Chapter 20
Floodplain Management in Rapti River Basin

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Abstract Floodplains are resources of immense value. They are the lowland adjoining the channels of rivers, streams, and other watercourses or the shorelines of oceans, lakes, or other bodies of standing water. The common framework for floodplain management comprises four general types of activities: modifying flooding, modifying susceptibility to flooding, modifying the impact of flooding, and preserving the natural and beneficial functions of floodplains. Given this overview, this chapter is a study of the floodplain management issues of Rapti River, flowing through eastern Uttar Pradesh. Regular floods in general and unprecedented floods in known pockets are common features of the Rapti River Basin. The study suggests the utilization of performance indicators to evaluate the progress and success of floodplain management programs. A decentralized resource allocation at the local level with standardization of terminology, collection of appropriate data concerning the socioeconomic profile of the flood-prone community, and flood behavior is necessary for efficient flood management.

Keywords Flood plains • Flood plain management • Rapti river basin • Planning • Uttar Pradesh (India)

20.1 Introduction

Floodplains are resources of immense value. Since the beginning of civilization, floodplains have been favored locations for living. The rivers provide flat and fertile land for crops, abundant underground as well as surface water, a natural site for defense, and easy routes for trade and communication. Thus, intensive use of floodplains is a common development strategy often chosen by society. Many important

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cities in Asia, Europe, and America have been established on the floodplains. Delhi, Varanasi, Allahabad, Kolkata, Chennai, and Cuttack are a few examples in India. The intensive use of floodplains for commercial and residential purposes has undoubtedly contributed to the economic success and sustainability of larger parts of India. However, increasing population pressure along with encroachment of marginal floodplains is now putting those residential and commercial activities at severe risk of flood damage. Major floodplains along the Rivers Ganga, Yamuna, Brahmaputra, and their tributaries in the north and notable peninsular rivers in the south are known for their productive and carrying capacity. They have also their distinct history of flooding and accompanying human misery in terms of loss of lives and property. Despite all these drawbacks, modern society places extreme demand on those resources. As a result there is a growing debate among policy makers, planners, and researchers that floods and floodplains now need to be managed because the floodplains are areas of primary environmental significance and their well-being is essential to the survival of many ecosystems.

20.2 Flooding and Floodplains

Floodplains are the lowlands adjoining the channels of rivers, streams, and other watercourses or the shorelines of oceans, lakes, or other bodies of standing water. These are lands that have been or may be inundated by flood water. Floodplains develop on the lower course of the rivers. From time to time excess rainfall or snow-melt cause rivers to overflow their banks and reclaim the floodplains. It is an integral part of the river system, even though the river uses it occasionally to pass down flood flows. Floods are critical factors in the health of the floodplain itself. Whenever the floodplain is free from floodwater, it is beneficially used as a part of the land system for diverse economic activities.

Depending upon the objective of the study, floodplains may be defined and mapped in different ways. Geomorphologists define floodplains as an area inundated by flood events of a particular magnitude and frequencies; to planners and lawyers, it may be an area defined by statute. From the aspect of risk assessment and hazard problems, floodplains often are categorized and termed as floodways, flood fringe, probable maximum flood-prone area (PMF), and defined flood area (DFA) by disaster managers. A particularly useful distinction on many floodplains from the point of view of hazard problems is that between the floodway and the floodway fringe. The floodway is the area of the floodplain, usually marginal to the main channel, in which land filling or flow concentration as a result of construction would significantly increase flood level. The floodway fringe area lies adjacent to the floodway and is where water is stored during flood. The distinction is formally recognized by the U.S. Army Corps of Engineers and other agencies in the United States (U.S.) for flood zoning purposes (Fig. 20.1). Similarly, the best practice principles and guidelines of floodplain management in Australia define floodplains in terms of the probable maximum flood (PMF). The area defined by a PMF event

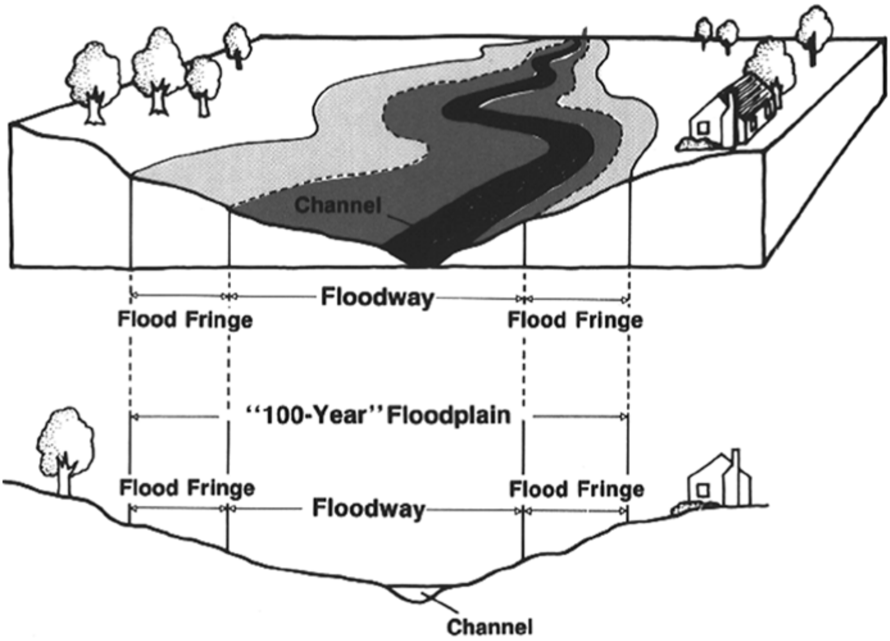

Fig. 20.1 The floodplain with floodway (From FEMA 1992, p. 8)

is flood prone. Land outside the PMF is truly flood free. However, for practical feasibility it is allocated for defined flood events on which planning and development controls are based (Fig. 20.1).

