagladiya Rivers:

2.6.1. a) Stream Order, Stream Length and Bifurcation Ratio:

Morphometric analysis is a necessary input in river basin development and management planning. Various parameters of Pagladiya-Morapagladiya drainage complex have been worked out including stream numbers, total stream channel length, mean stream length, bifurcation ratio, drainage density and drainage frequency.

Drainage basin characteristics of Pagladiya and Morapagladiya rivers have been worked out under linear and areal aspects like stream ordering, stream length and bifurcation ratio. By stream ordering lines of stream network is identified systematically. Strahler's (1964) method has been adopted for stream ordering of Pagladiya and Morapagladiya rivers (Fig. 2.5). Among these rivers Pagladiya is belonging to V order and Morapagladiya to II order. It is observed that apart from integrated stream network a large number of low order stream occur in both the basins (Table 2.2).The I order has the highest number of streams i.e., 30, while the II and III orders posses 16 and 8 streams respectively in Pagladiya basin. In the Morapagladiya basin only 6 streams occur in II order out of total 7 streams.

In the Pagladiya basin the maximum length of stream segments is exhibited by II order streams and then total stream length decreases as the order increases. The stream length ratio ranges from 0.196 to 2.481 with an average length ratio of 1.032. The average stream length ranges between 2.02 and 25.07. The I order streams show a minimum average stream length of 2.02 km, while the IV order shows a maximum value of 25.07 km. In the case of Morapagladiya river I order stream has only 6 streams with a total length of 30 km and II order 52 km. The average length ratio between these two orders (i.e., I and II) is 1.733. Average streams length for I order is 5.00 km, while for the II order is 52 km. This indicates that lithology is main controlling factor for the whole study area. The small channels of I and II order develop over the upper piedmont plain. Likewise the III and IV order streams are found in lower piedmont plain and younger alluvial plain respectively.

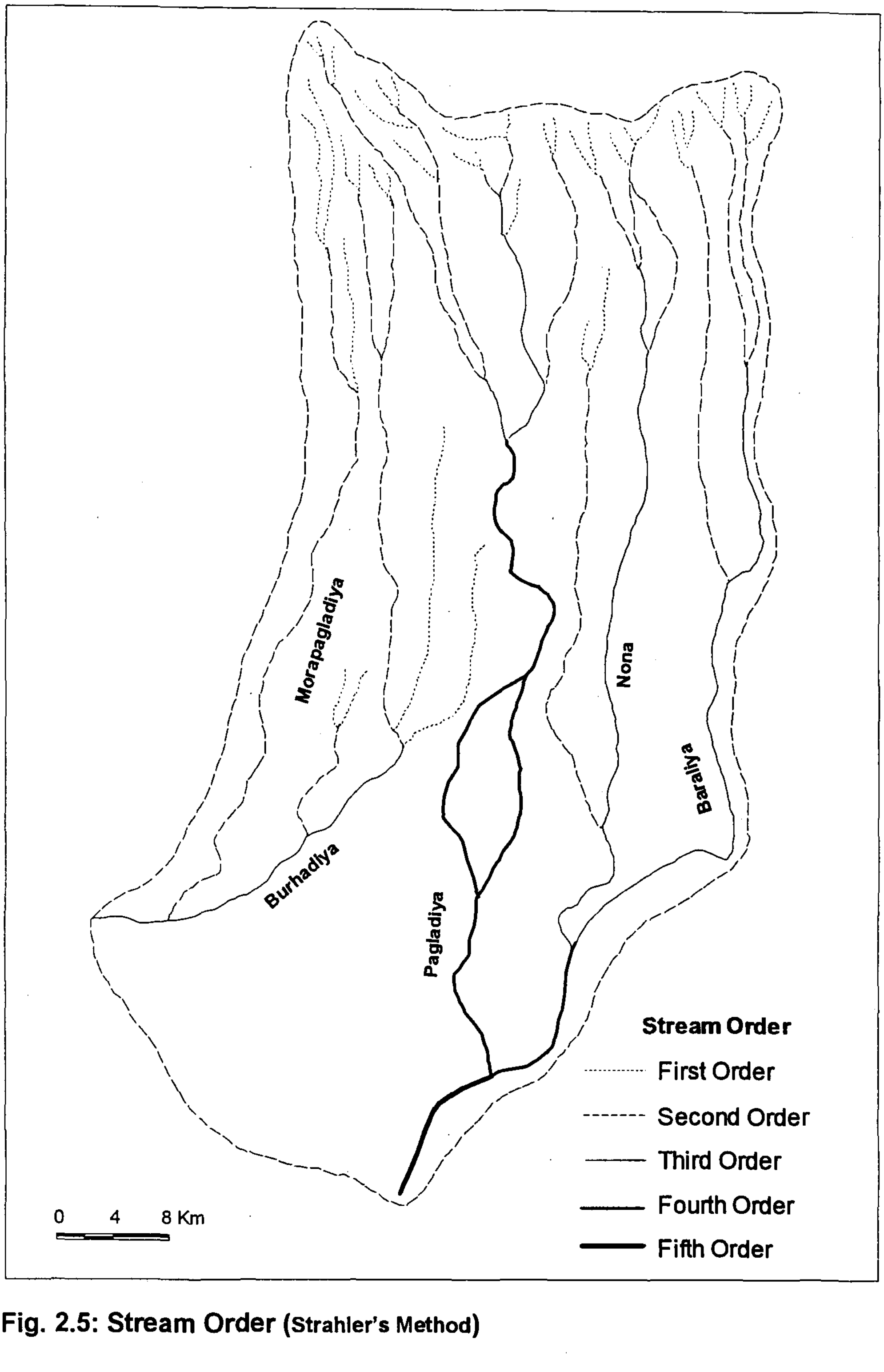

Fig. 2.5: Stream Order (Strahler's Method)

Table 2.2: Stream Order, Number and Bifurcation Ratio of Pagladiya and Morapagladiya Rivers

Basin	Stream Order	Stream Number	Stream Length (km)	Length Ratio	Average Length Ratio	Average Stream Length Ratio	Bifurcation Ratio (Rb)	Average Rb
Pagla-diya	1	30	60.7			2.02		
				2.481			1.57	
	II	16	150.6			9.41		
				0.899			2.00	
	III	8	135.4		1.032	16.93		2.382
				0.555			2.66	
	IV	3	75.2			25.07		
				0.196			3.00	
	V	1	14.8			14.80		
	Total	58	436.7					
Mora-pagla-diya	1	6	30			5.00		
				1.733	1.733		6.00	6.00
	II	1	52			52.00		
	Total	7	82					

Calculated by the researcher

Bifurcation ratio is the ratio of the total number of streams of one order to that of the next higher order. The mean bifurcation ratio of the Pagladiya river is 2.382 while of Morapagladiya is 6. High values of bifurcation ratio are observed between IV and V order in Pagladiya basin. It is in fact very interesting to note that the Pagladiya basin is subjected to yearly floods every summer while there is comparatively less occurrences of flood in the Morapagladiya basin. The bifurcation ratio of Morapagladiya is exceptionally high and under such condition floods are expected to be natural. To explain these phenomena clearly it is important to understand other paramenters of drainage like drainage density and frequency which is given below.

2.6.1. b) Drainage Density and Drainage Frequency:

Drainage density is indicative of the length of stream per unit area which has been now immensely used in delineating some of the morphometric characteristics of drainage basin. It reflects the effect of altitude, relief, geological structure, slope, soil, vegetation cover, rainfall and run-off characteristics on the drainage net and its evolution.

Table 2.3: Drainage Density, Drainage Frequency and Basin Length Ratio

Basin	Drainage Density L/A	Drainage Frequency Nu/Au	Basin Length Ratio Lu/Lu-1
Pagladiya	0.26 km/km^2	0.034/km^2	1.011
Morapagladiya	0.56 km/km^2	0.110/km^2	1.016

Calculated by the researcher

The study region has drainage density varying from 0.26 to 0.56 km per sq. km. While the highest density lies in the foothill zone of dissected terrain of high altitude, the lowest one lies in the flood prone and swampy areas. The drainage density is highly distributed over the Bhabar zone parallel to the river Brahmaputra. The distributional pattern of drainage density reflects the geological, endogenic and exogenic processes for the assemblage of landforms. In the foothill zone of Bhutan-Himalayas, where moderate slope (average slope 1° to 3°) and rolling surface of the alluvial fan experience high annual rainfall (about 2500 cm) oozes out a number of rills, gullies and streams, some of them being persistent, some being transitory and others being intermittent. Another cause of high drainage density here is that, this part being under seismically active belt, perhaps affects the surface configuration of the area and ultimately leads to initiation of a number of gullies, rills and streams.

There are pockets of lowest drainage density, especially in the south western part of the study region. The lower part of Morapagladiya, Burhadiya, Pagladiya, Nona and Baraliya has drainage density less than 1, where absolute relief ranges from 45 m to 100 m only. The upper courses of Pagladiya and Baraliya on the foothill region have no high density areas since these rivers are big enough debouch into the plain at high angle of inclination.

Drainage frequency depends on development of watershed surface. The drainage frequency value of the Pagladiya basin is 0.034 per square km, while for Morapagladiya is 0.11 per sq. km (Table 2.3). The frequency value for both the basins is less and this is due to plain surface formed by depositional action of rivers which have low relief.

The analysis of drainage clearly shows that the Pagladiya river is characterized by low density and frequency of streams while the bifurcation ratio is also low. On the other hand Morapagladiya river has a high drainage density and frequency along with an exceptionally high bifurcation ratio. This would explain why Pagladiya river floods more frequently with a devastating effect. The bulk of water received by both the basins is large during summer but in the Pagladiya basin the water cannot be contained as the density of streams is low and the areal extent is large though bifurcation ratio is within an ideal range i.e., 3.5.

2.6.1.c) Basin Length Ratio:

The basin length ratio for Pagladiya and Morapagladiya rivers is only 1.011 and 1.016 respectively which indicate that the rivers are in an equilibrium condition on a flattish relief.

2.7 SOIL:

Soil is not only a biotic environment, but also one of the pivotal factors of landform development and modifications. It reflects the topographic, geomorphic, hydrologic and environmental dynamics and has an impact on the domain of fluvio-geomorphology and cultural geography.

Diversified soil characteristics have been observed due to their different evolutionary processes. The Pagladiya-Morapagladiya drainage complex covers hills and foothills, built-up plain and chronically flood affected low lying areas. As a consequence of these the area is characterized by coarse grained to fine grained soil. According to their nature of origin in the area they may be grouped into four distinguishable characters as mentioned in Table 2.4.

Soil of the study area may broadly be classified into three types corresponding to its physiographic setting (Das, 1981), viz., (i) New Alluvium, (ii) Old Alluvium and (iii) Sub-montane soil (Fig. 2.6).

(i) New Alluvium: The new alluvium covers a major part of the region extending from the bank of the Brahamaputra up to the northern fringe of the highland zone. The alluvium soils differ greatly in texture and consistency. It is generally grey, light brown, yellowish or blackish according to the place of origin. The soils of marshy areas are somewhat different from the other built-up area. The new alluvium soils are generally found near the river banks and in the flood plain area. In the lower built-up plain the soils are compact and composed of loam, silt and clay with humus content.

In the lower chronically flood affected plain, the soils are non-cohesive. These recent alluvium are composed of finer sand, silt and clay (Barman, 1986). But in perennial waterlogged areas, the soils are blackish in colour and muddy in nature. Sandy loamy soils are found also in different swamps and *beels* of the study area.

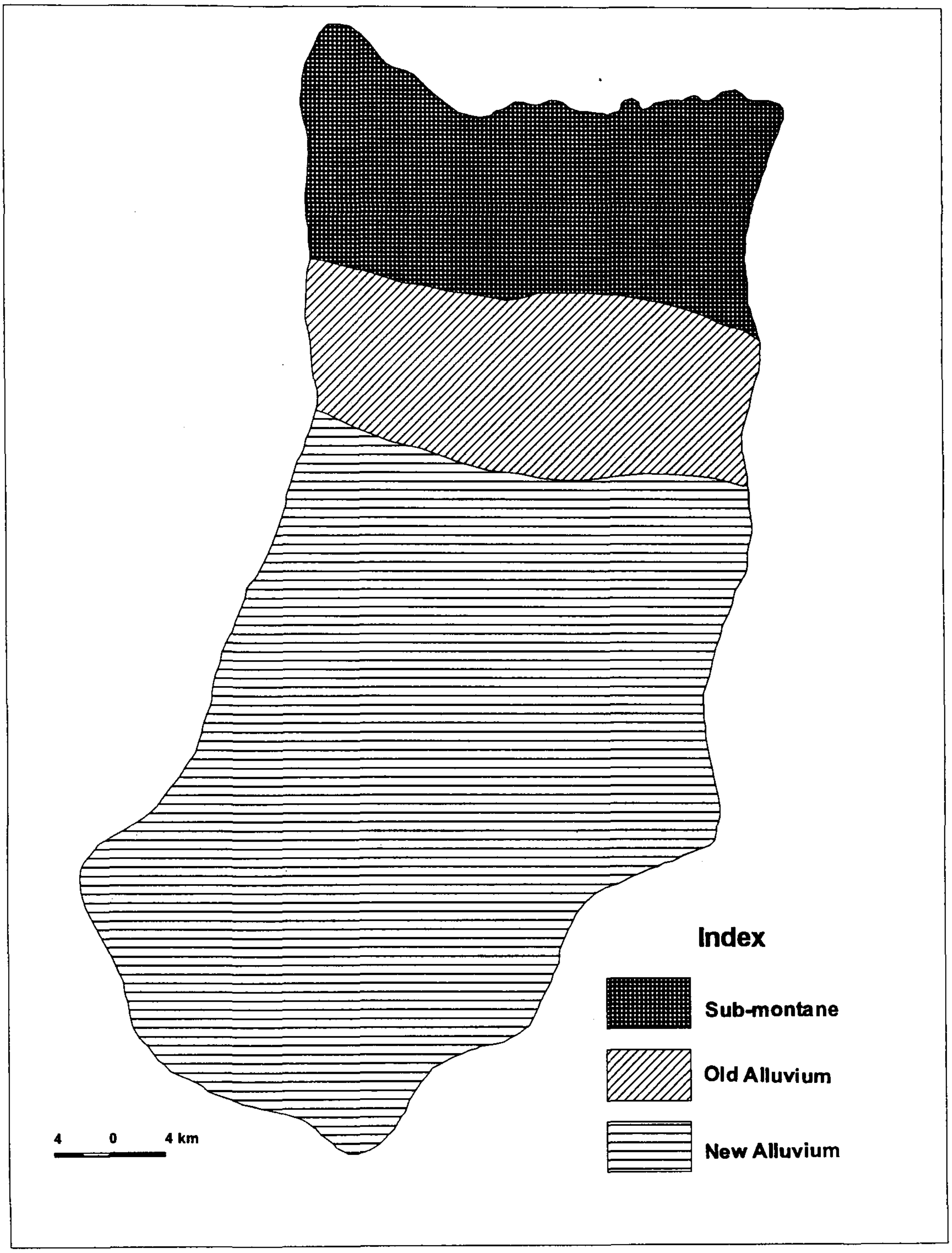

Fig. 2.6: Soil Zones

Generally, new alluvium fertile soils have pH value of 6.5. In the study region the pH value of soil varies from 7.3 to 4.3. Sandy loamy soils are very suitable for jute cultivation whereas heavy clay soil of low lands with percentage of nitrogen content are suitable for the cultivation of rice, wheat and pulses.

Table 2.4: Relief-Zone wise soil characteristics in the study area

Sl No.	Relief Zone	Soil Composition	Character
1.	Bhutan Hill-slope region	Red soil with gneisses, granite, pegmatites etc	Hard rock
2.	Foot-hill region		
	(a) Bhabar	Soil with boulders, gravels, pebbles, cobbles, sand and clay	Loose and unassorted
	(b) Tarai	Old alluvium and sand, silt and clay soaked with water	Partly cohesive
3.	Built-up area	Old and recent alluvium composed of finer sand, siltand clay	More cohesive
4.	Chronically flood affected areas	Recent alluvium of finer sand, silt and clay	Less cohesive than that of Built-up plain area

Based on the field observation; and after Barman (1986).

(ii) Old Alluvium: There is a small patch of old alluvium stretching east-west just between the foothill zone and the middle plain of the study area. It is more clayey, generally of dark colour and kankary composition. The depth of the soil found in the built-up zone ranges up to 4 m. The soil of this zone is compact with less permeability to water percolation (Das, 1981).

(iii) Sub-montane soil: Along the northern foothills of the drainage complex there is a narrow strip of the soils of sub-montane character. This type of soil is composed of loose and unassorted coarse sands and pebbles carried by the streams from the Himalayan uplands.

2.8. CLIMATE:

The climate of the Pagladiya-Morapagladiya drainage complex does not differ from that of the other parts of the Brahmaputra valley. The area lies within the regime of monsoon type of climate, with minor local variations. According to Koppen's classification of climate, the whole Ganga-Brahmaputra region falls under the humid mesothermal Gangetic type (CWg). But the comparison of climates of this region and the rest of Ganga valley shows slight difference in the distribution of various elements of weather and climate, such as rainfall, temperature and humidity. Therefore, it will be more appropriate to designate the climate a CWg type, i.e., humid and sub-tropical climate (Borthakur, 1986).

The climate, in general, is characterized by summer rain, extreme humidity and cool dry winter. The seasons in the study area can be easily distinguished from the nature of distribution of temperature, rainfall, rainy days and fog. Thus the distributional variation of these four elements in the months of the year clearly indicates four distinct seasons in the area, viz., (i) Winter, (ii) Pre-Monsoon, (iii) Monsoon and (iv) Retreating Monsoon.

(i) Winter: The winter season begins in the middle of November and continues up to the end of February. This season is characterized by cool weather, occasional scattered thunder showers, frequent morning fog and a clear sky and most pleasant and comfortable weather. The occasional rainfall during this season is mainly due to the western disturbances. The average rainfall is less than 50 mm and temperature varies between 11°C and 19°C. December and January are the driest months and generally January is the coldest month with a record of minimum temperature of 9.2°C and average rainfall of less than 11.33 mm in the month of January during 1971-2000 (Appendix-I).

(ii) Pre-Monsoon: This season starts by March and continues up to May. During this season, particularly in the month of April, occasional rainfalls occur as a result of 'Norwester' or 'Kalbaisakhai' of Bengal locally known as '*Bardai-chilla*'. The average rainfall, mean temperature and relative humidity are 150 mm, 24°C and 75 % respectively. In this season the mornings are cool, pleasant with mild winds, the afternoons are hot and irritating. This is due to the wide range of diurnal temperature.

(iii) Monsoon: The monsoon sets by the last week of May or early part of June and it lasts up to September or the first part of October. This season is characterized by cloudy weather, high humidity, heavy rainfall and weak surface wind. The intensity of rainfall generally increases towards north of the study area (Fig. 2.7). It is the rainy season when the area receives spells of continuous and moderate to heavy rains. July generally gets more than 70 per cent downpour and brings havoc of floods to this region. August is the hottest month of the year. The average annual rainfall and temperature in this season are more than 300 mm and 28° C respectively. This is the most important season during which *Sali* rice, the principal crop of the area is cultivated. During the months from June to September the rainfall is usually ranges from 200 mm to slightly more than 500 mm.

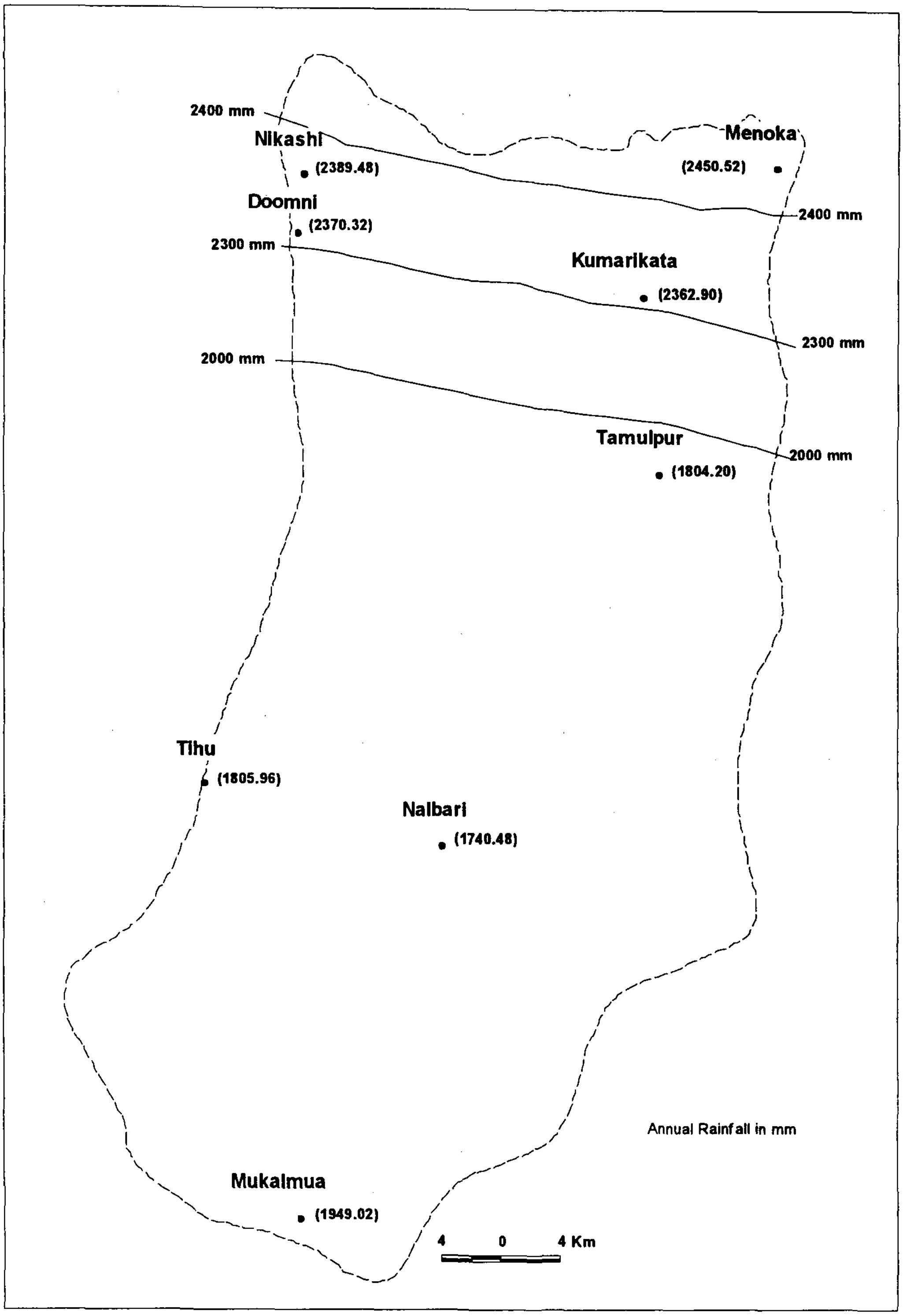

Fig. 2.7: Isohyetal Map

(iv) Retreating Monsoon: The monsoon withdraws from this region in the last part of September or in the first of October. After the withdrawal of the monsoon, light unsteady winds spread over the region and the weather gradually clears up. Consequently, the intensity of rainfall and the number of rainy days go on decreasing. Rainfall during the season is less than 40 mm. The temperature gradually falls but the diurnal range increases.

Although the region receives adequate rainfall (total annual average of about 1600 mm) for agricultural purposes it suffers from its temporal variations. Intensive concentration of rainfall to a few rainy months causes floods which depend on the setting in of monsoon. Sometimes delay of the monsoon leads to late agricultural activities or damage to standing crops. As the economy of the area is agricultural based, uncertainty looms the minds of the people at large and almost every summer flood creates havoc leading to huge losses. As explained above, the character of Pagladiya basin is more prone to floods and for this reason more attention is paid to this basin and the consequences that these floods create. The large volume of discharge from the basin resulting in floods and channel changes during summer is an important problem which will be dealt in the next chapter.

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CHAPTER – III

RIVER CHANNEL CHANGES AND FACTORS

Change of channel is a natural behaviour of a river and a universal fluvial process. It is associated with the alluviation process responsible for formulation of alluvial plains on the surface of the earth. Strictly speaking, change in the course of a river usually happens in the plain portion of a river valley. The rivers have a tendency to shift their courses particularly in the piedmont zone where they debouch into the plains leading to change of the courses downstream in the alluvial plains. When a river leaves its existing course and takes a new course to maintain its flow it is termed as shifting of course or the river itself. Changes in the course of a river can be attributed to tectonic, geomorphic and hydrologic forces, or human interference. These factors can act independently or in combination of more than one factor as well. Significantly to mention that due to tectonic upheavals, change in the course of a river may occur even in the upper reaches lying in the hills and mountains.

3.1 NATURE OF RIVER CHANNEL CHANGES:

The nature of river channel changes in the Pagladiya-Morapagladiya drainage complex can be discussed under the following categories:

3.1.1 History of Channel Formation:

During the last 160 years, there are many changes in the river channels and drainage system of this region. In this respect, therefore, the history of channel changes is considered taking a total view of the area.

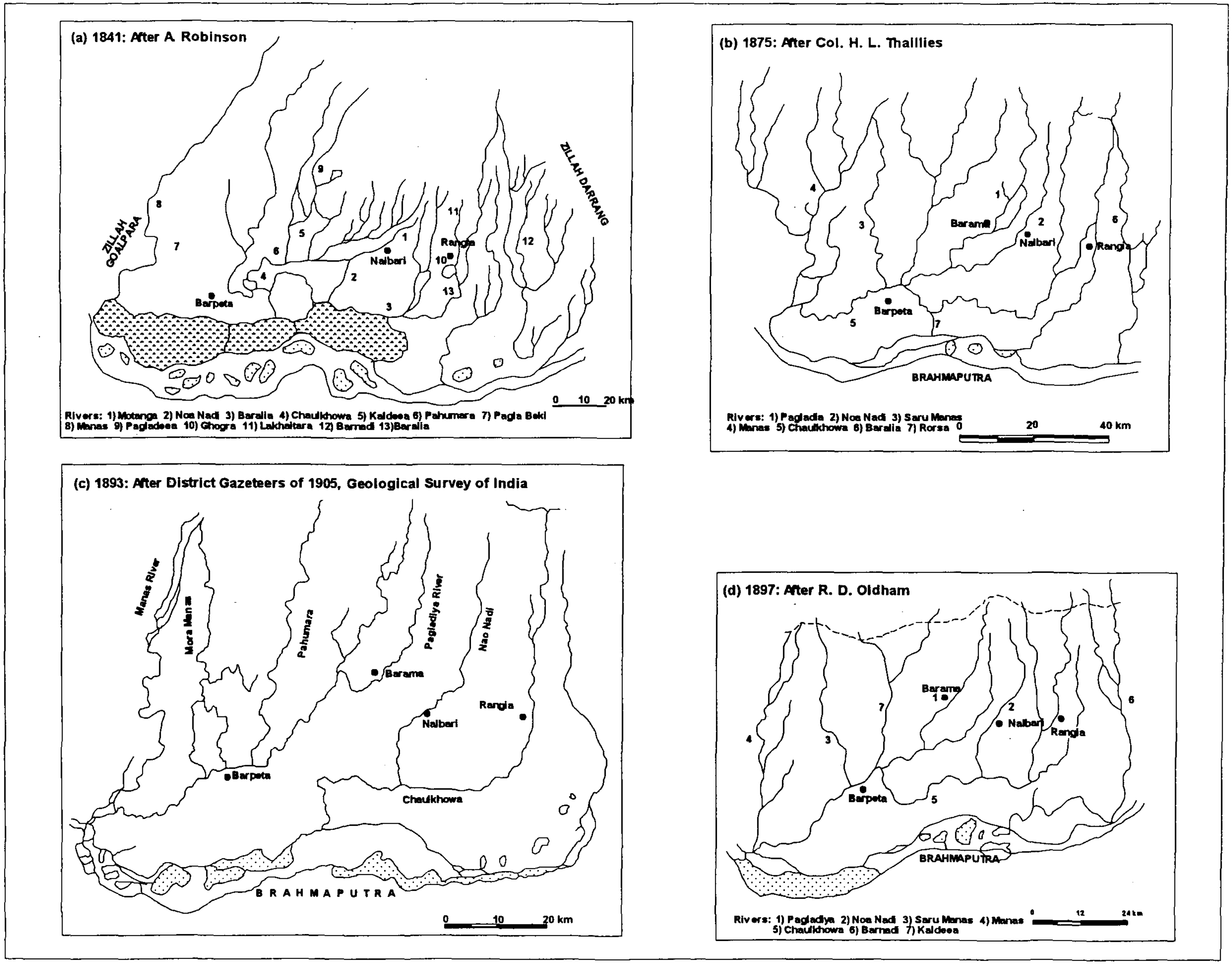

Fig. 3.1 a, b, c & d: Distributive Drainage Net in the Study area: 1841, 1875, 1893 & 1897

From the historical records it appears that in the 19th century, prior to the 1897 earthquake, there was only one river system, i.e., the Manas. All rivers starting from Jia-Barnadi (present Puthimari) were flowing through the Chaulkhowa river from the whole of the then North Kamrup district and emptied into Manas (Fig. 3.1.a,b,c & d). This indicates that, there was a river almost parallel to the Brahmaputra running along the Baraliya, Chaulkhowa (in the south of Nalbari town),Bhelengi *beel* and the present Chaulkhowa in the south of Barpeta (Fig. 3.1.a). At that time the river was known by the name Chaulkhowa which flowed from the east to west at a distance of about 20 km to the north of Brahmaputra river. It used to connect rivers like Barnadi, Baraliya, Jia-Bar, Noanadi, Pagladiya (present Morapagladiya), Kaldiya, Pahumara and Saru Manas including all other rivers of the then north Kamrup district plain. Similar descriptions were given by Wedo and Hunter (Oldham 1899). Hunter did not mention the name of Pagladiya in his description. Instead, he used the name Noanadi (Hunter, 1879). From the map reproduced in Oldham's report on the great earthquake of 1897 the location of this river was identified as a part of the present Pagladiya river, originally which emptied into Chaulkhowa river (Fig. 3.1.d).

The original Pagladiya was most probably the present Morapagladiya river which is still running about 25 km west from the Pagladiya river in its middle and lower course (Fig. 3.2). This river flowing from the foothill zone through the plains crossed NH-31 at Barama and joins Burhadiya river near Bhojkuchi which turns to the west to meet Tihu and Kaldiya rivers. In the lower course of Pagladiya river there was a small river called Rorsa (Hunter, 1879) which formed one of the principal outlet of Chaulkhowa into the Brahmaputra. However, the main channel of Chaulkhowa emptied into Manas river, a little north of the point where the former falls into the Brahmaputra.

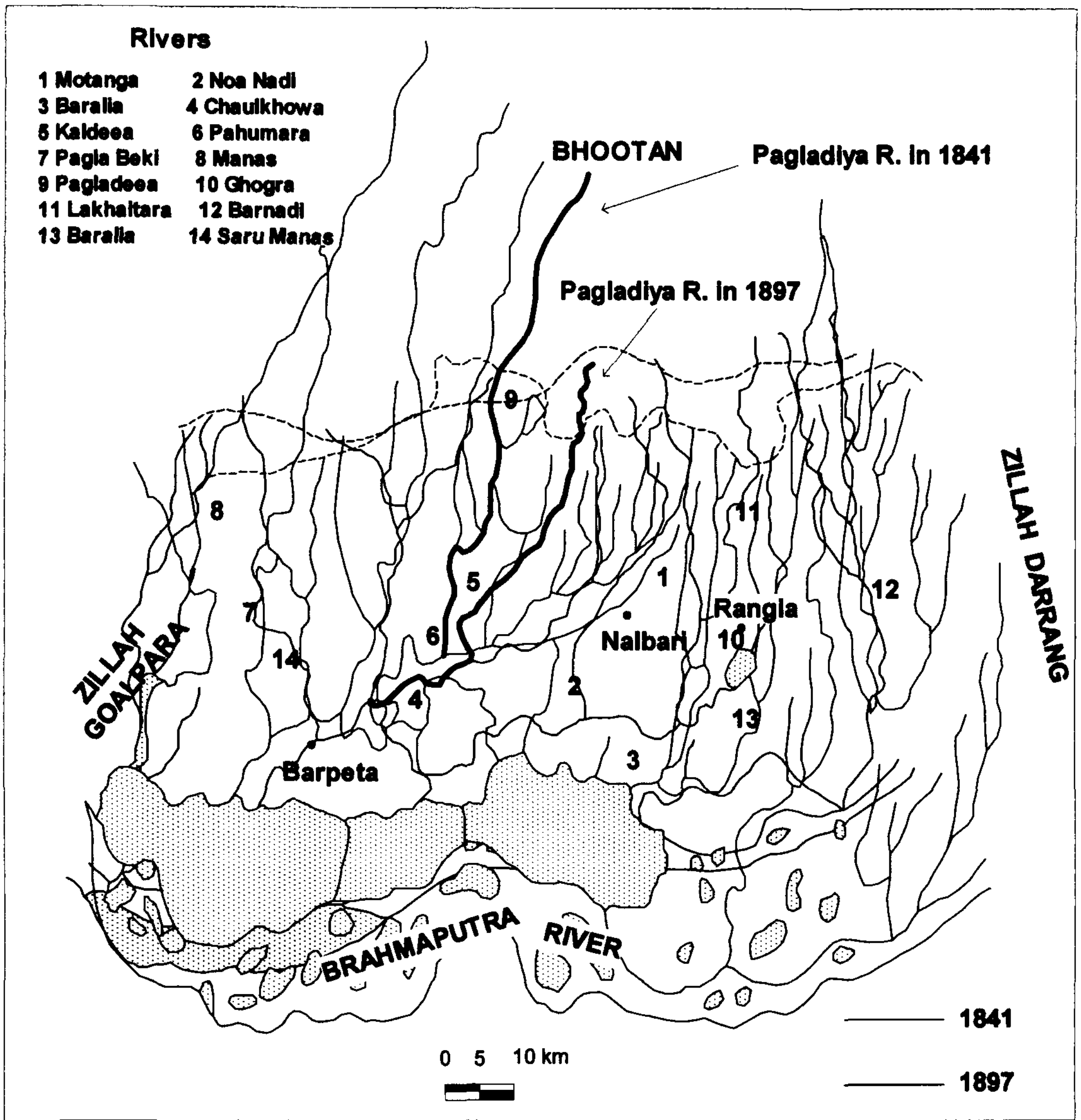

Fig. 3.2: Distributive Drainage Net 1841, (after A. Robinson) and 1897, (after R. D. Oldham)

Most of the lower reaches of Chaulkhowa gave rise to marshes, swamps and *beels*. During the 1897 earthquake the beds of the *beels* were elevated significantly in this part. For example, the Kapla *beel* was rose by about 6 m. At present, most of this part is converted into rich agricultural fields. After 1897 in the foothill zone the original channel of Pagladiya river bifurcated and the present Pagladiya river was formed as a result of the changes in the course of the Motanga river in the upper part and Noanadi in the middle and lower part. In the lower reaches the Pagladiya river had mainly two branches, the easternmost branch running through Katla *beel* and Dangar *beel* to meet the Baraliya river at Dosutimukh (1911-1912 map of Survey of India). The westernmost branch meet Chaulkhowa river through the Mora *beel* and Dubaria *beel*. Later on, both the branches were abandoned and the Pagladiya river flowed independently shifting eastwards about 1.5 km to meet the Brahmaputra river (1967-1968 map of Survey of India).

It is worth mentioning here that actually the eastern channel was diverted by man from about 6 km south of Nalbari town to Dosutimukh. In some literature of recent times it is found that Uttam Chandra Baruah (1869-1915), the then powerful Mouzadar of Barbhag diverted the river by digging a channel through *beels* and low-lying areas which were created by the 1897 great earthquake to join it with the Baraliya river at Dosutimukh (Sarma, 1969). The main aim of this diversion plan was that the river would drain out water from the swampy, low-lying areas to the Brahmaputra river and during the flood times these areas would be raised depositing sand and silt by the river. In fact, Dosutimukh and Sutarkuchi section was a part of original Chaulkhowa river prior to 1897 earthquake. Just after the earthquake the bed of this part of original Chaulkhowa river was elevated in Jagara, Mukalmua, Barnardi, Doulasal etc. in the southern part of the undivided Nalbari and Barpeta districts. As a result, this part of the river transformed to a *beel* and swampy area. Subsequently, Baraliya river which also used this part of the Chaulkhowa river turned southward and meet Pagladiya river passing through a channel just near Mukalmua. The Pagladiya river after meeting the Baraliya at Dosutimukh also passed through the same channel of Chaulkhowa and ultimately it has turned southward using the Moanmari *suti* (small stream) in the Adabari Laopara section. Thus the other lower part of the former Baraliya river was abandoned.

The development of the course of Pagladiya and other streams and landform has close link with the past topographic as well as drainage changes in the whole region. Some imprints of the old river channels are still available in the study area. The Phulguri *jan* (stream), Charaha *jan*, Bhalukmara *jan*, Jaha *jan* and the present marshy lands within the Nalbari town clearly reveal the old channels of the Noanadi, i.e., the present Pagladiya river. A part of the old channel of the Noanadi is no longer a river but a small drain lying between old Gurdon Higher Secondary School and PWD Bungalow and near the Nalbari Head Post-Office and Nalbari Girls' High School. Most of the parts of Bidyapur area of Nalbari town were formed by sand deposition of Pagladiya river. During 1984 and recent floods of July, 2004 major portion of the flood water of the river passed through Nalbari town area.

From above discussion it is obvious that Pagladiya river has been changing its course frequently since 1897.

3.1.2 Channel and Bankline Migration:

Bankline as well as channel migration is an important fluvial process. By this process a river tries to adjust itself with the changing fluvio-geomorphic conditions and ultimately to attain an equilibrium channel form. As it traverses through the flood plain the Pagladiya river also tries to adjust itself with the changing fluvio-geomorphic conditions of the region.

To study the temporal channel changing pattern superimposed maps for the periods 1911-'12 to 1967-'68 and 1986-'87 are presented in Fig. 3.3.a,b,c & d. During the last 160 years, the Pagladiya has migrated about 25 km towards east from its original channel Morapagladiya. The present Pagladiya becomes a new independent channel system and directly falls into the Brahmaputra river. On the other hand, the Morapagladiya is still flowing as a tributary to the Manas river system.

From the study it has been observed that the Pagladiya has also exhibited the general tendency of eastward lateral migration and formed its meandering channel. During high floods that occurred in 1952, 1954, 1984, 1996, 1998 and 2004 the river breached its western side embankment in many places between Nalbari town and Bar Agra village situated at about 6 km north of Nalbari town, and passed through Chengnoi - a small tributary of Burhadiya river. Again in 1969 and 1998 it breached the eastern embankment at Khat Katra and Khanajan villages and passed through Ghoga *beel* and turned through a small channel and joined again in the main river near just north of the railway bridge. In 2000 it also breached the eastern embankment at Sandha just about 2 km south of NT Road and passed through Guwakuchi, Bhanukuchi and Balikuchi villages of Barbhag area. Such temporal changes are observed in many of the lower part of the river.

