SR-1/98-99

HYDROLOGICAL INVENTORY OF RIVER BASINS IN EASTERN UTTAR PRADESH

आपो हि ष्ठा मयोभुवः

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667 (U.P.) INDIA

1998-99

PREFACE

The river Ganga is the longest river of the country flowing from the northern to eastern parts. It has been serving the nation as its lifeline through its vast irrigation potential and fertile flood planes. During its course through plains of Uttar Pradesh, the river flows in a wide belt constantly changing its course and receives a number of tributaries. This densely populated part of the Ganga basin with its rich water resources has always been subject to various socio-economic development. Enormous environmental problems due to rapid growth in population, urbanisation, agriculture and industry, deforestation and depletion of its natural resources have always been in limelight. Sub basins of various tributaries in this area also represents a unique feature of typical hydrological problems. Problems of water logging, pollution and floods are important issues besides reported drought in many areas.

The Ganga Plains North Regional Centre (Patna) of the Institute under its work program has envisaged a task to prepare a compilation work of hydrological inventory of river basins in Uttar Pradesh. The report has been prepared with an aim to bring all related hydrological issues at one place. It contains a brief description of the Ganga basin and its subbasins in Uttar Pradesh. It includes drainage maps of various subbasins, isohyetal maps and land use pattern etc. Details regarding location of various raingauge stations, gauge and discharge sites is also presented in the report. Further, hydrological and environmental problems of each sub basins are discussed in detail with the help of various illustrations showing distribution of Fluoride, Chloride, Salt affected and water logged areas.

This publication has been prepared by Shri A.K. Lohani, Scientist 'C' and Shri N. G. Pandey, Scientist 'B'. Assistance in preparation of this year book was provided by Shri A.K. Sivadas, Tech. Gr. III and Atm Prakash, Research Associate.

(S.M. Seth)
DIRECTOR

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The state of Uttar Pradesh is drained by the rivers Ganga and Yamuna and their tributaries. Yamuna itself is one of the tributaries of Ganga. The northern and eastern parts are drained by the main rivers and their tributaries like Ghagra, Sharda, Sarju, Rapti, Gomti and Ramganga. In the southwest, the drainage is through the rivers Chambal, Sindh, Betwa, Ken, Tons and Sone, all of which join the river Ganga, or its tributaries. For the last century, Ganga is being continuously harnessed by constructing a network of canal system. The river Ganga and its tributaries carry sediment, but they differ considerably in quality and quantity. The problem of sedimentation is one of the major factors, which creates flood problem in the Ganga sub-basin. Water logging, salinity and river water pollution in the Ganga sub-basin are having adverse impact on various agricultural activities.

The sub-basins of the river Ganga and its tributaries are facing various hydrological problems. The river Ganga spills over its banks at several places. While, water logging and usar efflorescence are serious problems in the Sharda Canal Command. The soil alkalinisation is the consequent effect of water logging. The Ganga Plains North Regional Centre of National Institute of Hydrology has taken up the task to prepare Hydrological Inventory of the various sub-basins of Uttar Pradesh. It includes geographical features of the study area and a list of various hydrological data collection sites along with their locations. Sub-basin wise details of the hydrological problems are also discussed in detail. Further, the report includes various illustrations including Fluoride and Chloride in ground water, Salt affected, water logged areas and increase in Usar land.

The main objective for prep ing the hydrological inventory of the Ganga basin is to provide information regarding availability of hydrological data and to highlight major hydrological problems of the basin. Such information may provide a useful input for water resources planning, management and research activities.

INTRODUCTION

The composite Ganga-Brahamaputra-Bara basin covers nearly one third of the land area of India. The Ganga sub-basin is a part of this basin and extends over an area of 1,086,000 sq. km. and lies in India, Tibet (China), Nepal and Bangladesh. The Gangatic plains, situated between the Himalays and the Deccan Plateau constitute the most fertile plains of the sub-basin ideally suited for intensive cultivation. The people living in the sub-basin in India represent about 41% of India's total population (1981 census), though they occupy only about 29.5% total culturable area of the country. The vastness of the Ganga basin is reflected in the diversity of its physiography, climate, soils, agricultural development and other related characteristics. Requirement of agricultural production, have, therefore, to be met with from the irrigated areas and from land relieved from drainage congestion.

With growing population, the needs of domestic and industrial water supply are substantial. The basin has hardly 15% area under forest cover. The high intensity of irrigation requires the diversion of practically entire dry-weather flow of this river to the upper Ganga canal at Haridwar and the eastern, middle and the lower Ganga canals. Consequently, there is scanty of dry weather flow in the Ganga at Kanpur and below. The Ganga receives over 60 % of its water from Yamuna, Ghagara, Kosi, and the Gandak in the central and eastern parts of the basin. The upper and middle stretches in the plains are more vulnerable to environmental imbalances and pollution due to relatively smaller flows.

Pollution of stream water by industrial effluent is another cause for concern and more fresh water is required to dilute the polluted water of streams. A large amount of municipal discharge along with industrial effluents, significant among them are tanning, fertilizer, paper, pump, sugar mills and chemicals from agricultural fields are inducted,

thus bringing about a considerable change in the river water. Such a change is of significance and has consequences not only for the civilization of different cities but also for rural population on the banks of river downstream. Ground water utilization for irrigation, domestic and industrial water supply is causing severe lowering of ground water table. It results that more energy is needed to pump water and land subsidence and pollution of ground water occurs in some places.

Occurrence of flood and drought is a natural phenomenon associated with the complexes of the hydrological cycle and the Ganga basin is no exception to it. Every year floods cause hardship, misery and damage to crops, life and property in one or the other part of the basin. The problems of flood are serious in States of Uttar Pradesh, Bihar and West Bengal. In Rajasthan and Madhya Pradesh, the problem is not so acute.

The problem of water logging and siltation in riverbeds is acute particularly in the command areas of the two major irrigation systems of Sharda Sahayak and Gandak. Excess seepage from the canal system and high infiltration from irrigated fields and ponding, causes rising of ground water table. The soil alkalinisation is the consequent effect of water logging, where pH increases and the soil looses its fertility.

Waters of the Ganga and its tributaries in U.P. are quite suitable for drinking purposes as per norms and guidelines laid down by the Bureau of Indian Standards, W.H.O. and Indian Council of Medical Research (Handa et. al., 1993). A major part of the wastes of effluents of urban sewage and other waste effluents e.g. from industries are being discharged into these streams and river without treatment. Therefore, it is imperative that a proper surveillance programme should be carried out to monitor the concentrations of trace elements so that preventive steps can be taken well in advance whenever the concentration of these elements crosses the prescribed limits or guidelines.

In the present study, an attempt has been made to highlight major hydrological problems of the study area. It contains information regarding river basin, climate, soil type, landuse pattern and other related features. Further, the salient features of Ramganga,

Yamuna, Ghaghra and Gomti river basins are presented. Locations of various gauge & discharge sites on Ganga river and its tributaries along with name of the concerned agency are also given. Flood is a regular feature in the river basin and therefore, Central Water Commission has been operating a well-developed network of observation and flood forecasting sites at important locations on the Ganga and its important tributaries. A map showing flood forecasting is also presented. Rainfall data in the Ganga sub-basin is being collected by various agencies including both Central Government Organisations and State Government Organisations. A list of various gauging sites functioning in the study area is also presented.

BLANK

GEOGRAPHICAL FEATURES OF THE GANGA BASIN

2.1 The Ganga Basin

The Ganga basin is spreaded over four countries i.e. India, Nepal, Tibet and Bangladesh. A major portion of the Basin lies in India. The basin area lying in each country with the percentage of basin area is summarised below (**Table.2.1.**):

Table 2.1: Percentage basin area of Ganga lying in different countries.

Sl. No.	Ganga basin Area in the country		
	Name of country	Basin area in Sq. Km.	Percentage of basin area in the country
1	India	8,61,400	79 2
2	Nepal	1,40,800	13.0
3	Tibet	38,800	3.6
4	Bangladesh	46,000	4.2
	Total	10,87,000	100

The Ganga basin, the largest river basin of India, occupies about 26.3% of the total geographical area of the country. It lies approximately between 73° 30' to 89° E longitude and 22° 30' to 31° 30' N latitude. The basin is bounded on the north by the

Himalayas and on the south by the *Vindhyas Mountains*. The ridge between the Indus system and the Ganga system alongwith great desert of Rajasthan and the Aravalli hills form the western boundary of the Ganga basin.

The river Ganga flows almost north-west to south east. The basin covers fully the state of Uttar Pradesh, Delhi and partially the states of Himanchal Pradesh, Haryana, Rajasthan, Madhya Pradesh, Bihar and West Bengal. A comparison of the statewise distribution of the Ganga basin area with the geographical area of these states is presented in **Table 2.2.**

Table 2.2: Statewise Distribution of the Ganga Basin Area

Sl. No.	Name of the State/Union Territory	Catchment Area in Sq. Km.	Total geographical area of the state	Percentage of the basin area
1	Himanchal Pradesh	4,317	55,673	0.5
2	Uttar Pradesh	2,94,364	2,94,364	34.2
3	Delhi	1,484	1,484	0.2
4	Haryana	34,341	44,222	4.0
5	Rajasthan	1,12,490	342,214	13.0
6	Madhya Pradesh	1,98,962	4,42,841	23.1
7	Bihar	1,43,961	1,73,876	16.7
8	West Bengal	71,485	87,853	8.3
	Total	8,61,404		100

2.2 Ganga River System

In the initial stage, up to Devaparyag, the river Ganga is known as Bhagirathi. At Devaparyag, another hilly stream the Alaknanda joins it; from this point, the combined stream is known as Ganga. Bhagirathi rises at the Gangotri glaciers in the Uttar Kashi district at an elevation of nearly 250 km through hilly terrain, than it debauches into the plains at Rishikesh. The Ganga-Brahmputra basin and political divisions are shown in **Figure 2.1**. In Uttar Pradesh the river Ganga flows over the fertile plains and receives the Ramganga before touching Allahabad. At Allahabad, it is joined by the Yamuna on its right bank. The Chambal, the Betwa and the Ken are the principal streams flowing into the Yamuna and they drain considerable areas of Madhya Pradesh. After Allahabad, the river sweeps for another 245 km to Varanasi and receives the Tons from the south. The Gomti joins it immediately below Varanasi. The total length of the Ganga from its sources to its outfall into the sea is measured along the Bhigarithi and the Hooghly is 2,525 km of which 1,450 km lie in Uttar Pradesh, 110 km along the U.P. - Bihar border, 445 km in Bihar and 520 km in West Bengal. The Ganga flows approximately in the direction of north-west to south-east. The Ganga basin is roughly rectangular in shape, the width in the western end, where the Yamuna and the Chambal originate from the north and the south respectively, being more. The plateau at the Central India forms the southern basin boundary. The width of the basin is the narrowest at the Rajmahal hills near Bihar-West Bengal Border, where the Ganga takes a turn towards south. The delta of the Ganga starts downstream of this turning, where the river bifurcates, one arm bearing