20.3 Floodplain Management

Parker (2000) and Smith (2013) have given a brief description of the hazard paradigm. For much of the twentieth century, floods and other hazards were primarily viewed as natural phenomena. This approach usually focuses upon the physical agents in the natural and human-modified environment that pose a threat to society. It is an agent-specific approach through which we view "the environment as hazard" (Burton et al. 1978). Here storm, precipitation, and runoff processes that generate a flood become the principal focus of attention. This approach has been increasingly criticized during the latter part of the twentieth century and another approach has evolved in opposition to the dominant hazard paradigm. The main competing approach focuses on flood hazard as a social phenomena. This approach is based upon the view that social, economic, and political conditions, and the variable quality of material life, are overwhelmingly important in the incidence and distribution of damage in disasters, including flood disasters (Parker 2000, p. 10). Thus, flood disasters are viewed not as natural phenomena but as being produced by society. Central to this social agent approach is the concept of vulnerability. This approach was reinforced by the works of Hewitt (1983) and Watts (1983). Different studies show that social agents may generate vulnerability to flood disasters in various forms: through physical exposure to floods as a result of occupying floodplains; through living in a dwelling having little resistance to flood; or through weaknesses that come with gender, age, health, etc. A third approach, known as the environmental approach to flood hazards and disasters, builds upon both of these approaches. The environmental approach is based on the view that both social and physical environments influence the creation of flood hazards and disasters.

Based upon these approaches, the common framework within which floodplain management operates comprises four general types of activities: modifying flooding, modifying susceptibility to flooding, modifying the impact of flooding, and preserving the natural and beneficial functions of floodplains (Federal Interagency Floodplain Management Task Force 1994).

Modifying flooding refers to structural flood control measures that aim to keep the flood water away from settlements. The purpose of this measure is to control flood water movement to keep it from doing damage to the built environment: this is popularly known as the "levees only" approach, which is still regarded as the dominant form of structural measures. Other forms of "modifying flooding" include dams and reservoirs, floodwalls, channel alteration, and on-site detention ponds.

The second approach, that of modifying susceptibility to flooding, connotes a set of activities designed to keep people and the built environment away from the flood hazard. Commonly known as nonstructural mitigation measures, these include floodplain zoning, detection, and warning, floodproofing, building codes, growth management policies, and community awareness programs through education. Floodplain zoning is a regulatory tool used to control type and development of land use. Zoning ordinances can prohibit new development that is not suitable for a particular type of land use. It also prohibits the development of critical facilities such as hospitals, schools, and hazardous industries in hazard-prone areas. Flood forecasting and warning systems can also reduce a community's susceptibility to flooding. Given proper warning with adequate time, there are several options that the communities can take to minimize their loss in a flood. Building codes can be designed and apply to ensure that new construction built in hazardous areas is resistant to damage.

The third type of activities that constitute floodplain management are those that modify the impact of flooding on people by sharing the financial losses caused by flood damage. Flood insurance, tax adjustment, and disaster relief are some of the ways in which monetary loss from floods is spread to a much larger population. The fourth set of floodplain management activities are those that seek to preserve the natural and beneficial functions of floodplains from an ecological perspective. The main aims of this approach are to reduce flood losses and to preserve and restore the natural resource and functions of these lands (Federal Interagency Floodplain Management Task Force 1994). It is recognized that floodplains do more than simply provide places to hold excess floodwaters: they can also help maintain groundwater supply and quality, provide fish and wildlife habitat, offer productive agricultural lands, and provide places for recreational uses and open space (Myers and Passerini 2000, p. 245).

20.4 Rapti River Basin

The River Rapti flows in the subhumid to humid monsoon region of the middle Ganga Plain. It is the largest tributary of the River Ghaghara, which in turn is a major constituent of the Ganga. The Rapti River Basin extends from 26°18′00″N to 28°33′06″N and 81°33′00″E to 83°45′06″E and covers an area of 25,793 km^2, of which 44 % (11,380 km^2) lies in Nepal and 58 % (14,413 km^2) in Eastern Uttar Pradesh (Fig. 20.2). The Rapti River flows through the districts of Rukum, Salyan, Rolpa, Gurmi, Arghakhanchi, Dang, and Bank of Nepal territory and the Bahraich, Shrawasti, Balrampur, Siddharthnagar, Santkabirnagar, Gorakhpur, and Deoria districts of Eastern Uttar Pradesh. It rises at an elevation of 3,048 m in the Dregaunra

