Photonirvachak
Journal of the Indian Society of Remote Sensing, Vol. 35, No. 4, 2007

REMOTE SENSING AND GIS APPLICATION IN CHANGE DETECTION OF THE BARAK RIVER CHANNEL, N.E. INDIA

J.D. DAS [*@], T. DUTTA [**] AND A.K. SARAF [***]
[*]Department of Earthquake Engineering, Indian Institute of Technology Roorkee, Roorkee, India
[**]Reliance Industries Ltd. (Petroleum Business)
[***]Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee, India
[@]Corresponding author : jddasfeq@iitr.ernet.in

ABSTRACT

Rivers flowing through the alluvium invariably have very low gradient forcing the river to flow slowly in a meandering and zigzag path. Nature and intensity of meandering is governed by the geological and tectonic conditions of the river basin. Barak River in tectonically active south Assam (Northeast India) exhibits intense meandering and shifting of the river course. Topographic data of two different years and satellite images of 4 different years covering a section of the Barak River have been investigated to verify the nature of changes undergone by the river through times. This study reveals active northward shift of the river and a prominent neck-cut off in the initial part of the study area. Northward shift of the river also occurred in the area west of Silchar. But, in the western part the river has shifted both towards north and south Oscillatory shifting in the river channel has also been noticed. The river has shown a overall northward shift which is probably due to uplift of the southern part of the Barak River valley.

Introduction

The Barak River originates from the 2995m high in Barail Range of Naga Hills and enters the plains of south Assam at longitude 93°E. The river bifurcates into Surma and Kusiyara Rivers in Bangladesh. Several tributaries join the Barak from north and south. Figure 1 is the study area showing meandering Barak River and other geomorphological features as displayed by the satellite image. The Barak River valley is represented by a narrow E-W trending elongated alluvial filled basin and is located at the northern edge of N-S trending fold ridges of the Indo-Burman frontal fold belt. Geologically, the fold ridges are made up of Tertiary (Miocene) rocks (Surmas and Tipams) forming alternating anticlinal

Received 12 October, 2006; in final form 10 July, 2007

ridges and synclinal valleys formed due to compressional tectonism suffered by the region (Ganguly, 1993; Das Gupta and Biswas, 2000; Nandy, 2001). Two such anticlinal fold ridges are exposed across the river basin and the Barak River makes deep incision through the ridges.

The Barak River falling in the tropical region of India is characterized by several abandoned meandering loops and exhibits shift and changes in the channel in a particular time span. Morphological changes of such a river channel may be attributed to water discharge rate, sediment load and gradient (Lane, 1957; Leopold and Wolman, 1957; Schumm *et al.*, 2000). Modification in river valley and its gradient might occur due to the tectonic activity. Developments of local meanders, any anomalous curve or turns, anomalous ponds, marshes or alluvial fills are possible indicators of tectonic acitivity (Tator, 1958; Lattman, 1959). If there is any domal or anticlinal uplift across a meandering river then the increase in river sinuosity occurs on the downstream side of the valley floor whereas on the upstream side straightening of channel is expected to occur (Ouchi, 1985). In a case study of Vishwamitri River in Gujarat (India), Raj *et al.* (2004) suggest eastward migration due to eastward tilting of land. Further, migration of the river might be caused by extensive lateral erosion, cutting the river bank on the convex side. Lateral cutting of river banks cause intersection of two opposite river parts and forming a detached loop forming an oxbow lake feature. Oxbow lake formation is due to either neck-cut-off or chute cut-off. The neck-cut-off occurs when the closest part of a meandering loop becomes closer forming a neck shape and finally intersects with the upstream side detaching the loop. Whereas, the chute cut-off occurs due to abrupt formation of channel connecting the closest part of the meandering loop due to locally increased gradient and velocity in the cut-off area. Cut-offs and ox-bow lakes are some of classic feature of meandering rivers and are recognized by fundamental components of flood plain of mobile rivers (Hooke, 1995).

Satellite image of the Barak River basin depicts the river flow pattern through various landforms very prominently (Fig. 1). The river flows from west to east in meandering path over the plains initially and then through very low altitude folds ridges towards west central. Fold ridges trend north-northeasterly with slight westward curvature. It may be observed that the river has to cross twice the fold ridges during its flow through the study area. The region shows presence of several water bodies marked by dark tone and closed boundary on the image.

The river appears to have changed its course at several places through space and time. Changes in its course have been detected prominently at four different places, which have been studied in details. These four different places of the river channel marked as Blocks 1, 2, 3 and 4 (Fig. 1). The whole length of the river in study area exhibits changes, but these four blocks were selected as the changes in the river channel could be detected in the available data set from 1955 to 1999 spreading over time span of 44 years. In order to work out the nature and amount of shift of the river channel, data of 6 different years have been considered. These data sets belong to the Toposheets of 1955 (1:250,000), 1972 (1:50,000), digital satellite data of Landsat MSS of 1975, TM of 1988, ETM+ of 1999 and Indian Remote Sensing satellite data LISS II of 1991. Methodology adopted in this study was to select the suitable data first and identification of the different blocks (areas of interest) showing significant changes in the river channel. The data sets were georeferenced on the basis of available geographical coordinate information which made the data comparable at the same scale for the analysis purpose. Several subsets (2 for toposheets and 4 for images) having same area coverage were prepared for each four blocks using image processing software (ERDAS Imagine 9.0). For the interpretation purpose morphological maps were prepared and the river banks from each data set have been digitized in GIS (ArcGIS 9.1) environment Some Ground Control Points (GCPs) were plotted to measure the distance of the river channel in order to quantify the shift of the different parts of the river channel in the selected blocks.