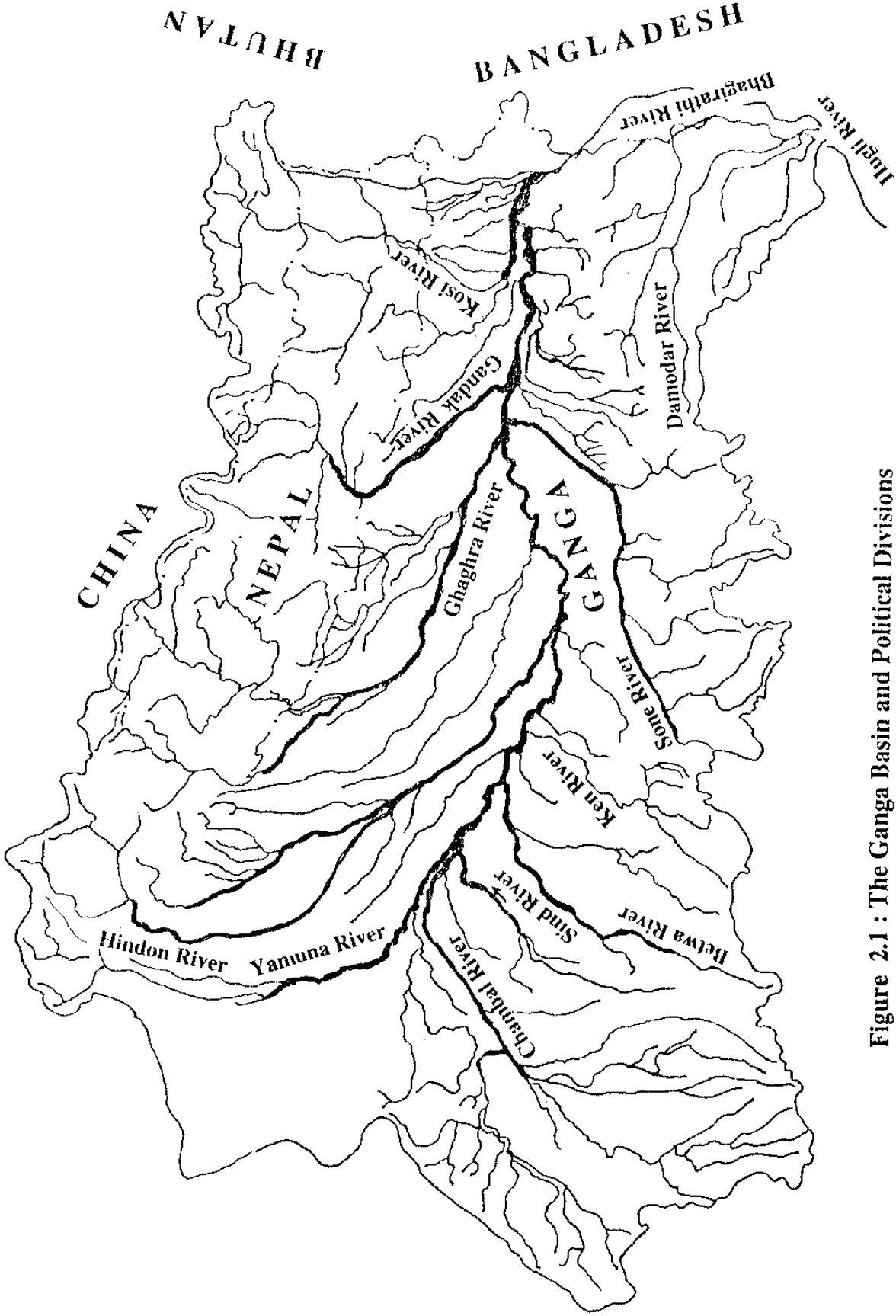
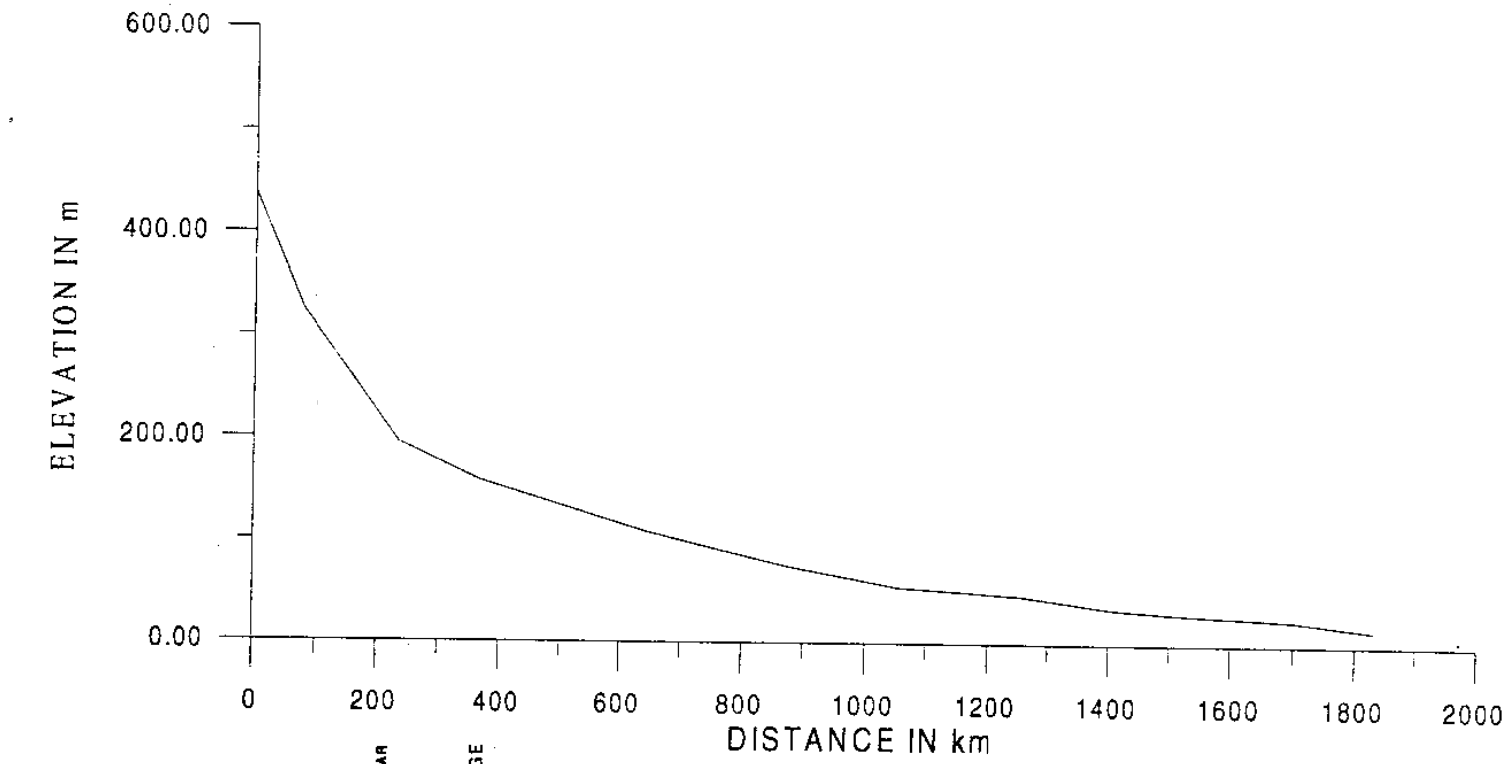


Figure 2.1 : The Ganga Basin and Political Divisions

the name of the Padma, flows through Bangladesh on its way to the sea and the other bearing the name of the Bhagirathi flows through West Bengal to the sea. The total length of the Ganga from its point of origin to the point where it falls into the sea is about 2525 km. The longitudinal section of its course of flow upto Farakka has been shown in **Fig 2.2**. Elevation of river basin, average land slope and some hydrological parameters of the river Ganga are given in **Table 2.3**.

Table 2.3: Hydrological Parameters of River Ganga at various Places From its Source to the Outfall into the Bay of Bengal in India

Station	Distance from source (km)	Elevation from mean sea level (m)	Average slope of land	Average mean annual flow (m^3/s)	Range of mean annual flow (m^3/s)
Rishikesh	250	350	1 in 67	856	1305-21631
Kanpur	800	138	-	1184	910-30763
Allahabad	1050	95	From Rishikesh to Allahabad 1 in 4,100	4226	2987-112206
Varanasi	1295	80		4106	2793-112206
Buxer	1430	60		4436	3438-192625
Patna	1600	50		7626	6341-192625
Munger					
Bhagalpur					
Rajmahal					
Farraka	2055		From Allahabad to Farraka, 1 in 13500	10159	
Calcutta		19	-	1056	
Nawadwip	2285	12		1314	1107-18666
Outfall to Bay of Bengal	2525		1 in 24000		



NAME OF SITE	DEOPRAYAG	RISHIKESH	GARHMUKTESHWAR	KACHLA BRIDGE	KANPUR	ALLAHABAD	VARANSI	BUXAR	PATNA	HATHI DAH	AZAMABAD	FARAKHA
DISTANCE IN Km	0	77	234	366	645	873	1052	1254	1409	1507	1701	1830
BED LEVEL m	437.60	324.58	194.89	158.00	108.12	75.39	54.82	47.09	34.22	30.06	34.40	14.80

Figure 2.2 : Longitudinal Section of The River Ganga

The river Ganga has a number of tributaries, which are important rivers by themselves. Studying the problems concerned with the agricultural and irrigation development in various reaches, the Irrigation Commission had considered the whole Ganga system under nine sub-basins (**Table 2.4**). While, the Rashtriya Barh Ayog had distributed the whole Ganga system into nineteen (19) systems for studying the problems concerned with floods in various starches of the Ganga basin. Classification of Ganga River System as given by Rashtriya Barh Ayog is summarised in **Table 2.5**.

Table 2.4: Distribution of Ganga River System Under Different Sub-basins According to Irrigation Commission.