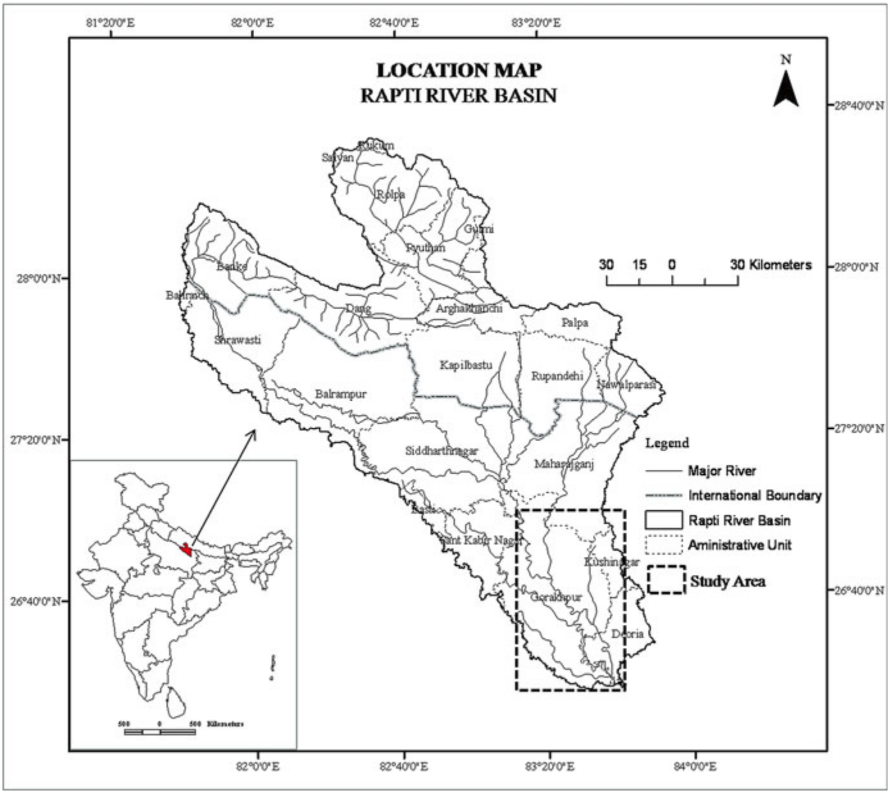

Fig. 20.2 The Rapti River Basin

range of Nepal Siwalik and covers a total distance of 782 km, of which 331 km lies in Nepal, before joining the Ghaghara at Barhaj in Deoria District of Eastern Uttar Pradesh. River Rapti is fed by numerous tributaries and affluent. Those of the northern or left bank originated from Siwalik and the *Bhabar* region; those on the south represent merely old beds of the river. Important left bank tributaries on the Rapti are Burhi Rapti, Ghonghi, Kain, and Rohin. The Bhakla, Ami, and Taraina are the notable right bank tributaries (Fig. 20.2). The basin consists geologically of two distinct portions: structurally it is a segment of the great Indo-Gangetic trough and it has also some marginal portion of the Himalaya's foothills region of the Siwalik. The Indo-Gangetic trough portion consists entirely of the alluvium, a composition of sand, silt, and clay in varying proportions. In respect of their geologic age, these deposits correspond with two main divisions of the quaternary era, the Pleistocene and the Recent. The alluvium is found in two broad groups: the older alluvium known as "*Bhangar*," the age of which is estimated as Middle Pleistocene, and the newer alluvium, *Khadar*, which is more recent and undergoing formation by the aggregational work of the rivers. Recent findings of the chrono-association of the Gandak megafans areas revealed that the alluvia of the Old Rapti Plain (Burhi Rapti) is that of 5,000 years before present (b.p.) and that of Rapti is more than 500 b.p. (Mohindra et al. 1992, p. 651).

The Rapti River Basin can be divided into two sub-catchments, namely, Lower Rapti and Upper Rapti (Central Ground Water Board 1984). Subsequently, both the sub-catchments can be divided into a number of watersheds (Fig. 20.2). The catchment areas of these watersheds vary from as small as 42,000 ha (LB-Ghaghara) to 145,000 ha (Ami) (Table 20.1).

Table 20.1 Watershed divisions of Rapti River Basin

Sub-catchment	Watershed number	Name of stream	Area (thousands of hectares, ha)	District covered
Lower Rapti (C) (682)	C1	LB-Ghaghara	42	Deoria, Saharsa
	C2	Taraina	55	Gorakhpur
	C3	Gaura	144	Gorakhpur, Deoria
	C4	Lower Rapti	123	Gorakhpur, Basti
	C5	Rohin	112	Gorakhpur
	C6	Chillua	91	Gorakhpur
	C7	Ami	145	Gorakhpur
Upper Rapti (D) (732)	D1	Main	63	Basti, Gorakhpur
	D2	Rapti	84	Gonad, Basti, Bahraich
	D3	Bhakla	93	Bahraich
	D4	Ghonghi	103	Basti, Gorakhpur
	D5	Burhi Rapti	88	Basti
	D6	Bhainbar	92	Gonda, Basti
	D7	Pera, Bahuwa	120	Gonad
	D8	Kain, Gholia	90	Bahraich, Gonda

Source: Department of Agriculture and Cooperation (1988): *Watershed Atlas of India*

20.5 Flood Hazards and Risk in the Floodplains of the Rapti River Basin

Regular floods in general and unprecedented floods in known pockets are common features of the Rapti River Basin. Every year, devastating floods leave several lakh hectares of cropland inundated and that many villages were either marooned or washed away. The floods were largely caused by the River Rapti and the Ghaghara besides other minor river systems such as Rohin, Ami, Burhi Rapti, Ghonghi, Kain, Bhakla, and Taraina. Heavy rainfall accompanied with breaching of embankments, man-made breaches to allow the release of excess water at some locations, coupled with main channel migration in some places are the main causes of devastating floods. The recorded history of floods in the basin dates back to the nineteenth century A.D. The available literature on past floods indicates that the basin has witnessed massive floods once or twice in every 50 years (Table 20.2). The basin witnessed the most devastating floods of the twentieth century in the year 1998, which surpassed all the earlier records. Almost all the notable rivers, namely, Rohin, Ami, Gorra, Kuwano, and Rapti, along with Ghaghara, exceeded their maximum flood level at once. The basin witnessed two successive floods in 1998. The first phase started on July 22–July 27/28, 1998. In the second phase, which started on August 20, 1998, the water level continued to increase and reached a peak at 77.54 m, that is, relatively more than 2.50 m from the danger level and 0.70 m more than the previously recorded highest flood level.