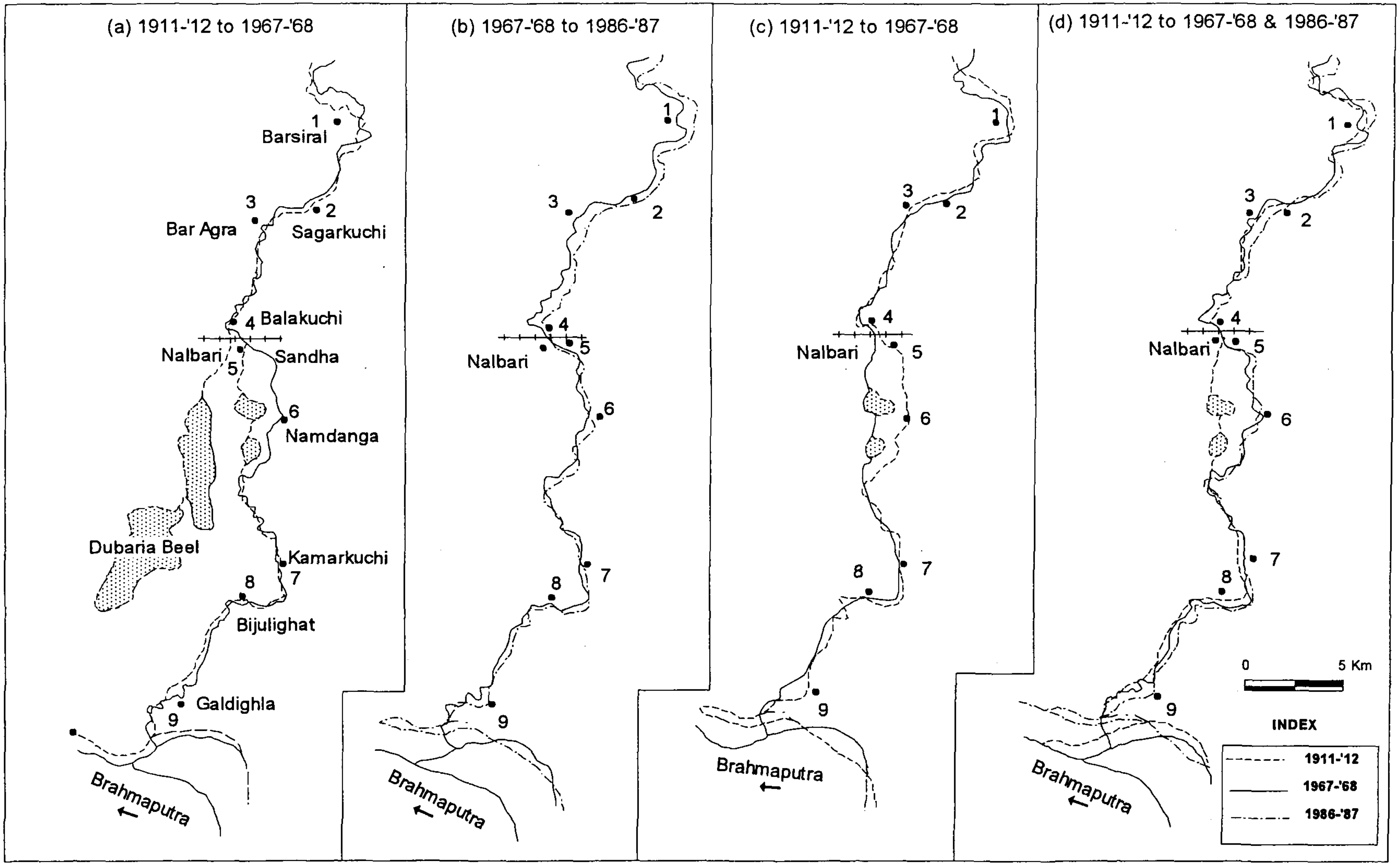

Fig. 3.3 a, b, c, & d: Pattern of Channel changes of the Pagladiya River for the periods- (a) 1911- '12– 1967- '68, (b) 1967- '68 – 1986- '87, (c) 1911- '12 – 1986- '87 and (d) 1911- '12 – 1967- '68 – 1986- '87

Most recently in 1984, 1988, 1996, 2000 and 2004 some changes had also been seen in channel migration in the tributaries of Pagladiya like Nona and Baraliya. Nona had changed at just south of the bridge crossing the NH-31 leaving its original downstream portion and moved towards east after breaching at its embankment. Thus the river takes a new channel while it also meanders as it travels to meet the Pagladiya. In recent years the Baraliya river also changed its course just 2 km upstream from the confluence with Pagladiya (at Dosutimukh near Garamsung). In the dry season the Baraliya river passes through Bharaltola *jan* and moves towards the Bullutjan, a river flowing parallel to south of Pagladiya river and empties into Brahmaputra river. Such type of changes occurring in different tributaries of Pagladiya river reflects the continuous changing fluvio-geomorphic characteristics of Pagladiya river system.

To understand such region-wise temporal variation in detail, large scale maps for the period 1911-`12 to 1967-`68 are shown in Fig. 3.4.a,b & c. A super-imposed map of 1971 and 1997 is also presented in Fig. 3.5 to show the bank channel pattern and changes of the Pagladiya river during these years. Detail maps for certain parts of the river course surveyed by the Embankment and Dam (E&D) Department, Government. of Assam are also shown in Fig. 3.6.a.b.and c.

From these maps the nature of channel migration of the Pagladiya river can be understood as a whole. During 1911-`12 to 1967-`68 between villages Barsiral and Majusiral the river moved 0.56 km on the average towards west. In between Bar Agra and Balakuchi village to the north of the NF Railway (North-East Frontier Railway) line the Pagladiya river sways in the east-west direction, with meandering bends moving about 0.40 km on average in both directions. Near Barkatalkuchi and Balakuchi, north of North-east Frontier Railway (NF Railway) line, the river moved

0.20 km towards north-east in 1967-`68 from the 1911-`12 position (Fig. 3.4.a). In between Sandha and Sonkuriha villages, the maximum shifting of the river was towards east. Here, it moved 1.78 km on the average towards east. Maximum migration of 2.5 km is observed at Namdonga village. Such sudden large scale shifting of channel is due to the fact that this region was formerly covered by Katal and Dangar *beels* and nearby marshy lands with sloping towards east. Outside this area, the rate of migration is reduced. In between Sonkuriha and Bijulighat the river moved 0.36 km on average towards east (Fig. 3.4.b). In the south of Bijulighat upto Adabari, the Pagladiya river migrated about 0.48 km. towards east. From Adabari to Chotemari the river meanders and migrates eastward. But after Chotemari, the river shifts towards west by about 0.64 km and meets the river Brahmaputra (Fig. 3.4.c). During 1967-`68 to 1986-`87 the river had migrated 0.25 km towards east on the average. Near the confluence with the Brahmaputra, south of Chotemari, it shifted 0.38 km towards west compared to the position of 1967-`68.

From the map (Fig. 3.6.a) it is seen that near the Chengnoi village in the first bend (from north) the right bank of the river in 2000 shifted 0.40 km towards east compared to the position of 1970. Similarly, in the same place the left bank moved 0.42 km in same direction. But in the second bend the right bank moved 0.49 km towards west, while the left bank also moved 0.45 km in same direction. Again in the third bend, the right bank moved 0.35 km, whereas the left bank 0.43 km towards east.

Another part of the river (Fig. 3.6.b) reveals that near the village Barkatalkuchi in 2000, the right bank of the river moved 0.45 km towards east and similarly the left bank also moved 0.40 km, from the position of 1970. In the village Balakuchi the right bank moved 0.25 km towards east and the left bank 0.26 km in the same direction.

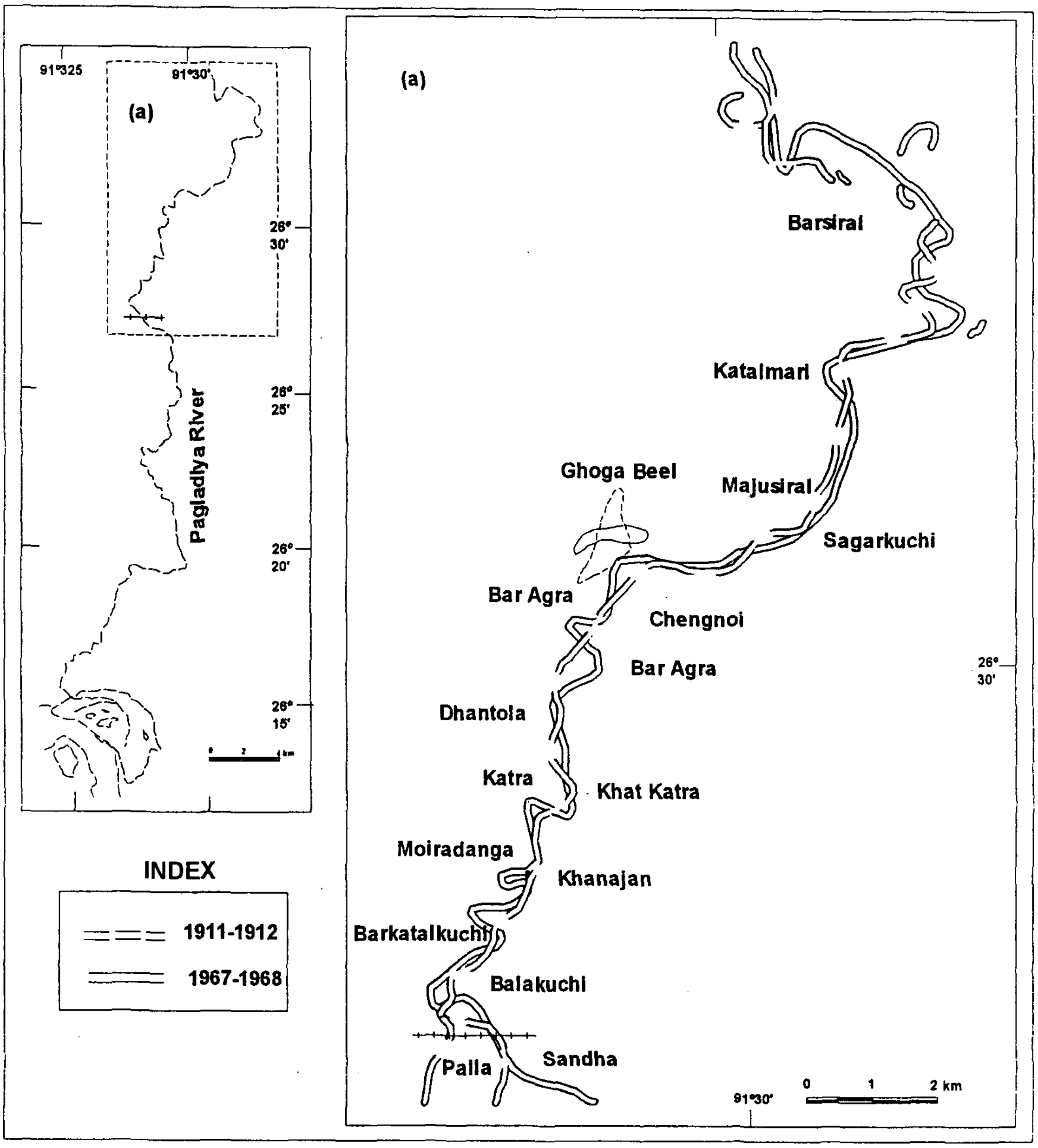

Fig. 3.4. a: Pattern of Channel changes of the Pagladiya River between Barsiral and Balakuchi for the period 1911- '12 to 1967- '68

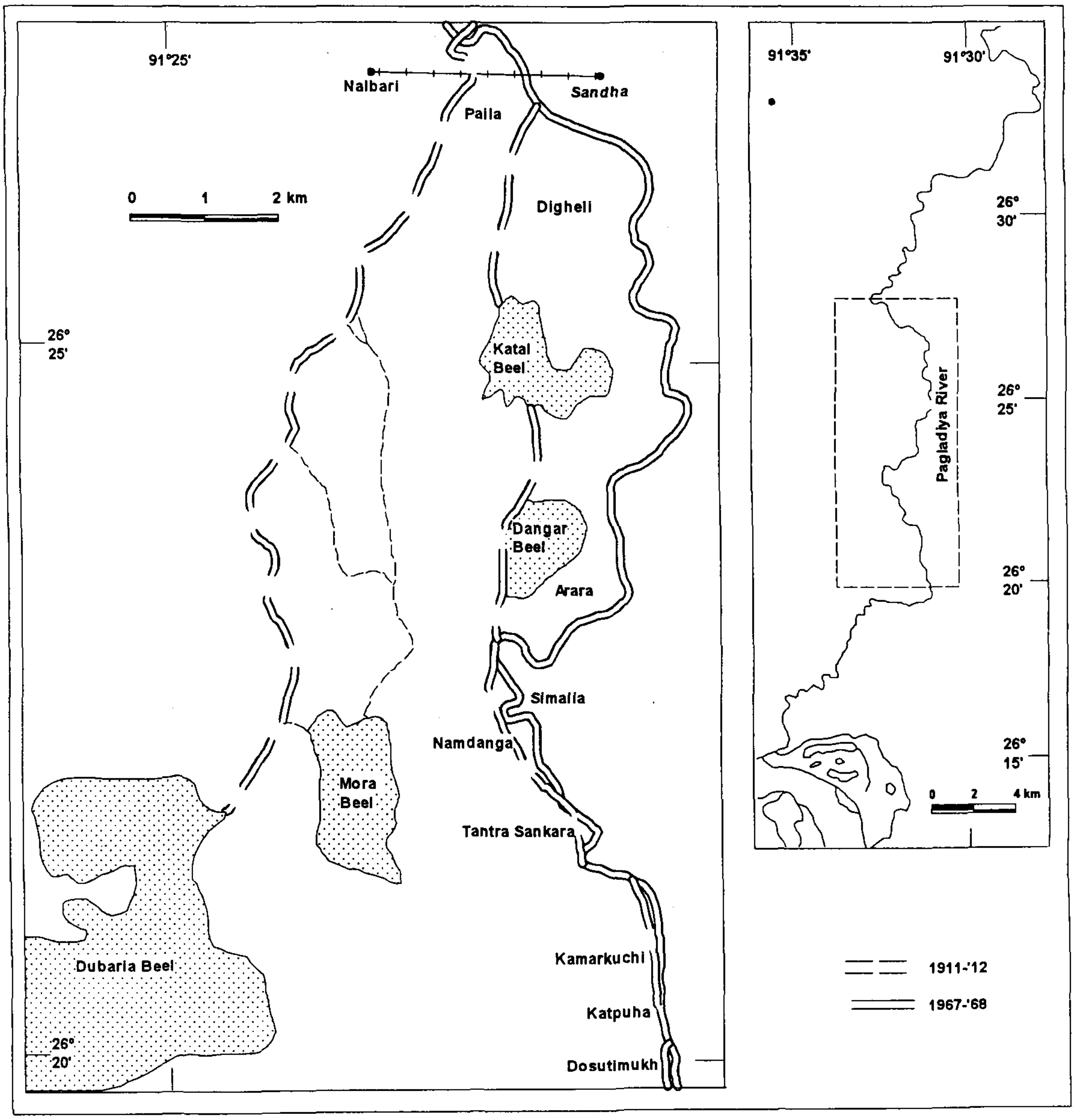

Fig. 3.4. b: Pattern of Channel changes of the Pagladiya River between Balakuchi and Dosutimukh for the period 1911- '12 to 1967- '68

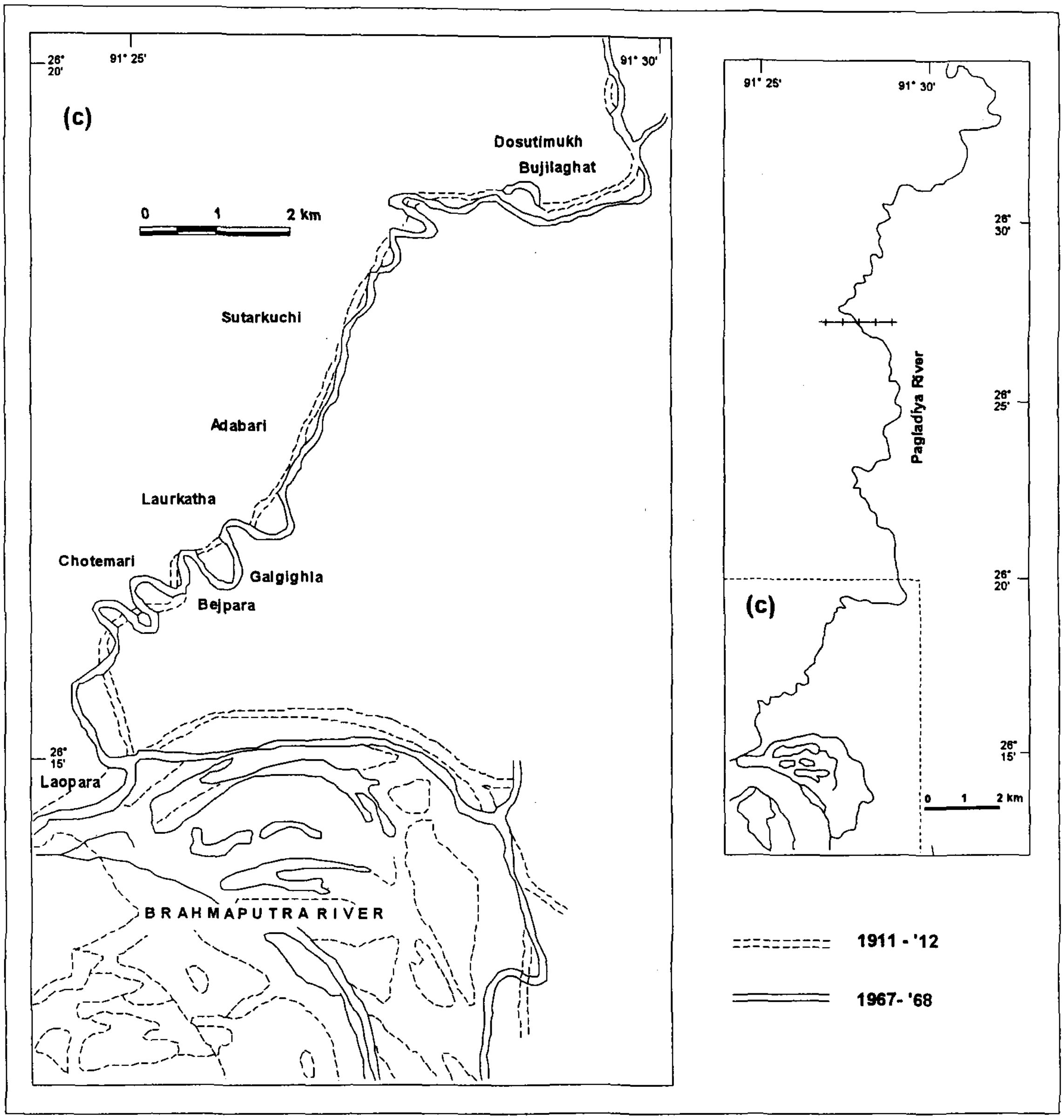

Fig. 3.4 c: Pattern of Channel change of the Pagladiya River between Dosutimukh and Brahmaputra River for the period of 1911- '12 to 1967- '68

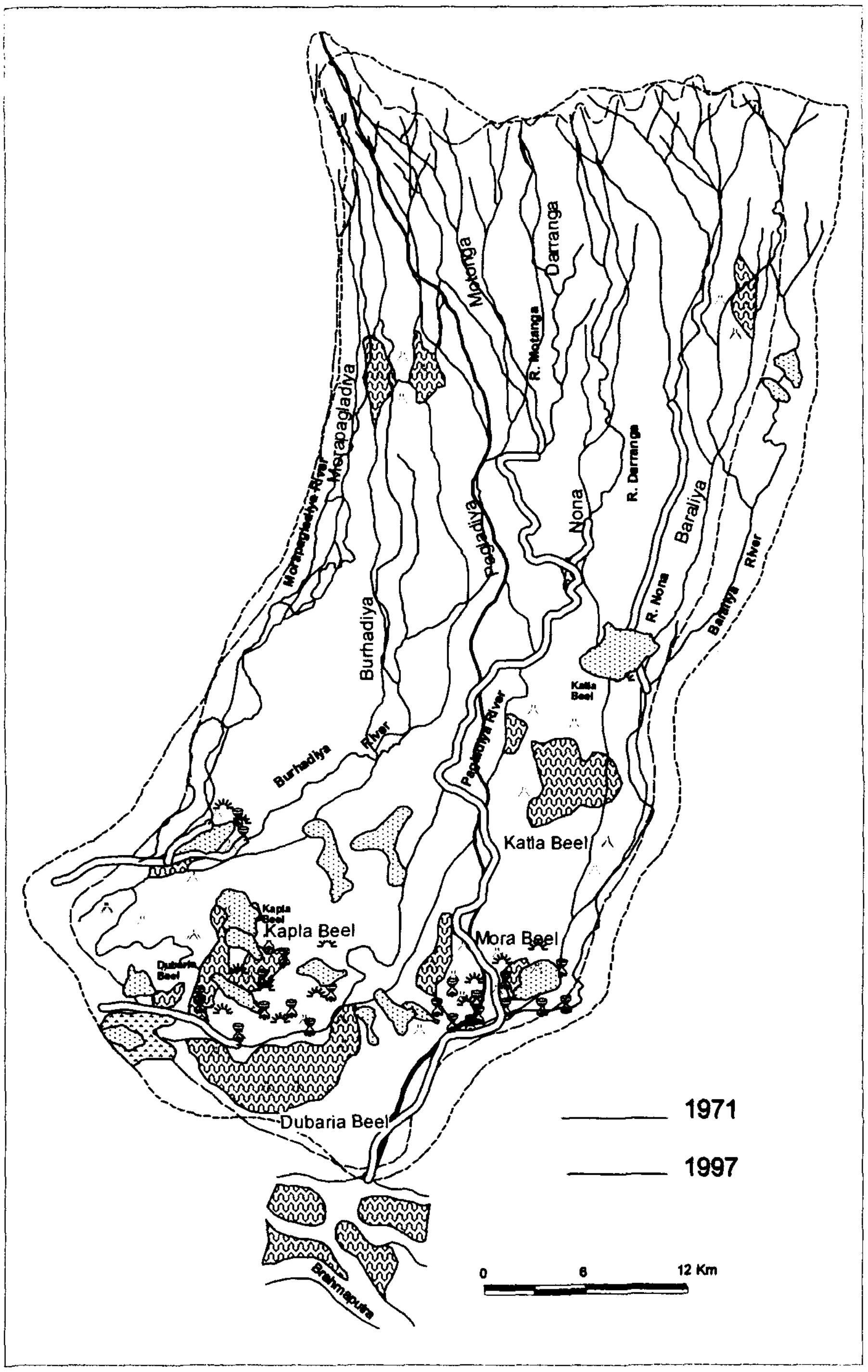

Fig. 3.5: River Channel Pattern, 1971 and 1997

In the (Fig. 3.6.c) the nature of channel changes during the years 1970 and 2000 are shown near village Sonkuriha and Simalia. There were two meandering bends. In the first bend the right bank shifted 0.10 km towards west whereas the left bank moved 0.09 km in the same direction. In the second bend towards south, the right bank moved 0.08 km towards east and the left bank shifted 0.85 km in the same direction also. But in the third bend, both the banks shifted towards west by about 0.05 km in each case. After this section, the river moved towards east. In 1985 in this part the first bend was straightened by digging a 0.4 km long channel by the E & D Department. In the other part of the lower course of Pagladiya during 1970 and 2000 the migration of bank lines remained almost same.

3.1.3 Types of Channel Change and Bankline Migration:

Four types of channel changes and bankline migration of Pagladiya river are noticed. The first three types are natural in nature while the fourth is anthropogenetic in nature. This is a general tendency in almost all the rivers of the study region.

(i) Straightening: The rivers straightened their courses by cutting off meanders in a number of places ;

(ii) Lateral migration: Lateral migration and widening of the river channels by bank slumping and cutting resulting in lateral changes of the channels ;

(iii) Meandering: Due to the formation of progressive point bars, the river channels are gradually meandering by laterally cutting of the banks ; and

(iv) Human interference: Construction of bunds and embankments for straightening the meandering bends and controlling multi-channels of the river course. Such cases are observed near Nalbari In another case, the westernmost channel of the river was abandoned due to the construction of an embankment and bund near the railway bridge. Lastly, the straightening of a meander by cutting about 0.4 km near Sonkuriha and Simalia in 1985 by the E & D Department is an apposite example of human interference.

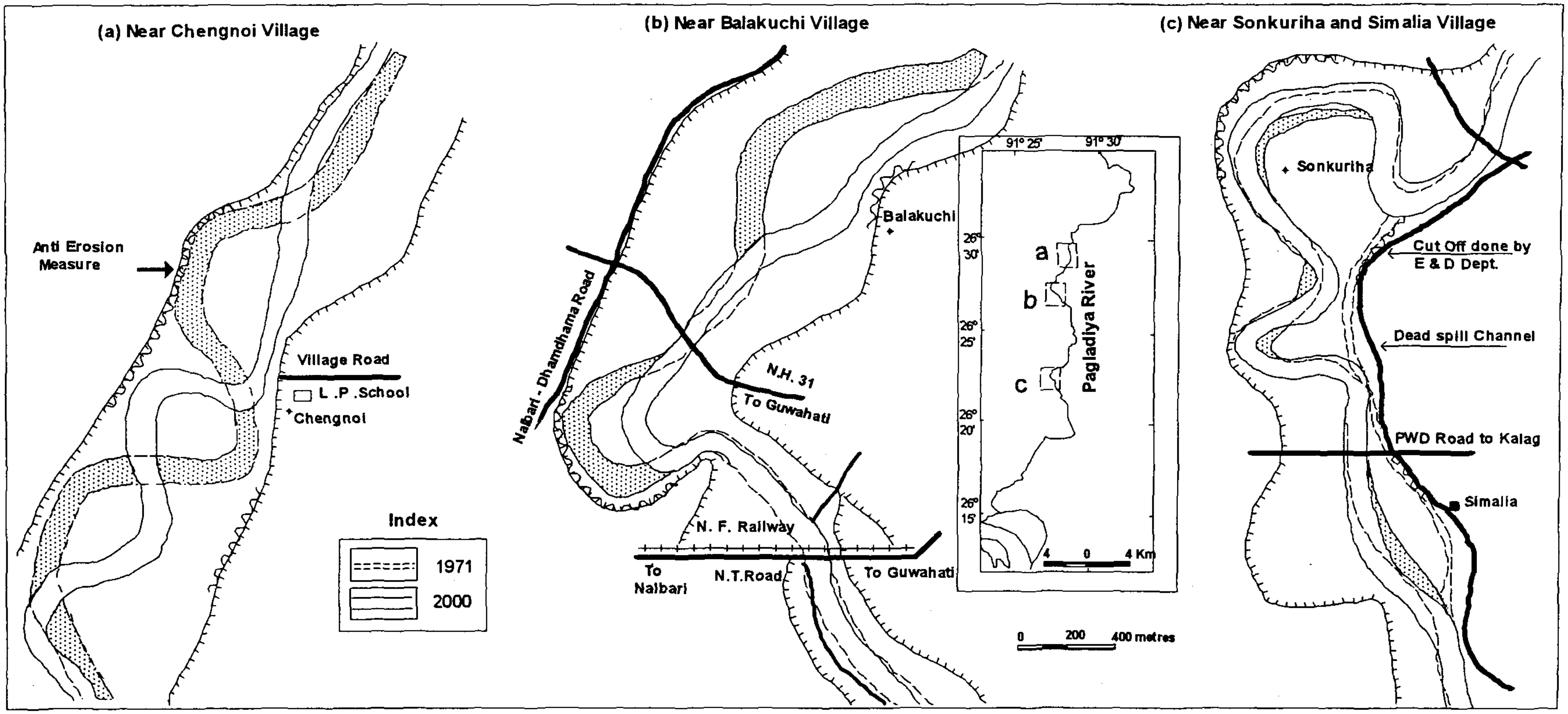

Fig. 3.6 a, b & c: Pattern of Bankline Migration of the Pagladiya River, 1970 and 2000 (a) Village Chengnoi (b) Village Balakuchi and (c) Village Sankuriha and Simalia

3.1.4 River Meandering and Sinuosity Indices of the Pagladiya and Morapagladiya Rivers:

The degree of meandering of a river can be gauged by calculating the different sinuosity indices. 'Meandering is applied to the sinuous channels that exhibit a certain degree and regularity of sinuosity' (Prasad, 1982). There are different formulae derived by different scholars like Leopold, Wolman and Miller (1964) for calculating sinuosity indices of a river. An attempt has been made here to find out different sinuosity indices as derived by Miller for the Pagladiya and Morapagladiya rivers in the study area. To understand the temporal variations of sinuosity indices and the nature of meandering of these rivers topographical maps of 1911-`12 and 1967-`68 are used. Moreover, the satellite imagery of 1967-`68 and 1989-`90 are also considered. The computed values for different sinuosity indices are shown in Table 3.1.

From the Table 3.1 it is observed that the Pagladiya river in the study region was sinuous, the S.S.I. (Standard Sinuosity Index) value being 1.291 in 1911-`12. But the S.S.I. value increases to 1.332 in 1967-`68. This indicates that the river becomes more sinuous and meandering in 1967-`68 than the previous period. By comparing H.S.I. (Hydraulic Sinuosity Index) and T.S.I. (Topographical Sinuosity Index) of both the periods, it can be inferred that as the river progresses in the cycle of erosion, the role of hydraulic sinuosity increases and the role of topographic sinuosity decreases.

In the case of Morapagladiya river the S.S.I. value is found 1.016 in 1911-'12 which slightly increases in 1967-'68 to 1.025. It indicates the sinuous nature of the river. Comparing H.S.I. and T.S.I. for both the periods it is observed that the role of hydraulic sinuosity is increased and role of topographic sinuosity decreased. Hence, it can be inferred that the Morapagladiya river also has a tendency to change its course with meandering channels (Fig. 3.7).

Table 3.1: Sinuousity Indices of Pagladiya and Morapagladiya rivers

River	Surveyed Year	Valley Length (V.L.) in Km	Channel Length (C.L.) In Km	Air Length (A.L.) In Km	Valley Index V.I. = (V.L./A.L.)	Channel Index C.I.= (C.L./A.L.)	Hydraulic Sinuousity Index H.S.I.=(C.I.-V.I.)/C.I.-1)X100 in Percentage	Topographical Sinuousity Index T.S.I.= (V.I.-1)/(C.I.-1)X100 in Percentage	Standard Sinuousity Index S.S.I.= (C.I./V.I.)=(C.L./V.L
Pagladiya	1911-'12	128.20	165.40	118.24	1.084	1.399	78.94	21.11	1.291
	1967-'68	132.38	176.42	123.50	1.072	1.428	83.17	16.82	1.332
Morapagladiya	1911-'12	78.85	80.15	76.38	1.032	1.049	34.69	65.31	1.016
	1967-'68	79.24	81.20	77.13	1.027	1.053	49.06	50.94	1.025

Based on Topographical Survey Maps of 1911-'12 and 1967-'68
Calculated by the researcher

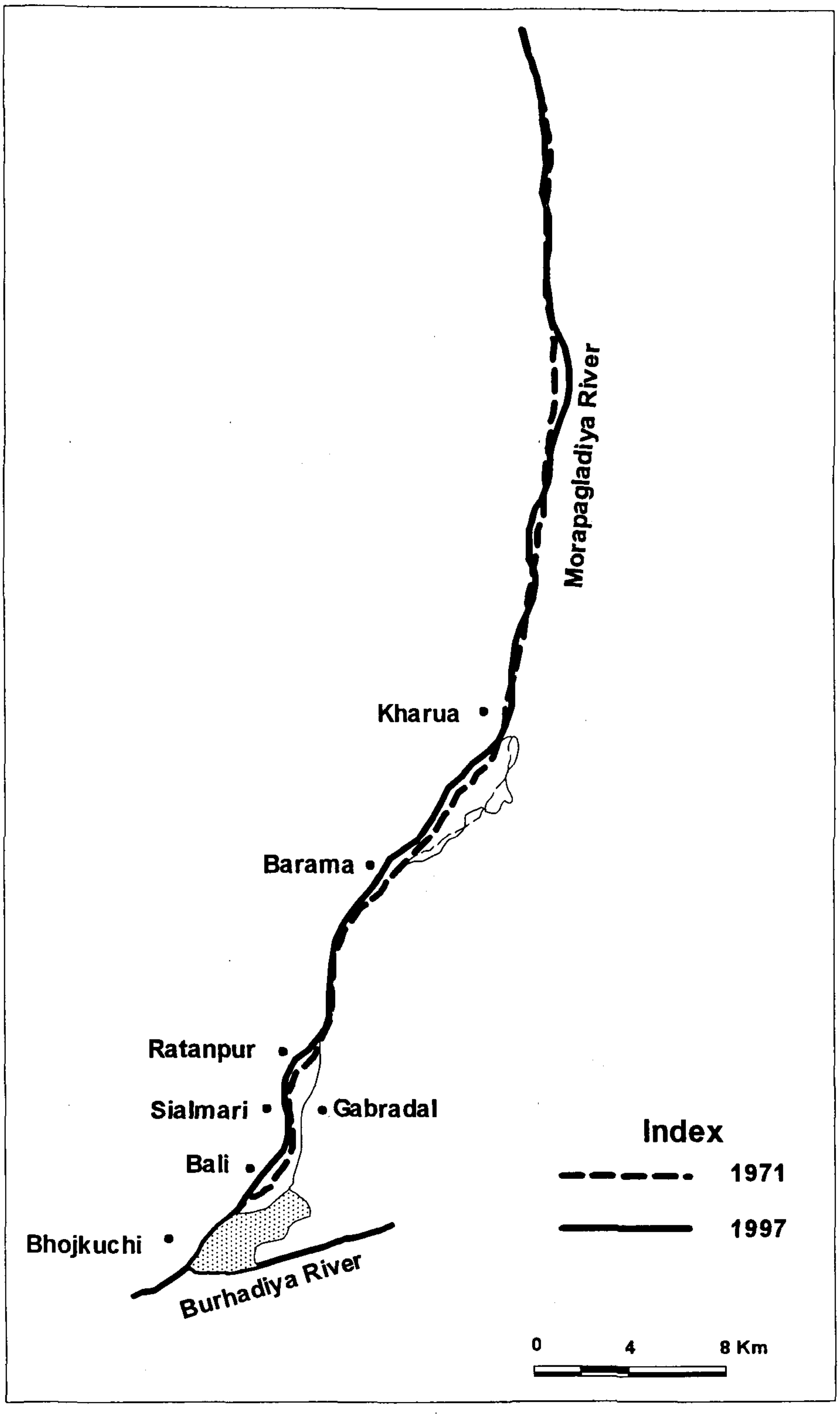

Fig. 3.7: Pattern of Channel change of Morapagladiya River during 1971 and 1997

3.2 FACTORS AFFECTING CHANNEL CHANGES:

The changes of channel as well as bankline migration of the Pagladiya river are observed as a result of the following factors:

(i) The construction of rail and different road bridges for surface transportation and communication at different places causes drainage constriction resulting in lateral migration in sections just upstream of the bridges north of NH-31 and NF Railway line. The velocity of river water increases just below the bridge, but decrease of velocity in down stream helps sedimentation and formation of sandbars causing lateral bank erosion. This is observed mainly near the NH-31 and NF Railway bridge.

(ii) Low gradient of the river bed in the study area is also a major factor of channel and meandering courses.

(iii) Sudden increase of discharge of water during summer causes floods. This influences bankline erosion, especially at the confluence of Baraliya with Pagladiya at Dosutimukh is an important noticeable factor.

(iv) The gradual widening of point bars from one bank to the other results in lateral bank erosion in the opposite bank creating changes and meandering of the channel course.

(v) Severe bank slumping changes the channel geometry which ultimately leads to channel changes. Such slumping is seen during the field survey at Batahgila, Khandajan, Barkatalkuchi, Sonkuriha, Adabari, Galdighla, Bejpara and Chotemari villages.

(vi) The earthquake of 1897 and 1950 caused physical changes in the Pagladiya-Morapagladiya drainage complex and influenced on channel changes. During the 1897 earthquake a large portion of the Barbhag area sank down and in the northern part of the area beds of rivers were elevated resulting in the changes of river courses. Pagladiya changed its original course just below the foothills and migrated towards east. The original course i.e., the present Morapagladiya is still running about in 25 km west. Hence, it may be inferred that instability of the area contributes to the different changes in the drainage complex in many ways.

(vii) During the high floods the river has been found changing its channel courses breaching both embankments in many places in the lower part of the river. Thus, the flood is considered as one of the most influencing factors of sudden channel changes.

(viii) Human interference like digging of sand used for different constructions during dry period from the bank and bed of the river in the study area specially near Nalbari town also attracted channel changes. Similarly, structures for the flood control and bank protection with their unscientific construction cause severe bank slumping and channel migration.

3.3 FLOOD – A FACTOR OF CHANNEL CHANGE:

Flood as an important geomorphic event occurs due to several causes like heavy precipitation, sudden release of water resulting from the thawing of snow cover or from blockage of flow by ice jams and landslides (in case of earthquake prone region like the Himalayas), cyclonic rainstorms etc.

Although, defining the term flood is difficult. Royward defined it 'as a body of water which rises to overflow land, which is not normally flooded' (Mitra, 2002). In the present context another definition of flood can be based considering the devastating nature of the hazards. According to this definition, the flood is a natural calamity of environment, destroys the socio-economic functions of region and enlarges inter-personal and inter-spatial disparities. It is a catastrophic agent which causes erosion, deposition and damages and changes the physiographic character of the valley (Das, 1987). Thus, the floods in the study region create all such problems including damage to crops, settlements, losses of lives of human and livestock, erosion of built-up lands and river banks, deposition of thick sand over agricultural land etc. References of such floods are found in old history books of Assam and books like Yogini Tantra, Gurucharit etc.

In the study area flood has been a recurring feature since early times. The area has been variably inundated by the floods of the Pagladiya, Morapagladiya and other streams in different periods. Historically, the settlers of the study area are well acquainted with the floods and spontaneously they have acquired the art of living with such phenomena to a considerable extent. In recent past due to variety of human interferences like reclamation of *beels* for human settlement and agriculture, construction of new roads and railway lines have blocked the natural flow of water thereby causing floods to be more devastating in areas which are earlier free from flood. Also dam failure has emerged as a new cause leading to flood hazard e.g., the unprecedented 2004 flood. The prevailing flood hazard in the study area is discussed under the following heads:

3.3.1 Nature of Flood Hazard:

In the study area floods generally occur due to the heavy rain during the monsoon months- May to October. During this period the Pagladiya river takes a furious look when it is in high spate. During the same time the Brahmaputra river also maintains a high water level. Most frequently the water level of Brahmaputra remains above the level of low-lying areas of its banks. Therefore, the backwater effect of the Brahmaputra generally spreads into the tributaries like Pagladiya and others. Although the floods of the study region are climatogenic, there have been influences of tectonic, physical, hydrologic and human interferences on their intensification (Barman, 1986).

Floods in the area can be attributed to a variety of natural, hydro-meteorological and anthropogenic origin. As stated earlier, flood intensity of the study region has close relationship with the tectonic activities of the whole region. Although detailed records of floods due to tectonic activities prior to 1897 are not available, Oldham's records (1899, 1981 reprint) of the great earthquake of 12th June, 1897 and another on 15th August, 1950 evince the intensity of flooding just after the occurrence of a severe earthquake. Due to the earthquake of 1897, considerable physiographic and topographic changes had taken place in the study area. The drainage systems of the area changed significantly. The beds of rivers like Manas, Beki, Pohumara, Kaldiya, Pagladiya, Puthimari especially in their lower courses were subsided (Revenue Department, Government of Assam, 1966; Barman, 1986). The Pagladiya took its present course leaving the original one as Morapagladiya.

On the other hand in the middle and upper portions, the beds of most of the rivers as mentioned earlier were rose up resulting in floods immediately after the earthquake. There are records of human migration from the lower valley portion of these rivers to the higher

Table 3.2: Highest Flood Level and Maximum Discharge of the Pagladiya River at N.T. Road crossing, 1971-2000
(Danger Level= 52.75 m)

Year	Highest Flood Level (H.F.L.) in m.	Maximum Discharge (m^3s^{-1})
1971	53.78	577
1972	54.21	1664
1973	53.94	880
1974	54.90	1289
1975	52.30	158
1976	53.63	383
1977	54.54	844
1978	53.16	302
1979	53.23	259
1980	53.36	509
1981	53.33	371
1982	53.15	240
1983	54.48	455
1984	55.20	471
1985	53.45	370
1986	53.00	216
1987	52.94	738
1988	54.20	952
1989	52.95	448
1990	53.12	474
1991	52.76	498
1992	54.86	462
1993	54.47	440
1994	53.10	528
1995	52.97	483
1996	54.19	492
1997	53.26	480
1998	54.68	712
1999	53.16	476
2000	54.89	728

Source: Brahmaputra Board and Pagladiya Investigation Division, Nalbari lands in the middle and upper valley sections lying to the north just after the earthquake of 1897 and the flood created by it. Similarly, due to the earthquake of 1950 heavy landslide in the upper courses of these rivers in the Himalayan region blocked the normal flow of water for some times. But due to heavy pressure of water in the upper reaches of north bank tributaries of Brahmaputra sudden release of large volume of water caused heavy floods in the down streams region. In the case of Pagladiya river 15 big floods have occurred during the period 1954-2004 (Task Force, 2005). During the high down pour of monsoonal months (May to October), the Pagladiya along with other tributaries remain in high spate. The high flood level and the maximum water discharge of the Pagladiya river at NT Road gauge station for period 1971-2000 are shown in Table 3.2. The table reveals that high flood water levels of all years except 1975 remained above the danger level (i.e. 52.75 m). The highest flood level of 55.20 m occurred on 15th September, 1984. Similarly, the other high levels of water were 54.90 m (1977), 54.48 m (1983), 54.21 m (1972) and 54.20 m (1988). Minimum value of flood level was 52.30m in 1975. On the other hand the maximum value of high discharge record was 1664 cumecs in 1972 and the minimum figure for discharge was 158 cumecs in 1975 (Fig. 3.8).

