Chapter 1

INTRODUCTION

Since time immemorial, many people in the world have depended on mighty rivers for their livelihood. However, these same rivers have been migrating, and thus, sweeping and ultimately removing agricultural land and cities in their path. River morphology changes with time and is affected by river discharge, velocity, sediment load, sediment characteristics and the composition of bed and bank material apart from varied geological controls. Prediction of when and where future erosion will occur and the extent of such erosion are very uncertain because of the many interacting factors involved.

A river is in a state of equilibrium if the discharge, sediment load, sediment size and slopes are delicately balanced such that there is no change in bed elevation in a given reach over a long period of time. A change in any of these controlling variables or the imposition of an artificial change by the construction of structures along or across the stream will disturb its equilibrium and the stream then aggrades or degrades. This process of aggradation or degradation may continue for a long time till a new equilibrium is established. In their natural condition rivers seldom reach a state of equilibrium, even over short reaches. Each river is different and every reach of a stream is different from almost all other reaches of the same stream. Meandering is one of the means through which rivers tend towards the so called dynamic or quasi-equilibrium state. River training and the construction of training works are also designed to achieve a proper equilibrium. The more the planned channel pattern, channel geometry, slope conditions, etc., correspond to the natural conditions of the river in question, the better will the river accept the new artificial state.

The proper understanding of meander development and channel pattern changes of alluvial rivers is of vital importance for citing varied river valley development and water hazard control structures in the backdrop of proliferation of human settlements in the flood plains. The practical reasons for studying river pattern change are wide and varying (Lewin, 1977). These include, firstly, an awareness that human activity in the vicinity of river channels has unfortunately proceeded in ignorance of the pattern changes that may be expected (Kondrat'yev, 1968), and that this ought to be corrected. Secondly, channel pattern change is one of the more rapid forms of geomorphological change, with developing forms and patterns of erosion and sedimentation that should be incorporated more fully into a general understanding of fluvial geomorphic systems. Thirdly, pattern changes involve the reworking of floodplain environments, and the soils, sedimentation, and morphological patterns that result, are of very broad concern (Allen, 1971; Burkham, 1972; Davies and Lewin, 1974; Lewin and Manton, 1975; Ruhe, 1975).

The manner in which rivers change the form and pattern of their channels has been a recurring theme in river studies for many years. Many workers have carried out studies on channel changes (Dury, 1977; Knight, 1975; Hickin and Nanson, 1975; Lewin and Hughes, 1976) and the field has been reviewed by Gregory (1977, 1979, 1983). River migration or river changes are taken to include any change in river channel geometry within the context of the cross section, the pattern or network of a drainage basin (Gregory, 1977). Planform analysis helps us to understand one of these, the changes in channel pattern in both time and space. Planform properties of meandering rivers include not only the geometry and sinuosity of the meandering course, but other properties such as variability of width and development of bars (Brice, 1984). Planform and planform changes are not independent of other aspects of river geometry, and together with these other aspects they deserve to be considered in relation to the hydraulics of channels with loose boundaries.

The Ganga river is one of the most important rivers in the Indian subcontinent. It has numerous large and small tributaries, of which the important ones are the Yamuna, the Gandak, the Kosi and the Mahananda. Together they comprise the Ganga basin which covers the States of Uttar Pradesh, Bihar, West Bengal and parts of Haryana, Rajasthan, Madhya Pradesh and the Union territory of Delhi. The total length of the river Ganga is 2,506 km and its catchment area is 10,73,070 km^2. The normal annual rainfall of this region varies from about 600 mm to 1900 mm of which more than 80 percent occurs during the South-West monsoon. The flooding and erosion problems are serious in Uttar Pradesh, Bihar and West Bengal. In Bihar, the floods are largely confined to the rivers of North Bihar and are an annual feature. Most of the rivers (e.g. the Burhi Gandak, the Bagmati, the Kamla Balan, other small rivers of the Adhwara group, the Kosi in the lower reaches and the Mahananda at the eastern end) spill over their banks causing considerable damage to crops and dislocating traffic. High floods occur in the Ganga occasionally causing considerable inundation of the marginal areas in Bihar.