Different Blocks of the Barak River

Block 1: This block occurs in the eastern most part of the study area wherein the river flows from west to east making a large northward curvature with two abandoned meandering loops (Fig. 1). The position of larger abandoned loop (on the south) with respect to the present river channel, indicate large-scale northward shift in the river course. However, shift in the river channel could also be detected in the present data set through different times i.e. from 1955 through to 1999. Figures 2 a-f show the Toposheets of 1955, 1972, Landsat MSS of 1975, TM of 1988, IRS LISS II of 1991, ETM+ PAN of 1999, along with geomorphological interpretations (Fig. 2g) and channel overlays of different years (Fig. 2h).

The geomorphological features of this part are mainly vegetation (arranged linearly with very coarse texture), barren land, abandoned loops and striation marks (Fig. 2g). Linearly arranged vegetation located far off from the river bank and abandoned river loops indicate position of the past

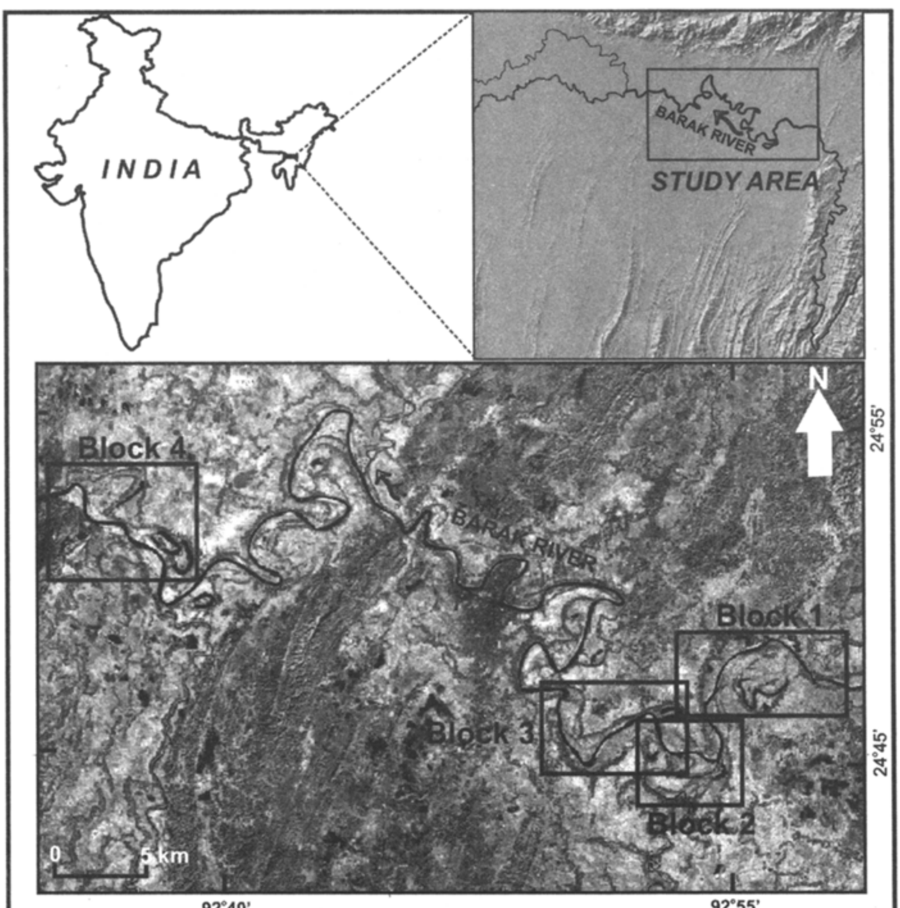

Fig. 1. The study area showing part of the Barak River and investigated blocks 1,2,3 and 4 are shown by boxes