Due to the earthquake of 1897 many places of Barbhag area were submerged and transformed to *beels* of various sizes and waterlogging areas. After the construction of embankment on the left bank of Pagladiya and on the right banks of the Nona and Baraliya and NF Railway line in the north, a new problem of water congestion was developed in an area of 5,600 hectares of Barbhag (Fig. 3.9). During the rainy monsoon months the surface run-off from the entire northern region between Pagladiya and Nona flows into this region through 196 m and 195 m bridge openings of NH-31 and NF Railway line respectively near Nalbari town and spreads over the whole Barbhag area.

In between the Pagladiya and Nona rivers, a small channel called Ghogra *nadi* runs almost parallel to Nona and joins the Nona at about 11 km down stream from the NF Railway line. It carries a significant amount of water to the Nona during the monsoon months. At the time of construction of right embankment of Nona, a 30 m opening at

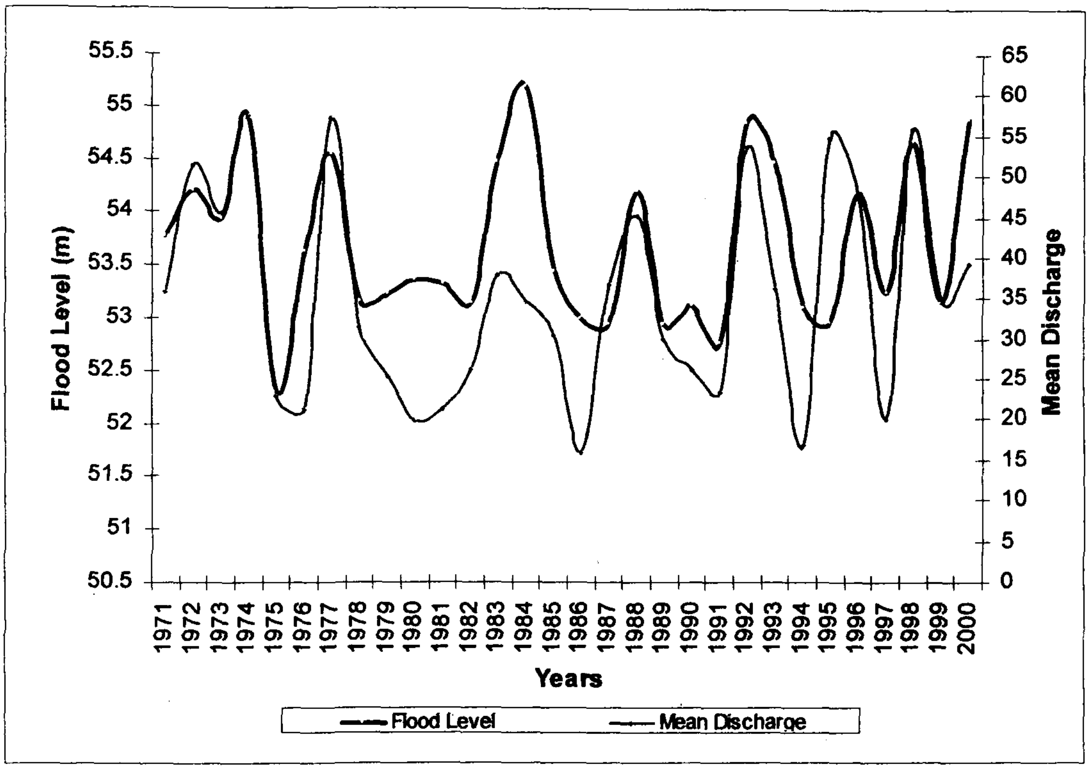

Fig. 3.8: Flood Levels and Annual Discharge of Pagladiya River, 1971-2000

Singimari village was left without embankment (ref. Fig. 3.9); as a result, the river bed of the Nona was elevated to a greater extent due to heavy siltation. Therefore, during the monsoon period the water from the Ghogra cannot pass through the Nona. When, the Nona is in high spate, its water flows towards the Ghogra and pass through Singimari opening to enter to the Barbhag area.

Moreover, there is another 2 km long opening in the right embankment of the Nona and Baraliya near the confluence. Water from Baraliya also enters into the Barbhag area through this opening and creates water congestion in this region. There is a 3 m X 3 m sluice gate across the Pagladiya river near Dosutimukh (Fig. 3.9). This opening is not sufficient to pass out water from the area. The elevated bed of the Pagladiya river also aggravates the problem by restricting the flow of water through this sluice gate. The general level of villages like Arangmow, Nakheti, Ratkuchi of Barbhag area are about 2 m lower than the bed of the Pagladiya river. Thus waterlogging occurs throughout the year in and around these villages. Therefore, flood hazard created by the Pagladiya, Nona and Baraliya is very acute in the Barbhag area of lower Pagladiya basin.

Similarly, in the lower active flood prone area floods occur annually ranging from 3 to 8 times. Although the occurrence of flood in the drainage complex is a regular high intensity phenomenon, up to 1954 no detail records of the nature of flood hazards and damages are available. In this context, Nath (1989) tried to describe with quantitative data the magnitude of floods that occurred during 1969, 1977, 1984 and 1988 in this region.

3.3.2 Some Examples:

To illustrate the nature of floods in the Pagladiya-Morapagladiya drainage complex, descriptions of flood events in the recent years, viz., 1984, 1988, 1996, 2000 and 2004 are presented here (Fig. 3.10). Correspondingly, the annual rainfall of these years is higher than normal and is shown in Table 3.3.

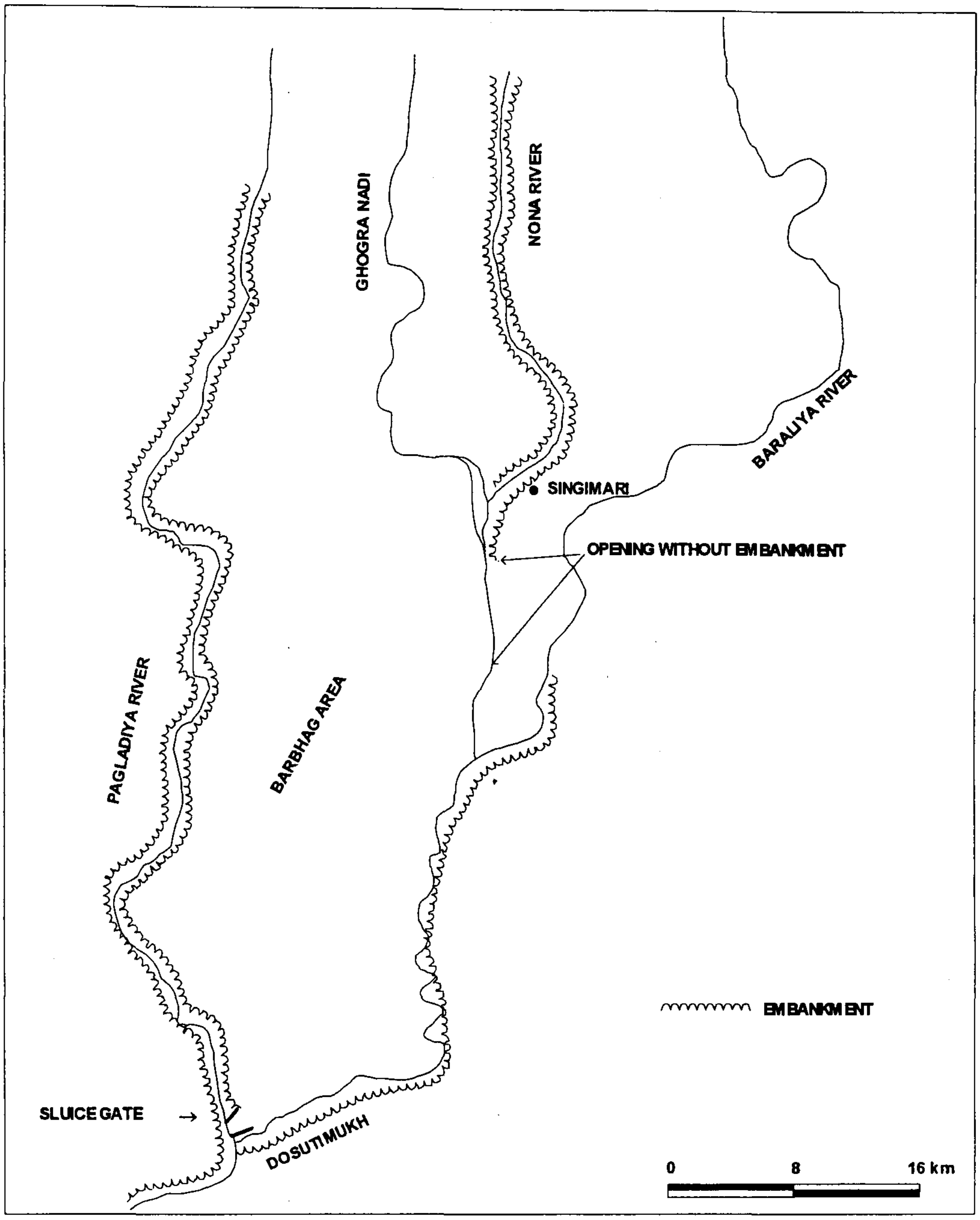

Fig. 3.9: Barbhag Area: Showing sluice Gate and Opening of Embankment

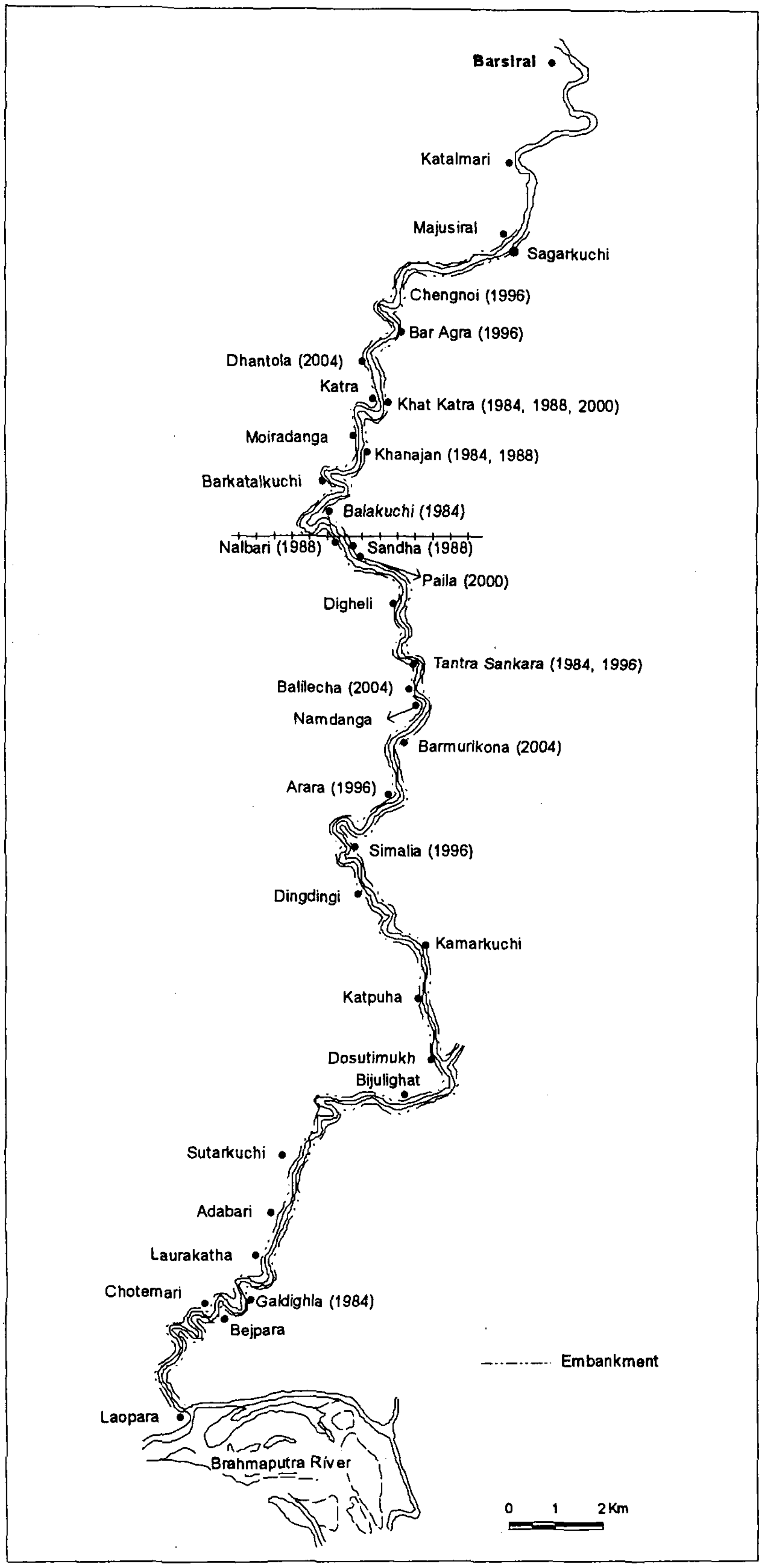

Fig. 3.10: Breaching of Embankment of Pagladiya River during High Floods, 1984-2000

Table 3.3: Annual Rainfall in Nalbari, 1971-2000

Years	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Rainfall (mm)	1778	1881	1576	1656	1487	1707	1821	1451	1318	958
Years	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Rainfal (mm)	1125	1405	1423	1852	1429	1402	1218	1683	1471	1563
Years	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Rainfall (mm)	1390	1619	1648	1507	1417	1697	1416	1704	1612	1728

Source: Office of the Executive Engineer (Irrigation, Nalbari)

The flood of 1984 was the worst. During the flood the Pagladiya, Morapagladiya rivers and other rivers were in high spate and inundated a vast area including the urban areas of Nalbari, Barama, Kaithalkuchi, Ghograpar and eastern part of Tihu town. The following are the important events:

i) On 24th May, the river Pagladiya breached about 50 m of its left bank ring bund at Galdighla village at the lower reach of the river ;

ii) On the 15th September at 8.45 a.m. the river bank embankment was breached about 63 m near Tantra Sankara village (west) due to seepage and on the same day at 11.00 a.m. another breaching of 20 m width had taken place at Balakuchi village near Nalbari. There were two other breaches, one on eastern embankment at Khat Katra and other at Khanajan village and passed through Ghoga *beel*. The railway lines - both metre and broad gauge and the NT Road were washed away at 100 m distance from the western end of the railway bridge. Flood water entered into the Nalbari town from south-western side through the bridge at Tantra Sankara. Within a short time flood water submerged the whole area of Nalbari town and nearby rural settlements, agricultural fields causing heavy damages to crops and public and private properties.

iii) The highest water level was 55.20 m at NT Road crossing on 15th September, 1984 and the discharge of water was 470.67 cumecs of Pagladiya river.

In 1988, due to heavy and continuous rain in the catchment area of Pagladiya-Morapagladiya drainage complex lying in the foothills of Bhutan as well as in the plains of lower Assam during May-June high floods occurred in the Pagladiya, Morapagladiya, Burhadiya and other tributaries.

i) The water level in Pagladiya river rose up to 54.20 m at NT Road crossing on the 11th June, 1988 with maximum discharge of 952 cumecs. The river eroded away the entire left bank near Khat Katra and Khanajan villages and caused heavy floods over the area starting from Khat Katra and Khanajan villages up to the Barbhag area. Flood water spilling through this gap breached NH-31 and the railway line with western part of the bridge across the Pagladiya river near village Sandha. The rail and road communications were disrupted for several days in the entire area. Few other breaches also occurred near Balakuchi 3 km north of the Nalbari town on the eastern embankment through which water flowed down to Nona causing heavy damage to crops by depositing sand and silt over the agricultural fields.

ii) The Morapagladiya and Burhadiya rivers also created havoc in the Bhojkuchi, Sialmari, Bali and Gobradal villages breaching embankment near Bhojkuchi and Sialmari. Road communication was severely affected for few days and all agricultural crops were damaged.

In 1996, floods occurred due to continuous heavy rain during the last week of May to first week of June. The water level of Pagladiya river at NT Road crossing rose up to the level of 54.19 m on 8th July which was almost same with that of 1988. The Pagladiya breached the embankments at 5 points, 2 on the west bank and 3 on the east bank respectively. From the gaps on the west bank the water passed through the Chengnoi channel to the Burhadiya and inundated a vast area of Pagladiya and Burhadiya basins. The road between Barama and Rangia through Nalbari was closed to traffic. Near the west approach of the Pagladiya bridge at Nalbari, the railway line was completely submerged by the flood water and train communication was also disrupted for several days.

In 2000, the Pagladiya river inundated a vast area including Nalbari town and surrounding villages by its flood water. The river on the 10th June breached its east bank at Khat Katra and Paila villages at the south of the railway line after continuous heavy showers in the entire area. The rain and road communication between Rangia and Nalbari remained suspended for 4 days from 11th June to 14th June. The flood caused heavy damage to crops, public and private property. The Barbhag area evinced a great miseries to the people and loss of private properties like houses, livestocks etc. During flood the highest water level of Pagladiya was 54.89 m. The nature of flood damage in the study area is shown in the Table 3.4.

Table 3.4: Nature of Flood Damage in the Study Area, 1962-2000

Year	No. of settlements affected	No. of families affected	No. of population affected
1962	239	N.A.	2,000
1966	42	5309	37,246
1967	220	N.A.	N.A.
1969	208	6,369	48,512
1977	417	N.A.	N.A.
1984	507	32,130	1,42,570
1988	429	10,547	60,125
1996	312	8,715	59,218
1998	294	N.A.	N.A.
2000	462	8,455	54,615

N. A. – Not Available.
Source: Department of Revenue; Economics and Statistics, Govt. of Assam.

3.3.3 Flood, 2004:

The most recent flood of 2004 has left a trail of devastation everywhere in the Pagladiya-Morapagladiya drainage complex including the whole Nalbari district of Assam. One month was all it took to transform Pagladiya, Morapagladiya, Burhadiya, Nona and other rivers of benevolence into terrifying torrent of death and destruction. For settlers along the banks of the Pagladiya, Morapagladiya and others flood was emerging as a curse.

During the last week of May to July due to heavy and continuous rainfall in the catchment areas of Pagladiya, Morapagladiya, Burahadiya, Nona and Baraliya rivers lying in the Bhutan-Himalayas resulted in a major flood in the area. Added to this the dam failure in the Bhutan portion of Pagladiya river deteriorated the situation much more. The embankment of Pagladiya on west bank breached at Dhantola about 2 km north of NH-31. The water rose to an unprecedented level of 55.72 m at NT Road crossing on the 15th July, 2004. The river eroded away the banks and spilling flood water through this gap submerged the NH-31 at different parts from Nalbari to Barama. Few other breaches also occurred on the west bank at Barmurikona and Balilecha villages.

The flood water remained for 8 days submerging about 610 villages in the study area. In the greater Nalbari-Barbhag area the Pagladiya river became most hazardous and most of the settlers of the villages, like Bangalmur, Bengenamari, Pandula, Damodardham, Uttarkuchi, Simalia, Dasimalia, Moura, Khudra Sankara, Balajan, Digheli, Bardighla, Paila, Japarkuchi, Teresia, Balilecha, Amayapur, Arara, Bhadra, Sarihatoli, Barkura, Censorghat, Batahgila, Sutarkuchi, Kardaitola, Hatinamati, Sandha, Haripur, Garaimari, Malipara, Tinipukhuri, Narayanpur, Alliya, Burhinagar, Dhantola, Katla Barkuchi, Mairadanga, Ghilajari, Sukekuchi, Kaihati, Banekuchi, Chamata etc. were worst suffers.

In Masalpur and Baganpara revenue circles the Pagladiya and Morapagladiya rivers inundated many villages. The worst hit villages were- Nabasti, Bagulamari, Pub-Dihirapur, Palachi, Pakhamara, Chaibari, Kharua, Diyapar, Gayabari, Barikadonga and Khatabari. Morapagladiya created havoc causing erosion near Barikadonga and Khatabari. In Barikadonga 16 families and in Khatabari 27 families suffered lot from erosion of their homesteads.

Unprecedented flood havoc experienced in Kumarikata area including Dakshin Pakowa, Madhya Barkhetri and Dakshin Bahjani where villages like Khakharisal, Gadira, Gangapur, Mahbiyani, Dangardi, Katnikuchi, Larakuchi, Bhoiraghol, Baithabhanga, Kumarikata, Deharkalakuchi, Paschim Khatarkuchi, Batsar, Bagurihati were submerged in water for more than 15 days. The people belonging to Muslim, *Koibartta* and Bengali communities settled in the area mostly depend upon fishing and peasant agriculture. All their crops were completely washed away by the flood water of Pagladiya river.

In Tamulpur revenue circle in the north of study area the villages belong to Bodo, Kachari, Bengali and Adibasi communities, due to change of course of Pagladiya river 219 families became homeless. Rivers coming from Bhutan, viz., Pagladiya, Darranga, Dimila, Kalanadi, Motanga, Balti, Darranga and Baraliya affected 40,000 people with siltation, erosion and changing courses through agricultural fields. People settled in Charanjangal, Thalkuchi, Madaltana, Madarbari, Balabari, Hahkata, Chapatal are the worst affected in the circle. The Pagladiya river in Thalkuchi Pagladiya Dam Project site washed away all the foundations for infrastructure of the Central Government Project eroding the west bank of the river. The settlements of Charanjangal village became island like due to the damage of all road networks to the village from other places for several days on the east of the Pagladiya river. The width of the river extended about 400 m near the Thalkuchi village as the river eroded 140 m towards its west bank.

In this circle total 79 villages were severely affected. The numbers of partly affected villages were 33 and fully affected 3. The fully affected were Charanjangal, Piplani, and Angarkata. The total land area damaged by flood of Pagladiya river were 10,000 hectares. The estimated total loss of the circle was Rupees 40,67,000/-.

The Morapagladiya river which is known as Dirring in its upper part affected villages like Subankhata, Palashi, Chinadibasti, Jopadong and Hedayetpur. The Morapagladiya river changed its course in Dighaldonga village and damaged agricultural land, roads and homesteads. In its lower course villages like Gabradal, Sialmari, Haribhanga, Bhojkuchi, Makrapar, Bali, Sanora, Gamarimuri, Barama, Suradi, Barjhar were the worst affected. The river breached its western bank at Barbori under Barama police station and at Sialmari village 5 km east of Tihu town. On the other hand, the Burhadiya river breached its north bank in Bhojkuchi village at three points. Through these gaps of breaches from both Morapagladiya and Burhadiya rivers flood water entered into the whole Nambarbhag and Tihu mouza area and submerged for 10 days. The PWD roads of the area with other village roads were completely damaged and remained cutoff with the NH-31. The railway services were also disrupted for a week since the railway tracks in between Tihu and Kaithalkuchi station were submerged.

The flood water of Burhadiya river near Banekuchi completely damaged NH-31 where about 50 m of the national highway was washed away. On the damaged part a bailey bridge was established by the Army of Red Horn Division, Rangia for movement of traffic for more than 2 months.

The following Table 3.5 gives a clear picture of the damage of 2004 flood in the study area.

Table-3.5: Flood damage in 2004 Flood

Population Affected (No.)	Village Affected (No.)	House Damaged (No.)	Dead Persons (No.)	Livestock Dead (No.)	PWD Road (Km.)	Damaged Bridges (No.)	Agricultural Land (Hectares)	School Buildings Damaged (No.)	Fisheries Damaged (No.)	Total Flood Damage (Rs. In Lakhs)
4,87,000	610	15,150	17	482	266	96	27,962	46	3400	6,436

Source: Task Force for Flood Management and Erosion Control, 2005

The 2004 flood severely affected the socio- economic development of the study area. Almost all roads and crop lands of the region were damaged. The flood occurred just at the time of harvesting of *Ahu* rice. The flood damaged the crops in the field. Due to the heavy deposition of infertile sands over the agricultural fields in the northern part of the region the production of *Sali* rice was also poor in this year. Moreover, the flood caused heavy damage to public property like school buildings, roads, bridges, government office buildings and other infrastructure.

3.4 FACTORS OF FREQUENT OCCURRENCE OF FLOODS:

The frequent occurrence of flood during monsoon season in the Pagladiya-Morapagladiya drainage complex may be attributed to four major factors, viz.,(i) Climatic, (ii) Physiographic, (iii) Tectonic and (iv) Anthropogenic.

(i) Climatic Factor: The main causes of flood are: (a) The excessive rainfall especially in the Bhutan portion of the Pagladiya catchment, (b) as well as melting of snow, and (c) bursting of blockades of water formed by landslides. The most important of these is heavy and prolonged rainfall in the catchment.

As regards the climatic factor, the intensity of rainfall is usually high during the monsoon (total 1890.6 mm in 2001 and 2824.1 mm in 2002). In this season the rivers collect sufficient head waters which debouch abruptly on the plain from hills and overflow the narrow channels of Pagladiya, Morapagladiya, Burhadiya, Nona and other rivers. The turbulent flow not only creates local floods, but also frequently digs out new channels on the flood plain of these rivers. The Pagladiya river repeats this tendency every year.

(ii) Physiographic Factor: The hills on the northern border of the study area are made up of relatively soft tertiary rocks. When the rainfall continues these rocks are further softened causing solifluction and the loose material is transported by sheet erosion to the valley floor. Due to change of gradient between the hills and the plains at the ratio of 30:1, the huge volume of sediment carried by water from the hills is practically deposited because of a reduced carrying capacity of the river. As a result the gradual rise of river bed causes heavy and frequent floods in the area.

(iii) Tectonic Factor: Besides, the tectonic activities in the Himalayan region and adjoining places is most probably readjusting the base level of rivers in this area resulting in unstable river courses. However, there is a need for in depth studies in this regard.

(iv) Anthropogenic factor: Due to increasing pressure of population on land in the active flood plain areas which earlier acted as natural absorbents of the excessive river water are now encroached upon and occupied by man for agriculture, settlement and other activities. Earlier, along the course of Pagladiya, Morapagladiya and Burhadiya rivers, forest cover was abundant with grazing reserves in some parts of the plain. Now these are occupied by human settlements and cultivated fields. The wanton deforestation in the foothill zone and reserve forests coupled with shifting cultivation accelerates the silting problem in the river beds and as a result leads to progressive severity of floods from year to year. The large scale deforestation and human encroachment in the flood plain shattered the ecological balance in the study area. The unabated growth of population and settlements in the active flood plain zone during the last three decades forced people to occupy the waterlogged areas also even below the normal flood level. As such, when flood occurs the problem becomes really serious. Moreover, dams and embankments that have been constructed for flood control cause adverse effects by way of aggravating floods and water-logging in many areas. For instance, the Barbhag-Kamarkuchi area became waterlogged after construction of embankments on the bank of Pagladiya. The Bhojkuchi-Barpit area has been facing similar problems due to the construction of embankments along the course of Morapagladiya and Burhadiya rivers.

3.5 FLOW AND SEDIMENT TRANSPORT PATTERN IN THE PAGLADIYA RIVER:

With the help of various measured data some of the important features of the hydrological regime of the Pagladiya river are discussed here.

Monthly mean discharge hydrograph: The monthly mean discharge data for the years 1971 to 2000 (Appendix-II) of the Pagladiya river at NT Road crossing are analysed for examining the pattern of flow in the river. The data shows that monthly variations in discharge are different in different years, but have maximum range during the summer monsoon months and minimum in the non-monsoonal winter months.

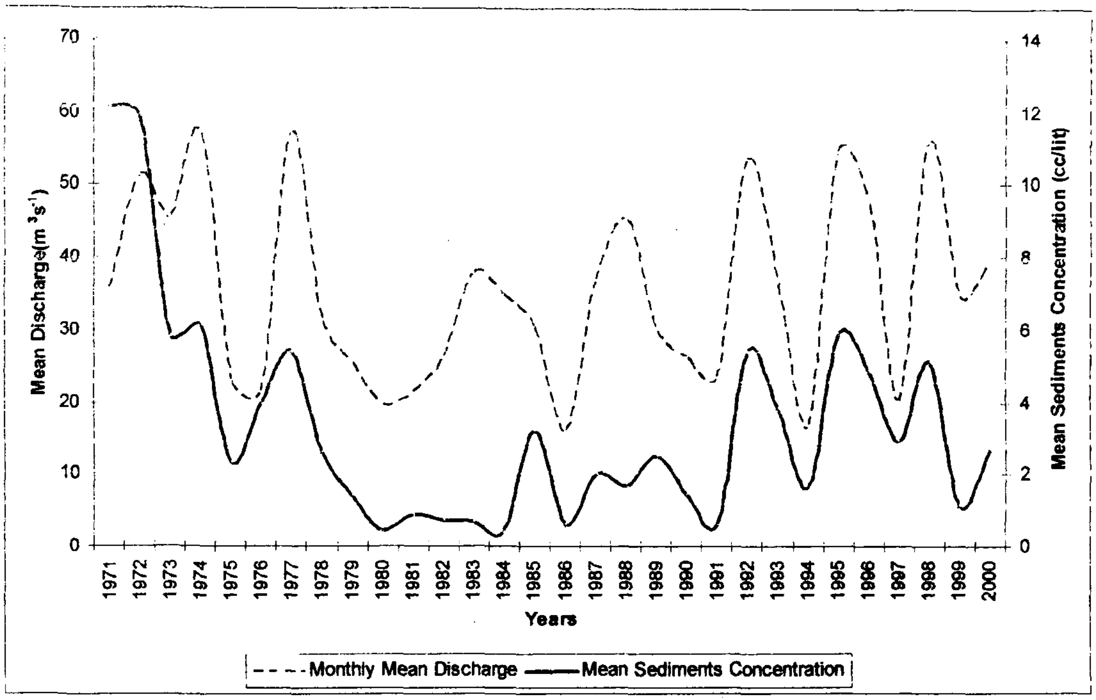

Fig. 3.11: Monthly Mean Discharge and Mean Sediment Concentration of Pagladiya River

The monthly mean discharge and mean sediment concentration hydrograph of Pagladiya river at NT Road crossing for monsoon months (May to October) during 1971-2000 is presented in Fig. 3.11. This shows the relationship between water discharge and sediment concentration of the river. The highest values of water levels during the monsoon months from 1971-2000 vary from 52.12 m (1990) to 55.20 m (1984). The danger level set at this measuring point is 52.75 m. The highest mean sediment was 12.42 cc/litre in 1984, whereas the mean discharge was highest (3692 cumecs) in 1974 and lowest (983 cumecs) in 1986 (Table 3.7).

Table 3.6: Recent estimates of important discharge rates and sediment concentration of Pagladiya River (May to October every year)

Year	Monthly mean discharge (m^3s^{-1})	Mean Sediment Concentration (cc/lit)
1974	3692	6.16
1986	983	0.62
1992	3291	5.38
1995	3350	5.89
1996	3076	4.88
1998	3577	5.10

Source: Brahmaputra Board, District Flood Control Office and Pagladiya Investigation Division, Nalbari.

3.6 FLOOD FREQUENCY ANALYSIS OF PAGLADIYA RIVER:

A number of physical characteristics of floods are important in considering the impact of flooding on man, i.e., the frequency of flooding, peakflow, total run-off volume etc.

Many of these characteristics can be explained with the help of some stastical methods including the method developed by E. J. Gumbel. In Gumbel's method peak or maximum discharges for different years are considered to show the flood frequency curve. The peak discharges are generally called flood, whether or not they actually cause inundation. The series of one peak per one year is called the annual series and the recurrence interval is the average span of time between two successive floods of that particular magnitude. As the magnitude increases, the probability of occurrence decreases. Among the various procedures for computing flood frequencies, return period analysis is based on discharge maxima in a series of years from which the recurrence interval or return period of flood can be calculated as,

$$T = (n+1)/N$$

Where,c T is the time for return period or recurrence interval in years,
n is the number of years of record, and
N is the rank of a particular event.

The resultant flood frequency curve shows the average time interval within which a flood of given size will occur as an annual maximum. Again, the recurrence interval and probability of occurrence are reciprocal to each other.

$$P = N/(n+1)$$

Where, P means probability.

The following Table 3.7 represents the values of annual maximum discharge observed at NT Road crossing of the Pagladiya river for 30 years from 1971 to 2000. These are illustrated in the Fig. 3.12 using semilog and probability graph paper of Gumbel style (Dury, 1969).

From the graph, the statement relating to the statistical probability of flood events can be made. The mean annual flood of 562.10 cumecs can be easily estimated from the graph as it has a recurrence interval of 2.39 years. The probability of occurrence of a flood of magnitude above 1,664 cumecs is 2.39 years. But this does not mean that at the end of every such interval flood of such magnitude regularly occurs. It is a statement of probability only giving the expected duration of time in which an event of the given magnitude may repeat itself.

Table 3.7: Maximum Annual Discharge of Pagladiya River, 1971-2000

Year	Max. Annual Discharge (m^3s^{-1})	Rank (N)	Discharge (m^3s^{-1})	Recurrence interval in Years T= (n+1)/ N	Probability P=N/ (n+1)
1971	577	9	577	3.44	0.290
1972	1664	1	1664	31.00	0.032
1973	880	4	880	7.75	0.129
1974	1289	2	1289	15.50	0.064
1975	158	30	158	1.03	0.967
1976	383	23	383	1.34	0.741
1977	844	5	844	6.20	0.161
1978	302	26	302	1.19	0.838
1979	259	28	259	1.10	0.930
1980	509	11	509	2.81	0.354
1981	371	24	371	1.29	0.774
1982	273	27	273	1.14	0.870
1983	456	20	456	1.55	0.645
1984	471	18	471	1.72	0.580
1985	370	25	370	1.24	0.806
1986	215	29	215	1.06	0.935
1987	738	6	738	5.16	0.193
1988	952	3	952	10.33	0.096
1989	448	21	448	1.47	0.677
1990	474	17	474	1.82	0.548
1991	498	12	498	2.58	0.387
1992	462	19	462	1.63	0.612
1993	440	22	440	1.40	0.709
1994	528	10	528	3.10	0.322
1995	483	14	483	2.21	0.451
1996	492	13	492	2.38	0.419
1997	480	15	480	2.06	0.483
1998	712	8	712	3.87	0.258
1999	476	16	476	1.93	0.516
2000	728	7	728	4.42	0.225

Source: Discharge data collected from Brahmaputra Board, District Flood Control Office and Pagladiya Investigation Division, Nalbari.

It has been observed that the peak discharge mostly occurs in the month of July and August due to heavy rainfall (Table 3.8), but the precise data varies by weeks in some years. Therefore, it is observed that peak discharge at a particular station is a function of local flood waves created by tributaries apart from the monsoonal rain in the Pagladiya basin.

Table 3.8: Monthly Rainfall (in mm) in Nalbari, 2000

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
13.1	8.2	162.2	336.0	321.0	843.9	536.9	311.8	198.0	47.6	36.9	8.5

Source: Directorate of Agriculture, Assam

3.5 FLOOD ZONES:

On the basis of the investigation of flood hazard, the study area can be divided into three main zones (Fig. 3.13). These are:

(i) Occasionally flooded zone of built-up area: The first zone covers a vast area lying in the built-up plain up to NF Railway line in the north and the region west of the river Pagladiya up to Morapagladiya and 45 m contour in the south. In this zone floods occur suddenly mainly due to the breaches of embankments and heavy continuous rainfall during the monsoon months creating heavy losses of life and property.

(ii) Chronically flooded zone of the lower flood plain of Pagladiya and Brahmaputra rivers: The second zone completely covers the lower active flood plain of the Pagladiya and Brahmaputra rivers. Here, flood water from Pagladiya and the backwater from the Brahmaputra river enter into the low-lying areas including the *beels* and marshy lands and create drainage congestion and inundation.

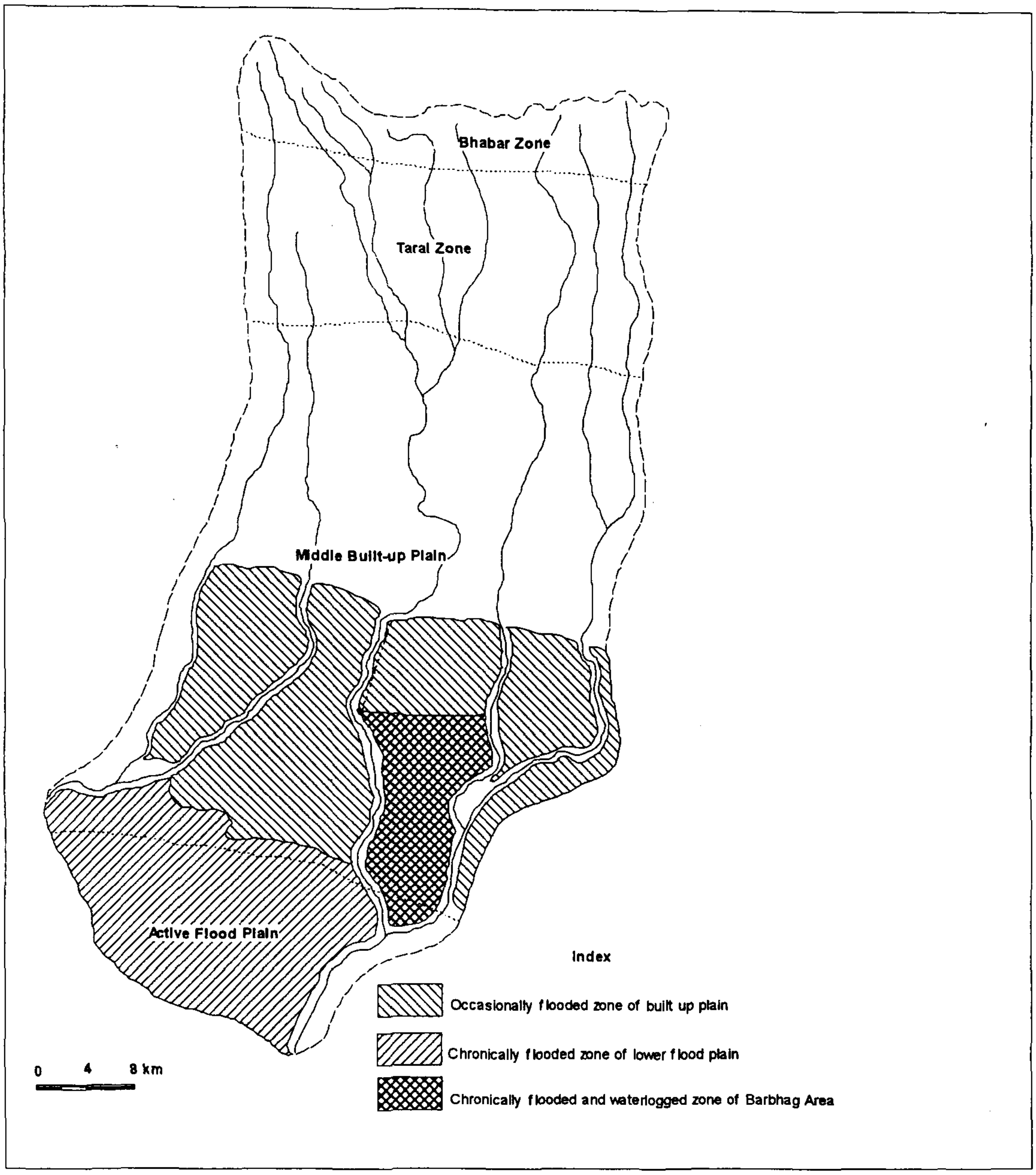

Fig. 3.13: Flood Zones in different Physiographic Units

(iii) Chronically flooded and waterlogged zone of the Barbhag area: The third zone is the waterlogged area of Barbhag. Due to 1897 and 1950 earthquakes the whole Barbhag area had undergone physical changes and caused water-logging and flooding. Although flood occurs over the area, yet the severity of flood is not equal. As elevation increases towards north, the intensity of flood decreases from south to north. Therefore, on the basis of severity and intensity of flood, the Barbhag area can be further sub-divided into the following four micro flood zones from south to north (Fig. 3.14). These zones are:

I. Most severely flooded and waterlogged area in the south,
II. Severely flooded and waterlogged area in the middle,
III. Less severely flooded area to the north of the second zone, and
IV. Moderately flooded area just south of the NF Railway line.

The micro flood zones are described in the following paragraphs.

Zone: I (Most severely flooded and waterlogged area): These villages are surrounded by *beels* and marshy lands. Among the *beels* of this region, the Bar *beel*, Dubaria *beel* are important. Flood generally occurs during the period from June to November. The highest level of flood water in this zone rises up to 6.5 m from the normal height of surrounding agricultural fields.