In addition to this, the Rivers Rohin, Ami, and Gorra also exceeded their recorded highest flood level. Also, notable small tributaries (called ‘Nala’ in local language) such as Faren Nala, Kalan Nala, Gobrahia Nala, Bar Nala, Taraina Nala, and Pon Nala, and major wetlands (called Tal in local langrage) such as Ramgarh Tal, Bakhira Tal, and Chillua Tal, inundated adjacent villages. Gauge level data revealed that within a period of 60 days the River Rapti showed the maximum number of peak flows and a quick or short response time. Within that time it continued to flow between the danger level and the highest recorded flood level of 1974. Surprisingly, the severity of the flood situation was confined to the lower hydrological regime of the Rapti basin. From the reported loss of life and properties damaged, the worst affected area of the flood was identified as the lower Rapti basin, comprising the districts of Gorakhpur, Deoria, Maharajganj, and Kushinagar; this designation was also verified from the satellite imagery taken during the time of floods. The magnitude of the catastrophe was exceptionally high in Gorakhpur division. The probable causes of the flood were identified as heavy rainfall and embankment failures followed by inadequate relief and rescue operations.

The southwest monsoon is the usual time of high floods in the basin. The general time for the onset of monsoons is June 17 and their retreat is as late as September 25, but sometimes this deviates by 30 days. The rainfall is not uniformly distributed in this period; there may be more than one intensive rainfall period. This period is found sometimes too early and sometimes too late. Therefore, floods in the basin occur as early as the first week of July and as late as the third week of September. The normal flood period is August 15 to September 15, which includes 70–80 % of

Table 20.2 Characteristics of flood hazard in Rapti River Basin

Sl. number	Time period	No. of recorded floods/year	Characteristics
1	1800–1850	2	Severe floods in the years 1823 and 1839
			Maximum damage to Ghaghara-Rapti Doab was caused by floods of 1823
			Floods in the year 1839 were caused by sudden rise in water levels of the Rivers Ghaghara, Rapti, and Ami; Gorakhpur City remained as an island
2	1850–1900	4	Floods of 1873 caused maximum damage to agricultural lands and settlements
		1871, 1873, 1889, 1892	Floods of 1892 recorded maximum inundation and inflicted heavy losses to Gorakhpur urban area
3	1900–1950	11	Flash floods of 1903 caused maximum damage to Rapti-Rohin Doab
		1903, 1906, 1910, 1922, 1924,1925, 1927, 1928, 1929, 1930, 1932	In 1906, the basin experienced the highest flood of the past 50 years
			Maximum inundation and damage were caused by failure of embankments
			Floods caused by continuous and heavy rainfall
			Flood water stagnated for a longer period of time, causing immense difficulty for cattle grazing
			Maximum damage to crops; some villages located on the riverbank totally wiped out
			The basin witnessed continuous floods from 1927 to 1932 in the Ami and Rapti Rivers that inundated kachhar areas of Sadar and Bansgaon Tehsil
4	1950–2000	19	Severe floods in the years 1974 and 1998
		1953, 1954, 1955, 1956, 1957, 1958, 1959, 160, 1961, 1967, 1968, 1970, 1971, 1973, 1974, 1993, 1998, 1999, 2000	Floods of 1974 surpassed early records, where simultaneous rise in water level of major rivers such as Rapti, Rohin, Ami, Mohab, Ghonghi, Bafela, Basmania, Pyas, Dudhi, Chandan, and Burhi Gandak caused flood havoc on the entire part of Eastern Uttar Pradesh
			About 27,913 ha of land was inundated, affecting 1,390 villages
			Total flood-affected population was estimated to be 631,045
			About 17 embankments were breached
			The floods of 1998 were caused by heavy rainfall in July (910.045 mm) and August (949.100 mm)
			Two peaks witnessed: first phase of flood inundation recorded July 22, 1998 and second phase August 20, 1998
			Embankments failed to withstand water pressure and breached at 20 sites, thereby affecting 1,414,790 of the populations of 1,594 villages in Gorakhpur district
			Total flood-inundated areas of 171,316 ha of which 92,804 ha was net sown area

the total flood frequency. The early flood frequency is 15 % and the late flood frequency is only 5 % of the total annual frequency (Yadav 1999, p. 47).

The Rapti brings down with it an immense quantity of silt that has gradually raised its bed at places above the level of the surrounding country, resulting in heavy floods and the adoption of a new channel. Thus, it shows extensive meandering and braided structure throughout its courses. Heavy downpour accompanied with distinct basin characteristics and human modifications to the natural drainage are the most important and intense causes for serious inundation and floods in the Rapti basin.