Sl. No.	Sub-basin
1	Chambal Sub-basin
2	Yamuna Sub-basin (excluding Chambal)
3	Ramganga Sub-basin
4	Tons, Karamanasha and other rivers
5	Gomti, Ghaghra and other rivers between them
6	Sone
7	Gandak and other left bank tributaries upto international border
8	Right bank tributaries of Sone
9	Main Ganga

Table 2.5: Distribution of Ganga River System Under Different Sub-basins According to Rastriya Barh Ayog.

Sl. No.	Classification of Ganga River System by Rashtriya Barh Ayog
1	Chambal Sub-basin
2	Yamuna Sub-basin
3	Ramganga Sub-basin
4	Gomti Sub-basin
5	Ghaghra Sub-basin
6	Sone Sub-basin
7	Gandak Sub-basin
8	Burhi Gandak Sub-basin
9	Adhwara Sub-basin
10	Bagmati Sub-basin
11	Kamla Sub-basin
12	Kosi Sub-basin
13	Mahananda Sub-basin
14	Punpun Sub-basin
15	Damodar Sub-basin
16	Ajoy Sub-basin
17	Dwarika Sub-basin
18	Haldi Sub-basin
19	Main Ganga Sub-basin

In the "*Comprehensive plan of flood control for the Ganga basin*" (Ganga Flood Control Commission, 1986), the river system is distributed into twenty three (23) sub-basins. The idea is to study in detail the characteristics of each of the independent tributaries of the Ganga river. The catchment area of different river systems within the Ganga basin is given in **Table 2.6.**

Table 2.6: The Drainage Area of Different River Systems Within Ganga Basin

Sl. No.	Name of the River System	Drainage Area Sq. Km.	Percentage of Ganga basin Area
1	Main Ganga including Karmanasa Baya, Bagmari-Pagla	1,13,163	13.14
2	Yamuna including Chambal, Betwa & Ken	3,63,082	42.15
3	Ramganga	32,493	3.77
4	Gomti	30,435	3.53
5	Ghaghra	57,647	6.70
6	Tons	16,860	1.96
7	Sone	71,259	8.27
8	Punpun	8,530	0.99
9	Kiul-Harohar	16,661	1.993
10	Badua-Chandan	4,840	0.56
11	Gandak	7,620	0.89
12	Burhi-Gandak	10,150	1.18
13	Bagmati	3,720	0.43

Sl. No.	Name of the River System	Drainage Area Sq. Km.	Percentage of Ganga basin Area
14	Adhwara	2,600	0.30
15	Kamla-Balan	2,980	0.35
16	Kosi	11,070	1.29
17	Mahananda	17,440	2.02
18	Jalangi	5,640	0.65
19	Mayurakshi-Babla	8,530	0.99
20	Ajoy	6,050	0.70
21	Damodar including Khari-Gangur-Ghia	31,220	3.62
22	Rupnarayan including Haldi, Rasulpur & Kangsabati	23,760	2.76
23	Tidal rivers	15,650	1.82
	TOTAL	8,61,400	100.00

DESCRIPTION OF THE STUDY AREA

In the present study, a part of the Ganga Basin lies in the plains of Uttar Pradesh is selected for preparing hydrological inventory. The state of Uttar Pradesh lies between latitudes 23°45' N and 31°30' N and longitudes 77°00' E and 85°00' E covering a total area of 2,94,413 sq. Kms. The state can broadly be divided into three physiographic units. These are described in **Table 3.1**.

Table 3.1: Physiographic classification of Uttar Pradesh.

Sl.	Physiographic Unit	Coverage
1	Himalayan Region	Part of the Himalayan chain in the North occupying 17 percent of total area of having 4 percent of total population.
2	Gangetic Plain	The Gangetic Alluvial Plain in the Centre covering 70 percent of total area and having 90 percent of the population.
3	Bundelkhand and Vindhya Plateau	The Bundelkhand granite massif and part of the Vindhyan ranges in the south occupying 13 percent of the total area and having 6 percent of the total population.

The major portion of the land in the state is utilised for agricultural purposes (**Figure 3.1**). The principal crops sown in the state are wheat, paddy, sugarcane, maize, barley, pulses and mustered. The Gangetic plains is drained by the river Ganga and it's various tributaries. They provide potential sources of irrigation and power, as they are perennial. Partly or fully basins of the rivers Ramganga, the Yamuna, the Ghaghara and the Gomti lies in the study area. These river systems are described below:

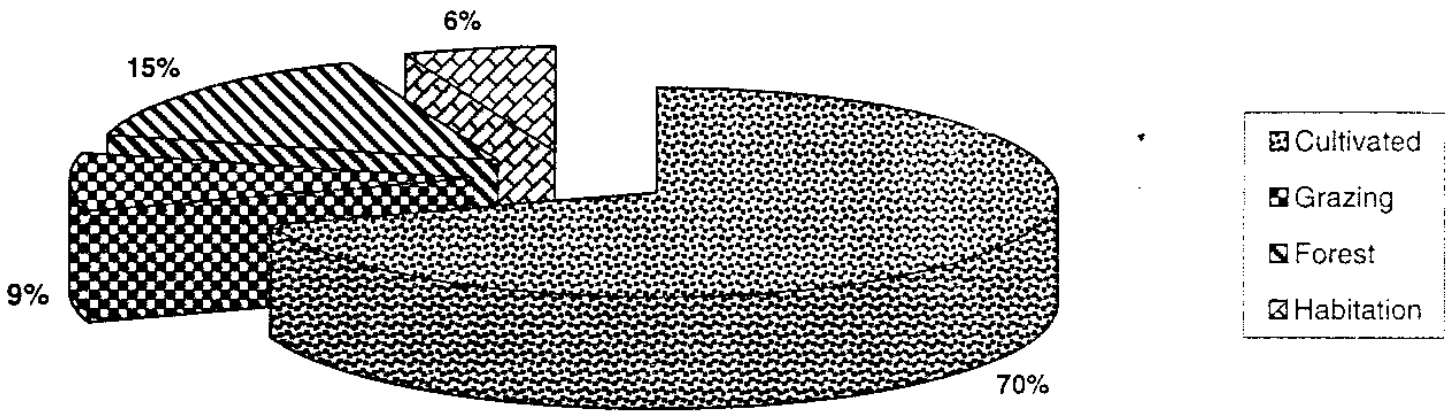


Fig. 3.1: Land Use Pattern in Ganga Basin in Uttar Pradesh

3.1 The Ramganga River System

The river Ramganga joins the Ganga on its left bank. It rises in the lower Himalaya at Latitude 30° 5' N and Longitude 79° 16' E at an altitude of about 3,110 m above mean sea level. Initially the river flows in a south-westerly direction for about 32 km before it turns right and flows in a south-westerly direction, successively through Almora and Garhwal districts for about 112 km. In these two districts the river flows through hilly terrain and abounds in a number falls and rapids. The river emerges from the hills and enters into the plains at Kalagarh near the boarder of Garhwal districts. At Kalagarh, a storage dam has been constructed across the river. Beyond Kalagarh, the river flows in a south easterly direction through the districts of Bijnore, Moradabad, Badaun, Rampur, Bareilly, and Shahjahanpur and finally joins the Ganga near about Kannauj in Fatehgarh district. Salient features of the river Ramganga are given in **Table 3.2**.

Table 3.2: Salient features of the Ramganga Basin.

1.	Location of Origin	Latitude 30° 5'N, Longitude 79° 16'E.
2.	Elevation at point of Origin	3,110 m above mean sea level
3.	Total length of the river Ramganga from its source to its outfall into the river Ganga	596 km.
4.	Major tributaries	Khoh, Gangan, Aril, Kosi, Deoha (Gorra)
5.	Catchment area	32493 sq. km.
6.	Catchment area lies in	Uttar Pradesh

3.2 The Yamuna River System

The Yamuna is the largest tributary of the Ganga. It joins the river Ganga on the right bank near Allahabad. The total length of the Yamuna from its source at Yamunotri to its confluence with the Ganga near Allahabad is about 1376 km. of which about 970 km is in Uttar Pradesh, 30 km from the common boundary between Himanchal Pradesh and Uttar Pradesh, 328 km. from the common boundary between Haryana and Uttar Pradesh, and the balance of 48 km in the Union territory of Delhi.

The ground levels in the basin vary from about 6,320 m above mean sea level near the Yamunotri Glacier to around 100 m above mean sea level near the confluence of the Yamuna with the Ganga at Allahabad. For getting general idea of the topography the basin can be classified into three groups as given in **Table 3.3.** Three percent (3%) area of the total basin is classified as hilly and the remaining is almost equally divided between plains and plateau region.

Table 3.3: Topographic classification in Yamuna Basin
(Approximate areas of each class in sq. km.)

Classification	Hilly	Foot Hills & Plateau Region	Plains & Valleys
State	Height above MSL		
	600 m	300 m – 600 m	100 m – 300 m
Uttar Pradesh	4,900	4,400	64,908
Himanchal Pradesh	5,200	599	-
Harayana	-	800	20,465
Rajasthan	1,600	55,610	45,673
Madhya Pradesh	-	111,508	28,700

Classification	Hilly	Foot Hills & Plateau Region	Plains & Valleys
Delhi	-	-	1,485
Total	11,700	172,917	161,231

(Source: Basin sub-basin inventory of water pollution- The Ganga Basin Part I – The Yamuna Basin)

The Yamuna rises in the Tehri Garhwal district of Uttar Pradesh from Yamunotri glacier near Bandarpunch in the Mussoorie Range of the lower Himalayas at an elevation of about 6320 m at latitude 30°58'N and longitude 78°27' E. Several tributaries originating from the lower Himalayan ranges and ridges joins the Yamuna river. The Tons, the largest Himalayan tributary of the Yamuna meets it below Kalsi. Giri is the another important tributary of the river Yamuna. It rises further north-west of the Tons near Simla and joins the river Yamuna near Paonta. The combined stream of the Yamuna and the tons flows through the Siwalik range of hills and debauches into the plains of Uttar Pradesh in the Saharanpur district. After flowing for distance of about 104 km. in a south-westerly direction, it receives the Maskara stream on its left bank. Near Bidaula in Muzaffar Nagar district of Uttar Pradesh, it turns due south for a distance of about 130 km. to reach Delhi. Beyond Delhi, the Yamuna continues to flow south up to Mathura, a distance of about 203 km. In this reach, the Hindon river joins the Yamuna on its left bank at Dankaur. From Mathura onwards, the river flows in south-easterly direction through Agra, Mainpura, Etah, Kanpur and Allahabad city. During its course through these districts, it is joined on the left bank by some small tributaries viz. The Karon, the Saugar and the Rind and by the major rivers, the Chambal, the Sindh, the Betwa and the

Ken on its right bank. **Figure 3.2** shows the subbasin of the river Yamuna. The two major tributaries viz. The Chambal and the Betwa have their own tributary system.