Zone: II (Severely flooded and waterlogged area): These villages are comparatively less severely affected by flood and waterlogging than those of zone:I. The elevation of this zone is slightly high.

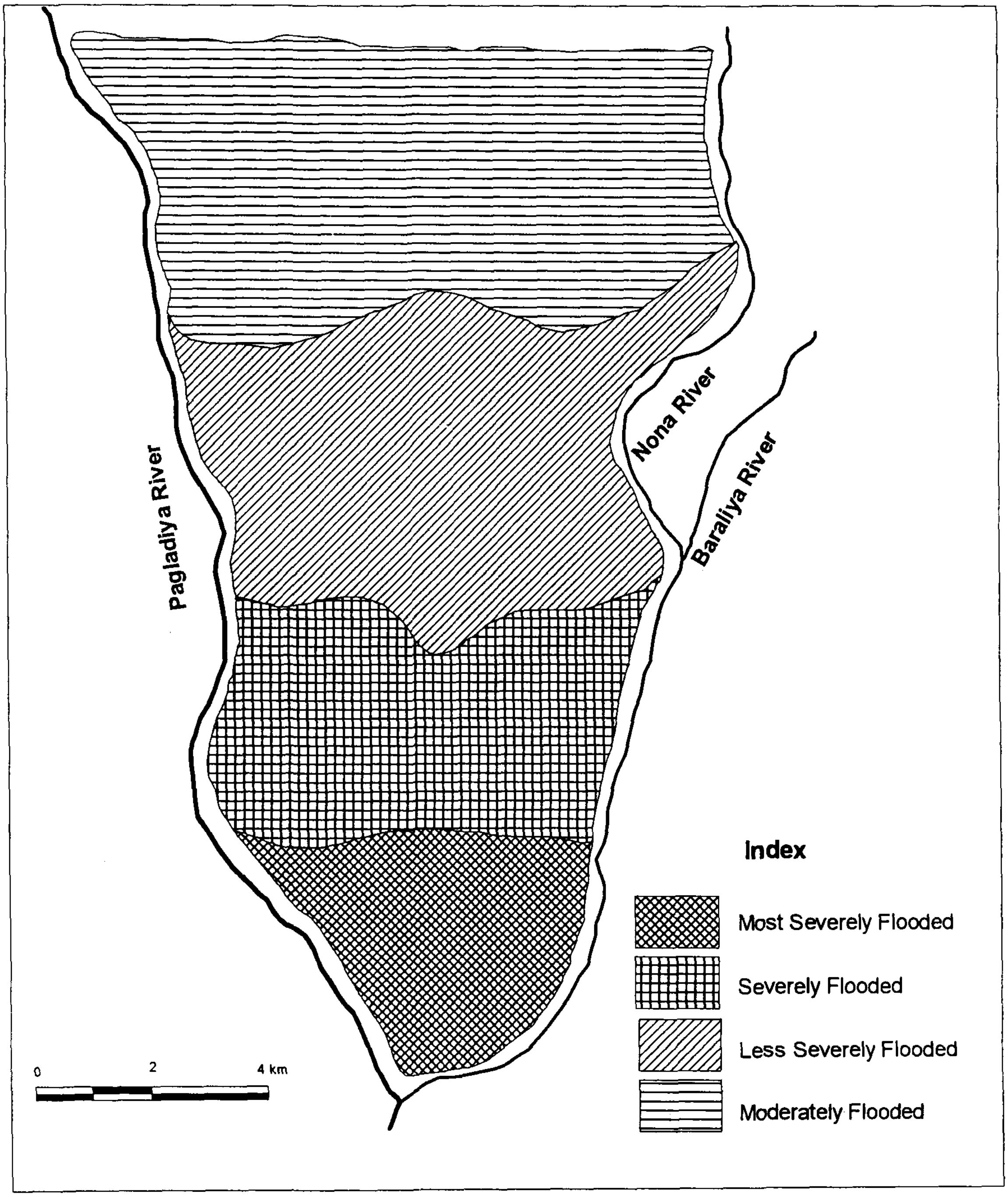

Fig. 3.14: Barbhag Area: Micro Flood Zones

Table 3.9: Flood Affected Villages in different micro flood zones

Sl.No	Zone I	Zone II	Zone III	Zone IV
1	Bar-Bukia	Dingdingi	Barmurikona	Sandha
2	Bar-Simalia	Pandula	Dhanara	Paikarkuci
3	Nakheti	Moura	Pajipara	Parakuchi
4	Ratkuchi	Bhanukuchi	Datara	Chenikuchi
5	Dokoha	Porakuchi	Amra	Guakuchi
6	Uttarkuchi	Kalag	Khat Katra	Patkata
7	Arangmow	Ranakuchi	Thanpatkuchi	Chilling
8	Raimadha	Barkulhati	Barigaon	Niz Borigog
9	Katalkuchi	Khudra Kulhati	Udaipur	
10	Kamarkuchi	Bangalmur	Bajali Udaipur	
11	Bargacha	Bar Barara		
12		Sonkani		
13		Athgharia		
14		Chatma		
15		Barkhola		
16		Larma		
17		Batakuchi		

Prepared by the researcher

Zone: III (Less severely flooded area): The settled area, village roads and agricultural fields are inundated during moderate type of flood in this zone.

Zone: IV (Moderately flooded area): In high flood due to breaches of embankments the settled areas of these villages are inundated. The nature of flood is not severe in this micro-zone and more or less same as the other built-up area of the study region.

From the above it can be drawn that the physiographic characteristics of this area presents the conditions that naturally give way to floods. The mountainous upper reaches of the basin that receive heavy rainfall each summer and cannot hold much water but a large amount of it flows as runoff down to the plains. The channels may not be able to contain the bulk of the water that flows and hence flood occurs. This not a recent phenomena but it has been happening for centuries for which the next chapter explains.

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Chapter - IV

HISTORICAL BASE AND EVOLUTION OF SETTLEMENTS

The historical background of an area or a region has a great bearing on the growth and development of settlement of a society or societies occupying it. The culture, socio-economic infrastructure, settlement distribution pattern and many other things take shape in an area from its historical base. Hence, it is very important to know the history of the area to understand the process of settlement evolution.

The dogmatic effects of different historical periods and cultural traits on rural settlements have brought about changes in their own way. Rural settlement is primarily an agricultural workshop. The shape, arrangement and distribution of settlements are often in conformity with the nature of work and agricultural techniques. The relics of implements used by them at some places can be helpful in forming rudimentary ideas of their lives. A careful inquiry into the origin of rural settlement is necessary because the present structure and character of rural settlement can hardly be compared without knowing the complex cultural background which began with its origin (Ahmed, 1954). The process of early settling led to the union of families into villages. The demarcation of fields from habitation developed a sense of integrated community life comprising several families. The idea of collective security and defense against different kinds of adverse environmental forces further strengthened the process of cohesion among families. But the first settlers have hardly left any actual record of the habitation in the area.

The settling of men in the clearing of dense forests may be regarded as the precursor of rural settlements. These early inhabitants were constantly exposed to different hazards and attack of wild animals. The instinct to combat the danger and need of collectivity and cooperation to construct houses (buildings), village well and tanks etc. brought people closer and closer. The settlements originated on relatively high sites along with fertile agricultural land and river levees where water supply was plentiful and life could be secure. These were, however, unplanned villages with poor transport facilities. For this reason they were often close to river banks.

The history of human settlement reveals that man has close association with the rivers since the early times. Men are always attracted to the riverine plains and human relationship with the river is reflected in the distributional pattern of settlement in the floodplain.

4.1 SETTLEMENTS IN THE HISTORICAL PAST:

It has already been mentioned that the study area covers the foothill, middle built-up and lower active flood plains of Pagladiya, Burhadiya and Morapagladiya rivers in the Nalbari district on the northern bank of Brahmaputra river. About 75% of the study area is composed of fertile alluvial soil of recent origin. Most of the indigenous scheduled tribes are inhabited in the foothill zone, while the high caste people live in the middle built-up plain and scheduled castes and immigrant Muslims from erstwhile East Pakistan (present Bangladesh) live in the lower active flood plain.

The geographical conditions of the study area with fertile plains, heavy rainfall, abundant water, luxuriant vegetation and rich fauna could attract the early settlers of different racial groups. Hence, there was flow of migrants into it from the pre-historic times. Historical records lead us to believe that in the epic age rulers of Danava and

Naraka-Bhagadutta ruled over the region from their administrative seat at Pragjyotishpur. This part was suitable for human habitation as no social, economic or political catastrophes had disturbed the normal life of the people. Moreover, the flood plain of the Brahmaputra river with Pagladiya, Burhadiya and Morapagladiya rivers with its soil fertility attracted people to settle there for pursuing their agricultural activities. The plain was also favourable for movement and transportation of agricultural products and other goods.

The region has a long history of human settlement and a rich ancient cultural heritage dating back to the epic age. The presence of *satras* (religious institutions of Vaishnavite culture), *devalayas* (places of worship of Saktism), *namghars* (prayer halls), *sanskrit tols* (residential educational institutions of Sanskrit) and *thans* (places of worship to God) indicates the presence of an early seat of Aryan culture in the region. Human settlement in this part of Assam valley probably started way back from 2000 B.C. The people moved from the banks of Hwang Ho and Yang-Tse-Kiang in China and North Burma to India through Assam. Not much is known about the early period.

These Mongoloid people had three main sub-groups, namely- Mon-Khmer, Tibeto-Burman and Siamese Chinese or Shan. The descendents of the Tibeto-Burman group known as the Bodo-Kacharis, settled in the plains of Brahmaputra valley. The Bodo-Kacharis were probably the early settlers of this region. Almost at the same time from the western part of India a group of Aryan people also entered into the Brahmaputra valley and established cities and kingdoms as early as the Mahabharata period. They belonged to priestly and warrior classes, and settled mainly in the middle built-up and lower plains. The Bodo-Kachari people had generally preferred relatively higher and forested ground. In recent years also the people belonging to Bodo-Kachari have migrated to elevated areas in the northern foothill zone leaving their original places in the middle built-up plain.

From the ancient epic age to the present period of Independent India, the region was ruled by several sets of rulers. From the historical records it is known that the Ahoms who belong to Mongoloid group came to Assam in the 13th century A.D. through the north eastern routes. They established a kingdom in Assam which continued till the coming of British in 1826 A.D. Under their patronage several towns and villages had grown in the Brahmaputra valley. During the Ahom rule from 1228 to 1838 A.D. the study area was annexed by the Ahom rulers. The Ahom kings were – Pratpsimha 1603-1641 A.D., Chakradhvaj Simha 1663-1670 A.D., Udayaditya Simha 1670-1673 A.D., Gadadhar Simha 1681-1696 A.D., Rudrasimha 1698-1714 A. D., Sivasimha 1714-144 A.D., Lakhisimha 1769-1780 A.D., and others later Gadadhar Bhuyan, Jaypal Bhuyan and Haradatta Biradatta etc.

It is mentioned in the Assam Buranji and Kamrupar Buranji (Acharya, 1966) that a new line of Kings founded by Arimatta or Gajanka (1365-1385 A.D.) followed by Sukranaka and Mriganka ruled the kingdom of Kamrupa. Arimatta ruled this kingdom from the headquarters located at the village named Arikuchi (Baruah, 1973) situated on the western bank of Pagladiya river at a distance of 11 km south-east from Nalbari town. He was the founder of *Vaidyagarh* (*garh-* high raised dam for protection from enemies) at Betna on the western bank of Pagladiya (Dutta, 1962). Phengua killed Arimatta and established his new capital with embankments at Dhamdhama on the west of Pagladiya (15 km north of Nalbari town) and named it *Phenguagarh* (Dhekialphukan, 1829). Arikuchi and Dhamdhama are good examples of old villages with dense settlements originated under the patronage of king Arimatta and Phengua.

The Chandakuchi village reflects a recountable feature of the Ahom period with historic activities of the Bujarbaruah families. The heroic brothers Haradatta and Biradatta attempted to overthrow the Ahom rule in 1796 A.D. from the province of Kamrupa which included the study area. Their residence was at Jikeri near Rangia on the east of Pagladiya river and village Tantra Sankara was the headquarters of their activities.

During the Burmese invasion of Assam in 1817, the study area was comparatively less affected. This was one of the main factors which prompted people to migrate from other parts of Assam to Barbhag and Nalbari area and settled there. This may be an important reason which explains the dense population of the area.

In the selection of settlement sites man is usually guided by some attractive and restrictive forces of nature. The plan of settlement sites has been mostly adjusted to the topography. As the study area is mainly covered by floodplain, the villages are built in slightly high lands above the flood level and river levees. The role of rivers in the distribution of settlement is most significant (Bhattacharyya, 1980). Besides physical factors, cultural institutions such as, *namghars,* temples, mosques, tanks etc. have influenced in the layout of villages in the study region.

The process of division of labour between different classes of inhabitants depending on their capabilities led to the division of the villages on the basis of *varnas* which in the beginning were merely professions followed by different people. Thus came into existence of profession based settlements as distinct from ones inhabited by general agricultural communities. Beyond the fringe areas of the central settlement, satellite settlement or sub-village locally called *chupa* or *chuburi* came to be occupied wholly by one group having the same profession at one time, people of the same profession preferred to settle in one place, and the place came to be known after the professions. As there are various professions, Malikuchi, Bezkuchi, Kamarkuchi, Sonkuriha, Sutarkuchi, Paikarkuchi etc. are the settlements originated during the Ahom period. As the time went by the *varnas* got stabilized into castes, the caste system bred intolerance of people of different castes towards another. The lower castes people gradually settled in separate *chupas*, leading to the origin of cluster and hamlet type settlements. Sonpur village on the west bank of Pagladiya and north of railway line in Nalbari may be cited as an example of this type of settlement belonging to scheduled caste. Initially the persons of one caste settled at a place, others of the same caste soon migrated to that place and a village had grown up around the original settlements. Villages like Gormara, Bagulamari, Bhojkuchi, Sandha, Japarkuchi are fairly indicative of this fact.

In rural areas human settlements are common when the land is suitable for agriculture possessing characteristics like adequate water supply, relatively high and free from floods. The origin of several villages in Pagladiya-Morapagladiya drainage complex is due to this reason. These factors also determine the morphology of rural settlements of this region.

The study area is also a meeting ground of three cults of Sanatan Hindu religion, viz., Vaishnav, Sakta and Saiva. Large number of *satras* and *temples* related to cults are in existence within the area. During the Ahom rule some Vaishnavite reformers and preachers established *satras, thans, devalayas* and *namghars* in different places of the study region for religions and social well-being of the people. The *satras* and *namghars* were also responsible for growth of settlements. These rural settlements can be termed as *satra* settlements. The important *satra* settlements are Billveswar satra, Jagra satra, Balilecha satra, Agnisala satra, Balikuchi satra, Kamarkuchi satra, Nalbari satra, Kulbil satra, Kanara satra etc. All these villages show a higher concentration of population.

New villages were developed due to expansion of families and migration to other areas. However, they have christened their new places with the old names of settlements adding prefix *Natun* or *Na* (new) and *Purana* (old) to refer to their former place of settlements. For example- Natunkhuti, Nakheti, Namati, Natun Dehar, Natun Sripur, Purana Sripur etc.

It is observed that a quite number of rural settlements originated due to historico-cultural hydronymic features, usually- tanks (locally called *pukhuri*). Villages surrounding Ganga pukhuri (during the regime of Gadhadhar Simha), Joypal Devalaya pukhuri, Jay Sagar pukhuri, Gamarimuri pukhuri, Billveswar Devalaya pukhuri, Dewan Kunda, Kalagar pukhuri etc. were founded by the Ahom king Siva Simha during 1714-1744 A. D.

During the Ahom period clan migration also led to growth of settlements. The Ahom kings granted lands to various professional clans for residential purposes, particularly to Brahmins for their temple service.

In the early times the Pagladiya and Morapagladiya with other small tributaries exerted barrier effect in the land routes and tracks. As a result, a village or hamlet frequently came into existence at the river crossings. Ulabarighat, Barmurikonaghat, Bijulighat, Sahpurghat and Burhadiyaghat of ferry point or boat point (*ghat*) have distinctive settlements.

A large number of villages had also grown up along the road network i.e. hodonymes. The best examples of these are Gosaikamal Ali, Phengua Ali, Hardatta-Biradatta Ali, Dhamdhama *Garh* and Boggles Road which gave rise to large settlements like Namati, Barama, Dhamdhama, Merkuchi, Bahjani, Kamarkuchi, Kalag etc. Development of nodes with opening of railway station and creation of cross roads also gave rise to new hamlets, which developed with advancement of time and needs of the inhabitants. Shops were attracted to such centres and they gradually developed into rural trading centres.

An analysis of place names of rural settlements gives suggestions and hints about the origin of villages. Though such analysis is complex, it provides some clues to the early human habitations of the area concerned. The linguistic elements in the rural areas also give clear evidence regarding the movement of people, area of their colonization and their relation to earlier and subsequent groups. They also help in indicating the period of their establishment as well as the reason for their nomenclature.

In a large number of instances, the place names are connected with the natural features like river, tank, forest, tree etc. The character of a settlement is often signified by a suffix or prefix in the place names, e.g., *Di* (Bodo- water), *Chara* (rivulet), *Dia* (streamlet), *Dhowa* (wash), *Dal* (a kind of weed), *Jan* (water passage), *Jhar* (marsly area), *Juli* (river), *Par* (bank, side), *Tari* (a garden), *Bali* (sand) etc. The name of the Tihu town located on the Tihu river bank was derived from the river. The Tihu river was originally known as

'Dihu' by the indigenous settlers belong to Bodo-Kachari of the area. Later it was termed as 'Tihu' with a permissible change with '*Di*' to '*Ti*' which can be ascertained as hydronymic origin. Besides, Debachara, Majdia, Angardhowa, Gabradal, Kharuajan, Kaljhar, Barjhar, Nagrijuli, Ghagrapar, Balikaria, Balilecha etc. are the suffix and prefix word place names which invariably indicate the influence of site on their origin. The name of any village ending with these suffix or prefix indicates that the villages have low land areas with good soil fertility suitable for paddy cultivation in its vicinity. The village ending with *Dhowa* indicates that the area is susceptible to floods, e.g., Angardhowa.

Villages with prefix *Bali* (sand), *Bar* (big), *Khudra* (small), *Niz* (central place), *Bhag* (a part), *Bhanga* (broken), *Bil* (a lake), *Bori* (village), *Char* (fertile river sandbar), *Bathan* (a place for buffalos, cattle herding) etc. also signify the locational characteristics of a village, located either near a river or water bodies. Some prefix word names are Balikaria, Balilecha, Barbhag, Barkura, Khudra-Sankara, Barimakha etc.

The study area was full of abundant natural vegetation in the beginning of the human habitation. Hence, we find number of place names of botanical origin. The old villages like Bahjani (*Bah-* Bambusa vulgaris), Batabari (*Bata-* Erianthus elephantinus), Bar Simaluguri (*Simalu-* Bombax ceiba), Belsor (*Bel-* Aegle marmelos), Bijulighat (*Bijuli-* Bambusa tulda), Gamarimuri (*Gamari-* Gmelina arborea), Kadamtola (*Kadam-* Authocaphalus indicus), Kendukuchi (*Kendu-* Diospyros peregriana), Khagrabari (*Khagra-* Pragnites karka), Kherani (*Kher-* Imperata cylindrica), Tamulpur (*Tamul-* Areca catechu), Thaikarkuchi (*Thaikara-* Garcinia pendenculata) are the names of villages originated in the area abundant with natural vegetations.

The name 'Nalbari' of the district headquarter as well as for the whole district which covers the study area might have originated from the fact that the whole area on the bank of Pagladiya river was known for abundance of a particular wild riverine reed locally called '*Nal*' (Arundo donax). '*Bari*' means garden. Thus the name 'Nalbari' came in the combined form of '*Nal*' and '*Bari*' which was flora origin of riverine tract.

Similarly, the animal kingdom and the human habitation continued for several generations and their direct and indirect influence vis-a-vis can not be ignored. So, the influence of fauna on human settlement is inevitable. Alengidal (*Alengi*- Rasbora elenga), Bagulamari (*Bagula*- Bubulcus ibis), Bhalukdanga (*Bhaluk*- Ursus arctos), Garmara (*Gar*- Rhinoceros unicornis), Hahkata (*Hah*- Dendrocygna javanica), Sialmari (*Sial*- Vulpes vulpes), Solmari (*Sol*- Channa striatus) etc. suggest that the wild animals, fishes and birds were abundant in the marshy riverine tracts in the Pagladiya- Morapagladiya drainage complex.

A hamlet or a village subsequently grows after the people belonging to a clan settle down in an area. Thus certain areas came to be known by different clans. We find various place names associated with clan names in the study area. These are Bangalipara, Bamunbori, Bhutankhuti, Nathkuchi, Chutiapara, Garia Angradi, Pamuapathar etc.

During the British regime the construction of railway and motorable roads and opening of tea gardens in Assam opened new avenues of employment which led large number of people to migrate to Assam from other parts of India, Nepal and Bangladesh (East-Pakistan).This new migrants disturbed the original ethnic structure of settlements. The tea garden labourers belong to the tribes such as Munda, Ho, Santhal, Savara, Oraon, Gond etc. settled in the Doomni, Menaka and Nagrijuli tea estate areas in the north of the Pagladiya-Morapagladiya drainage complex.

4.2 SETTLEMENTS FROM 1947 ONWARDS:

The post-independence period witnessed a remarkable change in the demographic as well as settlement structure of the study area. Just after independence there resulted a large scale migration of minority Bengali Hindus from East-Pakistan (present Bangladesh). Again after the independence of Bangladesh (1971) large number of refugees took shelter in the active flood plain zone of the study area. Even at present also the illegal migrants have been changing the demographic and settlement pattern in the active flood plain zone.

After independence, settlements show a general tendency of dispersal because the fear of freebooters and foreigners has ended and the inhabitants felt greater freedom and security. Establishment of primary schools, rural health centres, panchayat bhawans, community hall, libraries, construction of roads and many other public buildings have rapidly changed the rural landscape. According to 1961 census, the villages were closely settled in the middle built-up plains and their distribution was mainly dependent upon the agricultural prosperity of the region. Many administrative changes have also brought about Nalbari, the present district headquarter on the western bank of Pagladiya river came into being as an urban centre with the setting up of its first town committee in March, 1938. It was raised to the status of Municipality in 1951. Nalbari was declared as a sub-divisional headquarter since 1st of August, 1967 and hitherto was constituted into a full-fledged district on 14th of August, 1985.

The growth of Nalbari demonstrates a similar pattern with most of the commercial and trade centre towns in Assam. The main phases in town founding and growth of Nalbari are the British period (1841-1947 A.D.) and independence period. During the first phase there was not much change in functional morphology and growth took place under influence of some stimuli such as central market for the surrounding rural areas and for administrative services for the whole area. The construction of railway line in the year 1909-1910 helped in ushering the commercial and trade activities of the town. In the post- independence period due to expansion of built-up area it has been associated with the increase of administrative functions, educational, medical and other socio-economic services. Along with motorable roads the settlement morphology of Nalbari and surrounding villages has been changed to a great extent. All the roadways including NH-31 provide inter-district and inter-state transport facility connecting with Guwahati and other towns of Assam. The main roads stretching to Dhamdhama towards north, Barpeta via Chamata towards west and Hajo towards south are connecting the rural settlements of the study area.

Tihu, the second town within the study area is the important service centre of the entire area including Baska, Namati, Nambarbhag and Dharmapur mauza of Nalbari district. It achieved the status of township in 1951 under the functional category of trade and commerce cum industry.

The growth and development of this town is connected with the British commercial enterprises through the development of railway and roads. The Britishers constructed the Tihu-Doomni road which was known as 'Chahabar Ali' from Tihu to

Doomni Tea Estate. This road was used for exporting tea and rice from Tihu- Baska area to Kolkata. After independence Tihu became the gateway for the south-western part of the region (i.e. the old Kamrup district) connecting with other towns and service centres of Assam. The state highway and other district roads like Tihu-Lachima road, Tihu-Masalpur road, Tihu-Haribhanga road, Tihu-Solmara road are the main terminals of transport and communication system. In the north about 3 km away from Tihu town, NH-31 stretches along east-west direction which is at present changing the settlement morphology of the town. Besides, the railway line provides inter-state and inter-district transport facility to the town. All the roads and railway transportation facility play a major role for attracting people to settle in the greater Tihu area.

The town is located in and surrounded by rich alluvial plains of Tihu, Morapagladiya and Burhadiya rivers resulting to high agricultural productivity. The greater Tihu-Baska area is known as the 'rice bowl' of the Nalbari district. The economic base of the settlers of the town and surrounding villages in the entire area is based on rice and other agricultural products like jute, oil seeds, pulses and vegetables etc. The growth of population in the town and surrounding villages is accompanied by expression of rural settlements coupled with the urban landscape of the town itself.

Due to devastation by floods and the resultant damage of habitation along Pagladiya river new settlements have developed in areas found protected from floods. Khagrabari, Nabasti, Kumarikata, Borajal, Balitara, Dhamdhama villages owe some new settlements of people migrated from flood affected villages within the study area due to breaching of Pagladiya river.

Recently, numerous rural settlements have grown up as a consequence of division of joint families. There are a number of settlements like Bali, Chamata, Gabradal, Paikarkuchi, Suradi, Jagra which owe their origin to such factors.

Besides, the outgrowth of the older rural settlements, several new settlements cropped up on account of high socio-economic development. Barama, Chamata, Kaithalkuchi, Morowa, Ghograpar, Masalpur, Dhamdhama, Nikashi are the major service centres transformed from rural landscape after construction of NH-31 and other PWD roads. The process of urban expansion has assimilated or rather absorbed several rural settlements. For example, the growth of Barama on the banks of Morapagladiya river absorbed Niz-Juluki and Barjhar; Chamata on the south of Burhadiya river absorbed Kulbil and Rupia Bathan; Kaithalkuchi on the east of Morapagladiya river absorbed Jowardi and Gamarimuri villages respectively. Thus all service centres have a number of constituent villages absorbed or merged within the perimeter of their influence zone. Sometimes, the outgrowth of settlements is not due to any natural process but is the result of expansion of trade activity or development of transport routes. Growth of settlements due to development of educational and medical institutions etc. led to the evolution of hamlets. This is a process of dispersal which has become quite noticeable in recent years. These issues will be dealt in detail in the next chapter.

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Chapter - V

DISTRIBUTION AND CHANGING PATTERN OF RURAL SETTLEMENTS

Distribution has always been considered as the basis in all geographical analysis. The study of distribution derives its significance from the fact that it is through the distribution that the complex, spatially varying area-specific relationship can be discovered. Similarities and differences among areas, which constitute the principal theme of geographical studies, are ultimately identified from the distribution of phenomenon. The distribution of rural settlements reflects the transformation of the natural landscape by different cultural factors.

In the study, our concern is with the spatial variations in the interaction between cultural and physical settings which flow from each other. The complexity of structure, terrain and drainage has caused relatively uneven distribution of settlements. In the words of Sauer (1963) 'distribution is the key to processes'. There is relationship between culture and historical process. Even if the historical processes were to remain constant, any change in culture would influence distribution. Hence, the most dynamic and strongest explanatory variable of distribution would be culture itself. But the physical factors like physiography and drainage play a dominant role in the distributional pattern of rural settlements.

Spatial distribution of settlements manifests the man-habitat relationship in the physical and functional space. The distribution of human occupance is the outcome of a large number of physical environmental, evolutionary, socio-economic and cultural attributes. The study of settlements and their spatial pattern is a useful instrument for analyzing the sequence of change in the cultural landscape (Singh, 1975). Distribution of settlements is created by an interplay of natural, ecological and human factors and the access to the resource is mainly institutional (Mukerji, 1980).The historical causes influencing the evolutionary process of occupance, physical environment and site, socio-economic level of growth and rural-urban interaction determine the spatial distributional character of settlements in a region. Thus the analysis of settlement site, size, type and pattern with their changes in time, nature of dispersion of settlements, and other related expressions form a basis for arriving at a conclusion to the spatial organization of settlements in a region. The area under study with 701 villages (Fig. 5.1) presents wide variations in the above contexts. The impact of rivers i.e., Pagladiya and Morapagladiya in the area is reflected in the spatial distribution and changing pattern of rural settlements.

5.1 RURAL SETTLEMENT SITES:

Site is one of the most significant factor determining rural settlements when studied in the background of theoretical framework with respect to culture-nature interactions. Its importance has for long been recognized by the human geographers. Blache (1952) stressed that the first element to be considered in the establishment of any settlement is the site where the settlement began.

Site may be regarded as that specific bit of the earth's surface on which a settlement of any size or form, actually stands. Its meaning and significance to the occupant groups are far deeper than the mere physical fact. It is the medium through which culture interacts with nature and through which a section of culture or social group attaches itself to the land. A piece of land, however, becomes a site only when a social group selects it, occupies it and relates itself to the locale.

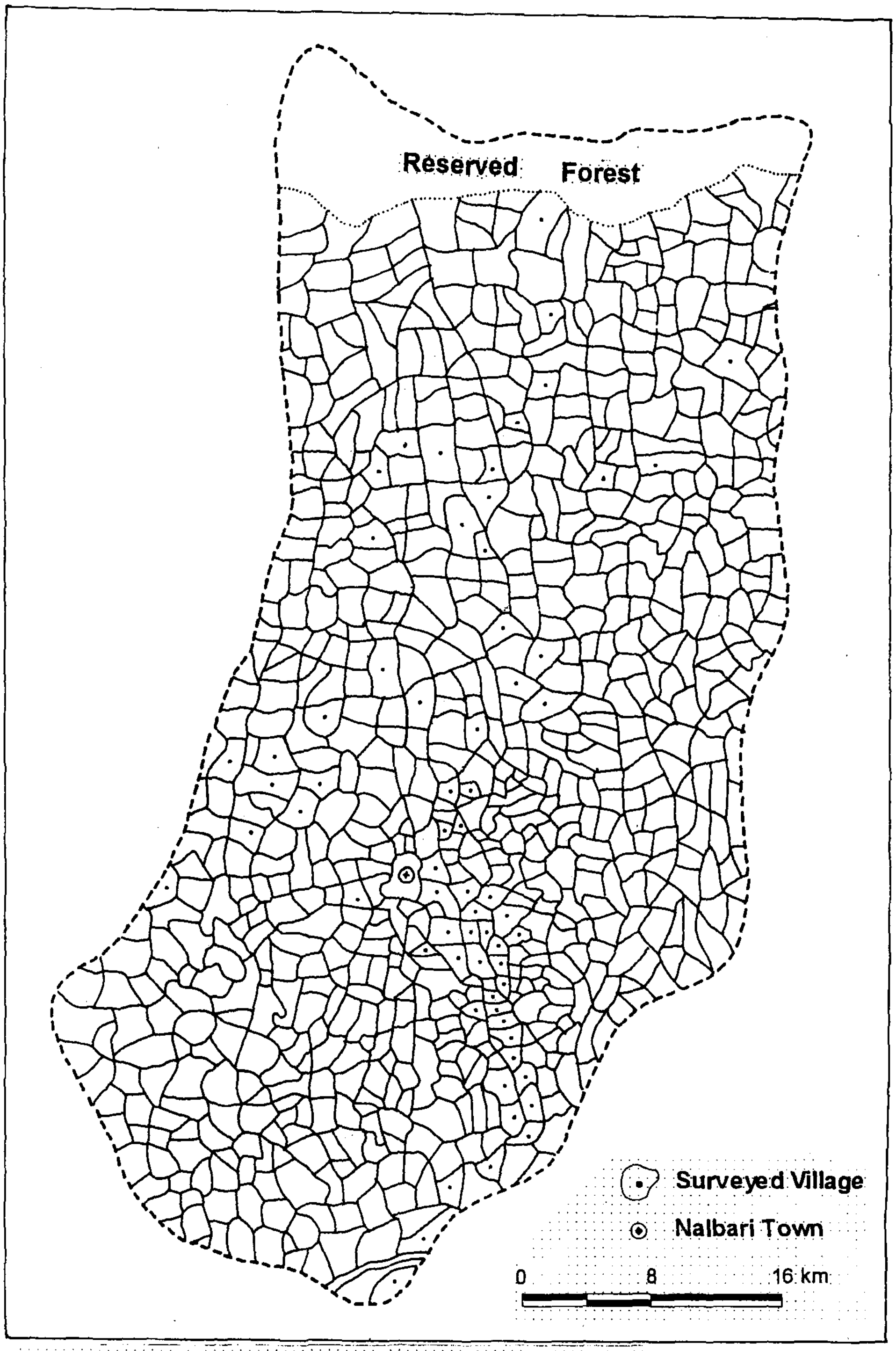

Fig. 5.1: Village Territories and Surveyed Villages

Site is essentially a topographic expression of the landscape and has been termed as the topological position. In terms of areal focus, site containing the settlement has to be studied *as an area* in itself and therefore, sustaining a vertical relationship. The site is essentially *in situ* in nature (Grover, 1985). Each site has a physical setting and a set of resources, which a social group perceives in accordance with its culturally induced needs and available technology inputs. It is on the site that the natural landscape is transformed into a cultural landscape which is then concretized in the material form of rural settlement. In many cases, the social group selects the site where its mode of living can be practiced optimally.

Sauer (1952), Chisholm (1968) and others have observed that the most important factors in the initial selection of sites are based on the following factors like proximity to water sources, availability of arable land, adequate protection and an easy access to the sources of fuel and building materials. Throughout the human history, nearness to the river has been the strongest determinant. In the study region, however, which is predominantly a flood plain area where water is available from the rivers Pagladiya, Morapagladiya, Burhadiya and other small tributaries and also where farming is the main occupation of living, productivity of land seems to have been the most powerful factor (Fig. 5.2).

The physiographic condition of a region has noticeable impact on human life and occupance. The physical factors significantly affect rural settlement sites, which control the form, size, distributional pattern and morphology of rural settlements. In the selection of settlement sites man is usually guided by the attractive and restrictive forces of physical

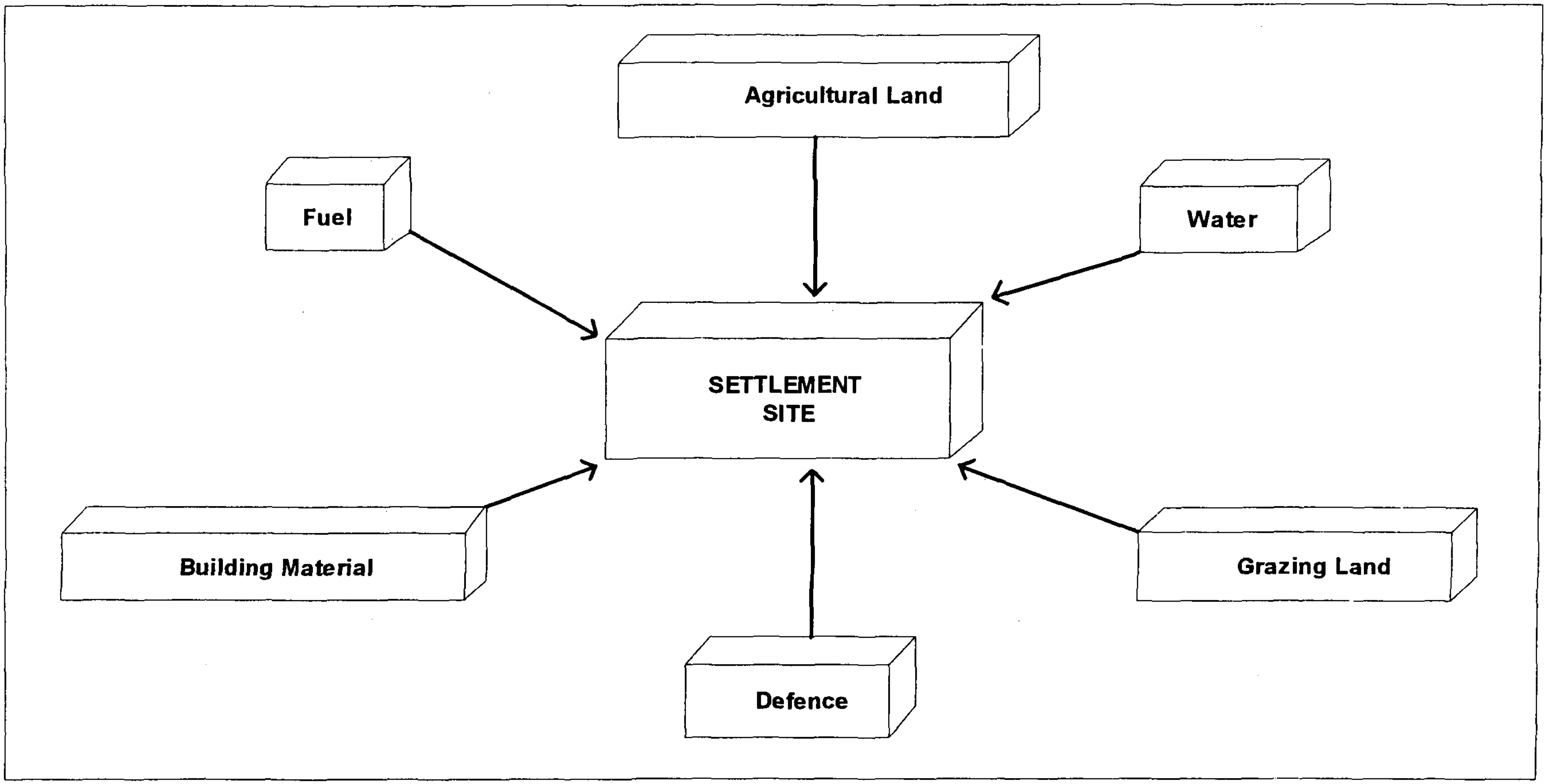

Fig. 5.2: Determinants of Settlement Sites Selection

settings, which include various elements, such as geology, relief, drainage, climate, soil and natural vegetation (Singh, 1955).

The Pagladiya-Morapagladiya drainage complex being a physiographically homogeneous alluvial plain with negligible variation in relief, the predominant physical factors influencing sites and distribution pattern of rural settlements are the location of flood affected areas, marshes, forest and the shifting courses of Pagladiya and Morapagladiya rivers. Besides, the cultural factors are also the major influencing factors of site selection for human habitation. All sites are different in topographic or landscape expression. On this basis they can be classified broadly at the highest level of generalization, into two broad categories:

(i) Physiographic-topographic: The physiographic-topographic category is comprised of those sites which are associated with physiographic features: landforms, vegetation, soil, rivers and other hydrographic surfaces. The study area contains a large variety of physiographic-topographic sites. Indeed so large is the variety that some of the types of sites are represented by only a few settlements.

(ii) Cultural-topographic sites: Cultural-topographic sites would include those which are mainly related to cultural features, such as roads, canals, socio-cultural institutions etc.

In order to make meaningful generalizations, the sites displaying the same topographic location have been grouped together and named after its location. Hence, their nomenclatures are like hill-plain contact sites, forest-edge sites, levee sites, dry-point sites etc. These are their topographic locations with reference to topographic features which can be made the basis of differentiating them or determining their similarities, thus, enabling one to construct a rational typology.