20.6 Floodplain Management in Rapti River Basin

State governments are responsible for flood and floodplain management in India; central funding only supports state programs. In the post-independence period, different committees were set up and partial studies were undertaken to minimize the flood risk. Even if those committees suggested an elaborate plan of structural and nonstructural flood mitigation measures from time to time, a generalized framework of disaster management process was visualized only after the enactment of the Disaster Management Act of 2005. With this act a major paradigm shift in public policy (from relief and rehabilitation to prevention, preparedness, response, and recovery) on disaster management took place. Accordingly, the states develop their own plans at state and local level for different types of disasters, including floods. In the Rapti River Basin, state agencies adopted different types of measures to manage flood risk. They can be grouped into two principal categories for discussion: structural flood mitigation measures, and nonstructural or flood emergency measures.

Further, experienced floodplain dwellers have developed their indigenous mode of flood risk management.

Structural flood mitigation measures refer to the works such as levees, detention basins, or channel improvements that are aimed at modifying flood behavior (i.e., keeping water away from people). Construction of levees or embankments, locally known as *bandh*, is the dominant form of structural measure adopted in the study area. Extensive embankments (especially on the lower Rapti basin) were constructed on both sides of the principal river, the Rapti, to protect urban as well as village settlements and agricultural lands. The general height of the embankments varies from 5 to 6 m. In some places freeboards are incorporated as a safety factor to embankment designs. Also, *ring bundh* or circular embankments are constructed to provide safety to those villages situated between the river and embankments. Most of those embankments were constructed during the late 1960s and mid-1970s. The embankments created a false sense of security against flood, as a result of which new settlements are coming up adjacent to those embankments. Similarly, the floodplain community is now putting land having a higher level of flood risk to intensive use. The embankments are designed to withstand low to moderate flood risk having a return period of 5–10 years but cannot withstand floods with a return period of

25 years or more as evident in the flood of 1998. The association between the water level of River Rapti at birdghat (gauge-level data) and the day of embankment failures in 1998 revealed that the embankments did not withstand the water pressure at 77 m of water level or the accompanying discharge of approximately 6,512.50 m^3/s. However, the embankments are capable of managing existing flood risk, enhancing future as well as residual flood risk. Table 20.3 shows some important features of those embankments.

Those embankments are periodically facing the problems of erosion, seepage of water, embankment failure from a heavy flood, and holes created by rats and other animals. Annual maintenance of the embankments, which extend up to 555 km, is becoming a difficult task for the local authority.

20.7 Nonstructural Measures

The nonstructural measures adopted in the study area are basically flood emergency measures such as flood forecasting and warning, evacuation, and recovery plans. These plans are aimed at reducing flood hazards by modifying the response of the population at risk so that they will be better able to handle actual flood events.

20.8 Flood Forecasting and Warning

Flood forecasting is a scientific evaluation of an event in real time leading to the issue of a general alert about hazardous conditions (Smith and Ward 1998, p. 265). The practical aim of flood forecasting is to reduce the loss of life and the economic damage caused by floods. Thus, the accurate forecasting of flood conditions is an essential prerequisite for the provision of reliable flood warning schemes. In recent years, flood forecasting accuracy has increased greatly with improvements in telecommunications and computerized data handling and processing. The need for reliability in flood forecasting has been stressed frequently. Errors in the forecast of flood stage or of the time of arrival of flood conditions may lead to underpreparation and loss from avoidable damage or to overpreparation, unnecessary expense and anxiety, and a subsequent loss of credibility. Further, social acceptability of the flood forecasting and warning is becoming a major issue.

The flood forecasting network of the Rapti River Basin comes under the supervision of Middle Ganga Division No. 1, Lucknow. The entire network of the basin is administered through two subdivisional headquarters. The upper region of the Rapti comes under the upper Rapti-Ghaghra subdivision with headquarters at Gonda. The subdivision has four gauging sites on the River Rapti, namely, Kakardhari, Bhinga, Balrampur, and Bansi, and one gauging site at Kakarauli on the River Burhi Rapti. Similarly, the lower Rapti region is administered by the lower Rapti-Ghaghra subdivision with headquarters at Gorakhpur, with two sites (Regauli and Birdghat) on the River Rapti and only one site on the River Rohin (Trimohanighat). All these sites

Table 20.3 Embankment failures in Rapti River Basin

						Embankment failure					
			Embankments			1974			1998		
Sl. no.	District	River	Number	Total length (km)	Protected area (in hectares, ha	Number	Number of affected villages	Total affected population	Number	Number of affected villages	Total affected population
1	Gorakhpur	Rapti, Rohin, Kuwana, Ghaghara	65	439.95	102,610.0	19	1,390	6.3 lakh	20	1,594	14.14 lakh
2	Deoria	Rapti, Ghaghara, Gurra	14	115.22 555.17	40,449.00	N.A.	N.A.	N.A.	10	585	7.50 lakh

Source: Office of the District Magistrate (2001a, b)

Table 20.4 Rapti River Basin: details of all sites for flood forecasting and warning

Name of river	Gauging site	Type of site	Coordinate		Danger level (m)	Highest flood level recorded (m)	Year
			Latitude	Longitude			
Rapti	Kakardhari	G	27°51′	81°49′	131.00	131.35	1979
	Bhinga	GDQ	27°40′	81°51′	119.50	120.10	1997
	Balrampur	GDSQ	27°27′	82°12′	104.62	105.25	2000
	Bansi	G	27°11′	82°58′	84.90	85.82	1998
	Regauli	GDSQ	26°46′	83°18′	80.30	82.12	2000
	Gorakhpur (Birdghat)	GDSQ	26°46′	83°21′	74.98	77.54	1998
Burhi Rapti	Kakrahi	G	27°14′	82°59′	85.65	88.97	1998
Kunhra	Uska bazar	G	27°12′	83°09′	83.52	85.62	1998
Rohin	Trimohani Ghat	G	27°06 ′	83°25′	82.44	85.43	2001

Source: Central Water Commission (2008); G = Gauge; D = Discharge; S = Silt; Q = Water quality

are operated and maintained by the Central Water Commission. Even if the basin has a good network of gauging stations and flood forecasting and warning performance, their practical utility remains a cause of concern during emergency management because of the low level of social acceptability, lack of faith, accompanying rumor, unsatisfactory evacuation, rescue, and relief camps, and a sense of insecurity for property and belongings among the floodplain dwellers (Table 20.4).