The Yamuna catchment extends over an area of 3,63,082 sq. km. and its drainage comprises the parts of the State of Himanchal Pradesh, Haryana, Rajasthan, Madhya Pradesh, Uttar Pradesh and entire area of the Union territory of Delhi. The salient features of the Yamuna basin are given in **Table 3.4**.

Table 3.4: Salient features of the Yamuna Basin.

1.	Location of Origin	Latitude 30° 58'N, Longitude 78° 27'E.
2.	Elevation at point of Origin	6,320 m above mean sea level
3.	Total length of the river Ramganga from its source to its outfall into the river Ganga	1376 km.
4.	Major tributaries	Tons, Giri, Maskara, Hindon, Karon, Saugar, Rind, Chambal, Sindh, Betwa, Ken
5.	Catchment area	3,63,082 sq. km.
6.	Catchment area lies in	Uttar Pradesh, Haryana, Himanchal Pradesh, Rajasthan, Madhya Pradesh,

3.3 The Ghaghra River System

The Ghaghra is one of the important left bank tributaries of the river Ganga. In the upper reaches, the river Ghaghra is known as the Manchu and Karnali in Nepal. It rises in the Himalayan glaciers near Lampia-pass at an elevation of 4800 m. at latitude 30°38' N and longitude 80°57'E about 60 km south west of Mansarowar. After flowing for about 72 km. the river enters Nepal territory. The river receives the Mugu Karnali and the Tiha on its

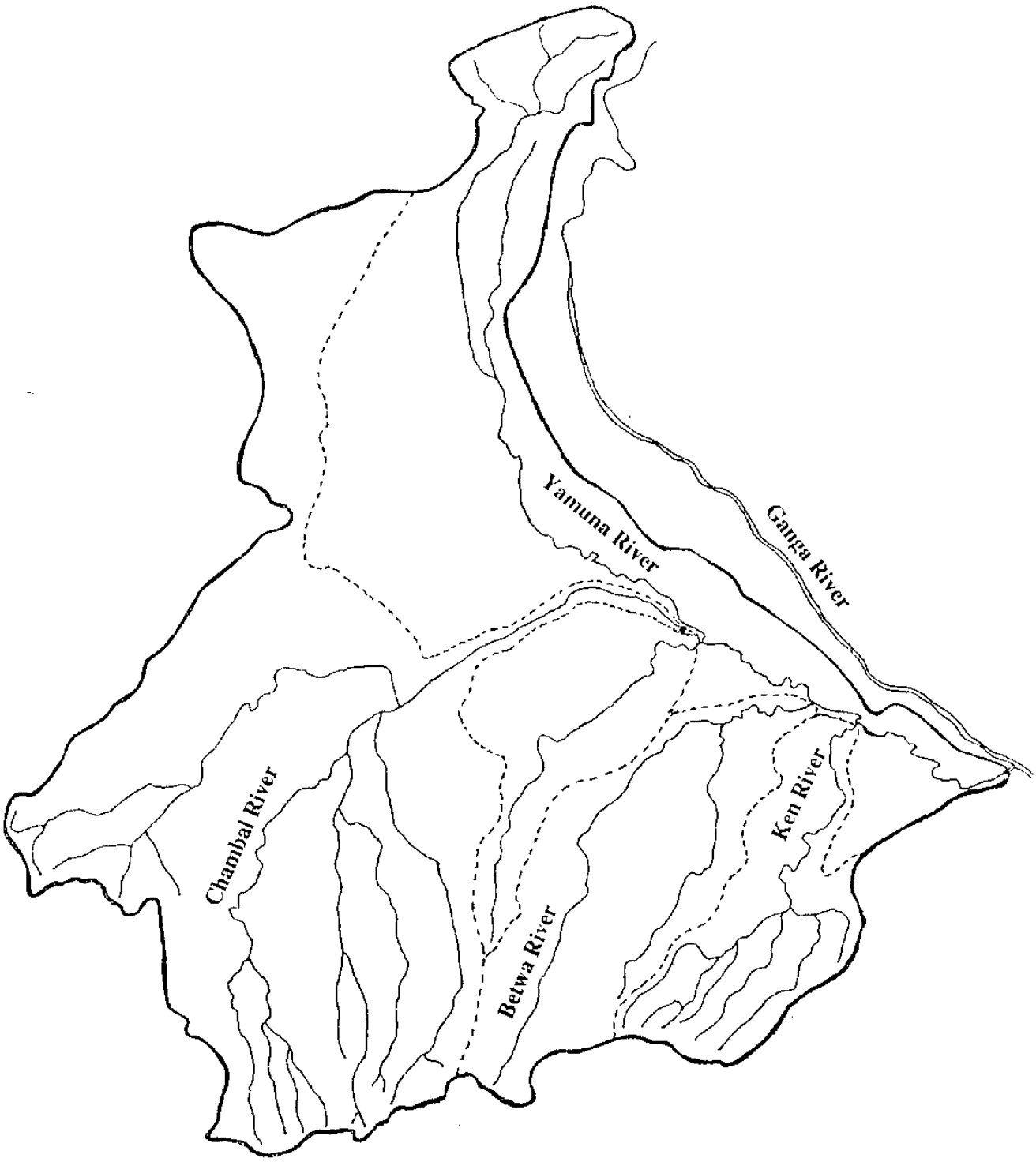


Figure 3.2 : The Yamuna Sub-basin

left bank. In the reach between Churighat and Dhundras, the river is joined by the Seti on its right bank. The river Bheri joins it on its left bank near Kueghat.

After traversing for some length in the plains, the river branches off into several channels downstream of Chisapani. The Kauriala and the Girwa are the important tributaries. The Kauriala, before leaving Nepal, receives the Mohan river on its right. The Kauriala and the Girwa rejoin at Bharatpur in Bahraich district of Uttar Pradesh. Near Gularia the river receives the Sarjuon on its right and further downstream the Beheri Sarju on its left. The Sarda, the most important tributary of the Ghaghra, joins the Kauriala at Rampur. After the junction with the Sarda, the river is known as the Ghaghra. In the Gonda district the lower Sarju and the Tirhi join the Ghaghra. The river Ghaghra flows in many channels through the districts of Gorokhpur, Deoria, Azamgarh, and Ballia. Near Dhuriapur, the Kuwana river joins the Ghaghra. The course of the Ghaghra is confined to a single channel at Dhorighat. The Rapti and the Little Gandak join it from the left. After receiving the Jharahi and the Daha, two small streams on its left, the river finally joins the river Ganga few km. downstream of Chapra town in Bihar. Subbasins of river Ghaghra (excluding river Rapti) and Rapti are shown in **Figures 3.3** and **3.4**.

The Ghaghra flows for a total length of about 1080 km., the upper half of which lies in Tibet and Nepal and the lower half in India. Out of the total catchment area of 1,27,950 sq.km., the area in India is only 57,647 sq.km. and the balance lies in Tibet and Nepal. The salient features of the Yamuna basin are given in **Table 3.5**.

Table 3.5: Salient features of the Ghaghra Basin.

1.	Location of Origin	Latitude 30° 38'N, Longitude 80° 57'E.
2.	Elevation at point of Origin	4,800 m above mean sea level
3.	Total length of the river Ramganga from its source to its outfall into the river Ganga	1080 km.