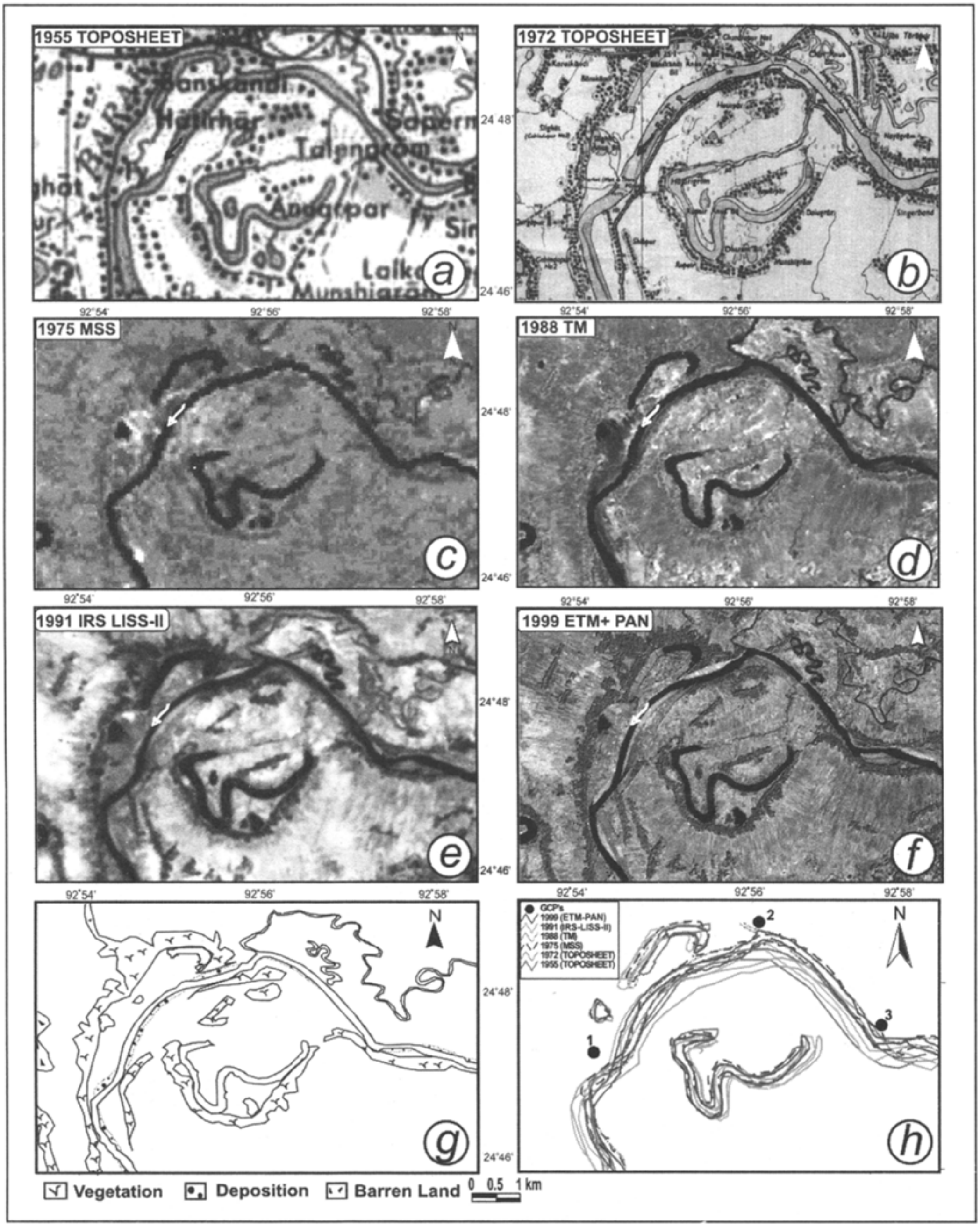

Fig. 2. Block 1 of the Barak River through different times. a) Toposheet (1:250,000) of 1955, b) Toposheet (1:50,000) of 1972, c) Landsat MSS satellite image of 1975, d) Landsat TM satellite image of 1988, e) IRS LISS-II image of 1991, f) Landsat ETM+PAN image of 1999, g) geomorphological interpretation map of the block and h) river bank lines of different years derived from a, b, c, d, e and f and ground control points (GCP) 1,2 and 3.

river channel and provides evidence for reconstruction of past position of the channel. Some striation marks are seen on the image, which might have caused due to the water retrieving after the flood. Three GCP's have been selected and plotted to quantify the shift of river channel (Fig. 2h). Distances of the river banks from three GCP's are also shown graphically (Fig. 3).

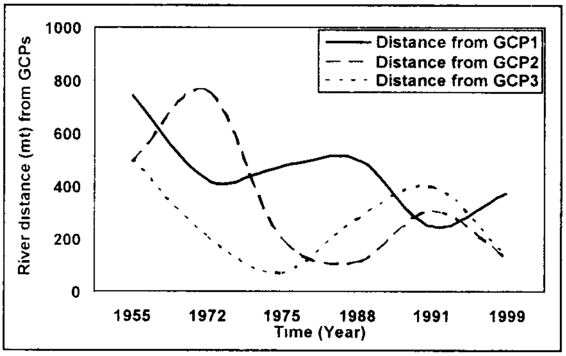

Fig. 3. Graphical representation of measured distances from GCPs to river banks (Block 1)

It may be noticed that the distance of the river bank from GCP1 was maximum in 1955 i.e. 744 meters with a decreasing tendency up to 1999. But, from 1972 to 1988 the distance increased gradually then again decreased considerably in 1991 exhibiting oscillatory nature. Similarly, in the case of GCP2 and GCP3 the distance between the control point and river bank oscillated. Graphical presentation of it also shows oscillatory nature. However, it may be observed that distance between GCP2 and the river in 1988 and that between GCP3 and the river in 1975 has drastically reduced indicating strong river shift towards GCP i.e. northward. Moreover, from characteristics and ground signatures in respect of abandoned loop and vegetation pattern available on satellite images it may be interpreted that the river has migrated northward in this loop for a considerable distance leaving behind the large meandering loop.

Block 2: The second block is the adjacent one of first block and lies just southwest in the downstream direction (Fig. 1). It may be observed that at this place the river makes a huge meandering loop (Fig. 4) which was later abandoned due to neck cut off as can be seen on the image of 1999. Now the river flows through considerably shortened course. Cut off of meandering loop has occurred sometime in between 1991 and 1999 (Fig. 4f). Before 1991 there was no oxbow lake as evidenced by the toposheets and images. Figures 4 a-f show the Toposheets of 1955, 1972, Landsat MSS of 1975, TM of 1988, IRS LISS II of 1991, ETM+ PAN of 1999 along with geomorphological interpretations (Fig. 4g) and channel overlays of different years (Fig. 4h).

In this block specific arrangement of vegetation, depositional and erosional sites and abandoned loops are the main geomorphological features. The dense vegetation area almost follows the trend of the river channel (present and past) as displayed by the images. This information could be used to verify the migration trend of the part A of the river as discussed below.