20.9 Flood Emergency Plans

The Rapti basin has a well-established flood emergency plan to cater to any exigency; it was strengthened with the enactment of the Disaster Management Act of 2005. Different nodal units operate at the grassroots level to minimize the flood risk. Some important units with their specific functions are given next.

20.9.1 Barh Chawki

Barh Chawki is the local level flood emergency unit located in remote villages. The primary task of this unit is to collect information on an actual flood situation at the village level and to report to the district administration on a regular basis. It also provides information on flood forecasting and warnings issued by the concerned department to the villagers. Each Barh Chawki serves six to seven villages in flood-prone areas. It caters to the needs of those villages in flood relief, rescue, and information dissemination. This unit is headed by an assistant development officer and supported by a lekhpal, multipurpose workers, and workers from health and animal husbandry departments. All the Barh Chawki operate under the direction of a

Subdivisional Magistrate (SDM) and automatically come into operation when the water level of the nearby river crosses the danger mark. The assigned works of the Barh Chawki are (1) to communicate flood-related information to the control room on a daily basis, (2) to keep information on the condition of the embankments and to inform the control room in special cases, (3) to appraise flood-related local issues and to mitigate them in time with prior consultation with the *Barh Surakhya Samiti*, (4) to send health workers throughout the flood-affected villages to ensure first aid, immunizations, and treatments to the villagers, (5) to store equipment and tools needed for emergency management such as a boat, emergency lights, polythene sheets, etc., and (6) to function as a primary unit of maintaining records on floods and flood-related damages/loses.

20.9.2 Relief Center

During the time of flood disaster, relief materials such as food grains, fodder, other essential items, and money are distributed from this centre. Usually the Barh Chawki and the Relief Centre are located in the same place, but in case of waterlogging and complete inundation of the *barh-chawkis*, relief centers are located in nearby safer places, keeping in mind easy accessibility and transport network facilities. Each relief center caters to the needs of 10 to 15 villages. The center distributes the relief materials to the flooded villages through a locally made boat or motorboat. The nodal officer of this center is an additional development officer (ADO), or Naib Tehsildar.

20.9.3 Relief Camp

A network of relief camps is identified in every district. Public institutions such as colleges, schools, public buildings, embankments, roads, and other places situated on higher ground are considered, designated, and notified as relief camps. Before the flood events basic facilities such as drinking water, food, lights, fodder for animals, and medicines are ensured by the sub-divisional magistrate (SDM), who is in charge of all relief camps.

20.9.4 Barh Sector

To facilitate flood relief and rescue operation and survey, the districts are divided into different sectors. Generally, each developmental block (which is affected by flood) is designated as a flood sector or Barh sector. The block development officer (BDO) is the nodal officer; each is responsible for the smooth operations of the barh chawki, relief center, and relief camp that come under their jurisdiction. The BDOs work with the control and direction of an additional district magistrate (ADM).

20.9.5 Flood Cell

The flood cell is the highest decision-making body at the district level. The additional district magistrate for finance and revenue (ADM) heads the cell with representative members from the Department of Irrigation, Health, Police, Jal Nigam, Nagar Nigam, Veterinary, and Electricity. The ADM, finance and revenue, is designated as a full-time district disaster relief officer. He is supposed to communicate between different departments and to facilitate relief and rescue work at the district level. The primary work of the cell is planning for flood control and micro-planning for flood relief. The cell also coordinates with NGOs, civic society, government, and private institutions during the time of floods and ensures the distribution of work among them. The flood control room at the district level operates within their supervision.

20.9.6 Flood Control Room

The primary task of the flood control room is to collect and communicate flood-related information at the district level. Communication plays a vital role in rescue and relief operations. Real-time dissemination of information related to flood behavior facilitates rescue and evacuation work. The control room registers complaints regarding flood-related work even before the flood condition. The information officer informs about flood conditions through a press release to counter unnecessary rumors.

20.10 The Floodplain Community and Their Management Measures

The floodplain residents of the Rapti River Basin have developed an elaborate system of indigenous adjustments to the floods, consisting of measures that are traditional in type to minimize the negative impacts of recurrent flooding. During the time of field observations and questionnaire surveys, several indigenous adjustments to minimize flood risk were found in the basin that can be analyzed under the following headings: (1) indigenous flood-proofing of shelters, and (2) indigenous agricultural adjustments to floods.