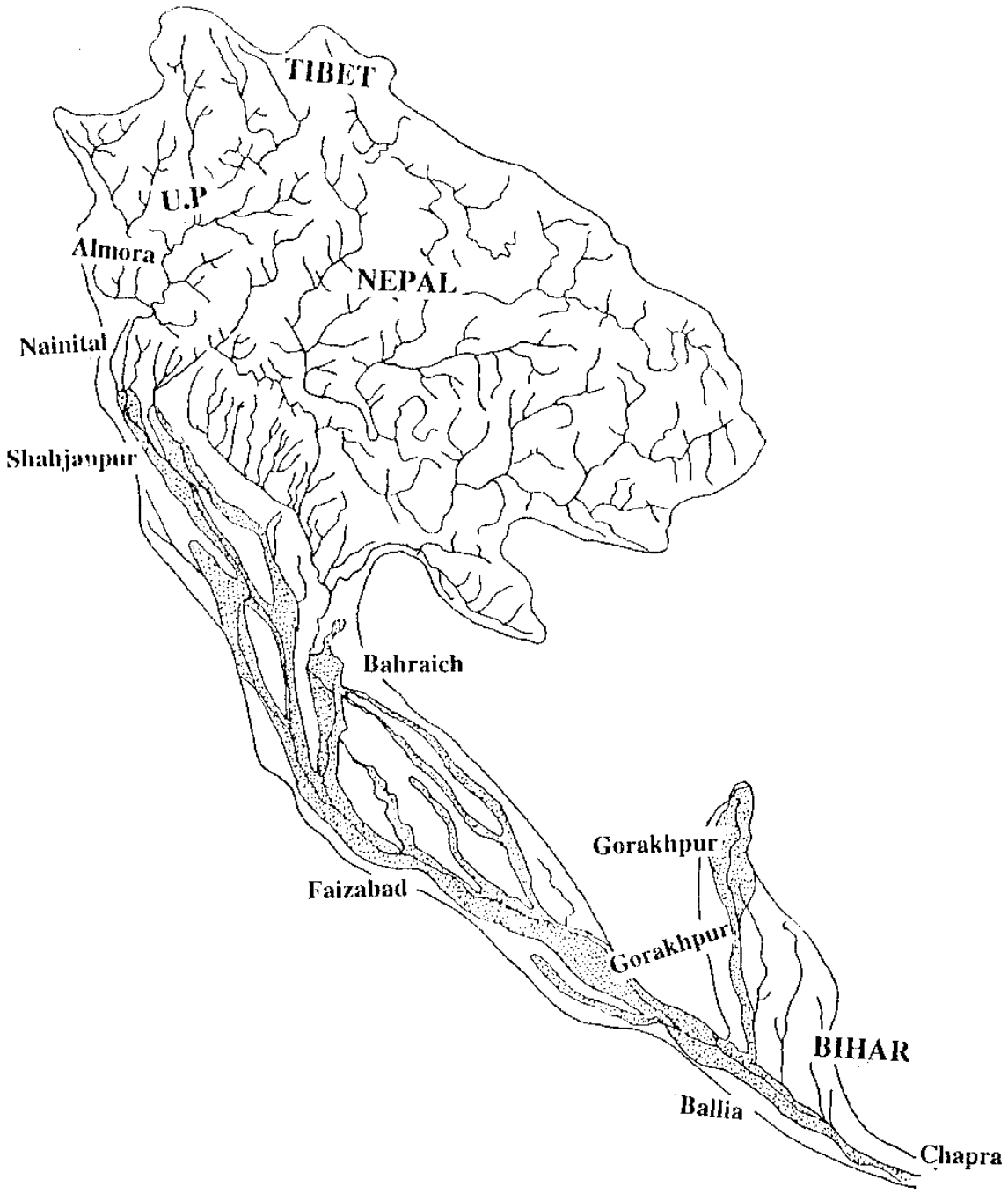


Figure 3.3 : The Ghaghra Sub-basin

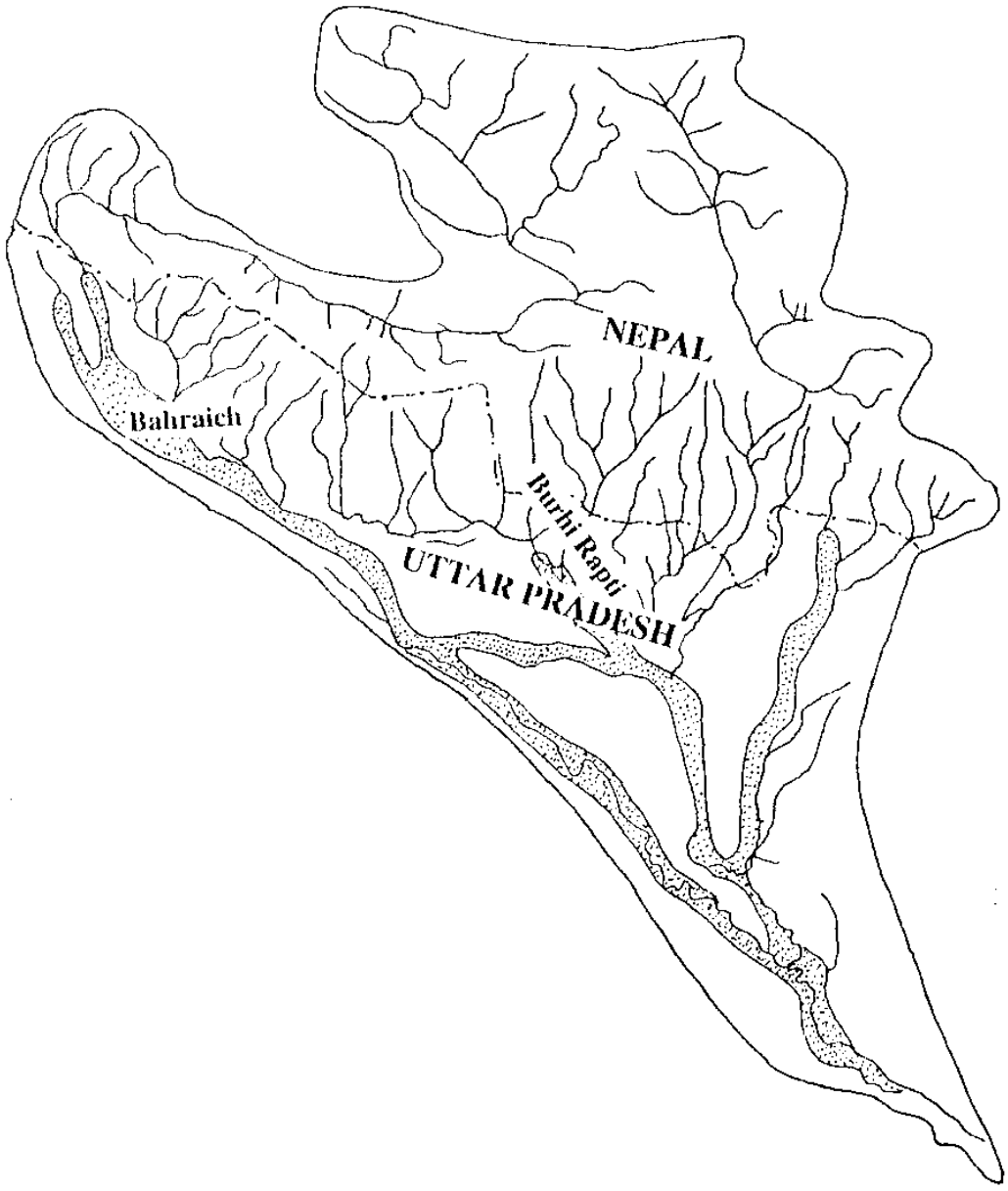


Figure 3.4 : The Rapti Sub-basin

4.	Major tributaries	Migu, Karnali, Tiha, Seti, Bheri, Kauriala, Girwa, Mohan, Sarda, Rapti, Little Gandak
5.	Catchment area	1,27,950 sq. km.
6.	Catchment area lies in	India (57,647 sq. km.) Nepal & Tibet (China) (70,303 sq. km.)

3.4 The Gomti River System

The total length of Gomti is about 900 km. and it flows entirely in Uttar Pradesh. It rises near Mainkot, about 3 km. east of Pilibhit town in Pilibhit district of Uttar Pradeshat at an elevation of about 200 metre at 28°34' N latitude and 80° 07'E longitude and drains the area lying between Ramganga and Sarda in the upper reaches and between the area of the Ganga and the Ghaghra in the lower reaches. Initially, the river has a course of about 24 kms. in the Pilibhit district where it is joined by the Gachiaon on its left bank. It traverses further through Shahjahanpur district for a length of about 60 km. in a well defined course, with a sluggish flow. After flowing through Shahjahanpur district for a length of about 56 km., the Gomti receives two more tributaries namely the Jokni and the Barua. Then the river Gomti flow through Khiri and Lucknow districts where it receives small tributaries, namely the Chhuha on its right bank and the Sarayan on its left bank. The river passes through Lucknow town in a south-easterly direction. Leaving Lucknow district, the river flows through districts of Barabanki, Sultanpur, Faisabad, Jounpur, and finally before its confluence with the Ganga, forms the boundary between Varanasi and Gazipur districts. The river Sai, which is the most important tributary of the Gomti, joins it near Saidpurin in Gazipur district. The subbasin of river Gomti is shown in **Figure 3.5**.

The catchment of the river Gomti covers an area of 30,435 sq.km. and it lies entirely in the state of Uttar Pradesh. Salient features of the Gomti Basin are presented in **Table 3.6**. The important tributaries of the Gomti join it on the left bank are the Jokni, the Khatna, the Sarayan, the Roth, and the Kalyani. The right bank tributaries are Bhainsi, the Chhuha, the Behta, the Kadhu, the Pilliand the Sai.

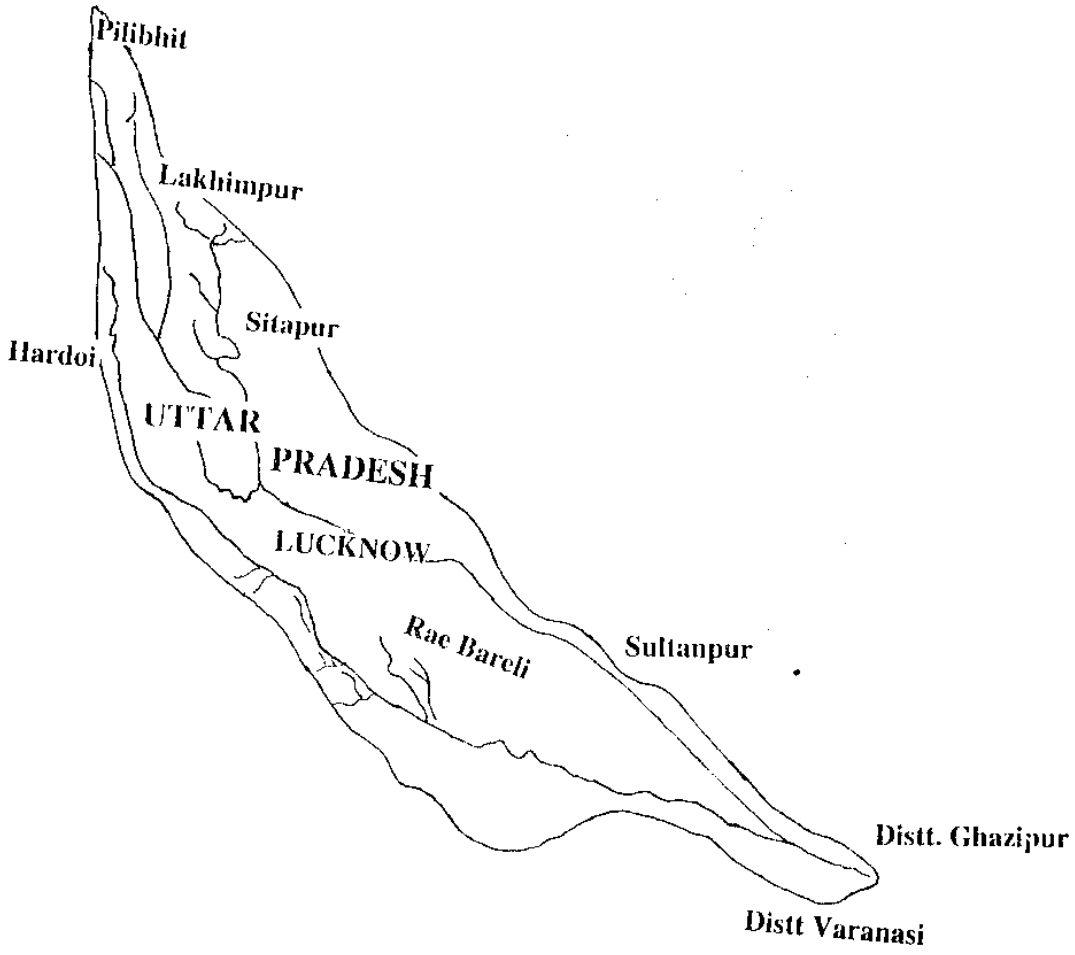


Figure 3.5 : The Gomti Sub-basin

Table 3.6: Salient features of the Gomti Basin.