The resultant site types identified and classified through observation in the study area and studies of the large scale topographical sheets (1:50,000) are:

(I) Site Types of Northern Foothill Zone: Following the different settlement patterns in the northern foothill zone three main types of sites can be identified: (a) the hill-plain contact sites (Tarai), (b) the forest-edge sites and (c) tea garden sites.

a) The hill-plain contact tract is full of tall grasses with unhealthy damp soil. This area is the home of mostly indigenous Bodo group of tribes and Nepali immigrants. Human settlement is very sparse here. The location of sites includes two types, namely - (i) the settlements located in the foothill slope and (ii) those settlements located at the points where the ephemeral torrential hill streams enter into the plains. These small sites are everywhere dissected by streams and rivulets which divide the area into triangular surfaces of varying sizes. Until recently these streams and rivulets carried enormous load of gravel and silt. They have greatly affected the internal morphology of the settlements.
The location of sites at the junction of the hill slopes and the flat plain surface enables the practice of two kinds of land utilization. While the former has a cover of shrubs and grasses and is, therefore, used mainly for cattle grazing by the Nepalese, the latter is entirely covered with agricultural fields. Due to the pressure of population on arable land in the middle plain some people have

been migrated to this zone. The settlements like Bagulamari, Nalbarigaon, Nabasti, Natunkuchi, Pamuapathar, Rampur etc. reveal the characteristics of new settlements. Darranga, Uttarkuchi, Patkijuli, Paharpur, Hatiduba, Darrangamela, Kalajhar, Chandranagar are the villages located in the foothills of Bhutan (Fig. 5.3.a).

b) The hill-plain contact sites must have been closely related to the forest edge sites. One of the principal characteristics of northern foothill landscape is the scattered occurrence of forests along the rivers Pagladiya, Motanga, Darranga, Nona, Baraliya, Morapagladiya and other major streams. Though the forests are reserved by the Department of Forests, Government of Assam the Nepalese immigrants and indigenous tribes encroached these forest lands clearing the forest. Such forest-edge sites located adjacent to the rivers and streams along with agricultural lands are selected for settlement at present and are slowly degenerating forest areas. Batabari, Subankhata, Sapatal, Darrangamela are the best examples of forest-edge sites of rural settlements (Fig. 5.3.b).

c) Tea gardens of Doomni, Menaka and Nagrijuli in Uttar Baska and Defeli mouza respectively provide the facilities of tea garden sites (Fig. 5.3.c). Such settlement sites of tea garden labourers, ex-labourers and officials of the gardens form a typical settlement site owned by the tea estates. This site offers the advantages of (i) employment in the tea gardens, (ii) domestic requirements, (iii) protection from flood hazards and (d) transportation. These initial

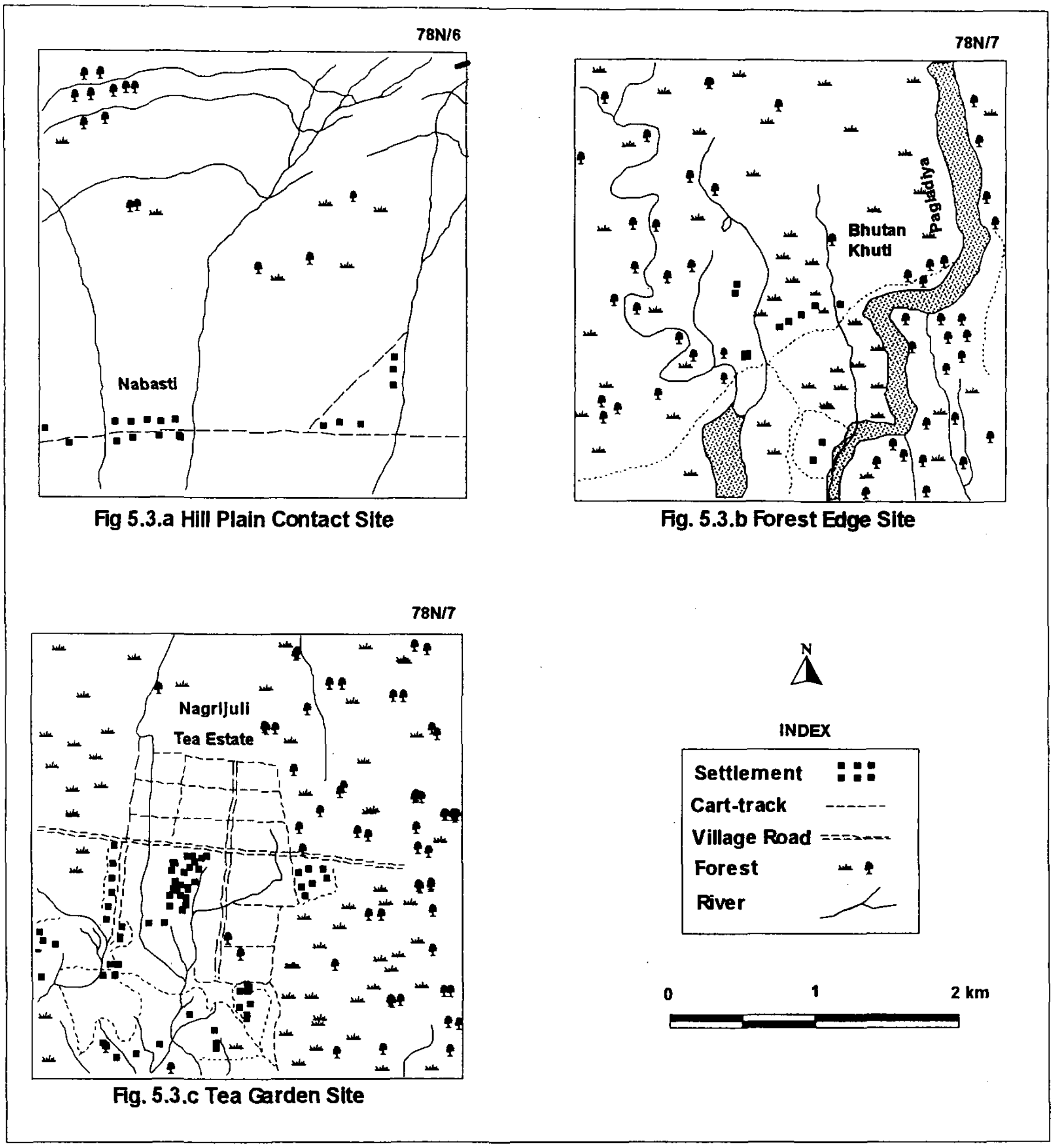

Fig. 5.3 a, b & c: Rural Settlement Sites

advantages were recognized by the later settlers and as a result, these sites were continuously occupied.

(II) Site Types of Middle Plain : The fairly fertile alluvial middle plain of river Brahmaputra with its tributaries of Pagladiya, Burhadiya and Morapagladiya is marked by compact and semi-compact settlements. The region has a high density of population due to favourable geographical conditions. In this region the houses are built in large or small clusters as per location of the agricultural fields. The following settlement types in the middle plain are marked with dominant site conditions (a) the presence of river levees and (b) the dry elevated point sites.

a) Generally, the old villages are found on the banks of Pagladiya, Burhadiya and Morapagladiya rivers and their neighbourhood. The natural levees of the Pagladiya, Burhadiya and Morapagladiya are by far the most favourable settlement sites in the study region. The settlements cling even to minor sources of water and at places are aligned with rivers. There is a concentration of rural settlements on the levees of Pagladiya in the mouzas of Paschim Banbhag, Khata, Natun Dehar, Pokowa, Dharmapur, Bahjani, Batahgila and Upar Barbhag. Soil fertility and availability of river water have provided a further inducement (Fig. 5.4.a).

From the viewpoint of selection of settlement sites on the levees, it can be inferred that there is a relationship between the age of the settlements and their distance from the present course of the Pagladaya river. The greater the distance from the Pagladiya, the greater seems to be their antiquity.Likewise, the old and large size rural settlements are located on the levees of Morapagladiya and Burhadiya rivers in the mouzas of Pub Baska, Paschim Baska, Nambarbhag, Dharmapur and Natun Dehar. Good accessibility and fertile lands are the root causes of the evolution of old settlements in this area.

b) The dry point sites are located on the elevated plains of Pagladiya and Morapagladiya rivers. Proximity to water needed for both domestic uses and irrigation as well as to protect the settlements being flooded were vital considerations in the initial selection of these sites. The dry point sites, when occupied initially located near water sources. These large or small clusters are supported by fertile cultivable lands. Besides, the favourable conditions for construction of railways and motorable roads have served as attractive forces for such selection. The rural settlements such as Chamata, Belsor, Kakaya, Kaithalkuchi, Namati, Chandkuchi, Makhibaha, Morowa are the apposite examples of dry point settlements in the study region (Fig. 5.4.b).

(III) Site Types in Active Flood Plain: The active flood plain zone near river Brahmaputra is swampy and contains a numerous *beels* and waterlogged areas. This zone is mostly inhabited by immigrant communities in the low-lying rice and jute fields. In this unique area the site types identified also differ from those of northern foothills and built-up plain. The major site types are: (a) wetland settlement sites, and (b) the active flood plain sites.

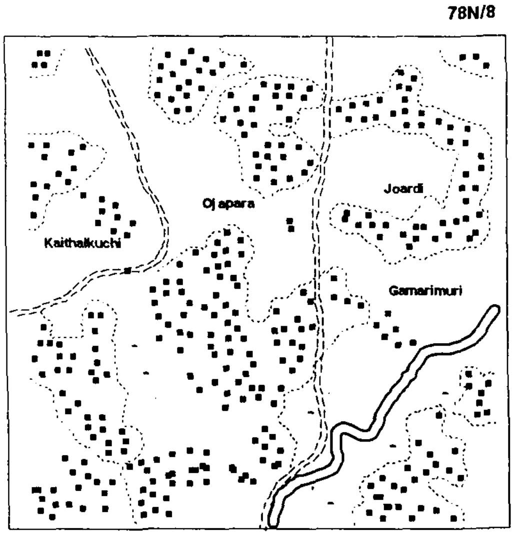

Fig. 5.4 a River Levee Sites

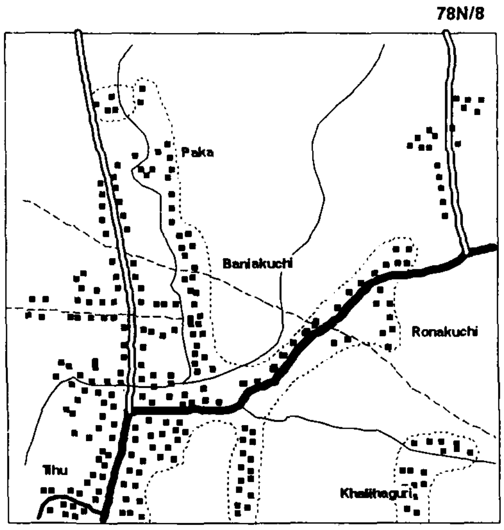

Fig. 5.4 b Dry Point Site

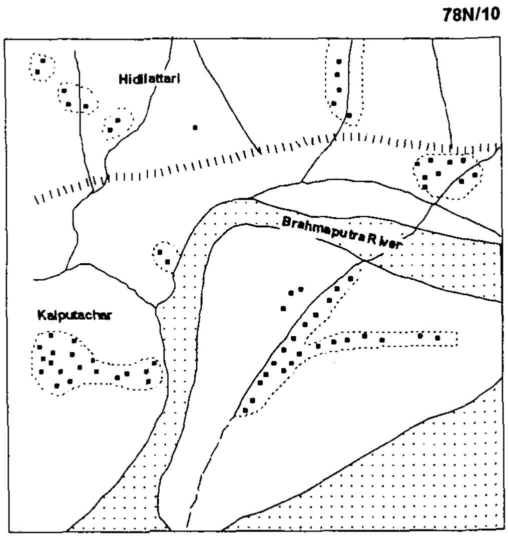

Fig. 5.5 a Wetland Sites

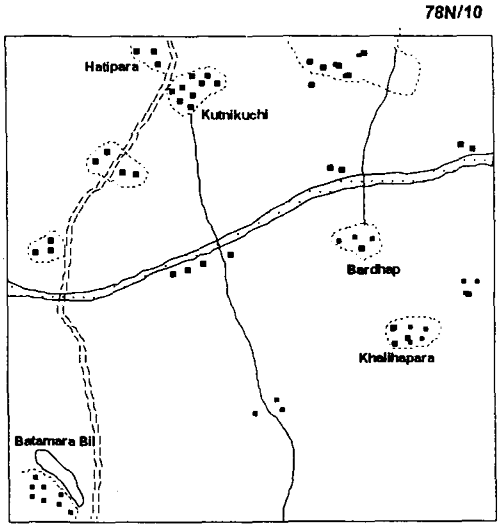

Fig. 5.5 b Active Flood Plain Site

Fig. 5.4 a, b, & 5.5 a, b: Rural Settlement Sites

a) The villages like Roumari, Bhangamari, Kurihamari, Chitalmari, Solmari, Khalihamari, etc. ending their names with their suffix *mari* indicate that formerly these sites of settlements were the areas suitable for fishing a varieties of fishes. Again Adattari, Meruttari, Tegherittari, Balattari also indicate the settlements of marshy and swampy tracts, i.e., wetlands of recent origin with the suffix *ttari* which means a high land surrounded by marshes, full of reeds and tall grasses. The social groups belonging to scheduled castes select such type of settlement sites to pursue their traditional fishing occupation (Fig. 5.5.a).

b) On the other hand, in the active flood plain of the study region the immigrant Muslims cluster their houses further away from river banks on artificially raised lands (Fig. 5.5.b). In the Uttar Barkhetri and Madhya Barkhetri mouzas of the Pagladiya-Morapagladiya drainage complex a vast waterlogged tract was created in the great earthquake of 1897 (Sarma, 1969). This is the most severe flood prone area inhabited by immigrant Muslims. They are engaged in producing *kharif* crops like rice and jute cultivation and also *rabi* crops like brinjal, potato, onion, tomato, mustard, peas, lentil and other vegetables which are highly productive on the fertile silt deposits.

Here, an assumption, that the different fluvio-morphological settings within the study region have their manifestation in the pattern variation of settlement sites is tested by Chi-square analysis. The formula for Chi-square test is as follows:

$$\text{Chi-Square} = \Sigma\, (O\text{-}E)^2/E$$

Where, O is the observed number of settlements,

E is the expected number of settlements, and

Σ is the instruction 'to sum' for all squares.

Table 5.1: Chi-Square Test on Pattern Variation of Rural Settlements Sites in the Study Area

Fluvio-morphological setting	Observed No. of rural settlements (O)	Expected No. of rural settlements (E)	$(O\text{-}E)^2$	$\frac{(O\text{-}E)^2}{E}$
1.Foothill Zone	177	233.6	3,203.56	13.71
2.Middle Plain	423	233.6	35,872.36	153.56
3.Active Flood Plain	101	233.6	16,796.16	71.90
Total Observation	701	700.8	55,872.08	239.17

Computed by the researcher

In order to test this assumption the value of chi-square was worked out as given in the Table 5.1. It was found that the computed value, i.e., 239.17 is much greater than the tabulated value 5.99 for 2 degrees of freedom at 5 per cent level of ignificance.Hence,the fluvio-morphological setting is significant and important influencing factor for the development of different settlement sites and the variation of rural settlements in the Pagladiya-Morapagladiya drainage complex. It may be inferred that the fluvio-morphological factors are strong enough as to influence the pattern of settlement sites to a great extent in the study area. The location of settlements seems to indicate that the middle plain particularly was more attractive to the early settlers than the foothill zone and the active flood plain. In conjunction to this, the influence of other cultural factors such as transportation network, potential agricultural lands, nearness to service centres etc. cannot be denied and have not been considered here. Therefore, there is probability that the distribution of settlement sites also may be a matter of chance.

5.2 PATTERN OF RURAL SETTLEMENTS:

The settlement pattern in any area is perhaps the ultimate expression of man's involvement in space and continuously evolving with the passage of time. The villages being an agglomeration of dwellings are the mainstay of rural life. It is also the primary stage of emerging nodes and its natural growth presents a well defined pattern. The morphogenesis of these settlements becomes interesting as their evolving pattern depends upon various geographic phenomena. The patterns of rural settlements are intimately related to various physical conditions, such as configuration of site, abundance of surface water, water bodies like rivers and streams, plain surfaces, fertile cultivable lands, waterlogged areas etc. Besides these physical conditions historical events and socio-economic factors also exert their influence. All these are of paramount importance in the growth of settlement patterns.

All the above mentioned factors are collectively responsible for the development of different settlement patterns. From field observations it can be inferred that the plan of villages is adapted to the relief features and aligned with rivers and streams as well as cultural and social elements. Beyond the socio-cultural elements the physical factors like relief, drainage pattern, marshy and waterlogged areas as well as fertile soils explain to a large extent the development and pattern of rural settlements.

However, some other common forces also contribute to the pattern of rural settlements. Firstly, the nuclear tendency in the early stages when physical and economic advantages direct the settling groups to cluster in few hamlets or villages and the process further advances with the growth of population. The other is the desire of most inhabitants to stand on their own feet as owner or tenant acquiring their own piece of land in other suitable sites and this results dispersion. In general, the settlements of the study area consist of a few thatched houses clustered together, separated from cultivated lands. Around the homestead arecanut, palms, coconut, betel-vine groves, banana, bamboo, bushes and various other trees mostly for basic household need are grown. The skyline as a green patch of trees on the cultivated fields is mostly flat and the evenness sometimes is only broken by some institutional buildings like schools, dispensaries, temples, mosques and others. This is a typical character of rural settlements in N E India. Inter-settlement and intra-settlement communication is generally limited to foot-paths in the inner parts. Sometimes, these are found to be interrupted by the river courses. Thus, both internal plan and external layout portray the different types of settlement pattern in the study area.

In the light of the above historical and geographical analysis of growth of settlements, with the effect of fluvio-morphological factors, several types of settlement pattern have been identified developed during the period from 1971 to 2001.

(i) Rectangular Pattern: This pattern of rural settlement is commonly found in the thickly populated areas of the middle built-up plain. It is the most common form of nucleated rural settlements. The main reason of emergence of this pattern is the rectangular form of the cultivated fields with their pre-set boundary lines roughly running along east-west and north-south direction. The rectangular alignment of dwellings with their main axis from north to south and east to west are determined by the built-up plain formed by the Pagladiya, Burhadiya and Morapagladiya rivers. In compact settlements the rectangular and square blocks of land give rise to greater concentration of dwellings which produces a rectangular settlement pattern. The village lanes and foot-paths usually meet at right angles while sometimes the foot-paths meet with river embankments. The axial road and the resultant rectangular character of land can be divided easily into house plots. The bank of the river as boundary of the settlement is sometimes used as foot-path or cart-track. This pattern provides best and most optimal use of land in a settlement. In the mouzas of high population density with compact settlements such as Nambarbhag, Dharmapur, Pokowa, Bahjani, Khata, Batahgila, Tihu, Namati, Natun Dehar etc. of the study area the rectangular pattern is common. The settlements, namely, Sandha, Belsor, Jagara, Pokowa, Haribhanga etc. belong to this category. The pattern of Sandha village has changed during the period from 1968 to 2004. In 1967-'68 the village showed square pattern and after few years (1986-'87) it took a rectangular pattern. The settlements have taken place towards south along a village road and towards east along the PWD road. It is interesting to note that the rectangular pattern of Sandha village has been determined by a great natural depression created in 1897 earthquake and the course of Pagladiya river which restricts its south-westward expansion. On the north, NH-31 and railway line run parallely in east-west direction and acts as barrier of its expansion towards agricultural fields, while in the east the low paddy fields restrict the eastward growth of settlements. As several cart-tracks and village roads traverse this settlement, they intersect each other to form a rectangular checkerboard plan (Fig. 5.6.a).

The village Pokowa is another example of restricted growth. It has grown on an upland in between Nalbari-Bihampur and Belsor-Jagara roads which act as barriers on the north and west respectively. Other PWD roads are running towards the south and east. Though settlement has been developed in the midst of fertile agricultural fields, two water-bodies are there on the south-east of the village. Hence, there is no scope for its expansion and still maintains its true rectangular characteristics. Likewise, Namati village shows a rectangular pattern developed along a marshy tract near a *jan* flowing to Morapagladiya river and a PWD road from NH-31 to Nikashi. The settlement of the village is restricted towards east by the waterlogging of abandoned channels of Laudongi *jan* (Fig. 5.6.b). In 1967-'68 the settlements of the Namati village was compact along the roads. After development of new roads and cart-tracks the village expanded towards the marshy lands located south west of the village (1986-'87).

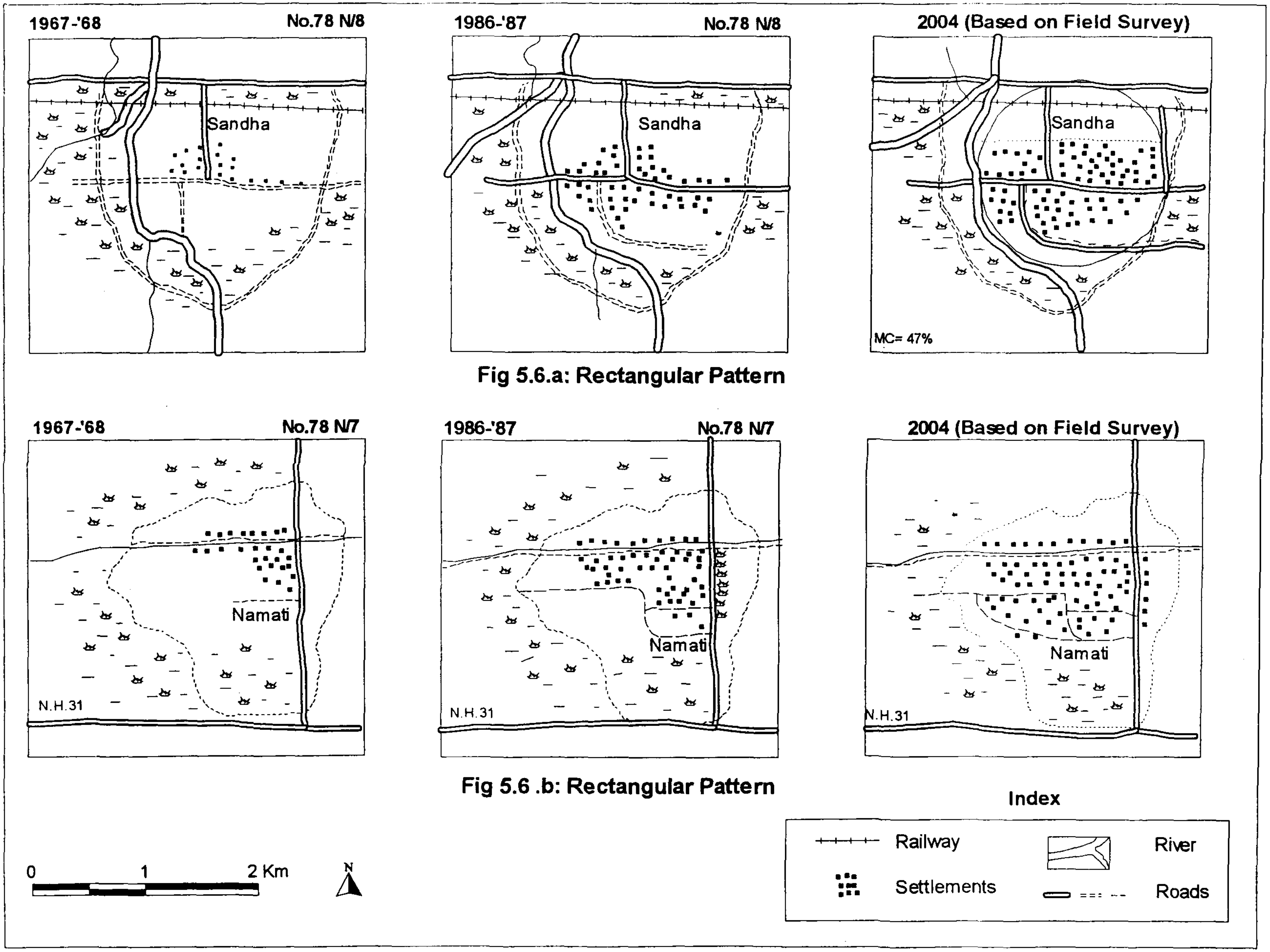

Fig. 5.6 a & b: Temporal changes of Village Patterns

(ii) Elongated or Linear Pattern: It is a common phenomenon that indigenous Assamese people live mostly in the linear villages developed along a road or a river where one apex of the villages is marked longer than the other (Bhattacharyya, *1980*). Linear pattern is easily recognized by its simple arrangement of houses along a line or a series of lines. It prolongs in one direction and restricts in another direction due to certain attractive or restrictive forces which encourage or discourage the growth of settlements. The occurrence of such a rural settlement pattern is guided by the site characteristics. In the flood affected areas the growth of settlement on the levee of a river is a common feature. While in the other areas where there is no danger of flood the proximity to river water for drinking and other household uses also may cause elongation of the settlement. On the edge of the hills or at point of difficult relief features such as, lowlands and low hills, settlements often develop a linear pattern indicating the impact of restrictive forces of nature.

Among the cultural features roads either metalled or unmetalled with village roads have greater influence in the elongation of settlement pattern. If there are important links through highways and cart-tracks besides rivers with the central places or markets the elongation may be striking. Elongation may create many problems in implementing some development plans for rural settlements.

In the study region such settlement pattern on both sides of the roads and rivers are discernable. The settlements in Balitara village (Fig. 5.6.c) since 1967-'68 depicts a linear pattern along the PWD road in north-south direction on the western bank of river Pagladiya. Due to population pressure new settlements were developed towards north. The pattern of village is not changed during the period from 1967-'68 to 2004 though towards west three village roads are constructed. Such a village is known as *strassendorf* which connotes street village. Bhojkuchi village located on low lying agricultural fields on the northern bank of river Burhadiya in Nambarbhag mouza is a typical example of this pattern with physical alignment.

(iii) Square Pattern: This type of settlement pattern known as *ciflik* is another characteristic feature of thickly populated area having good network of roads. This is the beginning stage of the rectangular pattern and both are complementary to each other. Square settlements often turn into rectangular form after slight growth in certain direction due to cultural advancement and physical favourable conditions like shifting of river course at a suitable distance etc. Such settlements are mostly lying at the crossings of roads and or roads crossing a river. This pattern is related to some physiographic features like thick orchards surrounding the settled area on all or some sides, and tanks, *beels* or marshy tracts which have similar restrictive influence. Mixed pattern of four squares might be seen when the village consists of four distinct settled units lying at the crossings of two main village roads or crossing of a river by a road.

The village like Sahpur, Karia, Sonkuriha, Kalag in Pub Banbhag mouza represent this pattern of rural settlement. The village Karia reveals the mixed pattern (Fig. 5.6.d) of four squares and surrounded by orchards, agricultural field and crossings of either two roads and or road with river Pagladiya (i.e., Nalbari-Hajo-Guwahati road crossing of river Pagladiya at Karia). Initially this village was strated with settlements along the Nalbari-Hajo Road. Gradually the settlements expanded towads east and west. It has not deviated from a square pattern since 1967-'68 till now.

(iv) Horse-Shoe or Semi-Circular Pattern: Horse-shoe or semi-circular pattern is one uncommon form seen in the middle and southern parts of the study area where sharp arcuate bend of some abandoned meandering channels of river Pagladiya and Morapagladiya are created. In the Pub Barkhetri, Madhya Barkhetri and Upar Barbhag mouzas along the deranged drainages and marshes locally called *beels*, hamlet type of settlements have grown up. The *beels* are the natural fisheries, so that the fisherman communities like *Kaibartta* and *Namasudra* are found to settle and giving rise to a new settlement pattern. The Ghoramara village in Madhya Baska mouza inhabited by scheduled castes follows a horse-shoe pattern. It is located by the side of a horse-shoe lake of Pagladiya river (Fig. 5.7.a). The settlements along an abandoned channel of Morapagladia river in Kathalbari village also shows similar pattern.

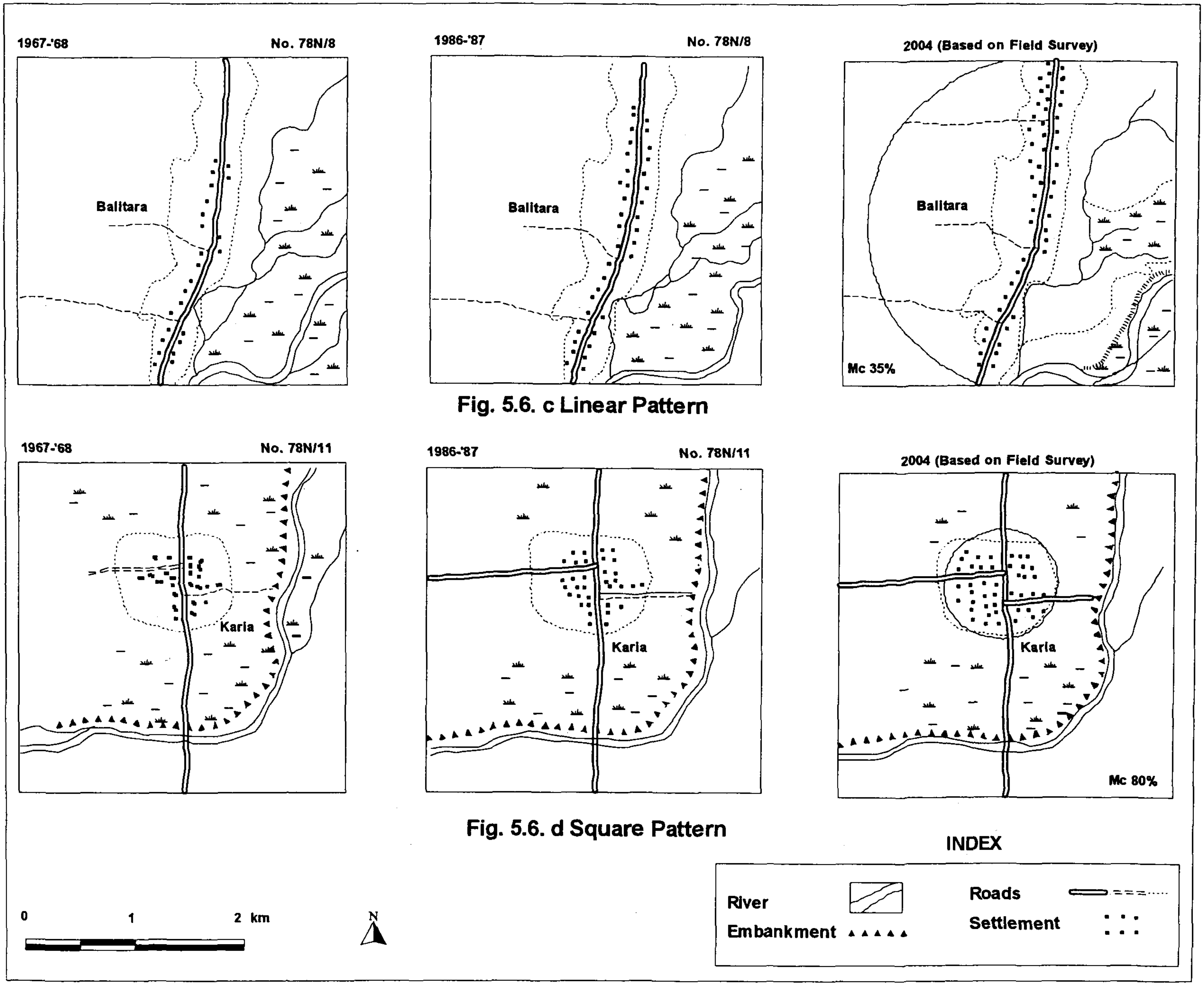

Fig. 5.6 c & d: Temporal changes of Village Patterns

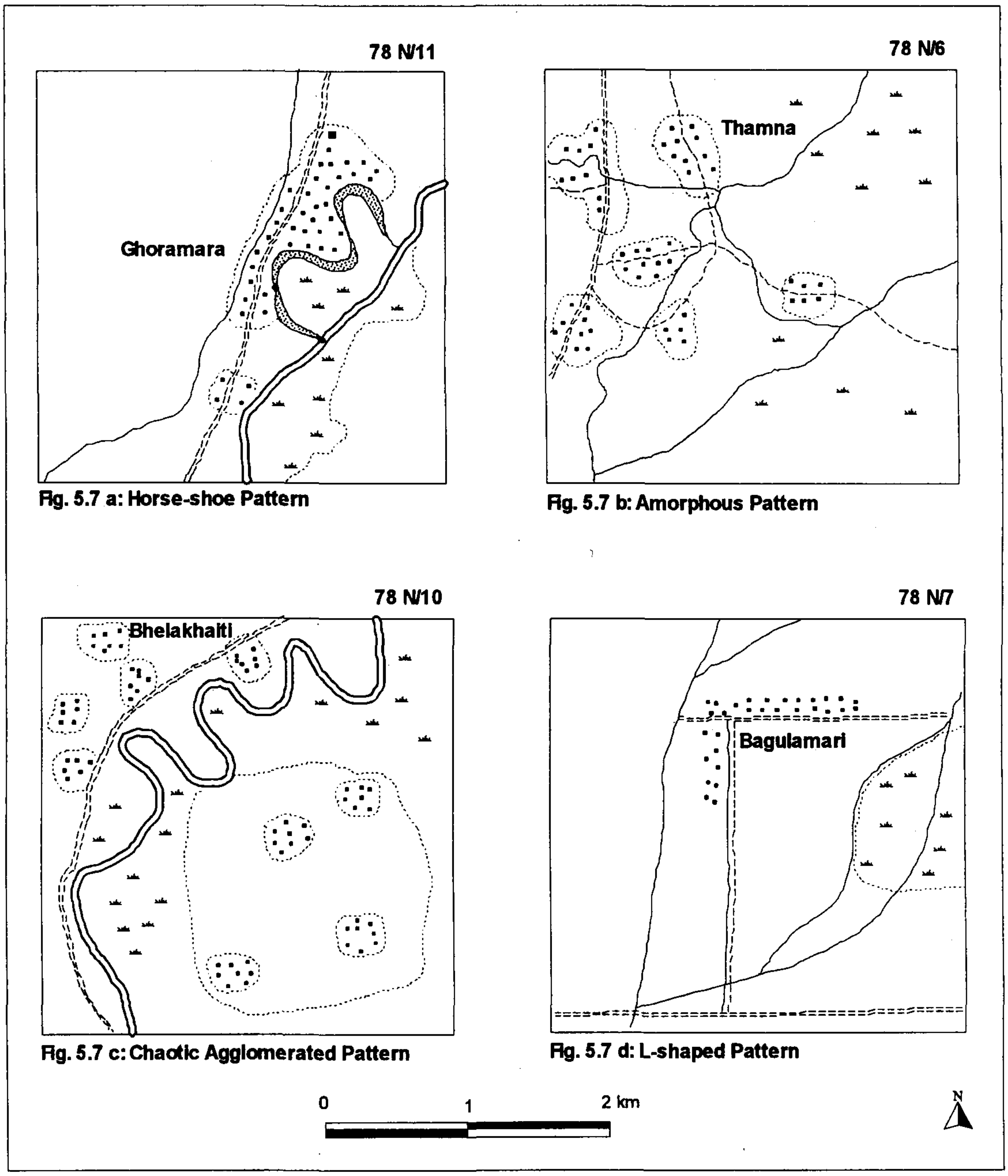

Fig. 5.7 a, b, c & d: Village Patterns

(v) Amorphous Pattern: The amorphous pattern is found in the middle plains adjoining the sub-Tarai belt. The settlements are dotted with many hamlets and individual farmsteads, all being very small rectangles linked with the central hamlet by crude foot-paths. Such loose distribution of settlements in between the compact settlement and the isolated farmsteads are found located along the streams and sub-tributaries of Pagladiya-Morapagladiya rivers. The suitable example of such settlement pattern is Thamna village in Baska mouza nearly 5 km west of Masalpur village located on the banks of streams of Morapagladiya and Tihu river (Fig. 5.7.b).

(vi) Chaotic Agglomerated Pattern: It is one of the most typical settlement patterns in the active flood plain zone of Uttar Barkhetri mouza predominantly inhabited by the immigrant Muslims and refugees. This type of settlement pattern is different from the others mentioned earlier. Majority of the people belonging to aforesaid communities are seen to settle in low-lying agricultural areas of the flood plain region. The settlements are mostly located within the cultivated fields without following any linear features. This results in the formation of nucleated chaotic agglomeration. Village Chotemari and Bhelakhaiti are examples of this pattern which are located in the low-lying areas created by river Chaulkhowa and an abandoned channel of river Pagladiya (Fig. 5.7.c).

(vii) L-shaped Pattern: The L-shaped settlement pattern has common occurrence at several settlement sites, where two linear forces meet at right angles to each other. This pattern is a subsidiary of a rectangular or square form. The linear forces may be two roads and cart-tracks or a road and water front meeting at right angles. There are several settlements in the study area which has grown along the curvature of the Pagladiya and Morapagladiya and their tributaries or roads. Their arcuate bend leads to the development of L-shape at a later stage. Village Bagulamari shows an L-shaped settlement pattern in Madhya Baska mouza along the PWD road and water front of a tributary of Morapagladiya river (Fig. 5.7.d). Japarkuchi village is another example of this pattern in Khata mouza where a PWD road meets the western bank of Pagladiya river.

In addition to the above mentioned settlement patterns, the distribution of some uncommon patterns such as Triangular, Parallelogram, Star-shaped, etc. occur rarely in the Pagladiya and Morapagladiya drainage complex.

The triangular settlement is formed by a road or elevated margin of a meander loop. The village Galdighla on the western bank of Pagladiya is an example of triangular settlement. The parallelogram shape is similar to rectangular and square patterns with slight variation. In the region under study, Nagrijuli is an example of parallelogram village built along village roads and streams.

The rural settlement pattern also can be studied from its geometrical perspective in comparison with a circle. Conceptually, the ideal shape of a village should be circular. Any departure from this can be measured geometrically to determine the distortion. It is always assumed that if any corner of a village has equal importance in a plain land without any physical and cultural obstruction and is built on a favourable site, the village must develop in a circular pattern around the central nucleus (Mandal, 1979). As has been discussed above, the nucleus can consist of a tank, a temple or mosque, dispensary, etc. However, in actual terms there are instances of deviation from such norms. It may be possible to find certain exceptional cases which do not conform to the set of rules. These settlements resemble to a certain degree to the three basic types of pattern, viz., rectangular, square and linear.

For the sake of comparison of the patterns through a geometrical perspective Gibb's (1966) formula has been adopted. According to Gibb determination of shape is important for understanding of the different deviations of settlements from the ideal shape. The formula for the measurement of this is:

$$Mc = (100 \times Aa) / \pi r^2$$

Where, Mc is the measure of circularity in shape,
Aa is the actual area contained in the settlement,
πr^2 is the area of circle with its circumference touching the two extreme points of a settlement.
The Mc values are mathematically independent of the size of the entities; and comparisons are also facilitated by the fact that the measure has an absolute maximum value of 100 per cent and for all the practical purposes, a fixed minimum of 0 per cent. It appears that as the Mc values decrease the settlement tends to resemble first a circular, then star, square, rectangular and at the end an elongated shape, in the order mentioned.

The above measure of circularity in shape has been applied to three villages having different settlement patterns, viz., Sandha, Karia, and Balitara. The results are given in the table below:

Table 5.2: Measure of the Degree of Circularity in the shape of three selected rural settlements

Name of the Rural Settlements	Area of circle in sq.km	Actual Area of the Settlements in sq.km	Circularity (Mc) in p.c.	Pattern
1.Sandha	9.08	4.30	47	Rectangular
2.Karia	5.31	4.28	80	Square
3.Balitara	18.10	6.45	35	Linear

From the table it is obvious that the three villages, viz., Sandha, Karia and Balitara possess Mc values 47 per cent, 80 per cent and 35 per cent respectively. As the Mc values decrease from 100 per cent the village Sandha tends to resemble with a rectangular shape while Karia and Balitara show geometrical shape of a square and a line forming linear pattern respectively. These variations in the circularity measures of the pattern of the three villages reveal both the intensity of compactness or scattering of settlements in the study area within a definite set of geographical environment.

5.3 NATURE OF DISPERSION OF SETTLEMENTS:

Dispersion of settlements in any geographical space evolving through all times is a function of several contingent factors. The historical processes of settling and their temporal changes introduced into both physical and the socio-economic forces and the modern cultural advancement of the society may be considered as the guiding factors of settlement dispersion within a region.

The nature of dispersion is basically related to the spatial pattern analysis of distribution. Dispersion may be defined as the degree of deviation of a set of points from random relative to some delimited area (Singh, 1975). As the size of spacing of settlements are the major constituting elements of their dispersal, the nature of dispersion emerges from size-spacing relationship of the occupance units and necessitates the measurement of these two components. It is mentionable that the actual pattern of distribution can be hardly predicted through any quantitative measure. Because, certain physical factors are responsible for distributional pattern and they maintain their uniqueness in any particular geographical space. The pattern and sequence of human occupance, the types and pattern of rural settlements and their historical lineaments in the regional fabric have operated as non-repetitive historical factors in the evolution of spatial pattern of spacing (Mukerji, 1975).

The first approach to measure the deviation of any spatial pattern of distribution of points from randomness was devised by plant ecologist P.G. Clark and F.C. Evans. Later M.F. Dacey tested this approach, commonly known as the Nearest Neighbour Analysis in the geographical context (Singh, Singh & Singh, 1976). It is a more useful, descriptive spatial statistic which relates the points in an area to the mean of the nearest neighbour distance. The nearest neighbour distance is the distance from a point in the distribution being studied to its nearest neighbour point. The nearest scale can be referred to as Rn scale, and the individual Rn value can be calculated as follows:

$$Rn = 2\bar{d}\sqrt{(n/A)}$$

Where, $\bar{d}$ is the mean nearest neighbour distance for all points of settlements,
n is the number of settlements being considered, and
a is the measurement of the area of spatial units.

Here, the points of settlements are considered to be randomly distributed conforming to Poisson's Probability. The Rn value always ranges between 0.00 and 2.149 meaning maximum dispersal at the end, with unity (1.00) indicating the presence of a random observed distribution, while the values near 0.00 indicate clustering of settlements for a completely clustered pattern to 2.149 for a completely ordered or uniform pattern through 1.00 for a random distribution (Mandal, 1979).