Two distinct modes of flood-proofing of shelters were identified in the floodplain dwellers of the upper Rapti catchment who are living in temporary dwellings made of locally available branches of trees, straw, and grasses. The huts are usually surrounded by trees. This mode of adjustment has nothing to do with the socioeconomic conditions of the floodplain dwellers; rather, it is a function of the multiple risks perceived by them: (a) dynamic shifting of the stream channel accompanied by massive bank erosion and (b) recurrent flooding. They often abandon the home and built a fresh one at a location that is not liable to see a channel shift in the near future. The main flood adoption measure observed in floodplains of the lower catchment is marked by raising the house plinth above normal flood levels as well as by building different types of platforms for different uses as human and cattle shelters. Responses of the floodplain dwellers to a predetermined checklist and open-ended questions indicate that some adjustments represent successful adaptations to normal flood regimes, whereas others are intended to provide protection from abnormal floods. The courtyard and the plinth level of individual homes were maintained and raised above flood level on a routine basis in all sampled villages by digging earth from local depressions and ponds surrounding the homesteads.

Among the other measures, many respondents of the upper catchment floodplain indicated that during the catastrophic of floods of 1961, 1981, and 2000, when the ground floor of a large number of houses was inundated, the residents were forced to take shelter on different types of platforms. Often temporary shelters were constructed inside the home for the purposes of cooking, resting, and sleeping. Second, elevated grounds of historical importance, embankments, schools, and colleges built on safer locations and railway lines were also frequently utilized as emergency shelters. Another major contingency measure was the provision of platforms for the storage of grains and animal feed. Residents often used the roof tops and branches of tall trees to store flood grains and cattle feed.

Besides protecting infrastructures on the floodplain from high-magnitude floods, one of the main goals of the floodplain residents of the Rapti River Basin is to adjust their agricultural practices with respect to flood cycles. Different varieties of rice crops (main crops grown in the rainy seasons) to varied flood depths at different levels of the floodplains have been the most common indigenous agricultural adjustment observed in the sampled villages. The respondents practiced different types of adjustments, some of which were measures to minimize crop losses from an abnormal flood regime while others were adjusted to recurrent normal regimes. Combinations of structural and nonstructural measures were adopted by the floodplain dwellers to protect their agricultural land. The structural measures involved construction of an earthen ridge along the agricultural field as a means to prevent shallow to moderate flood water; these are maintained and the height of the ridge is increased on a yearly basis. Other important measures adopted by the floodplain dwellers are crop selection based on speculation about floods and the management of land.

Selection of crops based on speculation about floods is best reflected in the lower regime of the basin. Because flood waters arrive suddenly and leave rapidly, floodplain dwellers of the upper regime are hardly concerned about the selection of flood-resistant crops. They were very much influenced by other location factors (for example, a sugar factory in Balrampur) and mostly grow sugarcane and rice in kharif season and wheat, mustard, and *arhar* in rabi season. The floodplain dwellers have great consideration for higher agricultural return. They grow kharif crops with minimum investment because of the impending flood danger. The most common adjustment of rice cropping to uncertainties of natural flood regimes was evident from the practice of mixed cropping of arhar, kodon, maize, and jowar. Here, paddy and jowar may resist low to medium flood levels whereas other crops will perish quickly. But in years without flood, *arhar* and kodon give better results. Thus, this measure assured that at least flood-tolerant paddy would be secured during an abnormal flood regime, whereas during a normal to no flood regime all these crops would succeed, often resulting in a bumper crop. Rabi crops account for the major share of their total food grains. The rabi crops thrive well because previous floods recharge soil fertility and moisture. Wheat is the dominant rabi crop grown by the floodplain dwellers of both the upper and lower Rapti basin.

Zaid crops are common in the lowland and waterlogged area of the floodplain. Extensive uses of the lowlands along the river's course or river islands were found. These areas are put under zaid crops by the poor and marginal section of the floodplain dwellers having no land ownership, who mostly grow water cucumber, watermelon, nenua, and other summer vegetables and a special type of rice known as *Bora*.

Although the basin has an established floodplain management program consisting of structural measures and flood emergency plans, there are several drawbacks. Notable among these are the following. Other structural and nonstructural measures such as land use planning controls and development and building controls were not included in the ongoing floodplain management measures. As the wetlands encroach, the water-retaining capacities of those natural detention basins are decreasing. Proper implementation of the land use policy is needed, and there is also need for standardization of embankment construction and maintenance so as to minimize corruption. Public institutions such as schools, primary health centers, Gram Panchayat buildings, fertilizer distribution centers, etc. in the floodplains are located in low-lying areas, thus facing the twin problems of flooding and waterlogging even in flood-free years. The grassroots-level emergency centers lack minimum facilities, resources, and trained manpower, thereby making their presence meaningless. Lack of integration of roles and responsibilities was the main hindrance for relief and rescue operations during the times of emergency. A contingency plan for emergency operations if the embankments fail is greatly needed.

20.11 Integrated Floodplain Management

An integrated approach to floodplain management is required to bring together the diverse issues and stakeholders that affect or are affected by floodplain management. This approach takes flooding behavior, flood risk, and flood hazard into account, along with all relevant planning factors (ARMCANZ 2000, p. 6). The main objective of this approach is to develop a floodplain management plan that facilitates the use of the floodplain for appropriate purposes, that limits flood hazard and damage to socially acceptable levels, enhances the waterway and floodplain environment, and fosters flood warning, response, evacuation, cleanup, and recovery during the onset and in the aftermath of a flood.

Thus, incorporation of an integrated approach into the ongoing floodplain management process in the study area requires attention to the following points.

20.11.1 A Proactive Management Plan

Floodplain management in the Rapti Basin needs to be proactive. Past flood measures in the basin were taken after a series of floods had occurred. Generally this type of approach leads to an ad hoc attitude and is limited in scope and effectiveness: it does little to control the increasing level of flood hazard across the Rapti Basin. Thus, we have to develop a culture of proactive response and planning to mitigate the problems.