1.	Location of Origin	Latitude 28° 34'N, Longitude 80° 07'E.
2.	Elevation at point of Origin	200 m above mean sea level
3.	Total length of the river Gomti from its origin to its outfall into the river Ganga	900 km.
4.	Major tributaries	Gachiaon, Jokni, Barua, Chhuha, Sarayan, Sai
5.	Catchment area	30,435 sq. km.
6.	Catchment area lies in	Uttar Pradesh,

3.5 Soil of the Study Area

Soils of the Ganga sub-basin are classified as mountain meadow soil, sub mountain soil, brown hill soil, terai soil, alluvial soil, calcareous alluvial soil and deltaic alluvium. These are described below:

3.5.1 Mountain Meadow Soil

The mountain meadow soils are found in the Himalayan region in an elevation of about 3,700 m. These are very thin in formation with different texture and structure. They are having mainly grass and it act as a binding material for such soils. In the area of very small soil thickness (i.e. 7 to 15 cms), the soils are termed as skeletal soils. These soils are easily disturbed by erosion. Wind can remove such soil from the rock surface.

3.5.2 Sub Mountain soil

These soils are siliceous in nature and the pH value of these soils are generally on the acidic side. These soils are found in the sub-Himalayan region under forest vegetation of coniferous type.

3.5.3 Brown Hill Soil

The brown hill soils are slightly acidic (pH value 6 to 6.5) in nature. They are composed of compact grey and dark brown clay loam. These soil often occur in hilly regions and under moderately heavy vegetation.

3.5.4 Terai Soil

These soils occur along the foot hills in the northern parts of Uttar Pradesh and are fairly deep and moderately fertile. Due to excessive moisture and fertility of the soil, the growth of vegetation and weeds is very high. With improved drainage these soils become highly productive.

3.5.5 Alluvial Soil

The colour of these soils ranges from pale-grey, yellow to yellow-brown and dark grey. The texture is generally silty-loam or silty-clay-loam. These soils responds well to manuring and need some drainage facilities. These soils represent the vast tracts of riverine alluvium of the Gangetic plain. The depth of alluvium extends many hundred meters.

3.5.6 Calcareous Alluvial Soil

These soils are light coloured and there texture varies from sandy loam to loam. They have the high content of $CaCo_3$. The pH value of the soil is on the alkaline side. These soils are alluvial soil and occur characteristically along the north eastern districts of Uttar Pradesh.

3.5.7 Deltaic Alluvium

The soils of the deltaic alluvium represent the hyterogeneous types of sediments brought by rivers and deposited at their mouths. The extensive deposition occurs at the mouth of the Ganga. The composition is extremely variable and they reflect characteristics of the region through which the rivers are flowing. The drainage conditions are satisfactory and they are extensively cultivated and cropped.

On the basis of above classification the soils of various districts of Uttar Pradesh are classified as given in **Table 3.7**.

Table3.7 : Soils of Ganga Basin in Uttar Pradesh

Sl No	Place	Type of Soil
1.	Agra	Medium black and alluvial
2.	Allahabad	Red and yellow and alluvial
3.	Aligarh	Alluvial and saline
4.	Banda	Alluvial and mixed red and black
5.	Bulandsahar	Alluvial and saline
6.	Kanpur	Alluvial and saline
7.	Dehradun	Brown hill
8.	Etah	Alluvial and saline
9.	Eutwah	Alluvial and saline
10.	Fatepur	Alluvial and saline
11.	Farukhabad	Alluvial
12.	Hamirpur	Mixed red and black
13.	Jalaun	Red sandy
14.	Janshi	Medium black and mixed red and black
15.	Mainpuri	Alluvial
16.	Meerat	Alluvial and saline
17.	Mathura	Alluvial and saline
18.	Muzaffarnagar	Alluvial brown hill
19.	Saharanpur	Brown hill
20.	Tehri Garwal	Brown hill and submountain
21.	Almora	Brown hill
22.	Nainital	Alluvial,terai and brown hill
23.	Garwal (Pauri)	Terai and brown hill
24.	Bijnore	Alluvial and terai
25.	Pilibhit	Alluvial and terai
26.	Moradabad	Alluvial
27.	Rampur	Alluvial and terai
28.	Bareilly	Alluvial and terai
29.	Shahjahanpur	Alluvial
30.	Badam	Alluvial
31.	Hardoi	Alluvial
32.	Lakhimpur (Kheri)	Terai
33.	Mirzapur	Red and yellow and alluvial
34.	Varanasi	Red and yellow and alluvial

Sl No	Place	Type of Soil
35.	Gazipur	Alluvial
36.	Sitapur	Alluvial
37.	Bohraich	Alluvial and terai
38.	Gonda	Alluvial and terai
39.	Barabanki	Alluvial
40.	Basti	Alluvial, Calcareous alluvial and terai
41.	Deoria	Alluvial and Calcareous alluvial
42.	Ballia	Alluvial
43.	Gorakhpur	Calcareous alluvial and terai
44.	Faizabad	Alluvial
45.	Azamgarh	Alluvial
46.	Jaunpur	Alluvial
47.	Sultanpur	Alluvial
48.	Lucknow	Alluvial
49.	Unnao	Alluvial and Saline
50.	Rai Bareilly	Alluvial
51.	Pratapgarh	Alluvial

HYDROLOGY AND IRRIGATION FACILITIES

4.1 Climate

The climate of the entire Uttar Pradesh is sub-tropical monsoon climate. During the summer, it is dry and hot and winter is moderate to severe cold. Winter season begins in October and ends in February. Summer is from March to middle of June. In the higher altitude region of the Himalayas, snowfall is a common feature from December to March. Some of the higher mountain peaks remain under snow. In the hills the minimum temperature reaches much below freezing point in most of the places. The maximum temperature in the plain varies from 43°C to 45°C in May and June while the minimum temperature ranges between 3°C and 4°C in January.

4.2 Rainfall

The monsoon, in the state of Uttar Pradesh sets in towards the end of June. It receives most of the rainfall through south-west monsoon. July and August are the wettest months and rainfall generally declines in September. Winter showers, which are scanty, are usually received towards the end of December and sometimes during January. The annual rainfall of the state varies between 600 mm and 2000 mm. Himalayan region gets about 1000 mm to 2000 mm while the plain area receives from 600 mm to 1400 mm and the southern plateau between 200 mm to 1200 mm. Data related to maximum and minimum rainfall, place of occurrence etc. of various subcatchments of the Ganga basin are presented in **Table 4.1**.

Table 4.1 : Rainfall information of various subcatchment in Ganga basin.

I		**RAMGANGA BASIN**	
	1.	Period of Monsoon	June to September
	2.	Name of the place receives highest annual rainfall	Nainital
	3.	Highest annual rainfall	157 cm
	4.	Name of the place receives lowest annual rainfall	Farukhabad
	5.	Lowest annual rainfall	79.2 cm
	6.	Maximum value of 24 hours rainfall with 50 years of frequency	28 cm (Occurs near Kalagarh)
II		**GOMTI BASIN**	
	1.	Period of Monsoon	June to September
	2.	Name of the place receives highest annual rainfall	Plibhit district
	3.	Maximum average annual rainfall	124 cm
	4.	Name of the place receives lowest annual rainfall	Unnao
	5.	Lowest annual rainfall	84 cm
	6.	Maximum value of 24 hours rainfall with 50 years of frequency	28 cm (Occurs in Plibhit district)
III		**GHAGHRA BASIN**	
	1.	Period of Monsoon	June to September
	2.	Name of the place receives maximum annual rainfall	Nainital
	3.	Maximum average annual rainfall	156 cm
	4.	Name of the place receives minimum annual rainfall	Sitapur
	5.	Minimum annual rainfall	97 cm
	6.	Maximum value of 24 hrs rainfall with 50 years of frequency	28 cm (Occurs in Almora district)
IV		**YAMUNA BASIN**	
	1.	Period of Monsoon	June to September
	2.	Average annual rainfall of Upper catchment	150 cm
	3.	Variation of rainfall in lower catchment	150 to 40 cm
	4.	Maximum value of 24 hrs rainfall with 50 years of frequency	28 cm (Occurs in Hilly tract of Vindhyan range)

4.3 Rainfall Pattern

The average values of the monthly, seasonal and annual rainfall in various sub-basins of the river Ganga basin are presented in **Table 4.2**. Distribution of annual and monsoon rainfall (June to September) in the Ganga basin is shown in **Figures 4.1** and **Figure 4.2**. It indicates that the annual rainfall varies between 750 mm and 1,500 mm in Himalayan belt with a few pockets of 2,500 mm lying mostly within Nepal territory. This range is 500 to 1,000 mm in Yamuna catchment. In the remaining areas of the Ganga subbasin, excluding the Yamuna and the Hooghly river systems, the variation is between 1,000 mm to 1,500 mm.

Table 4.2: Monthly, and Annual Rainfall (mm) in the Ganga Subbasin

Sl	Name of Sub-basin	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1	Yamuna Catchment	15	12	8	5	9	75	255	239	125	18	7	7	784
2	Ganga upto end including Ramganga	37	38	26	15	27	127	360	351	200	35	5	16	1238
3	River Ganga from Ramganga to its confluence with river Yamuna (Excluding Yamuna)	15	17	9	5	9	67	259	264	164	30	4	7	850
4	Ganga between its confluence with Yamuna and river Ghaghara(excluding Ghaghara including river Gomti)	18	21	9	6	13	104	309	307	198	44	7	6	1042