In the present work an attempt has been made to delineate the various dispersal regions in order to analyse the changing pattern of settlement dispersion for 1971 and 2001. For this purpose a mouza is considered as a spatial unit. The mouza wise Rn values computed for both the years are shown in the Table 5.3.

It is apparent from the table that the general dispersion trend of rural settlements during 1971-2001 tends to approach towards low to moderate uniformity. The values of randomness of all the mouzas being greater than 1.00, there is absence of complete clustering of rural settlements in the area. Three dispersal regions are delineated (Fig, 5.8 and 5.9) on the basis of Rn values obtained. These are:

(i) Lowly Dispersed or Low Uniformity (Rn values below 1.50): This group includes 8 mouzas, viz., Paschim Banbhag, Khata, Nambarbhag, Dharmapur, Pokowa, Bahjani, Upar Barbhag, and Khetri Dharmapur. These mouzas cover 211 villages (31.08 per cent of the total) and an area of 406.43 sq. km (23.12 per cent of the settled area) in1971. These mouzas are situated in the central part of the study area. The mean inter-settlement distance in this group is 0.99 km.

In 2001 this group consists of 10 mouzas including Pub Banbhag and Paschim Bangsor (part) with the former ones of 1971. These two mouzas are also situated in the lower built-up plain. This group covers 281 villages (40.09 per cent of the total) with an area of 546.50 sq. km (31.07 per cent of settled area). The mean inter-settlement distance is 0.96 km.

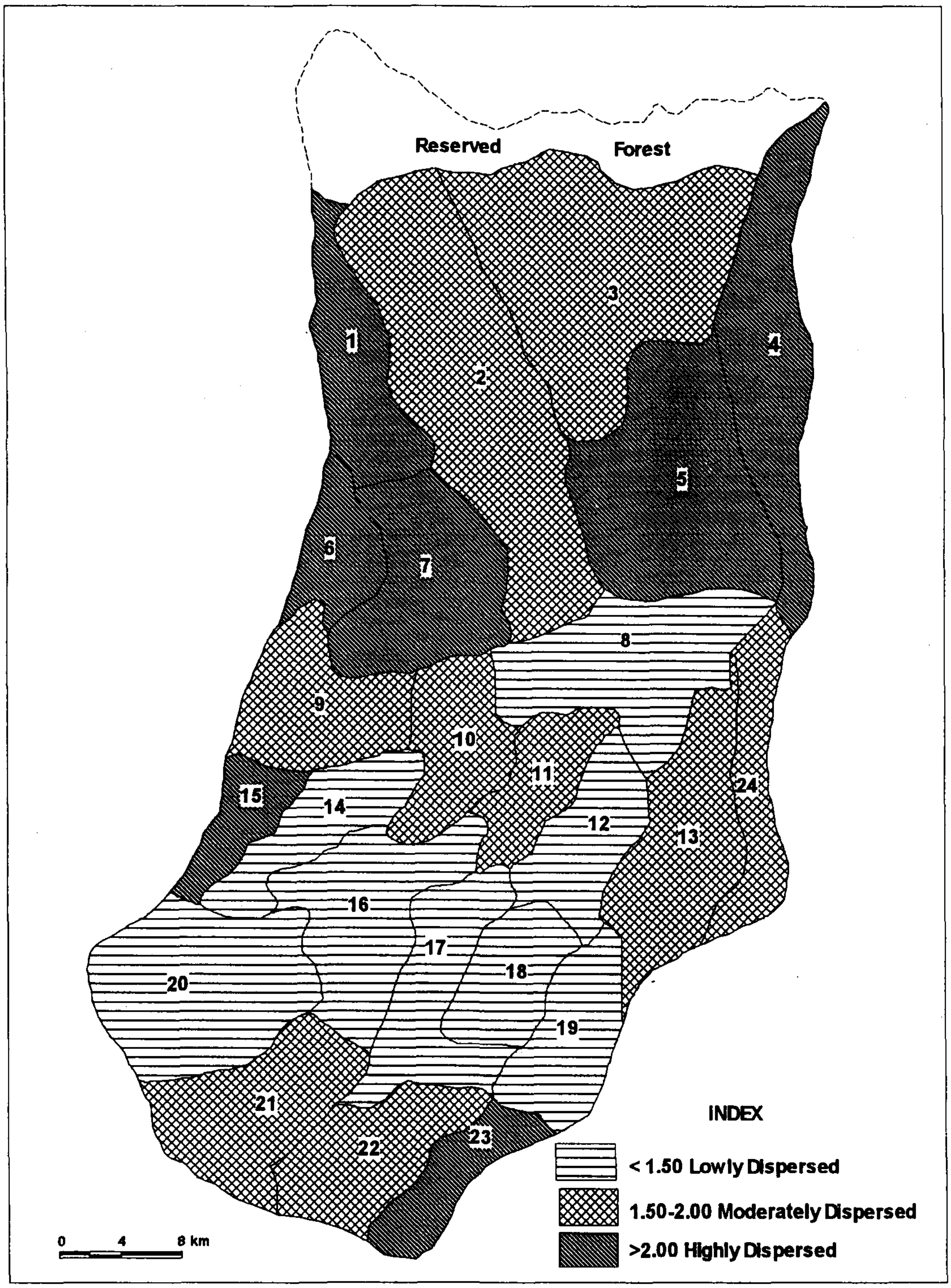

Fig. 5.8: Dispersion of Rural Settlements, 1971

Table 5.3: Mouza-wise Randomness Index of Rural Settlements, 1971 and 2001

Sl. No.	Mouza	Actual Mean Nearest Neighbour Distance in Km (đ)		No. Of Settlements (n)		Area in Sq. Km. (a)		Randomness (Rn)	
		1971	2001	1971	2001	1971	2001	1971	2001
1.	Uttar Baska	1.98	1.92	26	28	93.72	96.25	2.02	2.07
2.	Madhya Baska	2.11	1.95	47	48	207.61	211.75	1.98	1.86
3.	Kumarikata	1.78	1.46	83	86	187.54	192.00	1.59	1.95
4.	Defeli	1.90	152	14	15	46.12	48.01	2.09	1.70
5.	Pub Baska	1.92	1.48	47	50	116.28	121.83	2.47	1.90
6.	Dakshin Baska (Part)	1.88	1.80	11	12	34.18	38.12	2.14	2.02
7.	Paschim Baska	1.85	1.70	32	33	85.48	88.92	2.25	2.07
8.	Paschim Banbhag	0.96	0.76	39	40	77.10	78.90	1.36	1.08
9.	Namati (Part)	1.70	1.70	20	20	66.52	66.52	1.86	1.86
10.	Natun Dehar	1.66	1.40	13	14	35.73	39.77	1.99	1.66
11.	Batahgila	1.20	1.20	20	20	38.01	38.01	1.74	1.74
12.	Khata	0.69	0.69	40	40	37.32	37.32	1.43	1.43
13.	Pub Banbhag	0.95	0.68	51	52	71.64	73.82	1.60	1.14
14.	Nambarbhag	1.65	1.65	09	09	43.65	43.65	1.49	1.49
15.	Tihu (Part)	1.62	1.62	10	10	25.18	25.18	2.04	2.04
16.	Dharmapur	0.82	0.82	21	21	52.18	52.18	1.04	1.04
17.	Pokowa	0.85	0.85	26	26	58.77	58.77	1.13	1.13
18.	Bahjani	0.87	0.87	25	25	47.17	47.17	1.27	1.27
19.	Upar Barbhag	0.76	0.76	44	44	61.92	61.92	1.28	1.28
20.	Khetri Dharmapur (Part)	1.29	1.29	07	07	28.42	28.42	1.28	1.28
21.	Uttar Barkhetri (Part)	1.69	1.58	14	16	38.52	40.03	1.96	2.00
22.	Madhya Barkhetri	1.74	1.52	32	35	112.65	115.88	1.80	1.67
23.	Pub Barkhetri	1.77	1.47	32	33	87.90	90.12	2.13	1.78
24.	Paschim Bangsor (Part)	1.52	1.20	16	17	61.42	64.35	1.55	1.23

Source: District Census Handbook, Nalbari District, 1971 & 2001 & Computed by the researcher

It is observed that the number of mouzas of low uniformity is increased in 2001 in the built-up area. This is a physiographically flat plain composed of new alluvium deposited by Pagladiya, Morapagladiya, Burhadiya and Nona rivers. This influences the pattern of low dispersion of settlements in these mouzas. Since the soil of this area is very fertile, these mouzas are rich in rice growing. The density of population is also increasing in these mouzas. The surface transportation with motorable roads and railway line also contribute for low dispersion of settlements in the area.

(ii) Moderately Dispersed or Moderate Uniformity (Rn values 1.51-2.00): This category includes 9 mouzas in 1971 which increases up to 11 in 2001. These are, viz., Madhya Baska, Kumarikata, Defeli, Pub Baska, Namati, Natun Dehar, Batahgila, Tihu, Uttar Barkhetri, Madhya Barkhetri and Pub Barkhetri. Defeli, Pub Baska, Tihu and Pub Barkhetri mouzas posses Rn values more than 2.00 in 1971 which decrease in 2001. In 1971 this group covers the highest number of villages, i.e., 296 (43.62 per cent of the total) and the highest proportion of the area, i.e., 819.64 sq. km (47.79 per cent of the total area) with mean inter-settlement distance of 1.59 km.

In 2001 the number of villages and total area covered increases to 347 (49.50 per cent of the total) and 989.10 sq. km (56.23 per cent of the total area) respectively. But the mean inter-settlement distance slightly decreases to 1.54 sq. km. This is due to the increasing number of settlement in the mouzas of this category.

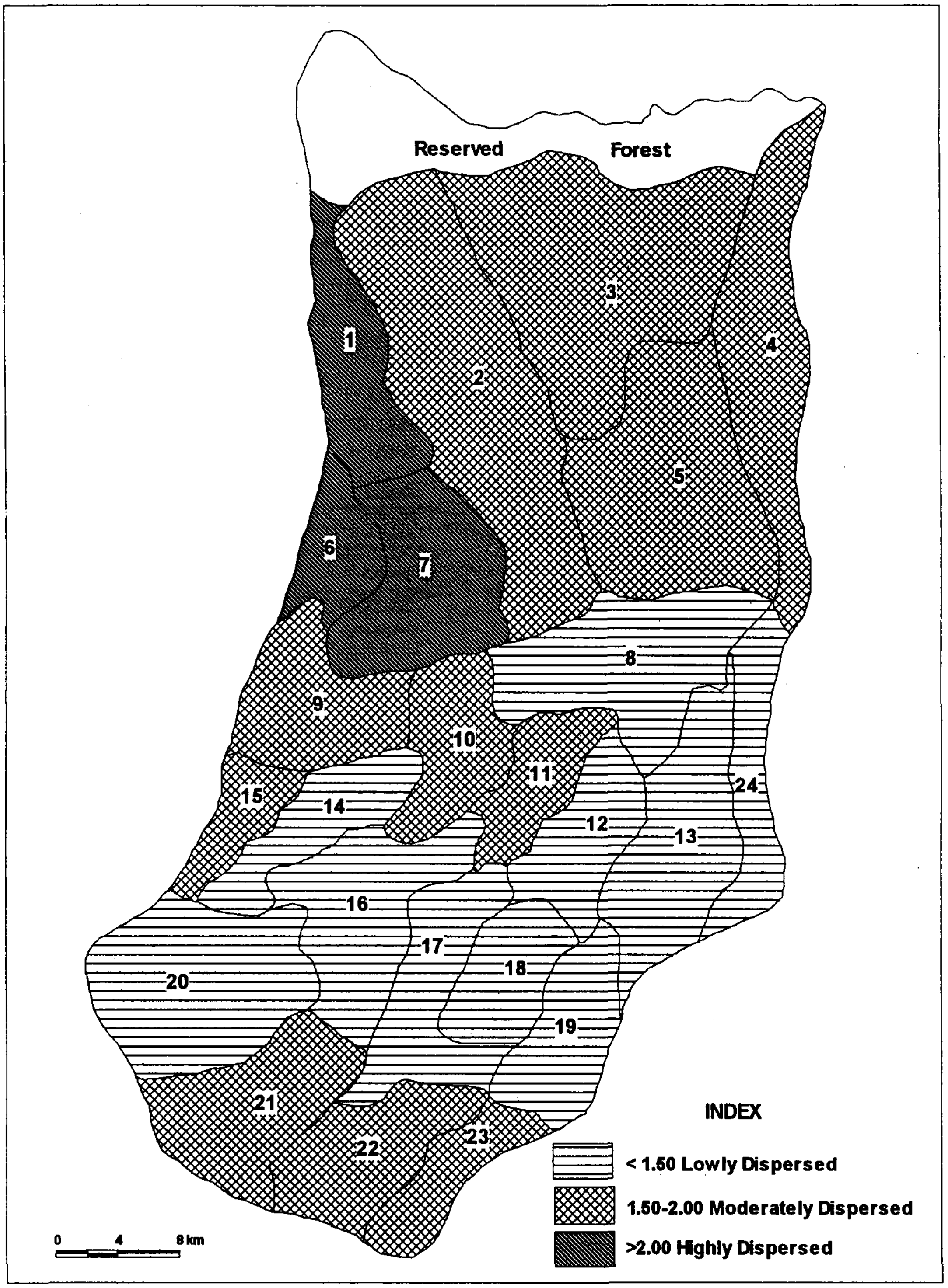

Fig. 5.9: Dispersion of Rural Settlements, 2001

It is observed that the mouzas of moderate dispersion show a high density of rivers, *beels* and marshy tracts. The people inhabitated in these mouzas are indigenous and their mode of living is based on the subsistence agriculture. Along with cultivation and fishing secondary activities like animal husbandry are also practiced by them. In comparison to the lowly dispersed area these mouzas are less populated with low density of population. Although in the mouzas of Pub Barkhetri and Madhya Barkhetri in the active flood plain area important settlements are developed and increased in number, no socio-economic development with good communication is seen. The new settlements of immigrant Muslims are dispersed in the low-lying areas of Pub Barkhetri and Madhya Barkhetri mouzas. The Madhya Baska, Pub Baska, Kumarikata and Defeli mouzas show relatively low density of population per sq. km. This is due to the fact that those mouzas extending up to the northern foothill are less favourable for human habitation. The foothill zone is unhygienic for settlement. Moreover, the road transportation is yet to be developed with other socio-economic amenities.

(iii) Highly Dispersed or High Uniformity (Rn values above 2.00): This group includes 7 mouzas in 1971, viz., Uttar Baska, Defeli, Pub Baska, Dakshin Baska, Paschim Baska, Tihu and Pub Barkhetri with total villages of 172 (25.32 per cent of the total) and an area of 488.86 sq. km (29.11 per cent of the total area). The inter-settlement distance in average is 1.62 km. But the number of mouzas decreases up to 3 in 2001. These are- Uttar Baska, Dakshin Baska and

Paschim Baska. All these mouzas are situated in the north-western part of the study area. The total number of villages and total area covered by this group are 73 (10.42 per cent of the total) and 223.29 sq. km (12.70 per cent of the total area) respectively with the mean inter-settlement distance of 1.81 km. In these mouzas tribes belonging to Bodo-Kachari are concentrated. The urban proximity acts as a repulsive force in the location and distribution of tribal settlements in the study area. This may also contribute to the concentration of tribes in these mouzas located in the northern part of foothill zone. The environmental conditions with infrastructural facilities are the main causes of high dispersion of rural settlements in the area.

The dispersion analysis based on the 1971 and 2001 settlement data highlights that due to increasing of settlements and population there is a general tendency of the rural settlements approaching towards low to moderate uniform pattern of settlement distribution. But the Rn values of Dharmapur and Pachim Banbhag mouzas respectively 1.04 and 1.08 in 2001 are very nearer to random situation (i.e., 1.00). However, it may be concluded that the adaptational behaviour of different social groups towards physical, cultural and economic environment is an important aspect which indirectly influence the spatial pattern of dispersion of rural settlements in the study area.

5.4 SETTLEMENT SIZE, INTENSITY AND INTER-VILLAGE DISTANCE:

The size of settlement is a distinctive expression of several aspects of human occupance. It reveals a relationship between culture and nature and the manner of settling.

Size also influences the functioning of the settlements in a system of settlements and of cultural, ecological and historical nexus (Grover, 1985). The size of rural settlements depends very much on the distributional pattern of settlement. The inter-village distance also influences the size of settlements. Where settlement sites are located at relatively long distances, settlements are larger while the villages having several sites within their revenue boundary possesses smaller settlement units. The impact of geomorphology on human occupance is reflected in settlement size, both on the basis of population and area and in the spacing of settlements. The size and spacing of settlements have close relation with settlement density and competition of people. The variation in size, intensity and spacing of rural settlements from area to area is an established fact due to variations in ecological conditions.

The area under study presents a set of variations in physical setting which manifests in the settlement size, spacing and intensity. The spatial organization of settlements in the area is guided by the physical factors like relief, drainage and water-logged areas, marshes, *beels*, abandoned channels and ox-bow lakes etc. Variations in the distribution of settlement pattern, number, intensity and inter-village distances are observed in the study area. According to the physiographic units of the region and frequency and intensity of flooding in these zones, such variations on distribution of settlements can be explained. The Table 5.4 represents the variations in settlement intensity.

According to the physiographic units of the region and frequency and intensity of flood in these zones, such variations on distribution of settlements can be explained. The Table 5.4 represents the variations in settlement intensity (village/100 sq.km) in the foothill zone, built-up plain and active flood plain areas. It shows that the settlement intensity of the foothill zone and active flood plain area is less than that of the middle built-up plain. On average the settlement intensity in the foothill zone and active flood plain is 32 and 33 village/100 sq. km respectively. In the built-up plain it is 44 village/100 sq. km. The intensity of settlements is highest in the Khata mouza in the built-up plain, the value being 107 villages/100sq. km. The Uttar Barkhetri (part) mouza in active flood plain possesses settlement density of 40 village / 100 sq. km. In Table 5.5 the settlement size,

Table 5.4: Variation in Settlement Intensity in different Physical units, 2001

Physical Unit	Associated Mouza	Settlement Intensity (Village/100sq.Km.)	Average Settlement Intensity In physical unit
1. Foothill zone	Uttar Baska	29	32
	Madhya Baska	23	
	Kumarikata	45	
	Defeli	31	
2. Middle Built-up Plain	Pokowa	44	44
	Dharmapur	40	
	Khetri Dharmapur(Part)	25	
	Bahjani	53	
	Upar Banbhag	71	
	Pub Banbhag	70	
	Khata	107	
	Tihu (Part)	40	
	Natun Dehar	44	
	Nambarbhag	21	
	Batahgila	53	
	Namati (Part)	30	
	Paschim Baska	37	
	Paschim Banbhag	51	
	Dakshin Baska (Part)	31	
	Pub Baska	37	
3. Active Flood plain	Madhya Barkhetri	30	33
	Pub Barkhetri	37	
	Paschim Bangsor (Part)	26	
	Uttar Barkhetri (Part)	40	

Estimated from Census Data & District Census Handbook of Nalbari, 2001.

inter-village distance and size of population per village in different physical units of the study area are presented. This table shows that in the foot-hill zone average village size is 3.32 sq. km, the average inter-village distance is 1.805 km and the average population size per village is 1,274. On the other hand, in the built-up plain these values are 2.51 sq. km, 1.554 km and 1,618 respectively. While in active flood plain these values are 3.08 sq. km, 1.750 km and 1,076 respectively.

It is observed in the field that the concentration of settlement is more in the built-up plain in comparison to the active flood plain and foot-hill zone. The average village size is less (i.e., 2.51 sq. km) in the built-up plain and the inter-village distance is also less (i.e., 1.554 km), as the theoretical inter-settlement distance is based on the density of rural settlement referred to the rural area.

It was found that the size of settlement increased fairly with the increase of distance from the river.. To analyse this assumption the Pearsonian Product Moment Correlation coefficient was applied to find out the relationship between the two variables, ie., size of settlements and distance of these sites from the river. A total of 35 rural settlements were taken as samples and their size estimated from census (2001) data. Their distance from the Pagladiya river was obtained from topographical sheets and the necessary calculations were done (Table 5.6). It is interesting to note that the correlation co-efficient (r) value comes to +0.716 showing that the relationship between the two is positive and extremely close. Again, the calculated value for 't' is 5.896, whereas the tabulated value of 't' for 33 degrees of freedom is 2.74 at 1 per cent, 2.04 at 5 per cent and 1.69 at 10 per cent level of significance. The computed value is fairly greater than the tabulated value of 't' at 1, 5, and

Table 5.5: Mouza-wise average Inter-Village Distances, Size and Population in different Physical units of the Study Area, 2001.

Physical Unit	Associated Mouza	No. of Villages (Settlements) (N)	Area in sq.km. (A)	Inter-Village Distance In Km. D=√A/N	Avg. Distance In the Physical unit	Avg. Size of Villages in sq.km. (A/N)	Avg. vill. Size In the Physical unit In sq.km.	Population (P)	Avg. size of Population S=P/N	Avg. size of Population per village In the Physical unit
1	2	3	4	5	6	7	8	9	10	11
(a) Foot-Hill Zone	Uttar Baska	28	96.25	1.85	1.805	3.44	3.32	32,250	1,152	1,274
	Madhya Baska	48	211.75	2.10		4.41		85,796	1,787	
	Kumarikata	86	192.00	1.49		2.23		78,014	907	
	Defeli	15	48.01	1.78		3.20		18,716	1,248	
(b) Built-up Plain	Pokowa	26	58.77	1.50	1.554	2.26	2.51	52,885	2,034	1,618
	Dharmapur	21	52.18	1.58		2.48		61,439	2,926	
	Khetri Dharmapur (Part)	07	28.42	2.01		4.06		13,465	1,924	
	Bahjani	25	47.17	1.37		1.89		44,669	1,787	
	Upar Banbhag	44	61.92	1.18		1.41		63,570	1,445	
	Pub Banbhag	52	73.82	1.19		1.42		44,503	856	
	Khata	40	37.32	0.97		0.93		39,627	991	
	Tihu (Part)	10	25.18	1.59		2.52		21,159	2,115	
	Nambarbhag	09	43.65	2.20		4.85		24,358	2,706	
	Natun Dehar	14	39.77	1.69		2.84		21,743	1,553	
	Batahgila	20	38.01	1.38		1.90		22,460	1,123	
	Namati (Part)	20	66.52	1.82		3.33		37,087	1,854	
	Paschim Baska	33	88.92	1.64		2.69		39,557	1,199	
	Paschim Banbhag	40	78.90	1.40		1.97		43,537	1,088	
	Dakshin Baska(Part)	12	38.12	1.78		3.18		15,218	1,268	
	Pub Baska	50	121.83	1.56		2.43		50,794	1,016	
(c) Active Flood plain	Madhya Barkhetri	35	115.88	1.82	1.750	3.31	3.08	43,107	1,232	1,076
	Pub Barkhetri	33	90.12	1.65		2.73		27,918	846	
	Paschim Bangsor (Part)	17	64.35	1.95		3.79		19,840	1,167	
	Uttar Barkhetri (Part)	16	40.03	1.58		2.50		16,932	1,058	

Calculated by the researcher from Census Data, 2001.

10 per cent level of significance. Therefore, an inference can be drawn empirically that there is high correlation between the size of settlements and the increasing distances

Table 5.6: Settlement (Village) Size and Distance from Pagladiya River, 2001

Physical Unit	Village	Distance from river In Km (X)	Settlement Size In sq.km (Y)	Co-efficient of Correlation (r)	
1	2	3	4	5	6
(a) Foot-Hill Zone	1. Khagrabari	5	3.31	+0.565	+ 0.716
	2. Nikashi	12.0	5.88		
	3. Doomni	15.0	12.13		
	4. Angarkata	7.6	2.81		
	5. Kumarikata	8.0	2.60		
	6. Thalkuchi	0.5	5.08		
	7. Narayanpur	11.2	3.70		
(b) Built-up Plain	1. Sandha	1.0	0.64	+0.459	
	2. Dhantola	1.0	1.11		
	3. Namati	1.0	2.94		
	4. Chengnoi	0.5	0.31		
	5. Nilpur	2.0	0.86		
	6. Borajal	5.0	2.43		
	7. Khat Katra	0.5	1.10		
	8. Kendukuchi	2.0	1.24		
	9. Paila	0.0	1.04		
	10.Japarkuchi	3.5	1.34		
	11.Digheli	1.0	2.10		
	12.Jaha	4.5	0.95		
	13.Niz-Pokowa	7.5	2.44		
	14.Chandkuchi	6.5	2.12		
	15.Katpuha	2.0	2.26		
	16.Guakuchi	2.0	1.71		
	17.KhudraSankara	1.5	0.37		
	18.Dhamdhama	1.0	0.29		
	19.Pandula	3.5	1.03		
	20.Kalag	3.0	0.93		
	21.Dingdingi	0.0	0.85		
(c) Active Flood-plain	1.Chotemari	0.0	1.65	+0.031	
	2.Balikuchi	1.5	1.73		
	3.Adabari	0.0	1.70		
	4.Ghoga	3.0	2.25		
	5.Mukalmua	5.0	1.77		
	6.Galdighla	0.0	1.73		
	7.Sutarkuchi	0.0	2.49		
		Σx= 117.80	Σy= 76.89		

Based on Census Data, 2001 and Topographical sheets.

from river. However, it varies from region to region. In the active flood plain zone it does not hold good. The computed value of 'r' for this zone is only +0.031 whereas in the case of foothill zone the 'r' value is +0.565 which is statistically significant. In the areas of built-up plain, in between these two zones, the relationship is moderate.

In real sense the settled areas of villages situated near the bank of Pagladiya are reduced to a greater extent due to the bank erosion, channel changes, flood, construction of embankments etc.

The influence of the Pagladiya on the human settlements seems to be very high. People look for flood free areas to settle and yet due to growing population land as a resource being scarce force people to risk their lives and move closer to the river. It is this reason that the srettlements nearer to the river that are affected during the summer floods. A detail picture of this is clearly discussed in the next chapter.

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Chapter - VI

GEOMORPHIC CHANGES AND DISPLACEMENT OF SETTLEMENTS

The geomorphic changes are usually very slow. The factors affecting changes in the landforms are of two categories: (i) endogenetic forces and (ii) exogenetic forces. Among these two the exogenetic forces are produced by external agents such as wind, water and snow etc. They erode the surface of the earth and transport the eroded materials and make depositions on it. These external (exogenetic) forces are also called 'processes' which posses a great importance in the study of geomorphology of an area.

River and streams have a prominent place in geomorphic changes through the process of erosion. Every stream tries to produce a slope from source to mouth that erosion and deposition activities are balanced.

6.1 GEOMORPHIC CHANGES:

In the study area the changes have been observed to be very fast. Both the erosional and depositional activities of Pagladiya and Morapagladiya rivers are prominent in different physiographic settings. In the foothill zone the erosional processes are more active with the following three actions: (i) hydraulic action, (ii) abrasion action and (iii) solution action. In the hydraulic and abrasion action the water coming down from Bhutan-Himalayas lifts the rock fragments and strikes against one another and wears them down. The stream water also carries some soluble components in the flowing water. All the eroded materials are transported downstream by the Pagladiya, Morapagladiya and other rivers from upper part to the middle and lower courses. After the rivers come down from foothills to plains, the slope becomes gentle

(Fig.6.1). This reduces the energy and competence of the rivers. However, new researches point out that it is not easy to understand the process of sediment deposition on flood plains especially with braided river morphology (Richardson & Thorne, 2001).

The meandering nature and channel changes of Pagladiya river have been observed to be more when compared to the other rivers. As a result, this increases the length of this river. Pagladiya river creates many meanders in its course in the middle built-up plain by erosion and deposition of sediment at various places. Due to this the river erodes rapidly against the concave sides of the river with under cutting of river bed. The hanging portion above the undercutting collapses particularly during the floods. This process steepens the slope on the concave side. On the other hand, the river flows with a lower velocity on the convex side and, therefore, more deposition takes place than erosion. On account of the concave nature of the meanders the slope on this side is very steep and forms escarpment slope, while on the convex side slip of slopes of low gradient is developed. The apposite example of this type of slope is found in Bijulighat in the western side of bridge on the Pagladiya river. During floods, the river course is straightened and of one end of a large meander connects to another closest end. As a result, the stream abandons its meandering course and flows straight on a short and direct course. Such an abandoned meander is found near Bijulighat. At the time of flood, these bends are filled with water for a short time. In Barsiral (north) three meandering channels abandoned by the Pagladiya river are seen. Similar geomorphic features along the Pagladiya river are developed in Katalmari (west), Khandajan, Moiradonga, Arara and in between Laurkatha and Chotemari especially near Galdighla and Bejpara villages (ref. Fig.3.4.a,b and c).

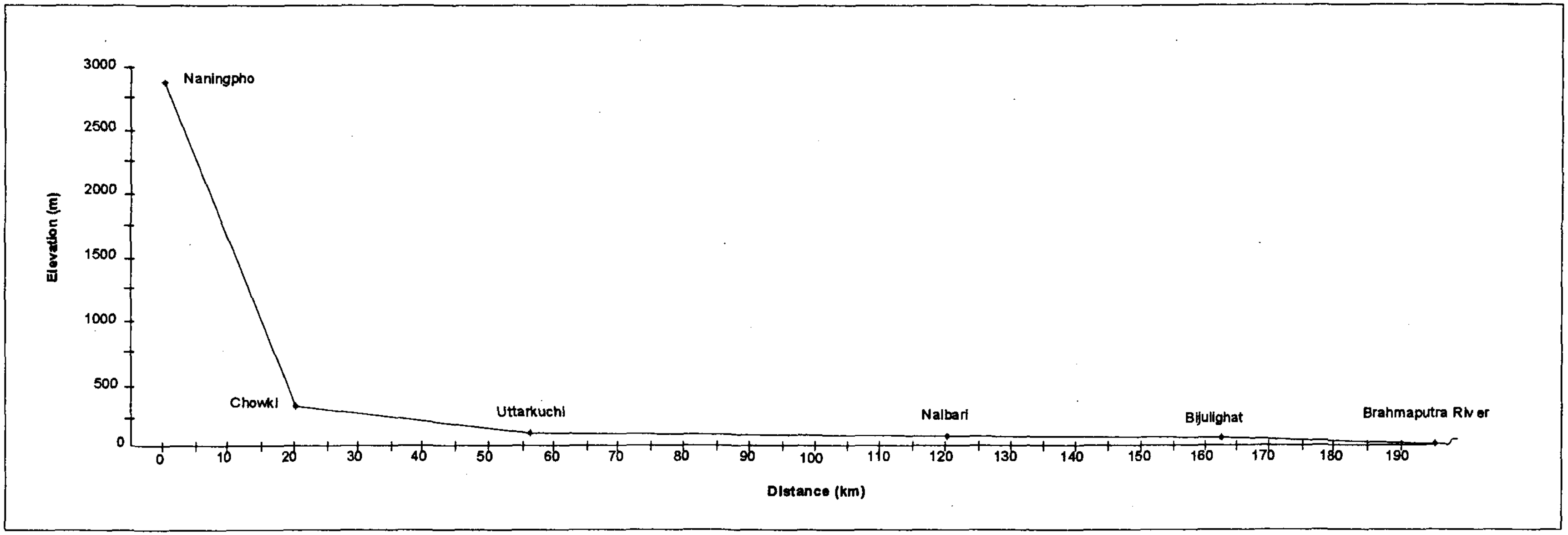


Fig. 6.1: Longitudinal Profile of Pagladiya River from Source to Confluence with Brahmaputra River

The Pagladiya river deposits sediment on both of its banks which rise like ridges and gently sloping outwards. When the river is flooded, the water rises up against these high ridges following which natural and high embankment like, levees on both sides of the river are developed. This is a characteristic feature found in the middle course of built-up zone.

Bank erosion has great effect on the changing geomorphic features. During the flood time bank erosion by lateral cutting during high velocity movement of water was extensive. Such phenomena took place in 1990 near Balakuchi village on the east bank of Pagladiya river just upstream of NH-31 bridge. Likewise in Galdighla village in 1989 due to bank erosion vast area of agricultural land and settled area was washed away. In the upper reach in Thalkuchi (near Pagladiya Dam Project site) the river extensively eroded its west bank during 2004 flood and washed away all the foundations of Pagladiya Dam Project and other infrastructure. The *Kali Mandir* (Hindu religious institution) in this area may be completely removed if the river continues to erode the west bank (as observed during field visit, 2005).

6.1.1 Impact of Channel Changes and Erosion:

The Pagladiya river is no doubt a mad river. It has changed its course several times. Details about the channel changes and bank line migration are discussed in the previous chapters. After the great earthquake of 1897 the Pagladiya river had abandoned its original course near the foothills of Bhutan and used the present channel capturing a part of Motanga and a part of Noanadi to become a new independent river to directly discharge into the Brahmaputra river. It has a general migration tendency towards east.

South of the NF Railway line in Barbhag area the river has migrated to a maximum distance of 2.5 km towards east abandoning its other channels in this area. Such types of channel change indicate the geomorphic changes and also have a great impact on settlements and land use of the study area. Comparing the topographical maps of 1911-'12 and 1967-'68, the changes of geomorphic features and impact on human settlements can be identified. Most part of the abandoned channels and *beel* areas like Dubaria, Mora, Katal, Dangar *beel* etc. had changed after deposition of silts and became shallow. As a result, these areas were changed either to agricultural land or newly settled area. Villages like Digheli, Balilecha, Sankara etc. originally were in the eastern side of the river. Now, due to change of the river course all these villages are situated in the western side. Villages like Tantra Sankara, Arara, Namdonga, Dingdingi, Kamarkuchi are divided into two parts by Pagladiya river which created a new course through settled areas. Originally settled areas of villages like Bhanukuchi, Pajipara, Barmurikona, Simalia etc. were about 2 to 3 km away from the river, but now they are on the bank of the river.

Due to channel change and bank erosion of Pagladiya river most of the settlements which were originally on the bank of the river are now relocated to areas next to the embankment. Such changes in recent years are observed in the villages like Balakuchi, Khatabari, Sandha, Paila, Tantra Sankara, Namdonga, Simalia, Sonkuriha, Galdighla, Bejpara etc.

The shifting of bank line has restricted the use of lands for human settlement particularly in the lower reaches of the Pagladiya river. Bank erosion, bank slumping, gully formation are the main reasons of degradation of potentiality of lands both for agriculture and settlements. In such cases people either used the embankment for settlement or abandon the place and migrated to other distant areas. As a result, displacement of settlement took place in the villages like Galdighla, Bejpara and Chotemari as observed during the field survey (June, 2005). Actually, the channel change, bank erosion and flood have combined affect on human settlement and land use. Table 6.1 shows the number of families affected in villages situated along the banks of Pagladiya river due to channel changes, bank erosion and flood hazard.

Table 6.1: Villages situated on the bank of Pagladiya river and number of families affected by channel change, bank erosion and flood hazard

Sl. No.	Villages	Affected Year	No. of settled Families displaced
1	Laopara	Prior to 1971	900
2	Khudra Katra	„	146
3	Dhantola	„	6
4	Khanajan	„	12
5	Khudra Agra	„	238
6	Moiradonga	„	10
7	Khudra Barkatalkuchi	„	6
8	Balakuchi	„	80
9	Nagarkuchi	„	120
10	Chengnoi	„	11
11	Khatabari	„	74
12	Paschim Parakuchi	1973	8
13	Paila	1974	15
14	Namdonga	1974	30
15	Tantra Sankarai	1984	70
16	Sonkuriha	1985	100
17	Simalia	1986	30
18	Katra	1988	8
19	Galdighla	1989	431
20	Gholarpara	1989	53
21	Naopara	1989	102
22	Bejpara	1989	10
23	Khat Katra	2000	14

Based on Field Survey, 2005

These villages when relocated changed their morphological characteristics. The relevant data and information in this regard are collected from the field by interviewing people from these localities. Majority of displaced families now are resettled either in neighbouring villages or within their own villages away from the river. For a clear understanding the explanation of this has been divided into two sections based on the time period.

(i) Villages displaced before 1971: The settlements that were completely displaced from their original locations are like- Laopara, Khudra Agra and Khudra Katra prior to 1971. In the 1971 census there was no population in Laopara and Khudra Agra. Nagarkuchi is another village which does not exist at present. People of this village had shifted their settlement to Kamarkuchi and nearby villages before 1945. Chengnoi, Dhantola, Khanajan, Moiradanga, Khudra Barkatalkuchi, Balakuchi, and Khatabari are other villages under this category.

(ii) Villages displaced between 1971-'81: In recent times, especially after 1971, settlements from villages like Chengnoi, Paschim Parakuchi, Paila and Namdonga have displaced elsewhere.

(iii) Villages displaced after 1981: Gholarpar, Naopara, were completely eroded away by the Brahmaputra and Pagladiya. Tantra Sankara, Sonkuriha, Simalia, Galdighla, Bejpara, Chotemari, Katra and Khat Katra have also been partly affected. The channel changes affect the geomorphic characteristics of the area as well as the location of settlements in the villages like Bhanukuchi, Pigurtola, Barkatalkuchi etc. Authentic data in respect of displaced settled families are not available prior to 1971. Fig. 6.2 a, b and c will clearly display the effect of floods on settlements in the different physiographic zones.

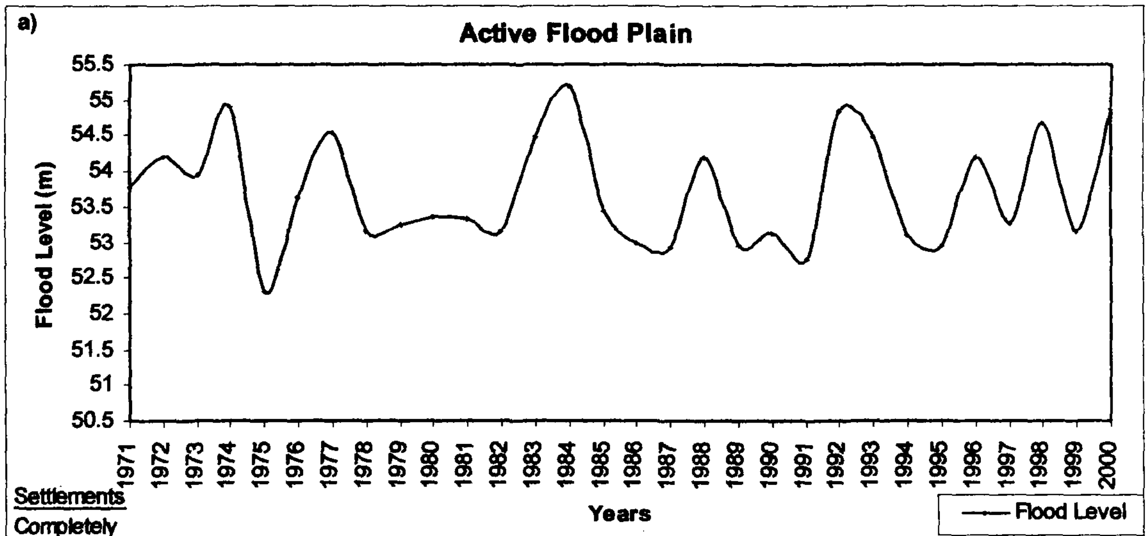
In the Table 6.2 list of villages eroded away mainly by the Brahmaputra and partly by the Pagladiya river according to the census of 2001 are shown. Settlements displaced from these villages migrated to nearby villages and government reserve lands like Latibari, Adabari, Mukalmua, Dongipara and Lauthari reserves.