The middle Ganga basin in Bihar is especially prone to river migration. For this reason, the river Ganga from Ara to Patna in the middle Ganga basin in Bihar was selected for river migration studies. In this stretch, the river changes its course considerably in magnitude as well as direction depending upon the discharge in the river. The banks on either sides of the river are almost flat and of alluvial soil formation. This makes the land very fertile. In absence of any industrial developments in the nearby area and it being one of the densely populated regions of the country, the pressure on land for sustaining life is very high.

Conventional measurements of planform characteristics of meandering rivers are a time consuming, laborious and expensive procedure. Their main disadvantage however is that they provide information only at a particular point and instant of time. On the other hand, remote sensing techniques are capable of providing information through time and space which can never be appreciated from the ground. Further, the migratory rivers invariably leave their footprints behind. These include meander scars, abandoned channels, oxbow lakes and natural levees, thus giving clues as to where and how the river migrated. However, because of the large size of these features, they cannot always be recognized in the field. Aerial photographs and satellite sensor images can provide an extremely powerful means of detecting these clues for the delineation and reconstruction of the river courses (Baker, 1986).

Satellite remote sensing presents an expedient, reliable and cost effective alternative method for demarcation of rivers at suitable time-space intervals to establish the stability or otherwise of their channels. Advantages of the information acquired by satellite remote sensing are of synoptic coverage and repetivity. Because of the repetitive nature of satellite coverage, space borne observations are particularly suited for monitoring dynamic changes in surface parameters in remote areas or areas that are difficult to access. Various satellites having sensors which operate both in the optical as well as in microwave region of Electro Magnetic Spectrum at different spatial resolutions (Table 1) can be used for obtaining valuable information on planform characteristics of river courses.

Table 1: Details of various satellites and sensors for monitoring and mapping of planform characteristics of rivers

Optical/ Microwave	Satellite	Sensor	Spatial resolution in metres	Revisit period in days
Optical	IRS-1B	LISS-I LISS-II	73 36.5	22 22
	IRS-1C	LISS-III WiFS PAN	23.5 188 5.8	24 5 24
	IRS-1D	LISS-III WiFS PAN	23.5 188 5.8	25 5 24
	IRS-P3	WiFS	188	5
	LANDSAT-4,5	TM	30	16
Microwave	ERS 1,2	C Band	30	16-18
	RADARSAT*	C Band System	100 (ScanSAR wide)	3 (at mid-latitudes)

*** Different resolution at different beam modes**

Availability of cloud free data from optical sensors during the monsoon season is a major constraint because of adverse cloud conditions. Hence, microwave data from ERS and RADARSAT, which have got cloud penetration capability, can be effectively used for monitoring and mapping of river courses during monsoon season. A number of studies on channel behavior and channel migration have been carried out in the Ganga and Brahmaputra basins by different investigators using satellite remote sensing data (Jain and Bhattacharya, 1979; Agarwal and Mishra, 1987; Philip et al., 1989; Jain and Ahmad, 1993; Nagarajan et al. 1993; Bardhan, 1993; Bhagawati, 1993; Chakrabarti, 1998; Chakravorty, 1998; Agrawal et al., 2001; Oak et al., 2001).

In the present study, the shifting course of river Ganga between Ara to Patna was evaluated using satellite remote sensing data. The shifting course of river Ganga from the year 1974-76 (SOI toposheet) to 1989 (IRS-1A LISS-II data), 1989 (IRS-1A LISS-II data) to 1996 (IRS-1C LISS-III data) and 1996 (IRS-1C LISS-III data) to 2000 (IRS-1C LISS-III data) was studied. Based on this analysis, the critical locations along the Ganga river course from Ara to Patna where shifting has occurred were identified. In order to study the extent of erosion and the population affected in the identified critical locations, detailed study was carried out using IRS-1C PAN data, having a spatial resolution of 5.8 m, for the years 1996 and 2000 along with SOI toposheet of the scale of 1:50,000 for the year 1974-76. The places/townships which have been affected/washed away and those that are likely to be affected in the near future were identified. These analyses were supplemented using merged IRS-1C LISS-III and PAN data for the year 2000. Further, the shifting pattern of the river Ganga has been studied in detail at the identified critical locations using the data pertaining to the years 1974-76, 1989, 1996, 1998 and 2000. The magnitude of the year wise shifts (km) and the rate of shifting (km/year) have been evaluated for each of the identified critical locations.