20.12 Integration of Policy, Legislation, and Floodplain Management Measures

A policy framework to support the management of floodplains should be developed to integrate all concerned agencies. The State and Central Government should work together to develop and implement integrated strategies against flood risk incorporating legislative, financial, and technical support. The policy should be supported by appropriate legislation, regulations, standards, guidelines, and planning policies that clearly and unambiguously define the responsibilities and liabilities of all agencies. The different departments such as Civil Administration, Irrigation, Road and Railways, Public Works, etc. have their own area of operation and plan of action to cater to flood risk. Their plans should not be antagonistic.

20.12.1 Flood Emergency Plan

The development and implementation of effective flood emergency plans are the only means of reducing the damage and hazard associated with residual risk. The floodplain management plans and the flood emergency plan should be complementary. The plan should assess a full range of floods, such as recurrence periods of 25, 50, and 100 years and, if possible, by defining a probable maximum flood, while developing the flood emergency plan. An emergency plan for handling potential embankment failures should be included.

20.12.2 Flood Study and Flood Risk Management

A detailed flood study is necessary to collect information on the extent, level, and velocity of flood waters and on the distribution of flood flows to enable us to define the extent of flood hazards across the floodplains. The study should incorporate both hydrological as well as hydraulic aspects of the flood waters. After this flood study, zoning on the basis of flood hazards should be undertaken to identify the floodplain dwellers exposed to or affected by the risk of flooding. Further, identification of public and private property, social systems, and environmental elements at risk of flooding should be incorporated while assessing flood risk and vulnerability analysis.

20.12.3 Flood Maps

Flood maps have a vital role in floodplain management. Flood maps that show the extent, depth, velocity, and hazard of flooding for designated flood events are an important tool in floodplain management as well as in emergency operations. During the time of emergency operations, an evacuation plan for each village indicating safe and accessible routes is needed by the armed forces. Similarly, for airdropping of relief materials, the geographic coordinates of submerged/marooned villages are needed. Thus, there is an urgent need to map the flood-inundated villages with precision and greater detail.

20.12.4 Community Expectations

Ideally, the community can expect that floodplains will be developed and used in an ecologically, economically, and socially sustainable fashion and in accordance with the broader principle of sustainable natural resource and environment management and of integrated or total catchment management. Thus, in every stage of planning, the community's aspirations and local needs should be incorporated through their direct involvement and participation in an inclusive manner.

Floodplain management needs to ensure that the following expectations of the community are met. People wish to be able to live and work on floodplains at no untoward risk to life and health or unacceptable risk of damage to goods, possession, and infrastructure because of flooding, which needs site-specific integrated management measures for existing, future, and residual flood problems. People can be secure in knowing that in the event of inevitable future floods, effective arrangements will be made to alleviate the economic and social costs of flooding, on both an individual and community basis, and recovery of the flooded area and its residents and occupants will be fostered. The community is to be actively involved in the floodplain management process, both in developing management plans and in meeting their obligations under those plans.

20.13 Policy Integration and Implementation

Effective policy and legislation are essential for providing a reliable social and legal foundation for floodplain management. An integrated policy framework is required within all agencies (national, state, local) to support the management of floodplains.

20.13.1 Risk Awareness

The local community or the floodplain dwellers need to be flood aware. For successful management of the floodplains, they need to understand the concept of flood risk and exposure to flood hazards. Their active participation in preventing unnecessary rumors and cooperation during relief and rescue operations is of outmost significance. For their understanding and awareness, appropriate flood risk terminology, and flood maps along with action plans in the form of informative brochures, should be given. Flood risk awareness should be promoted and communicated to the villagers through different plays (locally known as Nukaad Natak) in local languages, and in schools and colleges a flood risk awareness program should be included in course curricula as a part of extracurricular activity.

20.13.2 Appropriate Land Uses

Land use needs to be appropriate to the level of hazards. It must be matched carefully to both maximize the benefits of floodplain and minimize the risks and consequences of flooding. Table 20.5 shows, in principle, desirable locations of various land uses.

Appropriate land use can be ensured through land use planning controls such as floodplain zoning, which are aimed at ensuring that land use is compatible with flood risk; and development and building controls, such as minimum floor levels and flood proofing, aimed at reducing the risk of inundation and amount of damage that occurs when such a flood eventuates.

Table 20.5 Land use compatible with degree of hazard

Extreme	High	Medium	Low
Agriculture*	Agriculture	Agriculture	Agriculture
Recreation	Recreation	Recreation	Recreation
Open space	Open space	Open space	Open space
Environment (with special control)	Environment	Environment	Environment
	Commercial	Residential*	Residential
	Industrial	Commercial*	Commercial
		Industrial*	Industrial
		Schools*	Schools
		Public institutions	Public institutions
		Police station	Police stations
			Telephone exchange
			Hospitals
			Museums
			Army/Air Force station
			Airport

*With appropriate measures

Source: Agriculture and Resource Management Council of Australia and New Zealand (2000)

20.14 Conclusion

Floodplain management across India can only occur on an objective and equitable basis if appropriate performance indicators are defined and used to evaluate the progress and success of floodplain management programs. Monetary and other incentives should be given to the states and district authority. For this, we need standardization of terminology, and collection of appropriate data concerning the socioeconomic profile of the flood-prone community and flood behavior on an objective basis for the design and assessment of floodplain management programs.

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