Table 6.2: Displaced Settled Villages by Pagladiya and Brahmaputra rivers, 2001

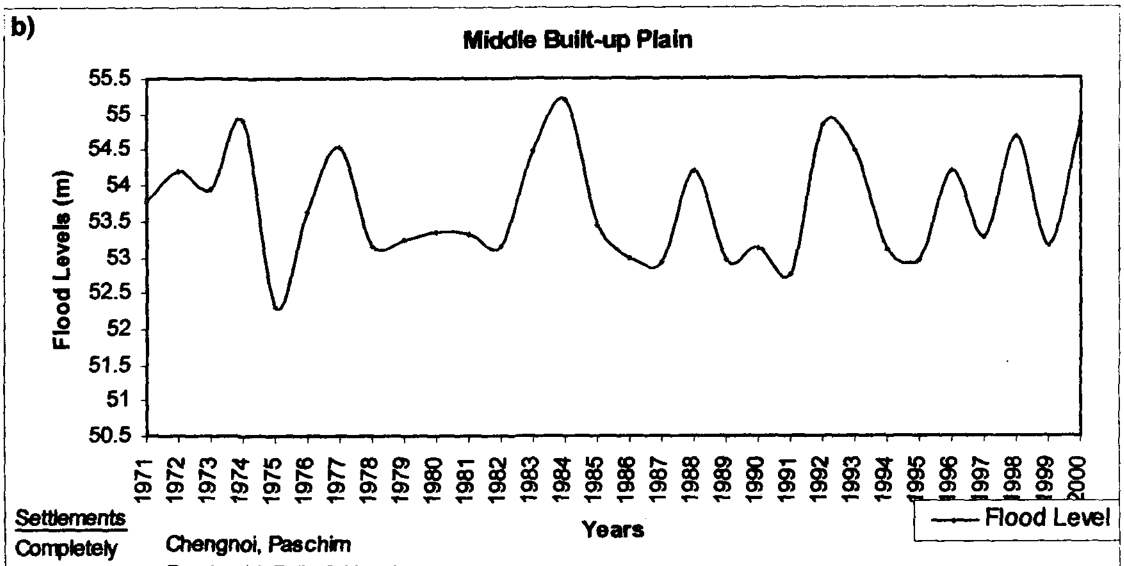
Sl. No.	Villages	Mouzas
1	Bhelamari No.-7	Madhya Barkhetri
2	Bhelamari (A-Block)	,,
3.	Batamara	,,
4.	Lauthari	,,
5.	Kalardi	,,
6.	Puran Chaprapara, No.-33	,,
7.	Chaprapara No.-2	,,
8.	Bhelengimari No.-1	,,
9.	Bhelengimari No.-2	,,
10.	Pub Kajia N.C.	,,
11.	Bhelamari No.-4	Pub Barkhetri
12.	Kaurekhaiti No.-4	,,
13.	Tilardiya	,,
14.	Barbala No.-1	,,
15.	Barbala No.-2	,,
16.	Barbala No.-3	,,
17.	Barbala No.-4	,,
18.	Barbala No.-5	,,
19.	Damal	Pachim Barkhetri
20.	Lautipara	,,
21.	Pub Kajia	,,
22.	Madhya Kajia	,,
23.	Gharuabaha Pathar	Uttar Barkhetri
24.	Bakrikuchi	,,
25.	Bhelguri	Dakshin Baska
26.	Morapagladiya F.V.	Madhya Baska
27.	Dihira R.F.	,,
28.	Khudra Agra	Batahgila

Source: Census Data, 2001

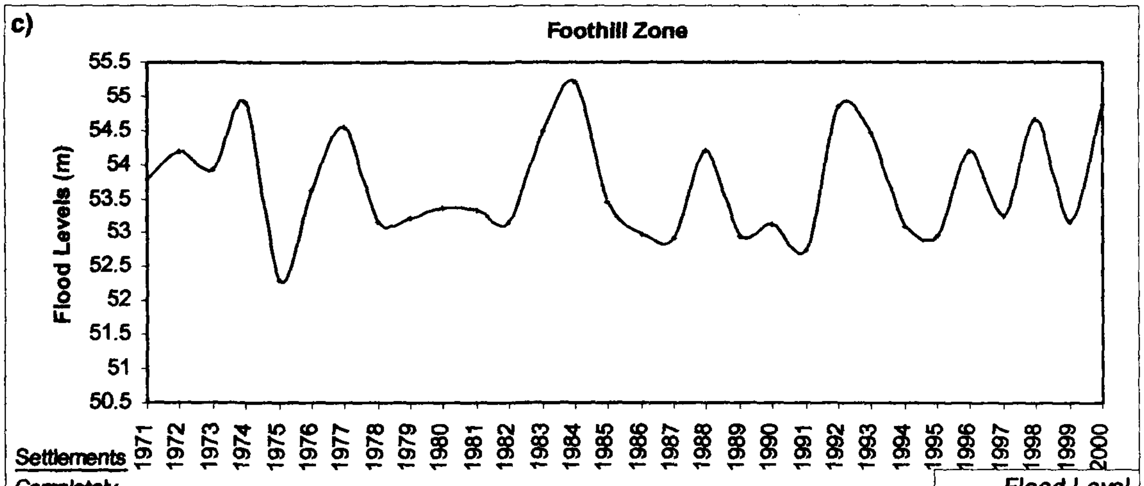
Due to erosion on the western bank of the Morapagladiya river in between Sialmari and Barpit area escarpment is formed. As a consequence 17 settled families had been displaced from their original site of settlement on the river bank during 1996 to 2000. They are settled now at a location away from the river bank. The Morapagladiya river near Barama College in Kathalbari village changed its course in 1977 and left a meander abandoning its original channel. At present this area is converted to agricultural land and new settlements are established there very recently. During the 2004 flood the river breached its western embankment due to bank slumping in Barbori village and caused displacement of 6 families eroding away their homesteads on its bank.



Settlements		
Completely eroded	Khudra Katra & Laopara	Gholarpar
Partially eroded	None	
Extension		Bejpara, Chotemari, Bhelamari, Lauthari, Bhelengimari, Bhelamari(Bl-A), Tilardiya, Barbala
New	Singimari, Adattari, Khalihamari,	Balttari, Kurihamari, Khalihamari, Ghoramara



Settlements	
Completely eroded	Chengnoi, Paschim Parakuchi, Paila & Namdonga
Partially eroded	Tantra Sankara, Sonkuriha, Simalia, Galdighla, Balakuchi, Bejpara, Chotemari, Katra & Khat Katra
Extension	None
New	Balitara, Balakuchi, Sonkuriha, Bijulighat, Dhamdhama, Borajal, Namati



Settlements	
Completely eroded	None
Partially eroded	Morapagladiya FV, Dihira RF
Extension	None
New	Bagulamari, Nabasti, Natunkuchi, Pamuapathar, Rampur

Fig. 6.2 a, b & c : Effect of Flood on Settlements in different Physiographic Units

6.1.2 Impact of Flood and Sand Deposition:

Flood as well as sand deposition processes have great impact on geomorphic changes in the study area. They also influence the size, site, distributional pattern and morphology of rural settlements in the flood plains. Different types of human settlements in a riverine plain are the results of human adjustment with the environment in the face of prevailing flood, erosion and depositional hazards.

Flood is a common geographic event. It has considerable impact on physical landscape in the flood plains. The study area is almost a flat alluvial plain with minor variations of relief having foothills zone, built-up areas, active flood plains, waterlogged areas, marshes, *beels*, abandoned channels and ox-bow lakes. Accordingly, variation of intensity and frequency of flooding in these areas are observed. Generally the damages and displacement of settlements during flood are caused by inundation and associated bank erosion. The study area accounts nearly 8 per cent of the total flood damaged area in Assam.

During the floods in recent years since 1988 the Nona river, a tributary to Pagladiya with heavy siltation had changed large tracts of agricultural land on its eastern bank to a sandy area with deranged stream channels. During the summer season this river too changes its course leading to displacement of settlements.

Sand deposition by flood water in the study area is another hazard faced by the settlers of the region. Due to heavy siltation and sand deposition in the river beds and banks confined within the embankments, the beds of Pagladiya, Morapagladiya and Nona rivers are significantly raised. The beds of Pagladiya and Nona rose from 1 to 3 m in average above its surrounding areas. It is higher than 4 m in some places like Arangmow, Nakheti and Ratkuchi villages of Barbhag area. Therefore, after the flood, water cannot drain out completely through the narrow sluice gate near Dosutimukh to the main channel (ref. Fig. 3.9). This creates long retention of water in agricultural fields and damages the crops completely. The Nalbari town itself is situated about half metre below the river bed of Pagladiya. Deposition of sand and silt in the Morapagladiya is comparatively less than in the Pagladiya and Nona. However, during monsoon season the Morapagladiya river too does a lot of damage inundating large areas and spoiling standing crops.

Floods occur mainly due to breaching of embankments in a particular area. During floods the rivers carry huge amount of suspended load and deposit them over the fertile agricultural fields and other areas used for human settlements. This may be up to a few metres of thickness and it is a major problem to clear up such deposits from the fields. The thickness of sand deposition decreases as the distance from the river increases. On the other hand, silt deposition of few centimetres may enhance the fertility of soil. In the built-up area of the study area, floods of this nature create sand deposition hazard which has a great impact on the surface configuration of the area, particularly along the river banks. For example, on 15th September, 1984 due to breaching of right embankment of the Pagladiya river near NF Railway bridge at Tantra Sankara (west) village, severe flood occurred in the Nalbari area and huge amount of sand was deposited over an area of 2,753 acres of land affecting Paila, Khatabari, Digheli, Tantra Sankara (west) and Balilecha villages (Plate 10). At some places in the Tantra Sankara (west) and Balilecha village sand was deposited up to a thickness of 2.5 m. The thickness of sand deposition decreases away from the Pagladiya. This has changed the area and reduced the productivity of land by about half. This is confirmed by the field study in the area. After the flood, the Department of Agriculture, Government of Assam used dredgers to clear sand from an area of 300 acres. Private trucks also carried the sand by digging out from the affected areas on the eastern bank of Pagladiya river on both sides of NH-31. Similarly, sands were dug out from the eastern bank of Nona south of NH-31 for use in various construction activities.

The change brought about during floods by the Morapagladiya, Burhadiya and Nona have been observed to be significant. The Morapagladiya in its middle course from Barama (i.e., NH-31) to Sialmari village severely damaged agricultural lands with siltation particularly in Gabradal, Sialmari and Ratanpur villages. The river in 1984, 1988, 1996 and 2004 breached its western banks frequently with bank slumping which changed its channel course with a meandering nature. As a result, partial displacement of settlements in these villages took place since 1984. The people shifted their settlements within the same village to safer places and also to nearby villages. Near its confluence with Burhadiya in Bhojkuchi village a vast marshy tract known as Barpit, was formed in the 1897 earthquake. Both the rivers (Morapagladiya and Burhadiya) filled up this area in recent years with transported sediments and changed the morphology of the entire area. At present this area is transformed to a natural levee where new settlements have developed. In this area an abandoned meander of the Morapagladiya river was observed during the field study. On the north bank of Burhadiya from Barpit reserve to Tihu-Solmara PWD road the river deposited sands every year during the flood and formed levees. The high velocity created by the rushing water straightens the meandering course. In 1984 Morapagladiya breached its west bank near Barbori and Kharua village in the north of NH-31 which created a hazardous situation with heavy silting in the agricultural fields and homestead lands.

6.2 DISPLACEMENT OF RURAL SETTLEMENTS:

Regular annual ravages of flood accompanied with bank erosion and heavy silting by Pagladiya, Morapagladiya and other rivers have been changing the features of the area. This has influenced directly and indirectly on displacement of rural settlements. People are forced to migrate from such affected villages to other areas which are free from flood.

The sizes of migration of people depend upon geomorphic condition of the area. They are different in built-up region, waterlogged areas (e.g., Barbhag area) and active flood plain zone. The pattern of human migration can be explained by the data shown in Table 6.3. It shows that in the built-up region around Nalbari 165 families migrated from 11 villages. Most of the families migrated to rural settlements within the study area except a few families migrated from Nandagaon to Bilasipara and Balilecha to places like Nagrijuli,Tamulpur, Latibari, Bholajhar, Suagpur, Laopara (Nagrijuli), Dubari, Namati, Khundiya, Gandhibari and urban places like Guwahati, Nalbari and Tezpur.

Generally, three types of migration have led to displacement of settlements in the drainage complex. First, general migration during the flood period; secondly, migration to urban areas because of the losses suffered due to floods and thirdly, migration to other rural areas outside their own flood affected settlements for cultivating crops in *pams* (temporary farm house) which ultimately leads to settle there permanently some of them. In the following paragraphs the same has been explained.

(i) Temporary displacement of settlements takes place during the flood period when people are evacuated from their residences. In the active floodplain area, about 94 per cent of the people in villages like Galdighla, Bejpara,

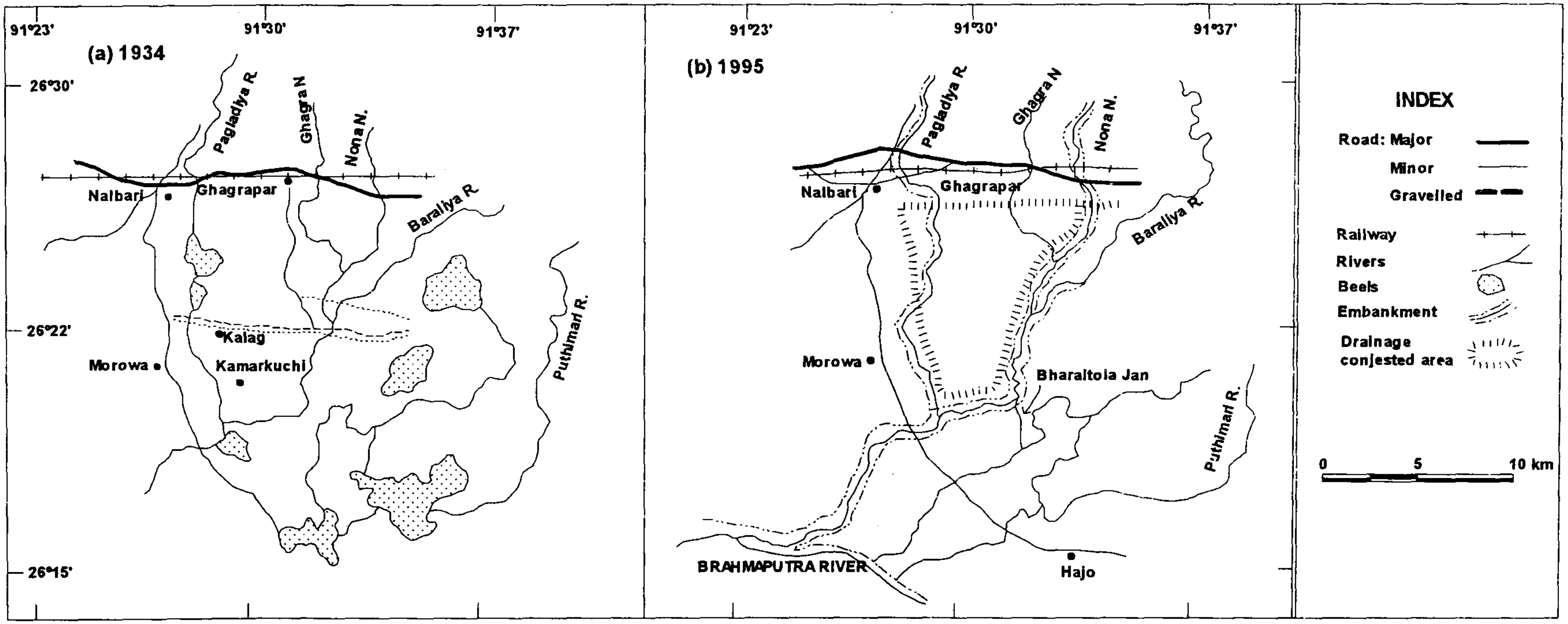


Fig. 6.3: Barbhag Area in (a) 1934 and (b) 1995

Chotemari take shelter on the embankments while other 6 per cent move to other distant places. In the case of the built-up area in and around Nalbari hardly 30 per cent people move to higher ground. Others adjust by making raised platforms, i.e., *changs*. In the 1984 flood in Tantra Sankara (west) 100 per cent people moved to the embankment while in Balilecha about 90 per cent people shifted to embankment and other lived in their own home. In Nalbari town, 98 per cent people lived in their home and only 2 percent people took shelter in nearby railway station, rail lines and NH-31. But in Barbhag area the situation was somewhat different. Hundred per cent of the poor settlers migrated to high lands, roads and embankments. In Arangmow most of the families used *chang-ghar* (plateform house) made especially for flood. Before reaching high spate of flood the elderly persons, ladies and children from the area shifted either to their relatives' house or temporary camps arranged in the flood free locations.

(ii) A number of families have left their homes in search of a better livelihood in the urban areas like Guwahati, Tezpur, Tinsuklia, Dibrugarh, Mongaldoi, Tangla, Majbat, Dhekiajuli and Missamari.

(iii)On the other hand there were families that migrated to other rural areas within the study area which are flood free. These families moved to Dhamdhama, Nabasti, Khagrabari, Digheli, Namati, Haribhanga, Kaithalkuchi, Chamata, Ghograpar, Borajal, Tamulpur, Balitara, Dangipara Reserve, etc.

Table 6.3: Number of Families displaced and Migrated from selected villages in the Study Area, 1971-2001

Regions	Displaced villages (Settlements)	Families migrated (Displaced)	Total	Migrated to which place	
				Within the study area	Outside the study area
(a)Built-up plain (around Nalbari)	1. Tantra Sankara	12	165	Digheli, Malikuchi, Nalbari, Dhamdhama, Kamarkuchi	--
	2. Nanda Gaon	06		Dhamdhama, Nalbari	Bilasipara
	3. Katpuha	05		Nalbari, Dhamdhama, Khagrabari	--
	4. Balilecha	16		Nalbari, Namati, Nabasti, Dhamdhama	Guwahati
	5. Paila	05		Digheli, Nabasti, Nalbari	--
	6. Namdonga	06		Nalbari, Nabasti, Khagrabari	--
	7. Balakuchi	90		Namati, Nabasti, Nalbari, Khudiya	--
	8. Sialmari	06		Haribhanga, Kaithalkuchi	--
	9. Gabradal	03		Ratanpur	--
	10. Bhojkuchi	05		Namati, Chamata	--
	11. Dhantola	11		Dhamdhama, Nalbari, Nabasti	--
(b) Built-up plain (Barbhag area)	12. Chatma	53	618	Nalbari, Ghograpar, Alliya, Borajal	Tamulpur, Tengabari, Nagrijuli, Guwahati
	13. Pandula	57		Nalbari, Barama, Dhamdhama, Borajal, Tamulpur	Majbat, Dhekiajuli, Tezpur, Missamari, Guwahati, Tinsukia
	14. Kamarkuchi	68		Nalbari, Tamulpur	Guwahati, Tezpur, Tinsukia, Dibrugarh, Paneri, Dhekiajuli, Tangla, Mangaldoi, Majbat
	15. Athgharia	38		Nalbari, Rangia,	Guwahati, Paneri, Tangla, Tezpur, Mangaldoi
	16. Barmurikona	12		Nalbari, Nabasti, Dhamdhama	Nagrijuli, Tamulpur
	17. Arangmow	390		Nalbari, Malikuchi, Digheli	Guwahati, Tezpur, Dhekiajuli, Dibrugarh, Majbat, Mangaldoi
	18. Dhamdhama (Khata)	02		Balitara, Dhamdhama (Baska),	--
	19. Dingdingi	14		Alliya, Madaltana, Nalbari	Harisinga
	20. Barsimalia	12		Nalbari, Dhamdhama (Baska), Borajal, Tamulpur	Guwahati
(c)Active flood plain	21. Chotemari	705	2086	Joysagar, Ghoga, Mukalmua,	--
	22. Laopara	892		Dangipara Reserve, Latibari, Adabari, Alliya, Nalbari, Nabasti, Borajal	Nagrijuli, Latibari, Bholajar
	23. Galdighla	431		Nalbari	Guwahati, Tezpur
	24. Bejpara	30		--	Tezpur, Dhekiajuli.

Based on Field Survey, 2004-2005

6.3 IMPACT OF FLOOD CONTROL MEASURES ON RURAL SETTLEMENTS:

6.3.1 Existing Flood Control Measures:

Struggle against floods is an unceasing and regular process. No part of the world, however, advanced, has solved the flood problem, nor does have any controlling monopoly upon it. Flood always overtaxes states' exchequer (Mitra, 2002). Flood hazard increases day by day with its devastating effects on life and property including physical changes on land by erosion and silting. The resultant effect of floods is not only because of the fluvio-morphological changes that take place but increasing human activities in the floodplain due to mounting pressure on land induce more suffering.

However, different flood protection and controlling measures were taken by the concerned authority of state and central government to minimize or mitigate flood damages by means of structural measures. In 1951 United Nations Organization had evolved the following four main approaches to mitigate the flood hazard (Mitra, 2002). These are:

(i) The construction of embankment (sometimes referred to as dykes or levees and flood walls) to confine the flood waters,

(ii) The improvement of river channels to enhance their discharge capacity, e.g., by straightening, widening or deepening,

(iii) The construction of by-pass and diversion channels to carry some of the excess flood water away from the area to be protected, and

(iv) The construction of reservoir for the temporary storage of flood waters.

A combination of two or more such approaches is required to combat or mitigate flood hazard of a river. Among them the raising of embankment along the river banks is the most simple and one of earlier measures commonly used to combat floods. As in the cases of other important rivers in Assam, the state government had constructed embankments along the both banks in the lower reaches of Pagladiya river to control flood. Along with the construction of embankments, some other anti-erosion works and straightening of the course by cutting the meandering bends or draining out the excess water through other channels are also used in the Pagladiya, Morapagladiya, Burhadiya, Baraliya and Nona rivers in the study area. A multi-purpose Pagladiya Dam Project at Thalkuchi, 25 km north of Nalbari town at a cost of Rs. 542.90 crores in January, 2001 was approved by Cabinet Committee on Economic Affairs (CCEA), Government of India and implementation of the project was entrusted to the Brahmaputra Board. This project is designed mainly to control flood in the first phase and to provide water for irrigation in the second phase. It is expected that this will be an effective long-term measure of controlling flood in the entire Pagladiya basin.

Among the existing flood control measures the construction of embankment of both banks is an important one. During 1954 to 1957, the Pagladiya river was embanked 34.60 km on left bank and 41.00 km on right bank starting from near Majusiral on right bank and Sagarkuchi village on left bank down to the bank of Brahmaputra river. Similarly, Morapagladiya, Baraliya, Nona, Burhadiya were also embanked in their lower courses. Among other measures anti-erosion works were already done for 36.80 km in 58 sites and another proposal of similar nature of work is made for 12 km in different sites on the banks of Pagladiya river. Likewise, in Sialmari village 1 km of embankment was taken under anti-erosion work of Morapagladiya river. In Barpit reserve under village Bhojkuchi a meander channel of Morapagladiya river near its confluence with Burhadiya was straightened in 2001 as anti-erosion measure for agricultural lands and homesteads. Moreover, sluice gate schemes on Pagladiya river have been taken at different places, those worth-mentioning are Dekatola, Barghopa, Ghogajan and Dosutimukh (ref. Fig. 3.9)

6.3.2 Anti-Erosion Measures

Besides, as anti-erosion measures boulder bar, bank revetment, purcupine bars, spurs were provided in vulnerable points. Revetment, ring bund were also constructed at places like Katra, Khanajan, Balajan, Loharkatha, Chotemari and Galdighla villages. To protect the railway bridge a triangular bund was constructed just after the 1984 flood in Balakuchi village. In 1985, near Sonkuriha and Simalia villages a meander of Pagladiya river was cut-out for 400 m to straighten the river course. After 1966 flood, digging of an abandoned channel connecting the Pagladiya and Morapagladiya rivers was done by the Department of Flood Control, Government of Assam to reduce the intensity of floods and erosion. This was done to allow flood water from the Pagladiya river to flow into Morapagladiya. However, it created another problem in the Morapagladiya and Burhadiya sub-basins. Now regular flood occurs during the monsoon months in the lower reaches of Morapagladiya and Burhadiya because of extra flood water from the Pagladiya

In 1988 to drain out water from the Barbhag area, a canal was dug out through the old Bhoraltola *jan* from Baraliya to Hajo *suti*. This reduces the flood intensity to some extent in Barbhag area for last few years.

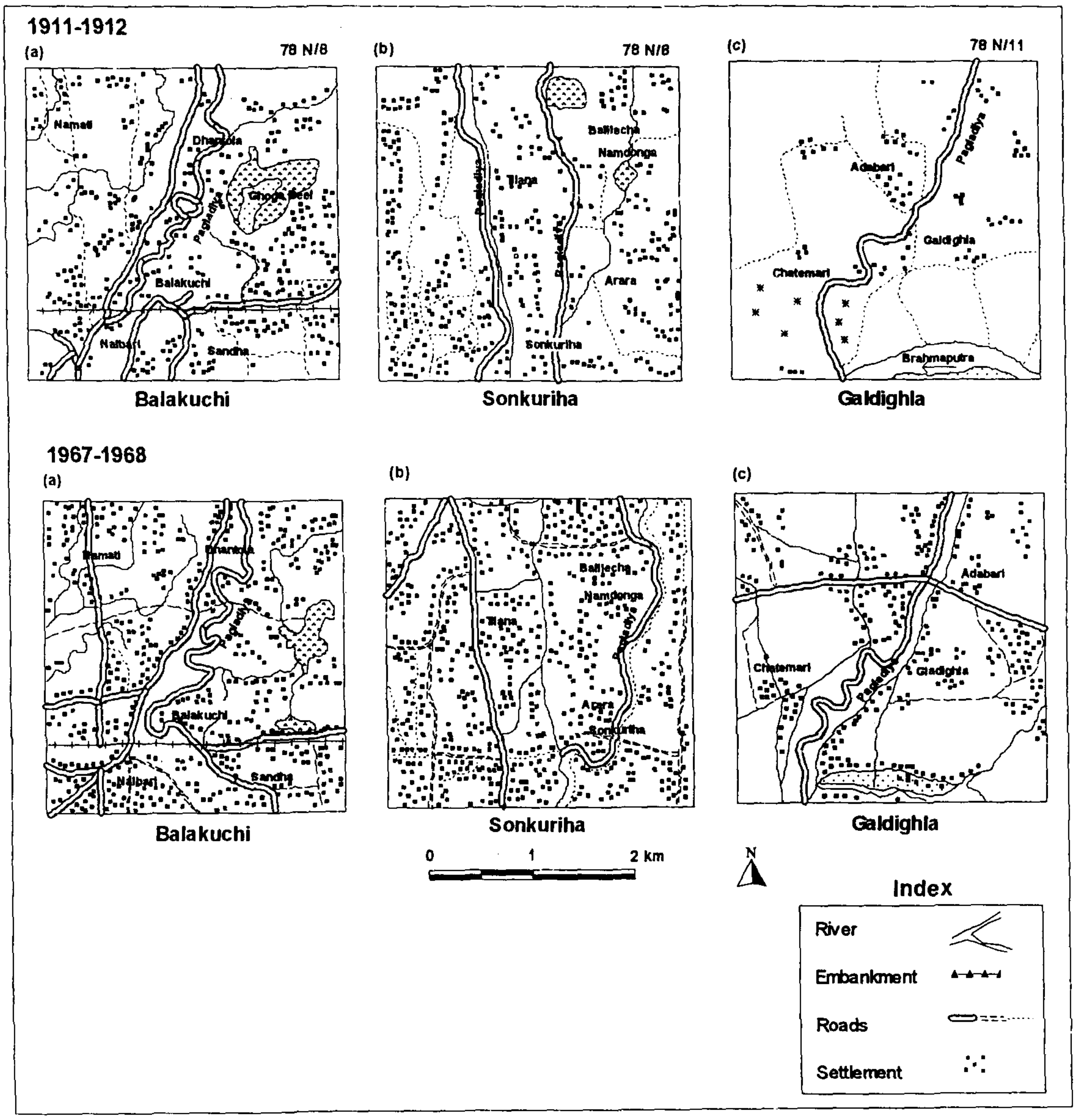


Fig. 6.4. a, b & c: Changes of Distribution, Pattern and Sites of Settlements due to Channel change, Flood and Construction of Embankments

6.3.3 Impact of Flood Control Measures in Rural Settlement:

Both good and bad effects of such flood control measures are experienced in the floodplain. It has been already mentioned that the embankments of the Pagladiya, Nona and Baraliya rivers along with elevated NF Railway line on the north create acute water congestion during the monsoon period. The area is popularly known as Barbhag (Fig. 6.3). The surface run-off during the monsoon period from the foothills of Bhutan between the Nona and Pagladiya enters into this area through the bridges on NH-31 and NF Railway lines creating floods. This is an example of an adverse effect of construction of embankments.

Bhojkuchi village on the west bank of Morapagladiya and north of Burhadiya has been facing flood problems annually (ref. Fig.3.7). Both these rivers breach the embankment every year accompanied with bank erosion leading to displacement of settlements and causes damage to crops, snapping communication lines and severe loss to public property.

A new trend of settlement growth along the embankments are seen which can be grouped as linear pattern of settlement. In the study area such a typical pattern is commonly observed in the lower active flood prone area and in the middle built-up area e.g. Balakuchi, Sonkuriha and Galdighla (Fig. 6.4 a,b&c). Construction of embankment also causes displacement of settlements. Original settlements, near the banks are completely abandoned after the construction of embankments. People leave their settlements and migrate outside the embankment which is free from flood (Fig. 6.5.a&b).

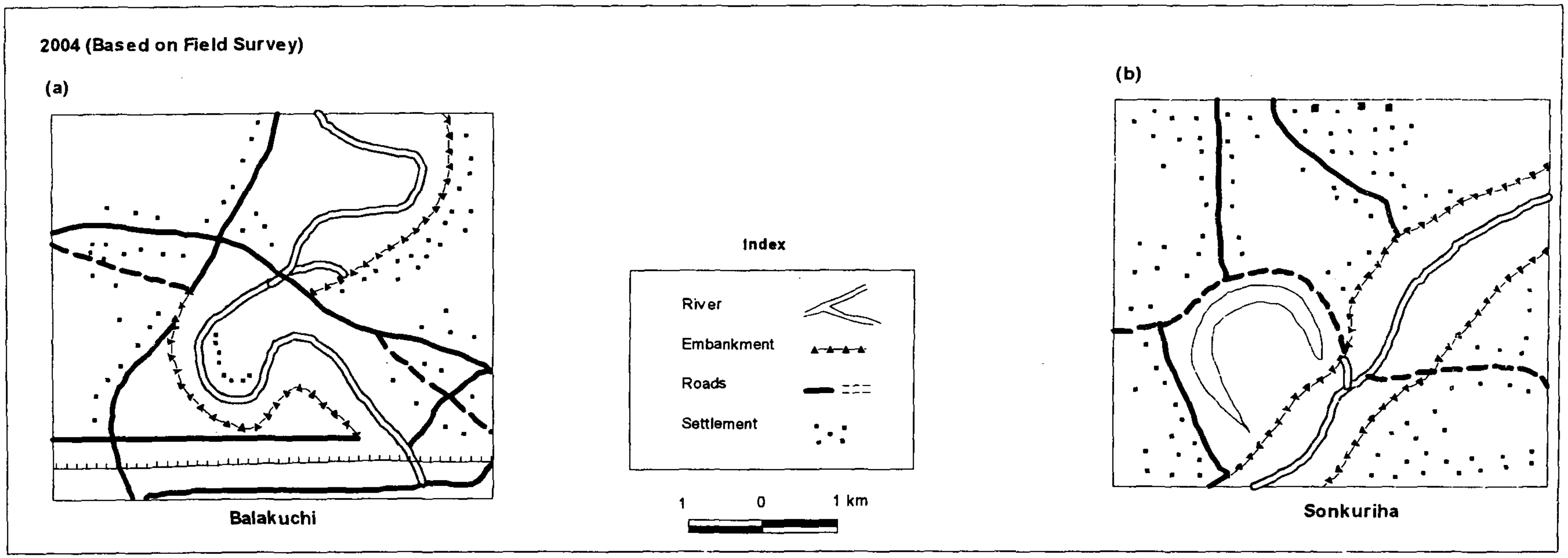


Fig. 6.5. a & b: Trend of New Settlement Growth along Embankments and Roads

From the field study in the area, it is observed that 60 per cent of the people are not satisfied with the existing structural flood control measures like embankment, ring bund, dyke etc. Their opinions are that, construction of embankment:

(i) increases the intensity and severity of floods,

(ii) rises the river beds by heavy siltation and sand deposition,

(iii) reduces the fertility of soils outside the dykes,

(iv) turns vast tract of cultivated and settled areas falling within the embankments into wasteland,

(v) causes displacement of settlements forcing the people who were originally in the river bank to change their earlier site of settlement creating additional pressure on agricultural land,

(vi) decreases the natural production of fishes outside the embankments, and

(vii) does not provide any permanent and practical solution to the flood problem.

A large section of the people (40%) suggest that embankment should be constructed more scientifically and other measures like digging of river beds, straightening the river channel etc. be taken up simultaneously.

6.4 ENVIRONMENTAL PERCEPTION AND HUMAN ADJUSTMENT TO FLUVIO-GEOMORPHIC ENVIRONMENT:

6.4.1 Environmental Perception:

Perception itself is a cognitive process and environmental perception of man is how to conceive or know the environment and acts accordingly. Therefore, it plays a great role in affecting and shaping the human behaviour in a variety of ways (Kayastha and Jadava, 1977). People of different communities have different perceptions about the same environment. The study area is composed of monotonous flat land with less physiographic variations. It consists of a narrow strip of foothill zone, built-up plain, active flood plain, marshy and swampy land, *beels* etc. The severity and intensity of flood occurrence are not same in the whole region. People of different communities are living here. The indigenous high castes communities of Assam live in the built-up area, whereas scheduled castes and immigrant Muslims mainly occupy the bank of rivers and *beels* in the lower active flood plain. The scheduled tribes people prefer highlands towards north of the foothill zone in the study area.

The site selected for settlement, design of houses and pattern of adjustment to the fluvio-geomorphic environment are controlled by the environmental setting and human perception about the environs. It is observed that some people of Barbhag area have temporary farms or *pams* in the flood free northern part of the study area. There are permanent to semi permanent settlements. But in the south, i.e., active flood plain some indigenous dwellers have periodic *pams* and *khuti* or *bathan* settlements. They only settle there for the non-monsoonal months for crops and livestock farming. During the flood time displacement occurs in such temporary settlements due to their shift with all belonging to their original flood free settlements.

6.4.2 Perception of Flood Hazard:

During the field study a survey about the perception of flood risk and probable flood occurrence in coming years are also done using the method suggested by Kayastha and Jadava (1977). The results are discussed here. In active flood plain area (i.e., in Galdighla and Bejpara) and southern waterlogged area of Barbhag (i.e., Arangmow, Barsimalia, Pandula and Kamarkuchi etc.) the number of flood in every 10 years (risk) is 9 with an average of 2 to 4 waves of flood during June to October in a given flood year. Flood water remains for 8 to 10 days in an average wave of flood. The risk is 1 to 2 in the villages situated near the banks of Pagladiya in the built-up area. In village like Nilpur the risk is practically zero.

In case of perception of probable flood in Galdighla and Bejpara the people (100 per cent) agreed upon the occurrence of annual floods. In Arangmow, Pandula, Barsimalia majority of the people (90 per cent) recognized annual recurrence of floods while some are doubtful. In Tantra Sankara and Balilecha the majority of the people did not perceive flood as a problem. The nature of damages is medium to low in the active flood plain and Barbhag area whereas in the built-up area especially near the river banks it is high.

In the villages situated on the banks of Morapagladiya and Burahadiya rivers in the flood prone part of the middle built-up plain the risk is 1 to 2 times in a year. The nature of damages is also high since the floods occur suddenly due to breaching of embankments. The people here in the villages like Sialmari, Gabradal, Bhojkuchi, Bali have not been adjusted to the flood hazard.

6.4.3 Human adjustment to the Fluvio-geomorphic Environment:

Despite the human losses that have been experienced floods have not discouraged settlements in river valleys. On the contrary there is substantial evidence that occupance of flood plain in many parts of the world is increasing. The Yellow river and Yangtse river in China have over flowed their banks many times in the past for thousand years and millions of people have been drowned as a result, yet the peasants continue to settle in flood plains. The people living since long back by the side of Pagladiya, Morapagladiya and other rivers in the study area exhibit different modes of adjustments to the floods. The river Pagladiya does not have its own permanent banks during the high flood events and changes its course breaching its embankments more than one. In the case of Morapagladiya and Burhadiya rivers such phenomena are less. But the Nona river also shows a same character with Pagladiya during the flood time changing its course without permanent banks. The people adopt different measures to minimize the damage caused by flood. The most common nature of human adjustment to floods in the region is found to be the 'accepting the loss' type. The people have the general attitude of accepting the losses because the people are poor and think they can do nothing to reduce flood damage. Therefore, they accept the loss caused by floods as a nature's curse on them.

The settlements of the flood plain is related to the prevailing fluvio-geomorphic environment of the study area, characterized by floods, erosion, sand deposition, channel changes, levee formation etc. However, in the study area people have taken various measures to adjust with these processes. Although, the traditional methods of adaptation and adjustment may possibly be replaced by flood control and anti-erosional measures introduced by the government agencies, the dwellers in the severely affected areas have adopted some structural measures to minimize the damage to settlements and losses due to flood, erosion etc. The measures taken so far are of the following categories:

(i) Raising of homesteads (*basti*) by earth filling and erection of houseswell above the average flood level.

(ii) Raising of bamboo and wooden platforms for placing straw heaps, cow shed etc.

(iii) Cultivation of varieties of crops before and after flood, and

(iv) Plantation of trees namely - coconut, betel nut, bamboo, banana etc.to check erosion and severity of damage to their homestead lands.

These traditional and temporary adjustments are still predominant as the majority of the people in the area are economically weak. In the annually flooded and low-lying area of Barbhag the homesteads are sufficiently raised by earth well above the average flood level. Their *chotals* (the courtyards) are much higher than roads, even 3 to 4 steps requires for climb up from the road. Again, the plinths of the houses are more than 1 m higher than the level of the courtyards in Arangmow village. In this area a good number of *chang-ghar* (platform house) especially made for flood are seen. But the constructions of these *chang-ghars* are gradually diminishing. It is because of the fact that at present the dwellers of this locality prefer to raise the level of the homesteads and construct even *pakka* houses above the high flood level. In the lower active flood affected area (particularly in Galdighla and Bejpara) near the bank of Pagladiya people prefer the high slope of the embankments and natural levees for their settlement. In Bejpara about 42 families live near both sides of an old embankment of 400 m long.

Besides during the flood season inhabitants of active floodplain areas try to get rid of flood hazard migrating to nearby high lands. Sometimes even they compel to live on roof tops and store food grains on *changs* above ground level. In this region country boats and rafts made of plantain are used for evacuation.

Although different adjustment measures are practiced by the people to minimize the loss and damages of floods, still the flood damages are increasing year by year. Therefore, people's adjustment to flood, bank erosion, sand deposition and channel change hazards are accepted as an unavoidable loss. This type of approach is an indication of inadequate protection measures and recurrent displacement of settlements and other kind of devastations. It is a traditional and common form of adjustment to flood hazard in areas of rural settlements and depressed economy of high hazard risk.

6.5 PAGLADIYA DAM PROJECT - ITS IMPACT ON RURAL SETTLEMENTS:

Considerable efforts have been made since 1954-'55 by constructing embankments and implementing anti-erosion and drainage improvement schemes to mitigate the flood havoc. However, people could benefit from it marginally and about 190 villages under 5 revenue circles are being affected by floods annually.

6.5.1 Location of the Dam Project Site:

The Pagladiya Dam Project is proposed to be constructed at Thalkuchi village, about 26 km north of Nalbari town in the study area near by the Indo-Bhutan international border. The project site consists of people of various castes and communities, but mainly is dominated by the tribes of Bodo ethnic group. After completion there would be 38 villages to be displaced.

6.5.2 Objectives:

The basic objectives of the Pagladiya Dam Project are:

(i) to protect 40,000 hectares of land from flood and erosion covering 190 villages of five revenue circles in Nalbari district,

(ii) to irrigate 54,160 hectares of land of 145 villages, and

(iii) to generate 3 Megawatt of electricity (Brahmaputra Board, 2001).

6.5.3 Geographical Observation:

The field survey undertaken in the project site in the month of January, 2005 revealed the flowing facts.

i. The site rests on the upper piedmont plain of Pleistocene origin.

ii. The site is slightly in down stream of the confluence of Pagladiya and Darranga rivers.

iii. The Pagladiya river is noted to be shifting its course at this point at an unprecedented rate towards west, twenty years earlier the course of the river was 3/4th km (0.75 km) east from where it is now. During 2004 flood in July it damaged an area of about 2 km in length and 200 m width.

iv. It is also eroding laterally, while at the same time showing braiding tendency.

v. Silting of the Pagladiya river is observed to be of high degree.

vi. The population of the villages to be displaced by the Dam is more than 50,000 (aprrox. 5000 families) which includes Bodos, Rabhas, Santhals, Nepalis and others.

It may be mentioned that the people who will be affected are mostly Bodos. They belong to a well knitted society with socio-cultural bonds attached to the land where they live. Their rehabilitation to other areas may alienate them from their land and this may pose socio-economic and political problems.

In conclusion, it can deduced from the preceding chapters and the present that the geomorphological change is an on going process which is beyond human control. The forces of nature like climate play a dominant role which man has to depend on. Hence, the changes created by nature will still progress for which humans have to adapt. These changes and the human approach to adaptation will be dealt in the next chapter.