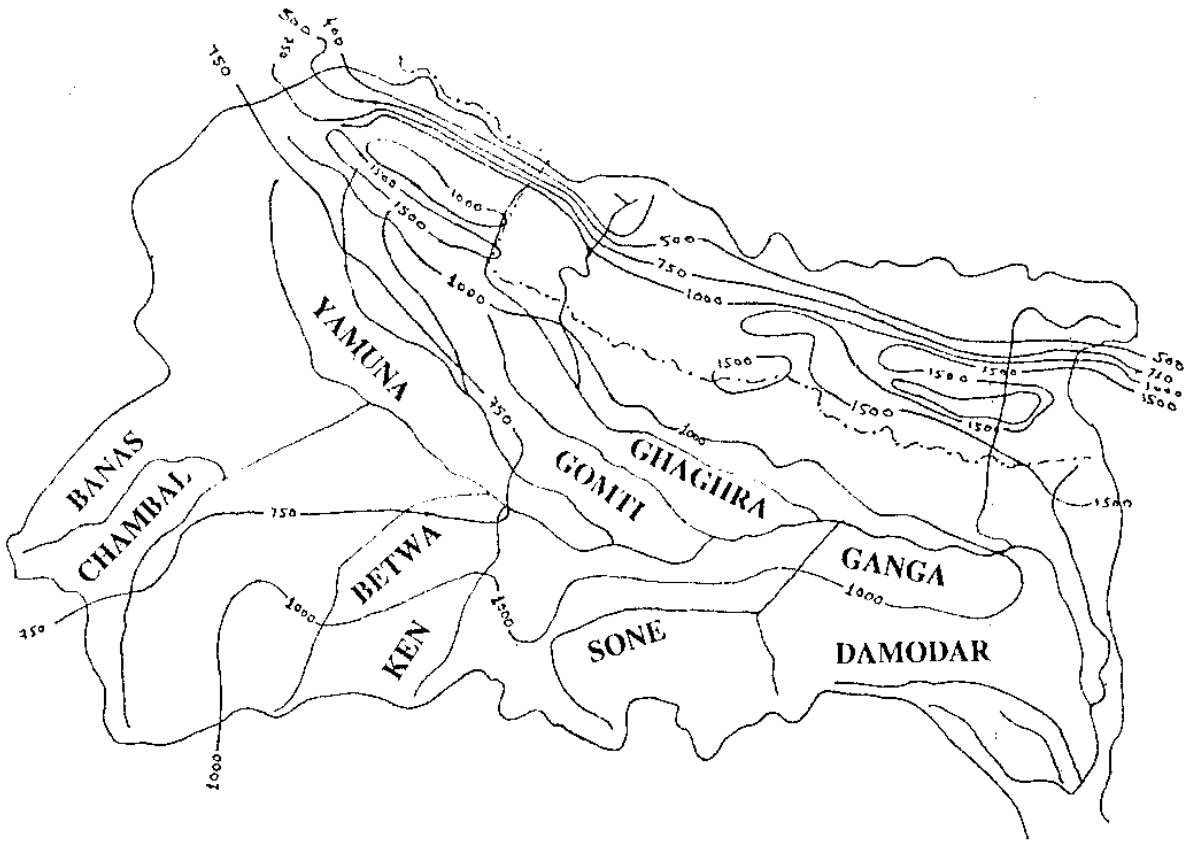


Figure 4.1 : Distribution of Monsoon Rainfall (June to September) in Ganga Basin

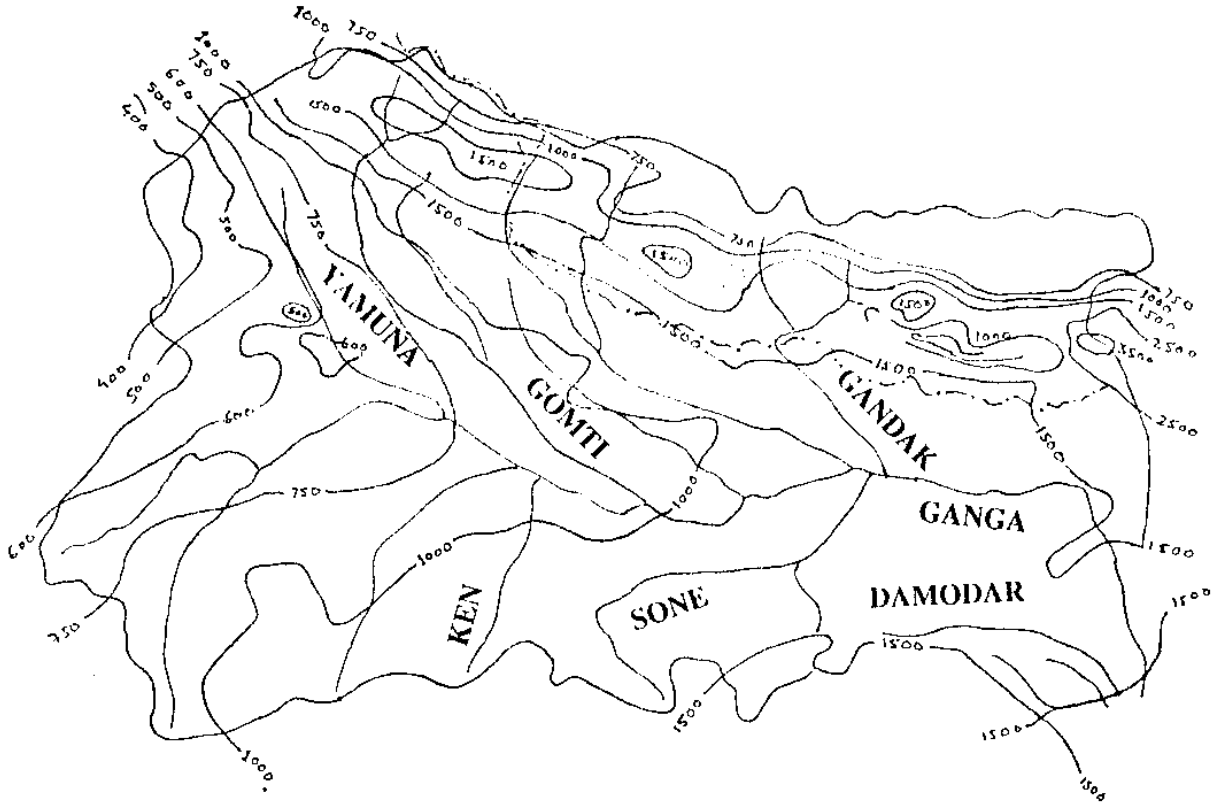


Figure 4.2 : Distribution of Annual Rainfall in Ganga Basin

Sl	Name of Sub-basin	January	February	March	April	May	June	July	August	September	October	November	December	Annual
5	River Ganga between its confluence with river Sone and river Kosi	15	20	12	15	43	172	316	329	220	59	10	3	1215

4.4 Infiltration

Infiltration studies have been carried out at few places in Uttar Pradesh. Some of these studies are tabulated below (**Table 4.3**):

Table 4.3 : Infiltration studies in Uttar Pradesh

Sl.	Infiltration Studies carried out by	River/Catchment	Districts covered
1	All India Soil and Land Use Survey, New Delhi	Ram ganga	Almora, Paurigarhwal
2	Ground Water Investigation Organisation	Along Hindon River	Sharanpur
3	Ground Water Department, Govt. of U.P.	-	Different Parts of U.P
4	Mohan and Gupta, 1983	Bhaintan Watershed	Tehri-Garwal
5	Prasad and Ali, 1989	Kanhar Catchment	Mirzapur

The ground water Department, Govt. of U.P. has carried out some infiltration tests in different parts of U.P. These values are presented in **Table 4.4**.

Table 4.4: Infiltration data from U.P. (Ground Water Department, U.P.)

Sl. No.	District	Block	Village	Soil Type	Infit. Rate (cm/hr)
1	Varanasi	Cholapur	Babhanpura	Silt loam	6.15
2	Varanasi	Cholapur	Danaganj	Silt loam	1.41

Sl. No.	District	Block	Village	Soil Type	Infit. Rate (cm/hr)
3	Bareilly	Alampur	Panwara	Silt loam to sand	3.84
4	Bareilly	Alampur-Zafrabad	Panwara	Silt loam	2.86
5	Bareilly	Alampur-Zafrabad	Balliya	Silt loam	0.963
6	Bareilly	Alampur-Zafrabad	Pathra	-	7.65
7	Agra	Fatehabad	Bilauni	-	0.86
8	Farrukhabad	Kannauj	Akbarpur	-	0.90
9	Lucknow	Chinhat	Simra	-	0.40
10	Lucknow	Chinhat	Vijaipur	-	0.58-1.24
11	Lucknow	Chinhat	Kanchanpur	-	2.8
11	Aligarh	Akarabad	Dhubiya	-	1.16
12	Aligarh	Akarabad	Kalianpur	-	0.65
13	Aligarh	Akarabad	Nagala Sartaj	-	0.63
14	Aligarh	Akarabad	Vijaygarh	-	0.38
15	Sultanpur	Bhadar	Sansarpur	-	0.72
16	Sultanpur	Bhadar	Piparpur	-	1.98
17	Sultanpur	Bhadar	Kalyanpur	-	0.72
18	Sultanpur	Bhadar	Ghoraha	-	2.10
19	Hardoi	Sandila	Ghoraha	-	0.54
20	Hardoi	Sandila	Mahsona	-	3.24
21	Hardoi	Sandila	Tilai Khurd	-	0.90
22	Hardoi	Bahendar	Raise	-	1.20
23	Hardoi	Kachhona	Malhupur	-	0.60
24	Hardoi	Kachhona	Sunni	-	1.30
25	Hardoi	Kachhona	Kakuhi	-	0.84

4.5 Groundwater

The eastern part of Uttar Pradesh occupies a part of the Ganga Alluvial Plain between the northern Siwalik hills and the southern peninsular shield. Geologically the area is covered by thick pile of Quaternary and Tertiary sediments over Bundelkhand geneissic complex and the Vindhyans. The Quaternary sediment comprises the Banda Older Alluvium (BOA), Varanasi Older Alluvium (VOA) and the Newer Alluvium.

Groundwater estimates reveal that the replenishable groundwater resources of eastern Uttar Pradesh is 2.82 m ha. M/year out of which about 15% is provided for domestic, industrial and other uses. Leaving behind 2.40 m ha. M/year for irrigation. During 1991 net draft was 0.86 m ha m. Thus, the balance of the resources left for future use was 1.5 m ha m/year. The level of groundwater development is about 36%, with ample scope to utilize the replenishable groundwater resource. Free flowing groundwater conditions having hydrostatic head between 1 and 4.65 m above ground level are present in the total belt of Maharajganj district in the foothills of Himalaya. A decline in water level of the order of 2 to 4 m is observed towards south of river Ghaghra, in the parts districts Pratapgarh and Jaunpur. There are a few blocks in Jaunpur where groundwater development has reaches the category of Grey. Besides, there is 10 to 20 m deep water level in the marginal alluvial area of district Allahabad with a declining trend.

4.6 Ganga Canal System

In the Ganga basin, several large, medium and small diversion canals have been constructed. The upper Ganga canal system, the first large scale irrigation project, was constructed during 1834-54 to serve ten western districts of Uttar Pradesh. In 1951, the design discharges capacity of upper Ganga Canal (UGC) was increased to 294 cumecs from 191 cumecs. The canal system comprises the main canal, Deoband branch, Anupshahar branch, Mat branch, Hathras branch and supply channel along with the network of distributiories and minors. The UGC system consists of 6540 km of canals with a nominal design duty of about 0.03 cumecs/100 ha.