It may be noticed that two parts marked as A, A' and B, B' (Fig. 4d) moved very close to each other, but with faster rates at the A-A'. Presence of linearly arranged vegetation pattern in the area marked by A and west of it indicate that the river was flowing earlier in a wide loop and a river bend (at A and GCP2) has constantly migrated eastward to ultimately making a contact with the other part at A'. Three GCP's are plotted to quantify the shift of river channel (Fig. 4h). Distances of the river banks from GCP1 in different times from 1955 through to 1999 do not show much change. But, from GCP2 the distance of the river has constantly increased from 125m in 1955 to 730m in 1991 and the river bend shifted eastward. In 1999 the river shows neck cut off and therefore, no data on distance. Similarly, in case of GCP3 the distance of the river to GCP increased from 1955 to 1999 at constant rate. Shift of two parts A and A' took place constantly and ultimately made an intersection causing a prominent neck cut off. Graphical presentation of it also shows

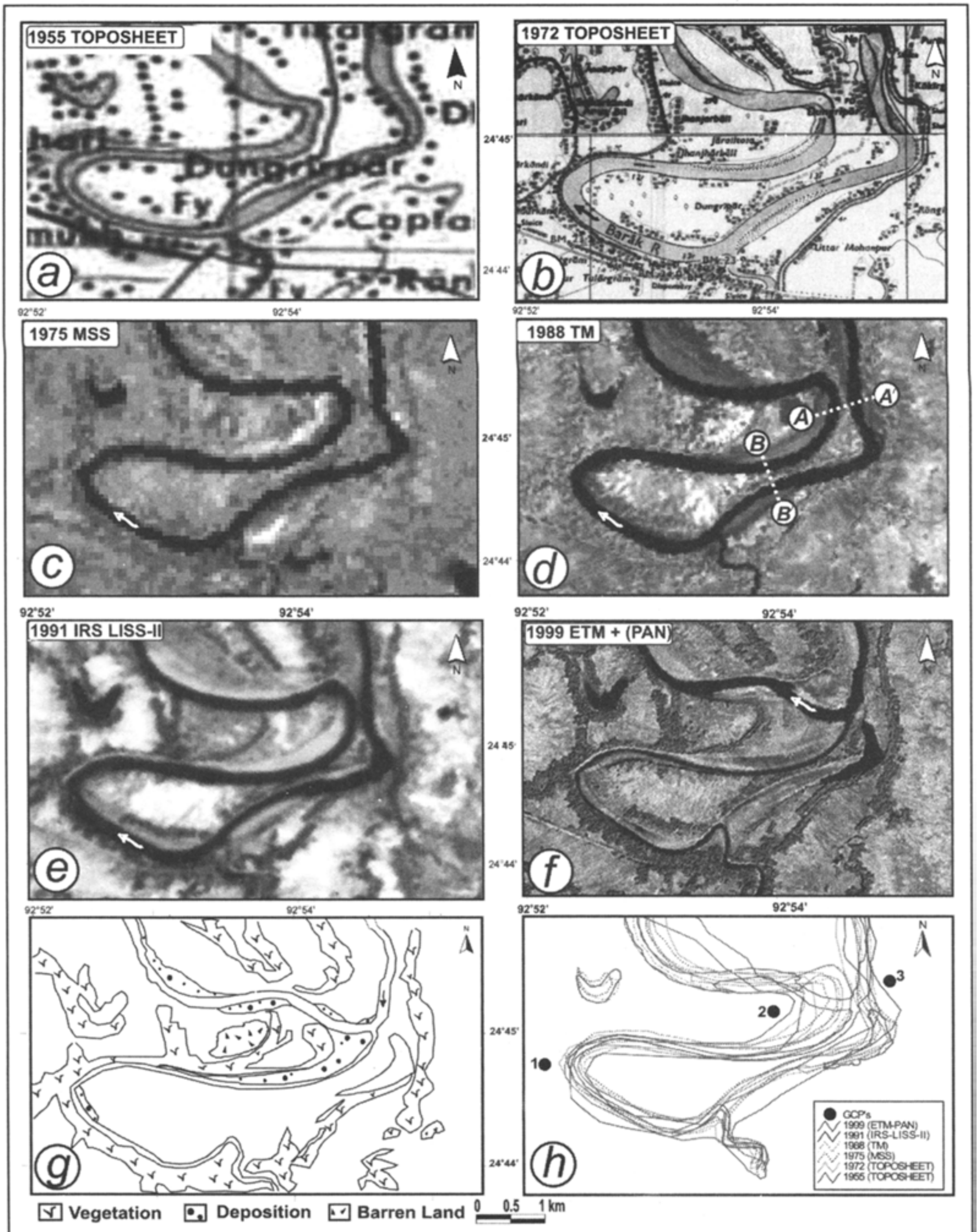

Fig. 4. Block 2 of the Barak River through different times. a) Toposheet (1:250,000) of 1955, b) Toposheet (1:50,000) of 1972, c) Landsat MSS satellite image of 1975, d) Landsat TM satellite image of 1988, e) IRS LISS-II image of 1991, f) Landsat ETM+PAN image of 1999, g) geomorphological interpretation map of the block and h) river bank lines of different years derived from a, b, c, d, e and f and ground control points (GCP) 1,2 and 3.

unidirectional constant increase of distances from GCPs 2 and 3 (Fig. 5).