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Chapter – VII

SUMMARY AND CONCLUSION

In the preceding chapters the explanation of the characteristics of the Pagladiya-Morapagladiya drainage complex was discussed. The two rivers which were once upon a time physically draining to one outlet experienced a change. This change led to the eastward shifting of the Pagladiya river to about 25 km away from where it was presumed to have existed. It is now draining directly to the Brahmaputra river when it actually drained to the Manas river system. The Pagladiya river was known to change its course from time to time and is still not stable. In the course of its change it does a lot of damage to life and property of the study area for which this work concentrates. The observations of the above can be expressed in the following paragraphs.

The Pagladiya river originates in the Bhutan hills at an altitude of 2,838 m (ASL) flows southward up to Chowki and enters into the plain of Assam. At first it turns towards the south-east direction and in between Bar Agra and Dosutimukh it moves almost in the southward direction and then turns towards south-west to meet Brahmaputra river. The elevation at this point is just 40 m (ASL).

From the earlier chapters it can be drawn that the entire area under consideration can be divided into the following zones:

(i) Physiographically the area can be divided into three distinct units, namely- i) The foothill zone, ii) The Middle Built-up plain and iii) The Aactive Flood plain.

(ii) On the basis of relief it can be divided into three Relief zones, namely- i) Foothill slope, ii) Middle Built-up plain and iii) Active Flood plain

(iii) On the basis of lithostratigraphic characteristics the study area can again be divided in to three zones, namely- i) Piedmont plain, ii) Younger Alluvial plain and iii) Flood plain.

(iv) In addition to this the soils of the area conforming to the above major units are divided into three zones: i) Sub-montane, ii) Old Alluvium and iii) New Alluvium.

The physical characteristics of the Pagladiya-Morapagladiya drainage complex is given below (Table 7.1)

Table 7.1: Phyiscal Characteristics of the Pagladiya-Morapagladiya drainage complex

Sl No.	Physiographic Zones	Relief Zone	Lithostratigraphic Units	Soil Zones
1.	Foothill	Foothill slope (Indo-Bhutan)	Piedmont plain	Sub-montane
		(a) Bhabar	Upper Piedmont plain	
		(b) Tarai	Lower Piedmont plain	
2.	Middle Built-up Plain	Built-up area	Younger alluvial plain	Old Alluvium
3.	Active Flood Plain	Chronically flood affected areas	Flood plain	New Alluvium

Compiled by the researcher

Geologic history of the study area and its surrounding depicts that there have been formations of layers of alluvium of both older and newer origin. The thickness of the alluvium in the area ranges between 91.5 m and 122 m.

The area is an earthquake prone area. The topography of the area was modified by the great earthquakes of 1897 and 1950. During the 1897 earthquake large areas like Barbhag and Barpit subsided. The *beels* along with Chaulkhowa were also uplifted significantly. Sand effusions in the bed of the Pagladiya river and Noanadi (which were flowing west of Nalbari town) made these rivers completely dry. The original channel of Pagladiya was later bifurcated in the foothill zone. The present Pagladiya river was formed as a result of the changes in the upper course of the Motanga river and in the middle and lower courses of Noanadi. It was after this that the Pagladiya took a new course to flow independently and join the Brahmaputra directly. The major tremor of 1950 earthquake and its aftershocks affected the study area. Land slips and rock falls occurred along the foothills of the Eastern Himalayas and as a result, the beds of Pagladiya and Nona rivers and Kapla *beel* were uplifted ranging between 0.60 to 0.90 m and thus affected the whole drainage complex. It also intensified the occurrence of flood in the area. The study of old maps, District Gazetteers and Oldham's report reveals this.

Diverse soil characteristics have been observed. The Pagladiya-Morapagladiya drainage complex has in its northern boundary hills and foothills, built-up plain in the central parts and chronically flood affected low-lying areas in the south. As a consequence of these, the area possesses coarse grained to fine grained soil.

The climate of the study area is characterized by modified tropical monsoon type of climate with hot and moist summer and cool dry winter (Borthakur, 1986). The climate of this area may be divided into four conspicuous seasons, viz., (i) Winter, (ii) Pre-monsoon, (iii) Monsoon and (iv) Retreating monsoon. The trend, tendency and distribution of temperature, rainfall, number of rainy days and foggy conditions are notable indices for identification of seasonality of the region. Rainfall, which is an important factor of floods, is relatively heavy. This area receives an average annual rainfall of 1600 mm.

It has been observed that the present geomorphic characteristics of the Pagladiya-Morapagladiya drainage complex have taken shape recently. The geologic and tectonic base of the region has given rise to a variety of landforms under varying climatic conditions influenced by dynamic geomorphic processes. Hot and humid climate, heavy rainfall, concentrated for few months of the year, causes landslides and erosion as well as solifluction. The incidence of such processes in the Bhutan foothills is most frequent due to heavy rainfall, high seismicity, and toe-cutting of hill slope by the river Pagladiya, Motanga, Darranga, Nona and Baraliya. Depositional and transportational processes are dominant on the built-up plain and active flood plain where the load brought from the upstream portions of the study area is deposited. Thus, erosional and depositional processes are obviously intensified by copious rainfall leading to more frequent floods.

During floods, there is a heavy deposition of suspended load. The Nona river, a tributary to Pagladiya river deposited large amount of sand and silt and changed vast tracts of agricultural area on its eastern bank into a sandy area with deranged stream channels. These rivers deposit so many loads during the summer season resulting to frequent changes in channels and courses leading to displacement of settlements. This has significantly raised the beds of Pagladiya, Morapagladiya and Nona rivers.

Channel and bank line migration is an important fluvial process. By this process a river tries to adjust itself with the changing fluvio-geomorphic conditions and ultimately to attain an equilibrium channel form. It is observed that Pagladiya river has a general tendency of lateral migration towards east except in few places. During high floods occurred from 1952-2004 the river breached its western side embankment in many places between Nalbari town and Bar Agra village and passed through Chengnoi, a tributary of Burhadiya river. In 1969 and 1998, the river breached its eastern embankment at Khat Katra and Khanajan villages and passed through Ghoga *beel.*

Table 7.2: Flood Zones and Channel Changes in different Physiographic Zones

Sl No.	Physiographic Zones	Relief Zone	Flood Zones	Soil Character	Character	Channel Changes
1.	Foothill	Foothill slope (Indo-Bhutan)	Not affected	Red soil with gneisses, granite, pegmatites etc	Hard rock	None
		(a) Bhabar		Soil with boulders, gravels, pebbles, cobbles, sand and clay	Loose and unassorted	
		(b) Tarai		Old alluvium and sand, silt and clay soaked with water	Partly cohesive	
2.	Middle Built-up Plain	Built-up area	Occasionally affected	Old and recent alluvium composed of finer sand, silt and clay	More cohesive	High incidence
			Chronically affected and waterlogged			
3.	Active Flood Plain	Chronically flood affected areas	Chronically affected	Recent alluvium of finer sand, silt and clay	Less cohesive than that of Built-up plain area	Observed

Channel changes are also seen in the tributaries of Pagladiya, viz., in Nona and Baraliya. Nona has changed its course leaving its original downstream portion at south of NH-31 and moved towards east taking a meandering form. Baraliya river also changed its course just at 2 km upstream from the meeting place with Pagladiya at Dosutimukh. Four types of channel changes and bankline migration of Pagladuya river are noticed in the area. These are - (i) straightening of course by cutting off meanders, (ii) the lateral migration, (iii) widening of the river channel by bank slumping and (iv) by cutting of its bank laterally.

There are many factors affecting channel changes in the study area. These can be summed up below:

(ix) Sudden increase of discharge of water during summer causes floods. This influences bank line erosion, especially at the confluence of Baraliya with Pagladiya at Dosutimukh is an important noticeable factor. Low gradient of the river bed from the foothills southwards till the Brahmaputra river is a major factor of channel changes.

(x) The river is not braided, but due to formation of progressive point bars, the river channels become gradually meandering by cutting its bank laterally. The gradual widening of point bars from one bank to the other results in lateral bank erosion in the opposite bank creating changes and meandering of the channel course.

(xi) Severe bank slumping changes the channel geometry which ultimately leads to channel changes. Such slumping are seen during the field survey at Batahgila, Khandajan, Barkatalkuchi, Sonkuriha, Adabari, Galdighla, Bejpara and Chotemari villages located in the Middle Built-up plain.

(xii) During the high floods the river has been found changing its channel courses breaching both embankments in many places in the lower part of the river.

Thus, the flood is considered as one of the most influencing factors of sudden channel changes.

(xiii) Human interference like digging of sand used for different constructions during dry period from the bank and bed of the river in the study area especially near Nalbari town also attracted channel changes. Similarly, structures for the flood control and bank protection with their unscientific construction cause severe bank slumping and channel migration.

(xiv) The construction of rail and different road bridges for surface transportation and communication at different places causes drainage constriction resulting in lateral migration in sections just upstream of the bridges north of NH-31 and NF Railway line. The velocity of river water increases just below the bridge, but decrease of velocity in down stream helps sedimentation and formation of sandbars causing lateral bank erosion. This is observed mainly near the NH-1 and NF Railway bridge.

The frequent occurrence of flood in the study area can be attributed to: (i) climatic factor, (ii) physiographic factor, (iii) tectonic factor and (iv) anthropogenic factor. The main causes of flood are excessive rainfall in the Bhutan foothill; melting of snow and bursting of blockades of water formed by landslide in Bhutan-Himalayas. During monsoon months rainfall is high (above 300 mm in average) and the headwaters debouch abruptly to the plain from foothill and overflow the narrow channels. The huge volume of turbulent flow and uncertain hydraulic movement not only create local floods but also frequently dig out new channels changing the river courses. There is a very close relationship between highest flood levels and rainfall received in the area.

From the following diagram (Fig. 7.1) it can be drawn that the floods of 1977, 1983, 1984, 1988, 1996, 1998 and 2000 were significant. This is also reflected in the rainfall pattern of nearest India Meteorological station data (Guwahati, Dhubri and Tangla) of these years. However, in 1984, the floods were highest but the monthly mean discharge was not too high in comparison with other years.

Secondly, the sudden drop in the gradient from the high and steep Bhutan Himalayas to the almost flat regions starting from the foothills to the flood plains of the Brahmaputra do not allow fast movement of huge amount of water that accumulates and gushes during the humid summer season. The huge volume of turbulent flow and uncertain hydraulic movement not only create local floods but also frequently dig out new channels changing the river courses

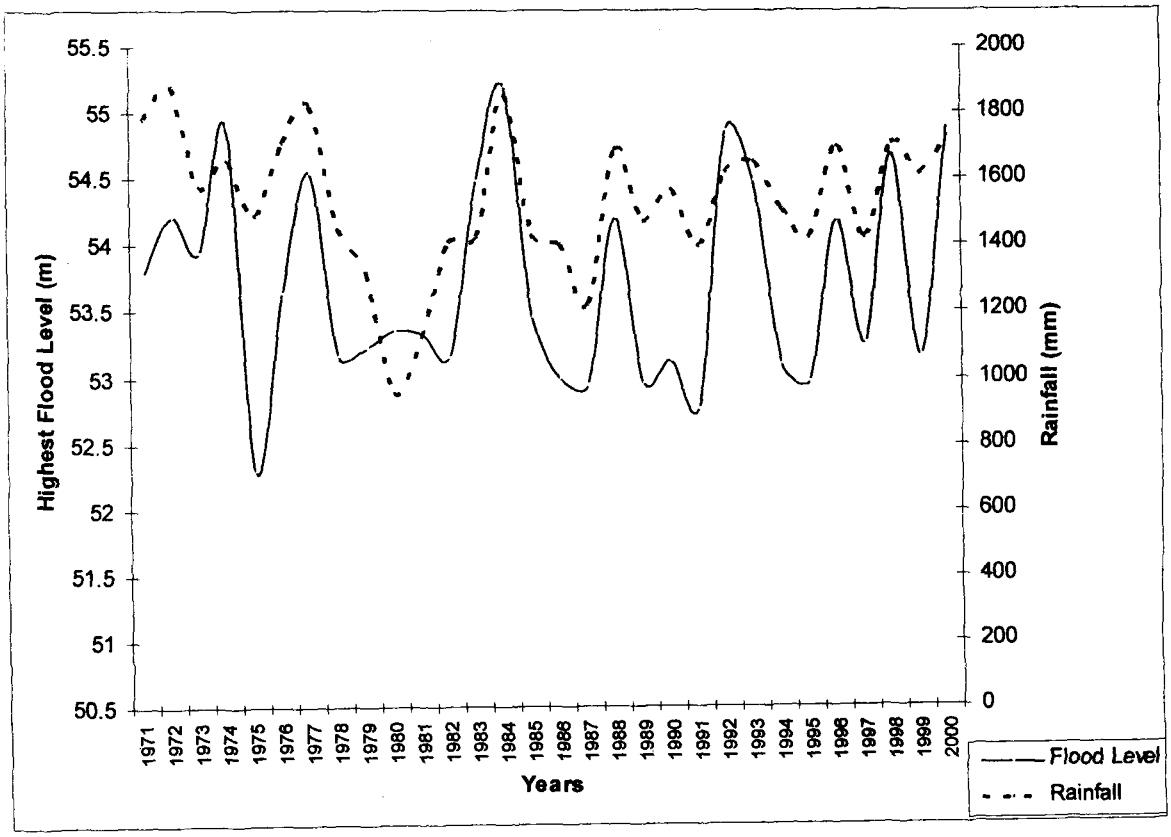

Fig. 7.1: Flood Levels and Rainfall Pattern, 1971-2000

Thirdly, human interference of natural ordered sequences for socio-economic benefits has never been without any error. Human occupation and activities have multiplied and spread all over leaving no space for natural phenomena to take place. The flood phenomena have left a trail of devastation time and again since man did what he should not have done. However, the Pagladiya river, did change its course in the last one hundred years or so which had enough evidence to show that it shifted eastwards about 25 km. In the unrecorded past it remains unknown how much it shifted. The Tista river and the Brahmaputra too (Richardson and Thorne, 2001) did change their courses in the past.

In the event of course changes of the rivers of the study area human population of the area suffered and continues to suffer huge losses. A large number of human settlements are submerged under flood water while some are totally destroyed. Some of them face the wrath of yearly recurrent floods and some of the settlements have been divided by the uncertain changes which take place from time to time. Such events affect human population as well as create situations for adaptation of the human population.

Floods have been observed to occur frequently in the lower half of the middle built-up plain. On the basis of intensity of flood hazards the lower half of the study area can be divided into three flood zones: (a) occasionally flooded zone of built-up area, (b) chronically flooded zone of the lower flood plain of Pagladiya and Brahmaputra and (c) chronically flooded and waterlogged zone of Barbhag area (ref. Fig. 3.13 & Fig. 6.2). Under such conditions settlements have been displaced due to channel changes and the concluding statements can be made in the following few points:

(i) Due to channel changes through bank line migration and breaching of embankments, about 3,000 families have been displaced during 1971-2000. Laopara village was completely eroded away near the confluence of Pagladiya with Brahmaputra and displaced 920 families.

(ii) Settlements like Balakuchi, Khatabari, Sandha, Paila, Tantra Sankara, Namdonga, Simalia, Sonkuriha, Galdighla, Bejpara which were originally on the bank of the river are now relocated to areas next to the embankment.

(iii) Villages like Digheli, Balilecha, Sankara etc. which were originally in the eastern side of the river are now situated in the western side of the river Pagladiya.

(iv) Pagladiya river which created a new course through settled areas divided the following villages of Tantra Sankara, Arara, Namdonga, Dingdingi, Kamarkuchi into two parts.

(v) Villages like Bhanukuchi, Pajipara, Barmurikona, Simalia etc. which were located about 2 to 3 km away from the river are now by the banks of the river Pagladiya.

(vi) The abandoned channels and *beels* have become shallow after deposition of silt and sand and are transformed either to agricultural land or settled areas.

A clear explanation of the effect of floods on settlements can be derived by drawing the relationship between floods and the damage to villages. The following Table 7.3 explicitly explain the effect of floods on the settlements of the study area for the years 1971-2000.

This can be summed up in the following lines:

(i) No settlements have been observed to be completely eroded in the Foothill zone. In the Middle Built-up plain four villages have been completely destroyed between 1971 and 1981. The Active Flood plain witnessed two villages being completely destroyed between 1981 and 2000.

(ii) In the Foothill Zone few villages were partially eroded, i.e., two villages between1971-81 and only between1981-2000. There were ten villages that were partially affected by floods in the Middle Built-up plain during the period 1981-2000 while the in Active Flood plain no villages were known to have been partially affected.

(iii) The expansion of villages has been observed mainly in the Active Flood plain area after 1981. This is most probably because of increase of population and immigrants. Eight villages have been observed to experience extension and they are located near the *beels* and marshy tracts. No such phenomena have been observed in the Foothill zone and Middle Built-up plain.

(iv) New settlements have developed in all the three physiographic units. Five villages have developed in the Foothill Zone and seven in the Middle Built-up Plain during 1971-2000. The Active Flood Plain saw a development of seven new settlements out of which four developed during 1981-2000 which was a result of population pressure on land.

Table 7.3: Villages Affected and Displaced in different Flood zones

Sl No.	Physiographic Zones	Relief Zone	Flood Zones	Affected/Displaced villages	
				Pagladiya basin	Morapagladiya basin
1.	Foothill	Foothill slope (Indo-Bhutan)	Partially affected	None	None
		(a) Bhabar		None	None
		(b) Tarai		Dihira, R.F.	Morapagladiya F.V.
2.	Middle Built-up Plain	Built-up area	Occasionally affected	Khudra Agra, Khudra Katra, Nagarkuchi, Dhantola, Chengnoi, Khanajan, Moiradanga, Balakuchi, Khatabari & Khudra Borkatalkucchi	None
			Chronically affected	Sonkuriha, Kamarkuchi, Simalia, Namdonga, Galdighla, Tilardiya, Lauthari, Paila, Bejpara & Arangmow (water-logged area)	Bhojkuchi, Bali, Sandheli, Haribhanga, Gabradal, Sialmari, Makrapar & Barpit
3.	Active Flood Plain	Chronically flood affected areas	Chronically affected	Adabari, Chotemari, Naopara, Gholarpar, Bhelamari, Batamara, Lauthari, Barbala (1-5), Damal & Pub-kajia.	None

Compiled by the researcher

FINDINGS:

Considering the preceding discussion and analysis of the facts presented, it was found that the Pagladiya and Morapagladiya rivers and their tributaries have changed their courses in the past. The changes are going on and each year human settlements are affected, the degree of damage being unpredictable depending much on variations of climatic parameters. Based on these facts the main findings of the present work can be summed in the following lines:

(i) The two episodes of earth movements that took place in 1897 and 1950 have made significant impact on the surface configuration of the study area hence initiating several changes in the channels and their flow pattern.

(ii) Climatic parameters play a very important role in determining floods. Rainfall is the most important component and the above analysis proves that floods have corresponded well with the pattern of rainfall.

(iii) The floods initiate changes in channels and river courses causing heavy damage to life and property. The permanent scars of such phenomena were recorded by completely destroyed settlements. Some other settlements were partially affected only to expand towards safer and flood free direction.

(iv) Sediment deposition by the rivers every year initiates changes in the channels.

(v) Construction of bridges for transport linkages have been seen to cause restriction of flow of large volume of water during the summer season thereby submerging areas which rarely experienced flood.

(vi) The Pagladiya river shows an eastward shifting trend in the past 100 years or so. It may be conjectured that there is constant tectonic adjustments taking place over this region which needs more intensive studies.

(vii) New settlements have been observed to evolve on higher elevation like levees, embankments or roadsides (as roads are at higher elevations presently acting as embankments) and also nearby *beels* and marshy areas.

The trend of new settlements being located near transport lines is obvious since people are preferring to be free from floods as well as availing easy transport facilities

Keeping in mind the above findings few suggestions can be forwarded for better management of the study area and similar situations in the region during the summer season when recurrent floods occur. These suggestions may help the different agencies and administrative organizations by reducing losses rather than aiming relief only. The following points attempts to sum up the suggestions.

(i) There is a great need to understand the earth movements and subsequent surface adjustments occurring in the area. The area and the region as a whole being classed under Zone V for earthquake vulnerability as well as facing recurring floods has problems to be addressed to.

(ii) Natural changes like earthquakes, excessive rainfall, storms etc., are not within human controls and hence there is a need to take adequate precautionary measures to prevent or at least mitigate losses. It is therefore proposed that there should be a 'line of vulnerability' which would address the yearly flood problem in order to reduce loss of life and property. It is also suggested that any settlement that fall within the line may be treated as susceptible to floods. Hence appropriate precautionary measures could be taken up for such locations. This 'line of vulnerability' could be drawn as follows:

a. For the Foothill Zone: 0.75 km from the current year bank line as the channel and course changes in this zone have not been observed to cross 0.50 km in the period of investigation

b. For the Middle Built-up Plain: 1.25 km from the current year bank line as the river in this part starts to meander.

c. For the Active Flood Plain: 3.0 km from the current year bank line since the river in this part is sluggish and had been observed to change its course to a maximum of 2.5 km in 1984.

(iii) Alternative long term measures, viz., 'living with the flood' as suggested by the National Commission on Flood should be adopted in the most chronically flood effected areas of lower Pagladiya basin. Raised platforms should be constructed in this area for common use as shelter during the flood so that relief and evacuation becomes easier.

(iv) Not to disturb the wetlands (*beels* and marshy lands) which are natural absorbents of major floods by reclamation and encroachment.

(v) To protect river banks and embankments locally available tall grasses and reeds should be planted along the sides. Planting of bananas have also proved to be helpful in maintaining stable river banks and also provide livelihood to villagers. This can be a community effort.

(vi) The proposed Multi-purpose Dam Project to be constructed at Thalkuchi, 26 Km north of Nalbari town predominantly inhabited by the Bodo tribe is a major threat to displace more than 50,000 people from 38 villages in and around the project site. This may create socio-economic as well as resettlement problems for the indigenous inhabitants who have been residing in this area for 50 to 100 years., It is important to give due consideration to proper rehabilitation, resettlement and after affect of the dam should be contemplated.

In conclusion, it may be reiterated that it is necessary to alleviate the problems faced by people of the Pagaldiya-Morapagladiya drainage complex. Various long-term and effective measures as suggested here may be taken in right earnest and expeditiously. To improve socio-economic condition of the inhabitants, scientific planning of settlements, land use and other development activities could be done. The data and information generated by this study may be useful and can be a stepping stone for further research and may also provide a reliable basis for such an integrated approach for development of the area.

Further, it may be suggested that more research work could be carried out on various aspects of fluvial geomorphology and settlement geography.

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(Appendix – I)

Pagladiya-Morapagladiya Drainage Complex
Average Annual Rainfall Distribution for Selected Stations, 1971-2000
(Rainfall in mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kumarikata	10.58	23.42	12.27	176.58	435.58	625.60	605.51	215.42	175.42	69.42	12.00	1.10
Tamulpur	0.62	29.53	19.14	101.12	279.76	481.75	319.75	265.08	149.75	88.55	38.62	30.50
Menoka	11.27	29.18	35.46	225.83	283.94	514.87	482.65	528.15	218.10	109.18	5.66	6.25
Doomni	0.11	5.17	30.36	170.42	442.16	452.28	585.19	268.68	294.46	102.75	16.22	2.49
Nikashi	3.48	26.58	8.87	185.62	265.51	387.20	595.39	377.77	208.69	295.61	18.85	6.89
Tihu	0.64	18.67	22.13	169.48	287.63	458.12	265.48	289.42	159.47	100.82	28.17	6.95
Nalbari	0.59	16.35	23.42	172.62	280.60	451.25	277.69	224.59	158.30	98.60	28.27	8.20
Mukalmua	1.59	7.90	15.17	50.41	336.91	518.62	214.03	297.68	362.70	84.00	40.18	20.12

Source: Office of the Executive Engineer (Irrigation), Nalbari.

(Appendix – II)

Monthly Mean Stage, Discharge of the Pagladiya River at N.T. Road Crossing 1971-2000

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1971	J	50.48	3.02
	F	50.53	5.43
	M	50.67	5.53
	A	50.62	5.39
	M	50.57	5.04
	J	50.73	24.11
	J	50.93	50.86
	A	51.11	84.36
	S	52.26	187.17
	O	50.93	30.06
	N	50.69	17.16
	D	50.57	11.25
			Mean = 35.67

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1972	J	50.54	10.46
	F	50.52	10.01
	M	50.67	18.24
	A	50.97	23.40
	M	51.84	79.32
	J	52.33	120.93
	J	52.64	184.19
	A	51.73	74.54
	S	51.58	51.20
	O	51.05	21.14
	N	50.88	12.56
	D	50.75	9.92
			Mean = 51.32

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1973	J	50.68	7.59
	F	50.70	5.28
	M	50.76	4.58
	A	50.84	7.72
	M	51.20	33.22
	J	52.41	168.80
	J	52.01	93.41
	A	51.83	104.58
	S	51.29	31.63
	O	51.32	51.12
	N	51.13	23.22
	D	51.05	12.09
			Mean = 45.27

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1974	J	51.03	13.81
	F	51.01	9.25
	M	51.02	6.46
	A	51.15	11.78
	M	51.39	48.41
	J	52.13	127.40
	J	53.26	180.96
	A	52.03	91.58
	S	52.65	116.66
	O	51.83	51.00
	N	51.39	20.12
	D	51.08	7.50
			Mean = 57.07

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1975	J	51.05	10.68
	F	51.03	8.43
	M	51.10	11.23
	A	51.14	13.53
	M	51.22	18.68
	J	51.19	31.76
	J	52.18	55.00
	A	51.85	47.70
	S	51.69	38.19
	O	51.62	23.25
	N	51.34	9.10
	D	51.29	7.52
			Mean = 22.93

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1976	J	51.25	5.71
	F	51.22	4.63
	M	51.15	2.80
	A	51.17	6.08
	M	51.32	7.06
	J	51.99	44.40
	J	52.51	90.32
	A	51.77	39.03
	S	51.64	19.62
	O	51.54	23.67
	N	51.37	8.34
	D	51.30	4.60
			Mean = 21.35

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1977	J	51.26	3.06
	F	51.22	2.65
	M	51.15	2.32
	A	51.72	36.68
	M	52.42	57.29
	J	52.49	152.83
	J	51.70	118.61
	A	53.07	153.51
	S	51.89	84.00
	O	51.79	39.54
	N	51.39	20.65
	D	51.36	14.47
			Mean = 57.13

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1978	J	51.26	4.60
	F	51.22	3.11
	M	51.14	2.01
	A	51.11	1.90
	M	51.69	18.83
	J	52.61	83.33
	J	52.18	90.16
	A	51.80	87.19
	S	51.51	54.20
	O	51.49	31.96
	N	51.43	18.82
	D	51.29	9.50
			Mean = 31.30

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1979	J	51.24	6.81
	F	51.23	5.25
	M	51.20	3.25
	A	51.48	6.46
	M	51.68	18.38
	J	51.56	12.63
	J	52.18	70.64
	A	52.07	47.74
	S	51.67	56.76
	O	51.52	48.03
	N	51.48	18.29
	D	51.30	10.12
			Mean = 25.36

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1980	J	51.25	7.48
	F	51.21	4.49
	M	51.29	3.82
	A	51.56	9.06
	M	51.59	14.83
	J	51.68	30.36
	J	52.29	94.70
	A	52.21	83.67
	S	51.78	46.06
	O	51.51	24.29
	N	51.30	0.41
	D	51.21	8.21
			Mean = 19.78

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1981	J	51.18	7.08
	F	51.17	6.27
	M	51.16	5.92
	A	51.17	6.09
	M	51.08	3.48
	J	51.38	5.51
	J	52.29	84.06
	A	51.74	56.07
	S	51.79	50.00
	O	51.42	18.42
	N	51.17	6.83
	D	51.16	5.84
			Mean = 21.30

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1982	J	51.12	4.79
	F	51.10	3.78
	M	51.07	2.98
	A	51.28	5.39
	M	51.33	14.52
	J	51.48	39.40
	J	52.12	100.41
	A	51.94	47.09
	S	52.11	105.25
	O	51.39	12.00
	N	51.31	10.49
	D	51.27	8.23
			Mean = 26.10

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1983	J	51.27	8.61
	F	51.25	8.32
	M	51.24	6.29
	A	51.22	4.80
	M	51.78	21.48
	J	52.14	57.30
	J	52.09	98.03
	A	51.97	58.71
	S	52.97	125.73
	O	51.49	44.61
	N	51.29	15.08
	D	51.24	5.80
			Mean = 37.90

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1984	J	51.20	4.95
	F	51.15	5.02
	M	51.07	4.13
	A	51.29	9.88
	M	52.24	47.06
	J	51.39	18.46
	J	52.57	80.84
	A	51.84	42.67
	S	53.19	148.03
	O	51.22	33.32
	N	51.04	13.00
	D	51.03	9.21
			Mean = 34.71

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1985	J	51.01	7.66
	F	50.90	5.77
	M	50.89	5.59
	A	51.03	11.19
	M	51.09	23.32
	J	52.27	116.68
	J	51.95	91.83
	A	51.62	48.45
	S	51.43	33.30
	O	51.21	12.26
	N	51.20	6.30
	D	51.18	4.02
			Mean = 30.36

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1986	J	51.17	3.45
	F	51.13	2.68
	M	51.10	2.00
	A	51.19	2.94
	M	51.30	7.94
	J	51.85	27.73
	J	51.70	37.42
	A	51.69	28.32
	S	51.47	40.27
	O	51.42	22.16
	N	51.07	8.64
	D	51.04	6.04
			Mean = 15.80

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1987	J	51.03	3.65
	F	50.99	3.39
	M	50.95	6.25
	A	50.98	4.98
	M	51.00	5.29
	J	51.87	49.43
	J	52.73	152.06
	A	52.24	102.07
	S	51.65	89.21
	O	51.41	20.58
	N	51.08	7.98
	D	51.04	5.00
			Mean = 36.82

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1988	J	51.02	5.74
	F	51.07	5.38
	M	50.91	4.78
	A	50.89	4.90
	M	52.31	45.77
	J	51.84	35.80
	J	52.59	108.70
	A	52.56	108.51
	S	52.26	100.50
	O	51.60	94.54
	N	51.17	13.98
	D	51.13	13.85
			Mean = 45.23

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1989	J	51.01	10.89
	F	51.05	10.94
	M	51.01	7.23
	A	50.96	10.97
	M	51.33	15.91
	J	52.08	117.38
	J	51.87	105.97
	A	51.35	42.49
	S	51.77	78.14
	O	51.42	36.21
	N	51.16	12.43
	D	51.20	10.59
			Mean = 30.01

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1990	J	51.08	7.08
	F	51.15	6.12
	M	51.20	5.86
	A	51.12	6.09
	M	51.82	8.32
	J	52.78	18.48
	J	52.63	89.63
	A	51.32	87.26
	S	52.27	49.24
	O	51.42	24.22
	N	51.19	6.29
	D	51.03	5.67
			Mean = 26.19

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1991	J	51.05	10.68
	F	51.08	10.03
	M	51.12	11.54
	A	51.20	13.57
	M	51.14	18.46
	J	51.22	31.76
	J	51.34	55.82
	A	51.62	47.90
	S	51.69	38.10
	O	51.32	23.24
	N	51.29	10.71
	D	51.09	9.36
			Mean = 23.43

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1992	J	51.01	3.08
	F	51.18	2.74
	M	51.28	2.49
	A	51.15	36.12
	M	51.68	57.18
	J	52.49	124.73
	J	51.70	108.53
	A	53.92	122.18
	S	51.37	89.23
	O	51.28	46.71
	N	51.39	39.54
	D	51.26	20.67
			Mean = 53.60

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1993	J	51.17	4.95
	F	51.20	5.20
	M	51.19	4.18
	A	51.32	9.89
	M	51.24	47.28
	J	51.49	18.92
	J	51.57	80.17
	A	51.84	42.36
	S	53.17	149.52
	O	51.22	48.42
	N	51.85	14.00
	D	51.03	11.32
			Mean = 36.35

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1994	J	51.17	3.45
	F	51.13	2.68
	M	51.01	2.00
	A	51.19	2.99
	M	51.23	13.92
	J	51.45	39.84
	J	51.85	40.27
	A	51.70	41.18
	S	51.69	22.16
	O	51.47	18.07
	N	51.41	8.62
	D	51.04	6.31
			Mean = 16.79

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1995	J	51.07	3.62
	F	50.99	3.42
	M	51.32	6.49
	A	51.47	4.88
	M	51.71	5.43
	J	51.24	49.68
	J	51.78	159.21
	A	51.65	151.77
	S	51.28	102.91
	O	51.41	89.26
	N	51.07	20.63
	D	51.03	8.20
			Mean = 54.40

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1996	J	51.07	5.81
	F	51.06	5.39
	M	51.12	5.78
	A	51.89	4.90
	M	51.86	41.53
	J	52.57	38.29
	J	52.66	117.50
	A	52.46	120.43
	S	52.82	100.57
	O	51.60	94.34
	N	51.20	18.55
	D	51.13	14.78
			Mean = 47.41

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1997	J	51.25	4.23
	F	51.40	4.48
	M	51.12	5.12
	A	51.43	6.17
	M	51.82	8.33
	J	51.68	14.73
	J	51.78	30.43
	A	51.67	87.18
	S	51.51	46.28
	O	51.28	24.19
	N	51.18	4.32
	D	51.07	6.76
			Mean = 20.18

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1998	J	51.21	3.08
	F	51.17	2.65
	M	51.10	2.31
	A	51.73	31.52
	M	51.48	48.28
	J	52.09	152.54
	J	51.65	118.58
	A	52.11	153.42
	S	51.84	84.09
	O	51.76	39.26
	N	51.39	20.65
	D	51.35	14.47
			Mean = 55.91

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
1999	J	51.15	3.02
	F	51.06	2.19
	M	51.01	2.17
	A	51.63	20.10
	M	51.42	22.90
	J	51.66	35.61
	J	51.60	149.08
	A	51.89	72.55
	S	51.68	47.27
	O	51.73	31.26
	N	51.20	18.22
	D	51.11	12.38
			Mean = 34.73

Year	Month	Monthly Mean	
		Stage	Discharge(M^3S^{-1})
(1)	(2)	(3)	(4)
2000	J	51.04	10.76
	F	51.10	10.84
	M	51.12	8.97
	A	50.97	12.54
	M	51.38	15.92
	J	52.10	118.38
	J	51.93	106.49
	A	51.48	48.97
	S	51.77	78.24
	O	51.62	36.27
	N	51.29	12.47
	D	51.18	11.53
			Mean = 39.27

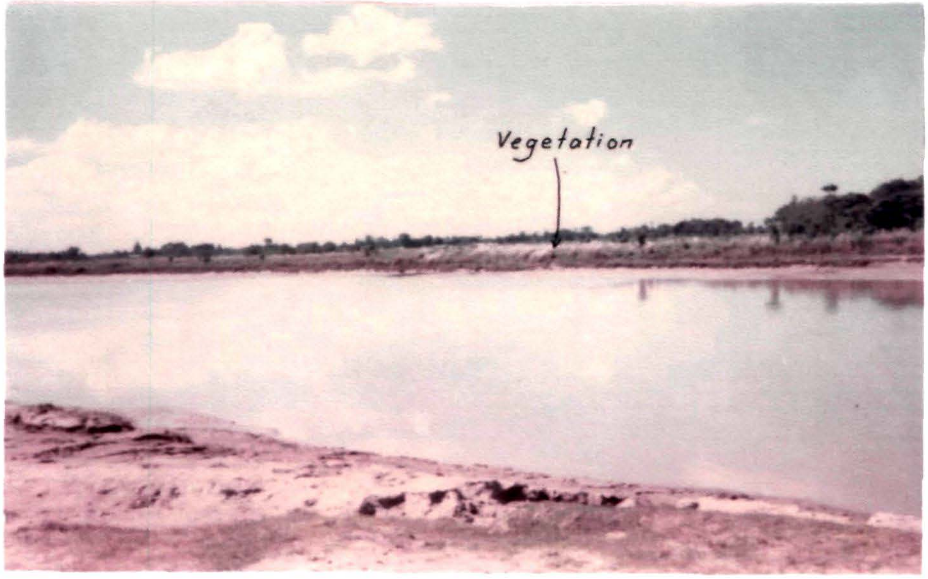

Plate 1 : Pagladiya river near Balakuchi village

Plate 2 : Rem nants of Khatabari village located around the coconut trees

Plate 3 : Bejpara village in between Pagladiya river and old channel of Brahmaputra

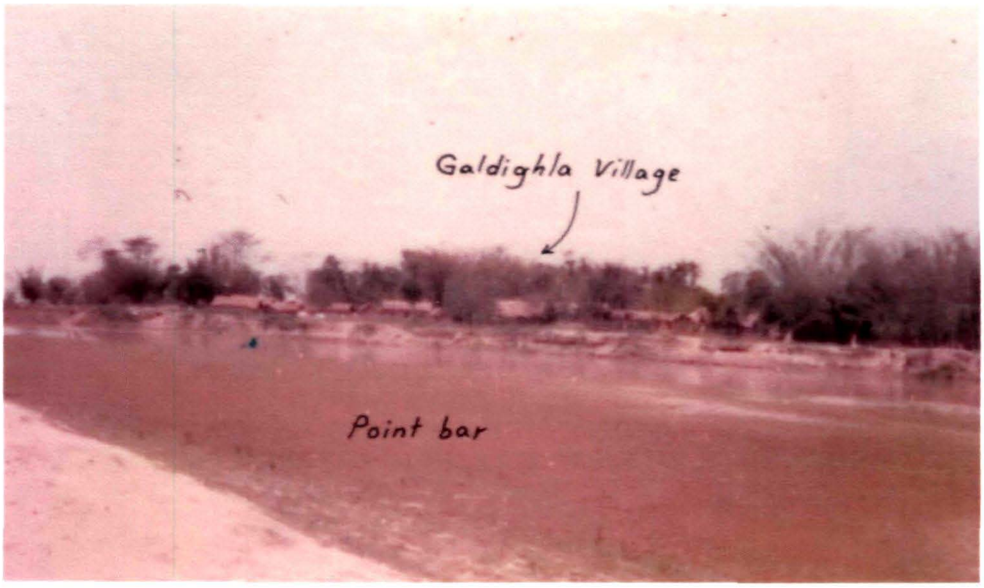

Plate 4 : Development of point bar on the bank opposite to Galdighla village

Plate 5 : A scheduled caste village in the active flood plain

Plate 6 : A Mosque under temporary shed which was displaced due to flood, 1984

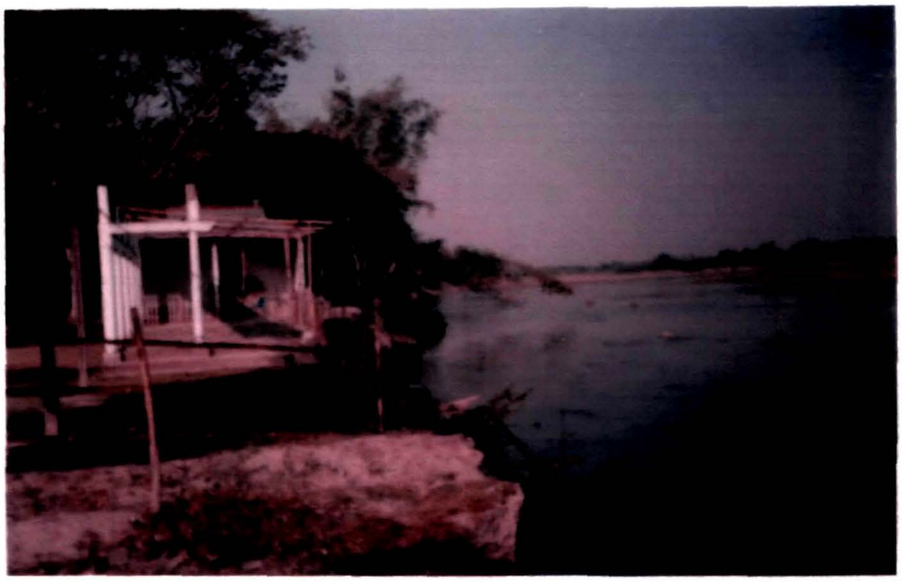

Plate 7 : A *Kali Mandir* is seen in devastating condition due to bank erosion

Plate 8 : Severe bank erosion near Thalkuchi village

Plate 9 : Meandering channel of Pagladiya river near Bijulighat

Plate 10 : Heavy sand deposition by Pagladiya river buried half an old temple (Below coconut tree)

Plate 11 : Bank erosion collapsed the foundation of Pagladiya Dam Project site at Thalkuchi

Plate 12 : Elevated bed of Pagladiya river due to heavy siltation

BIO-DATA

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