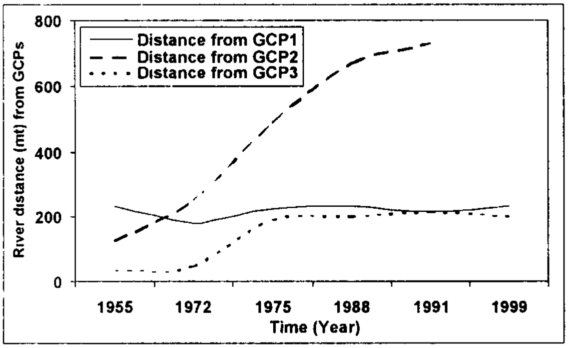

Fig. 5. Graphical representation of measured distances from GCPs to river banks (Block 2)

Block 3: At this place, the river flows making a northward and southward angular notch. Toposheets and satellite images show that substantial changes of the channel have occurred through times. The river channel exhibits a U-loop and a rounded loop at the eastern and western sides respectively as shown by the toposheet of 1955. The U-loop has become abandoned loop before 1972 itself as displayed on toposheet of 1972 whereas, the western rounded bend changed into a U-loop. The southern bend of the channel has become angular gradually from 1955 through to 1999. Maximum sharpness of the bend occurred between the years 1955 to 1999. Figures 6a-f show the toposheet of 1955, 1972, Landsat MSS of 1975, TM of 1988, ETM+ of 1999, IRS LISS II of 1991 along with geomorphological interpretation (Fig. 6g) and channel overlays of different years (Fig. 6h).

In this block the river forms wide flood plains and characterized by angular flow. The vegetation is seen to be arranged in a linear fashion away from the present river channel. There is also an oxbow lake in the north-eastern part of this block and the wide flood plain is marked by striation marks. Geomorphological features like abandoned loops, bank line and vegetation provide information on wide flood plain and earlier path of channel flow.

Three GCP's are plotted to quantify the shift of river channel (Fig. 6h). Measurements of distance of river bank from three GCP's indicate that the western sharp bend of the river became closer to the GCP1 indicating westward shift. At the location of GCP2 the river shows southward shift as the distance between GCP and river has gradually decreased. Whereas, in the case of GCP3 the distance has increased through time indicating westward shift. In general, the river channel exhibits wide flood plain. From graphical presentation (Fig. 7) river bank distances from GCP's through different years clearly indicate gradual closeness of river towards the GCP1 and GCP2 and gradual increase in distance of river from GCP3.

Block 4: This is the westernmost block of the study area considered for detailed investigation. At this place the river flows from southeast to northwest almost in a linear path with northward angular flow. Several abandoned loops are present in this area both on the northern and southern side. One loop out of two adjacent northern loops has been formed during the 17 years span between 1955 and 1972 as evidenced by the toposheets. However, it appears that the initial part of the river in this loop had intense meandering course through the southern and northern area of the present channel. Figures 8 a-f show the toposheet of 1955, 1972, Landsat MSS of 1975, TM of 1988, ETM+ of 1999, IRS LISS II of 1991 along with geomorphological interpretation (Fig. 8g) and channel overlays of different years (Fig. 8h).

Geomorphologically, a fold ridge and several meandering loops mark this block. The ridge has very low altitude on the northern side of the river. In the ridge area the river makes deep incision to attain the gradient. Presently, the wide flood plain can be seen to have formed and the main channel has almost linear course. Occurrence of abandoned loops and linear vegetation indicates that the river has migrated for considerable distance and shifted its channel by abandoning meandering loops.

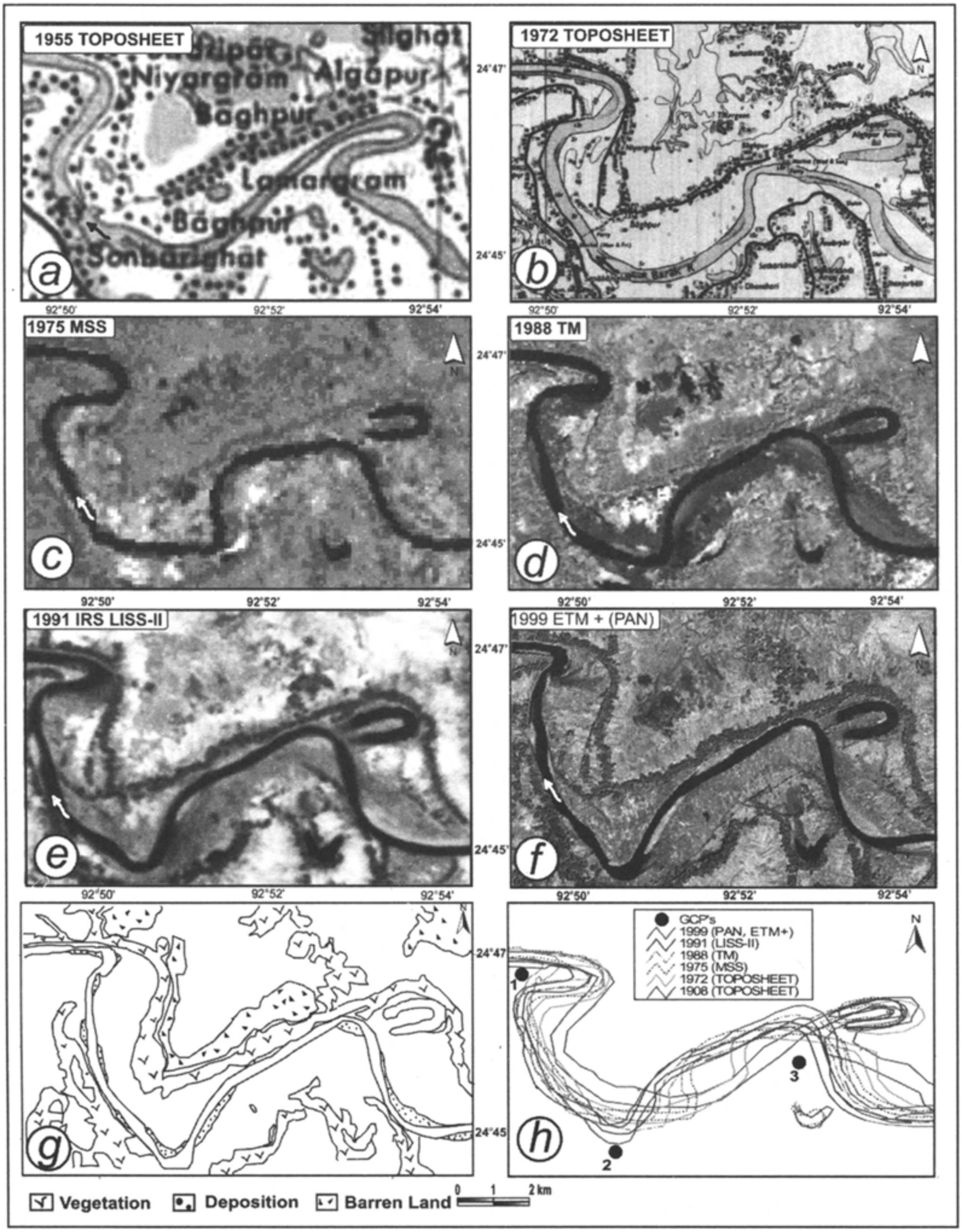

Fig. 6. Block 3 of the Barak River through different times. a) Toposheet (1:250,000) of 1955, b) Toposheet (1:50,000) of 1972, c) Landsat MSS satellite image of 1975, d) Landsat TM satellite image of 1988, e) IRS LISS-II image of 1991, f) Landsat ETM+PAN image of 1999, g) geomorphological interpretation map of the block and h) river bank lines of different years derived from a, b, c, d, e and f and ground control points (GCP) 1,2 and 3.

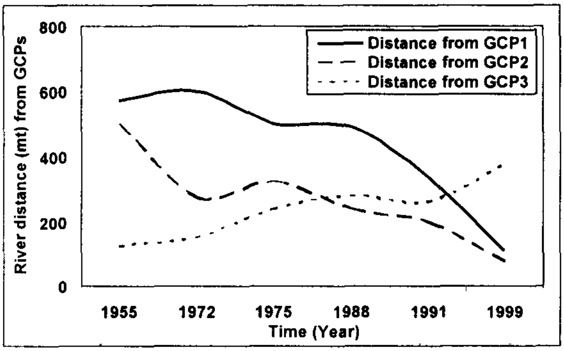

Fig. 7. Graphical representation of measured distances from GCPs to river banks (Block 3)

Three GCPs are plotted to quantify the shift of river channel (Fig. 8h). Distance of the river bank from GCP1 has decreased till 1988 then increased in 1991 and again decreased in 1999. In case of GCP2 the trend is similar to the former case. Whereas, the distances of the river banks from GCP3 first increased and then decreased in 1988. Again it may be seen that there is increase in distance of the river bank from GCP3 in 1991 before decreasing in 1999. Graphical plot of the data also reflect such oscillatory change in the river course (Fig. 9).

Results and Discussion

The topographic and remote sensing data covering part of the Barak River valley have provided significant information on the nature of river channel and geomorphological features. The data shows that the Barak River has undergone substantial changes of its channel position at several places in the study area as shown in Fig. 10. Abandoned loops are present at several places and at places these loops can be seen on both sides of the river. Further, linear arrangement of vegetation growing naturally following the river banks is identifiable on the satellite images. This vegetation pattern now exists away from the present river course as can be seen on Figs. 2,4,6,8 and 10. Correlating the river position with respect to abandoned loops and vegetation pattern, the river channel shift directions, indicated by the arrow marks, in Fig. 10 could be deciphered.

The Barak River shows strong northward shift at three places i.e. in blocks 1, 2 and west of Silchar. Northward shift in the eastern most part of the study area is actively taking place as a loop that existed on the south and has been abandoned recently. In block 1, the river shifted northward for considerable distance and even the tributary stream on the north also show northward shift. In this area shift is occurring northward even though there exists an area of depression towards south. Intensity of meandering has considerably been reduced in the initial part i.e. in block 1 and 2 and the river shows tendency to straighten up. These changes and continued northward shift of the river in this part is probably induced by northward tilt of the alluvial basin. Earthquakes occurring in this region might cause tilting of the area as recently in 1984 an earthquake of magnitude 5.5 had occurred in this area as shown in the Fig. 10.

In the area west of Silchar, the river used to flow making a southward loop on the eastern side of a fold ridge. And now the river flows further north abandoning loops as indicated by the two ox-bow lakes. Although, a depressed area also exist towards south as in the case of block 1 it is important to note that the river had to shift northward to find a suitable gradient. Then the river makes a long northwestward journey but takes a sharp southward turn again to flow meanderingly to the western side of the above fold ridge and at this place the river now shows westward shift. This nature of river shift might happen if a fold grows due to tectonic activities. In Block 4 the river has attained a considerably linear course after shifting towards south and as well as north. But, again a prominent northward shift has occurred just before anabranching of the Barak River. In view of above it is inferred that there had been overall northward shift that suffered by the Barak River, which could be correlated to the uplift of the southern part of the river valley.

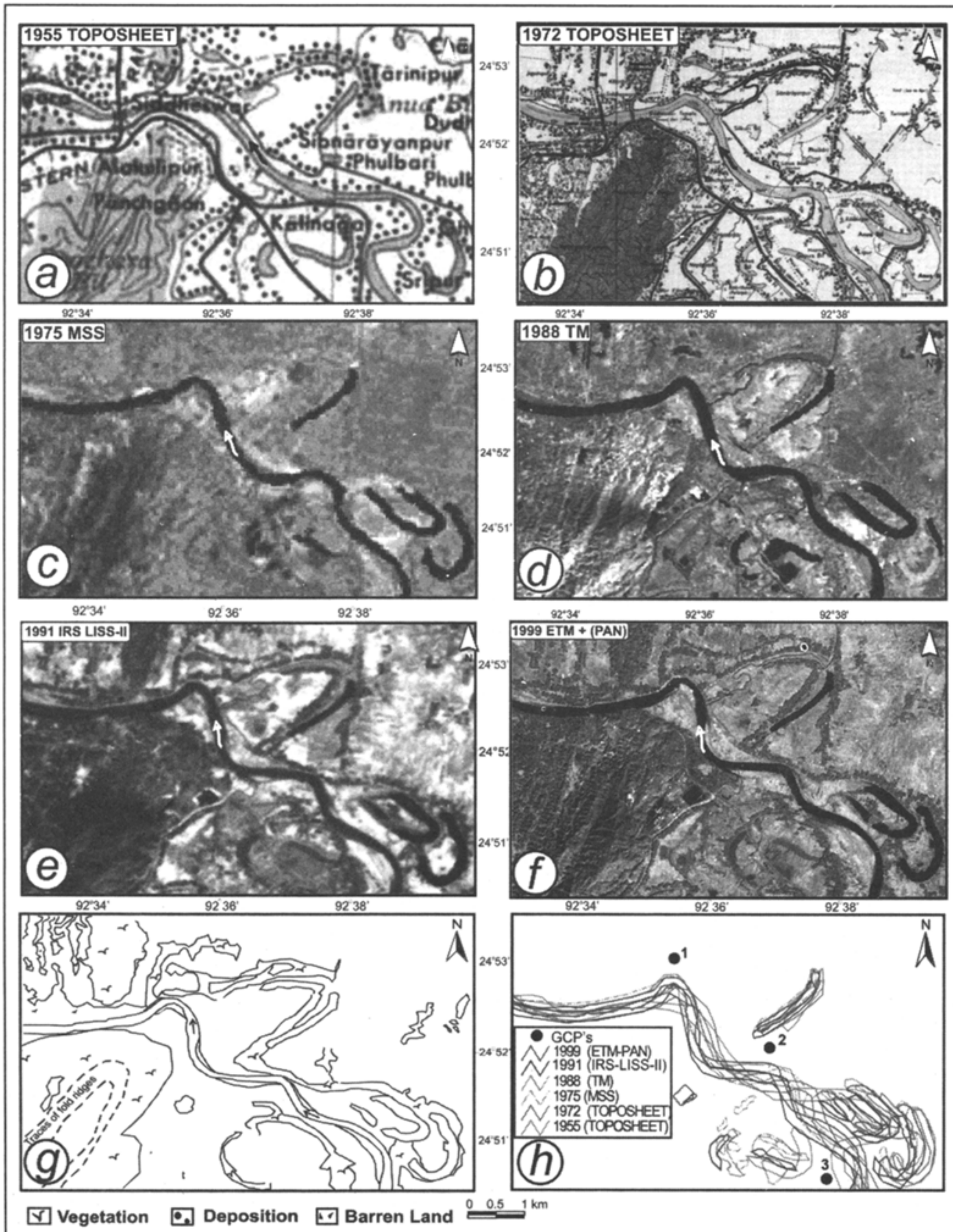

Fig. 8. Block 4 of the Barak River through different times. a) Toposheet (1:250,000) of 1955, b) Toposheet (1:50,000) of 1972, c) Landsat MSS satellite image of 1975, d) Landsat TM satellite image of 1988, e) IRS LISS-II image of 1991, f) Landsat ETM+PAN image of 1999, g) geomorphological interpretation map of the block and h) river bank lines of different years derived from a, b, c, d, e and f and ground control points (GCP) 1,2 and 3.

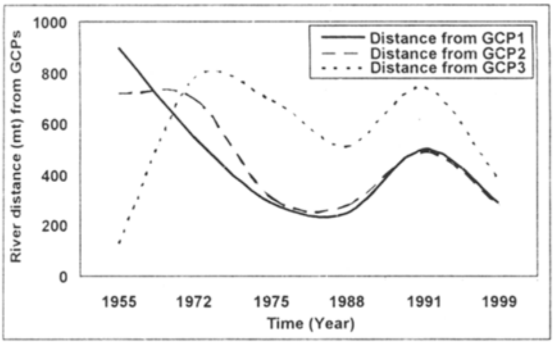

Fig. 9. Graphical representation of measured distances from GCPs to river banks (Block 4)

- At several places the river has abandoned its loops after the occurrence of cut-offs. The shape and extent of loops are well preserved on the ground to be picked up very prominently by the satellite images.
- Past position of the river channel and the trend of river channel shift could be ascertained based on position of abandoned loops and linearly arranged vegetation. In the initial part of the study area the river shows very strong and distinct northward shift and the recent shifting has been indicated by the latest abandoning of a southern loop (in block 2)

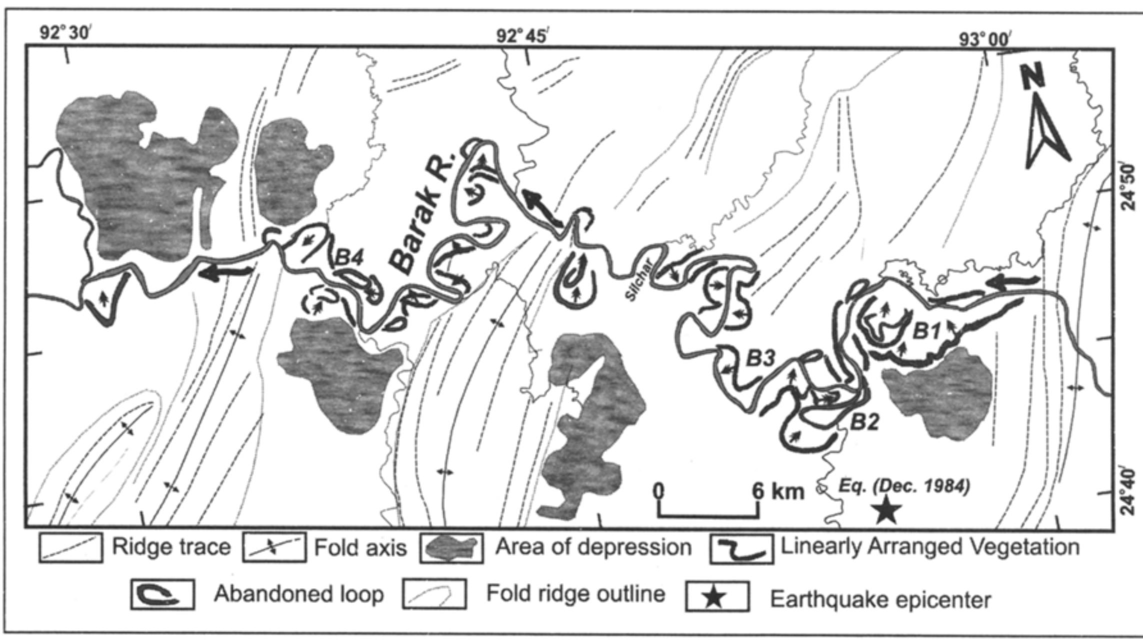

Fig. 10. Geomorphological map of the Barak River valley in the study area showing the river channel, abandoned loops, linearly arranged vegetation, area of depressions, fold ridges and their axes. B1, B2, B3 and B4 are the block locations as shown in figure 1. Arrows show the trend of river shift. ★Earthquake (30.12.1984, 5.5 Mb) epicenter.

Conclusion

- The meandering Barak River flowing in a single channel exhibits several changes through time and space as detected by the temporal topographic information and remote sensing data.

through the neck cut-off process. Shifting of the river channel in different blocks could be quantified with reference to some ground control points using GIS technique.

- The intensely meandering Barak River exhibits abandonment of several loops and overall northward shift. The river course has been straightened up considerably at some places leaving the highly meandered path. These changes appear to be attributed to northward tilting of the alluvium possibly caused by tectonic movement in the river basin as indicated by the occurrence of earthquake (5.5 Mb) of 1984 and seismic activities in the Indo-Burman fold belt.

- Consequent upon the frequent river bank cutting and loop abandoning, the habitation and agricultural practices are affected resulting in loss of soils. These effects may be controlled by efficient and proper planning of settlement and by constructing protection structures (earthen dams) at some selected places to protect river bank erosions.

Acknowledgement

The study is outcome of the research project funded by DST, New Delhi. Landsat satellite data (MSS, TM and ETM) are obtained from Global Land Cover Facilities, USA.

References

Das Gupta, A.B. and Biswas, A.K. (2000). *Geology of Assam* Geological Society of India, Bangalore, 169p.

Ganguly, S. (1993). Stratigraphy, sedimentation and hydrocarbon prospects of Tertiary succession of Tripura and Cacher, *Indian Journal of Geology*, **65**: 145-180.

Hooke, J.M. (1995). River channel adjustment to meander cutoffs on the River Bollin and River Dane, northwest England. *Geomorphology*, **14**: 235-253.

Lane, E.W. (1957). A study of the shape of channels formed by natural streams flowing in erodible material. U.S. Army Corps of Engineers, Missouri River Division, Sediment Series 9.

Lattman, L.H. (1959). Geomorphology: new tool for finding oil. *Oil Gas J.*, **57**: 231-236.

Leopold, L.B. and Wolman, M.G. (1957). River channel patterns; braided, meandering, and straight. U.S. Geol. Surv. Prof. Paper 282-B.

Nandy, D.R. (2001). *Geodynamics of northeastern India and the adjoining region*. ACB Publications, Kolkata, 209p.

Ouchi, S. (1985). Response of alluvial rivers to slow active tectonic movement. *Geological Society of America Bulletin*, **96**: 504-515.

Raj, R., Mulchandani, N., Bhandari, S., Maurya, D.M. and Chamyal, L.S. (2004). Channel shifting of a highly sinuous meandering river in alluvial plain, Vishwamitri river, Mainland Gujarat. *Current Science*, **86**: 1647-1653.

Schumm, S.A., Dumont, J.F. and Holbrook, J.M. (2000). *Active Tectonics and Alluvial Rivers*. Cambridge University Press, USA, 276p.

Tator, B.A. (1958). The aerial photograph and applied geomorphology. *Photogrametric Engg.*, **24**: 549-561.