In the year 1978, the Lower Ganga Canal (LGC) was constructed to overcome the increasing demand of irrigation water. The canal was taken-off from the upstream of Narora weir constructed across river Ganga near Narora. This system continued till 1965 when the head works were remodelled and a new barrage was constructed at the downstream of Narora weir. After construction of LGC, the command area of UGC was restricted upto start of Kanpur. When water supplies in river Yamuna drops below certain

level during non-monsoon period, Uppar Ganga Canal also feeds Agra canal through Jani escape via Hindon river and Heridon cut. Irrigation during Kharif season i.e. monsoon period was also introduced during twentieth century by constructing parallel Ganga canal (PLGC). To store monsoon flows, a storage dam was completed on river Ramganga, a tributary of River Ganga. It augments supplies to river Ganga during nonmonsoon period near Garhmukteswar which in turn is diverted into LGC through Narora barrage.

Two major canal systems i.e. Madhya Ganga Canal (MGC) and Eastern Ganga Canal (EGC) have been completed in nineteen eightees to extend irrigation during Kharif season. MGC takes off from Right Bank of Ganga at Raolighat. EGC takes off on the left bank at Bhimgoda barrage. This system irrigates 0.232 Mha area on left of river Ganga during Kharif season. **Figure 4.3** shows proposed crop areas in various canal systems.

Two irrigation canal systems (i) upper eastern Yamuna canal and (ii) lower Agra canal system irrigate the culturable land of U.P. The upper eastern Yamuna canal system taking off from the left bank at Tajewala Head Works and lower Agra canal system taking off from right bank at Okhla.

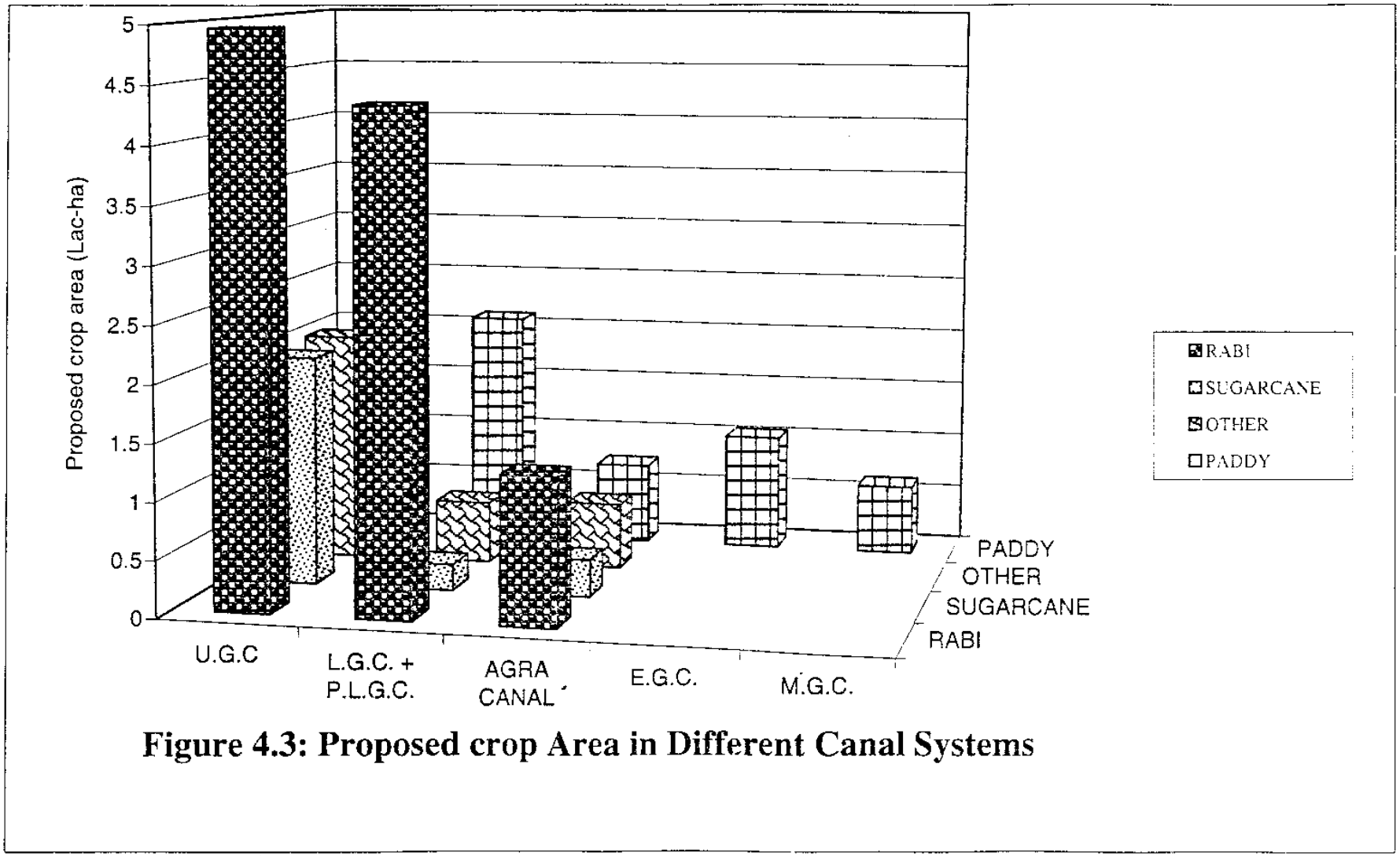


Figure 4.3: Proposed crop Area in Different Canal Systems

Hydrological Data Availability

5.1 Availability of Rainfall data

In the study area a number of raingauge stations are installed and observed by IMD. State Government and some of the local agencies are also maintaining some raingauge stations. A list of the raingauge stations maintained by IMD in Eastern U.P. is given in **Table 5.1**. An estimate of the raingauge stations required as per the norms of the WMO and the actual number of raingauge stations are presented in **Table 5.2**.

TABLE 5.1 : List of Raingauge Stations with Locations in Eastern Uttar Pradesh

Raingauge Station	Latitude (in degree and minutes)	Longitude (in degree & minutes)
Varanasi District		
1.Varanasi	25° 20'	83° 00'
2.Varanasi (obsy)	25° 18'	83° 01'
3.Chandauli	25° 17'	83° 16'
4.Gangapur	25° 27'	82° 53'
Mizapur District		
1.Mirzapur	25° 09'	82° 35'
2.Dudhi	24° 13'	83° 15'
3.Robertgunj	24° 42'	83° 04'
4.Chunar	25° 07'	82° 54'
5.Hasanpur	25° 05'	82° 02'
Jannpur District		
1.Jaunpur	25° 45'	82° 41'
2.Mariahu	25° 36'	82° 36'

Raingauge Station	Latitude (in degree and minutes)	Longitude (in degree & minutes)
3.Machhlishahr	25° 42'	82° 25'
4.Kerakat	25° 38'	82° 55'
5.Shahganj	26° 03'	82° 42'
Gazipur District		
1.Gazipur	25° 35'	83° 34'
2.Saidpur	25° 32'	83° 13'
3.Zamania	25° 26'	83° 34'
4.Muhammadabad	25° 37'	83° 45'
Ballia District		
1.Ballia	25° 44'	84° 10'
2.Rasra	25° 52'	83° 51'
3.Bansdih	25° 53'	84° 14'
4.Sikanderpur	26° 03'	84° 03'
Gorokhpur District		
1.Gorakpur	26° 45'	83° 22'
2.Gorakhpur (obsy)	26° 45'	83° 22'
3.Maharajganj	27° 09'	83° 34'
4.Banasgaon	26° 33'	83° 22'
5.Pharenda	27° 06'	83° 17'
Deoria District		
1.Deoria	26° 30'	83° 47'
2.Hata	26° 45'	83° 45'
3.Padrauna	26° 55'	83° 59'
4.Salimpur	26° 18'	83° 55'
Basti District		
1.Basti	26° 47'	82° 43'

Raingauge Station	Latitude (in degree and minutes)	Longitude (in degree & minutes)
2.Domeriaganj	27° 13'	82° 40'
3.Bansi	27° 10'	82° 56'
4.Haraiya	26° 48'	82° 28'
5.Khalialabad	26° 47'	83° 04'
Azamgarh District		
1.Azamgarh	26° 03'	83° 11'
2.Deogaon	25° 44'	82° 59'
3.Mahul	26° 05'	82° 52'
4.Jiwanpur	26° 09'	83° 20'
5.Mohammadabad	26° 02'	83° 23'
6.Ghosi	26° 06'	83° 32'
Banda District		
1.Bandra	25° 29'	80° 21'
2.Pailani	25° 45'	80° 26'
3.Girwan	25° 18'	80° 24'
4.Baberu	25° 33'	80° 43'
5.Badausa	25° 14'	80° 39'
6.Kamasin	25° 31'	80° 55'
7.Karwi	25° 12'	80° 55'
8.Mau	25° 16'	81° 23'
9.Manikpur	25° 02'	81° 07

Table 5.2: Raingauge required as per WMO guidelines in Ganga Sub-bsin

Sl.No.	Name of Sub-basin	Actual No. of raingauge station	Required No. as per norm	Extra needed
1	Main Ganga	289	155	-
2	Yamuna	382	135	-

Sl.No.	Name of Sub-basin	Actual No. of raingauge station	Required No. as per norm	Extra needed
3	Ramganga	89	70	-
4	Gomti	10	61	51
5	Ghaghra	55	118	63

5.2 Gauge and Discharge Measuring Sites

Gauge and discharges of various rivers in the Ganga sub-basin is measured by Central and State Government organisations. List of a gauge and discharge sites maintained by various organisation in the Ganga river basin is given in **Table 5.3**. A number of flood forecasting sites are also functioning in the sub-basin. These sites are shown in **Figure 5.1**.

Table 5.3:List of Gauge & Discharge Sites on Various Rivers in Ganga Basin

Sl. No.	Name of River	Name of G&D Sites	District	State	Concerned Agency
1.	Bhagirathi	Uttar-Kashi	Uttar-Kashi	U.P	
2.	"	Tehri	Tehri	"	
3.	Alaknanda	Joshimath	Pithirgarh	"	
4.	"	Rudraprayag		"	
5.	Mayar	Marora		"	
6.	Ganga	Haridwar	Hardwar	"	
7.	"	Narora	Buland Shaher	"	
8.	"	Fatehgarh		"	
9.	"	Ankinghat	Kanpur	"	CWC(MGD-II) Lucknow
10.	"	Kanpur	Kanpur	"	"
11.	"	Dalmau	Rai Bareilly	"	"

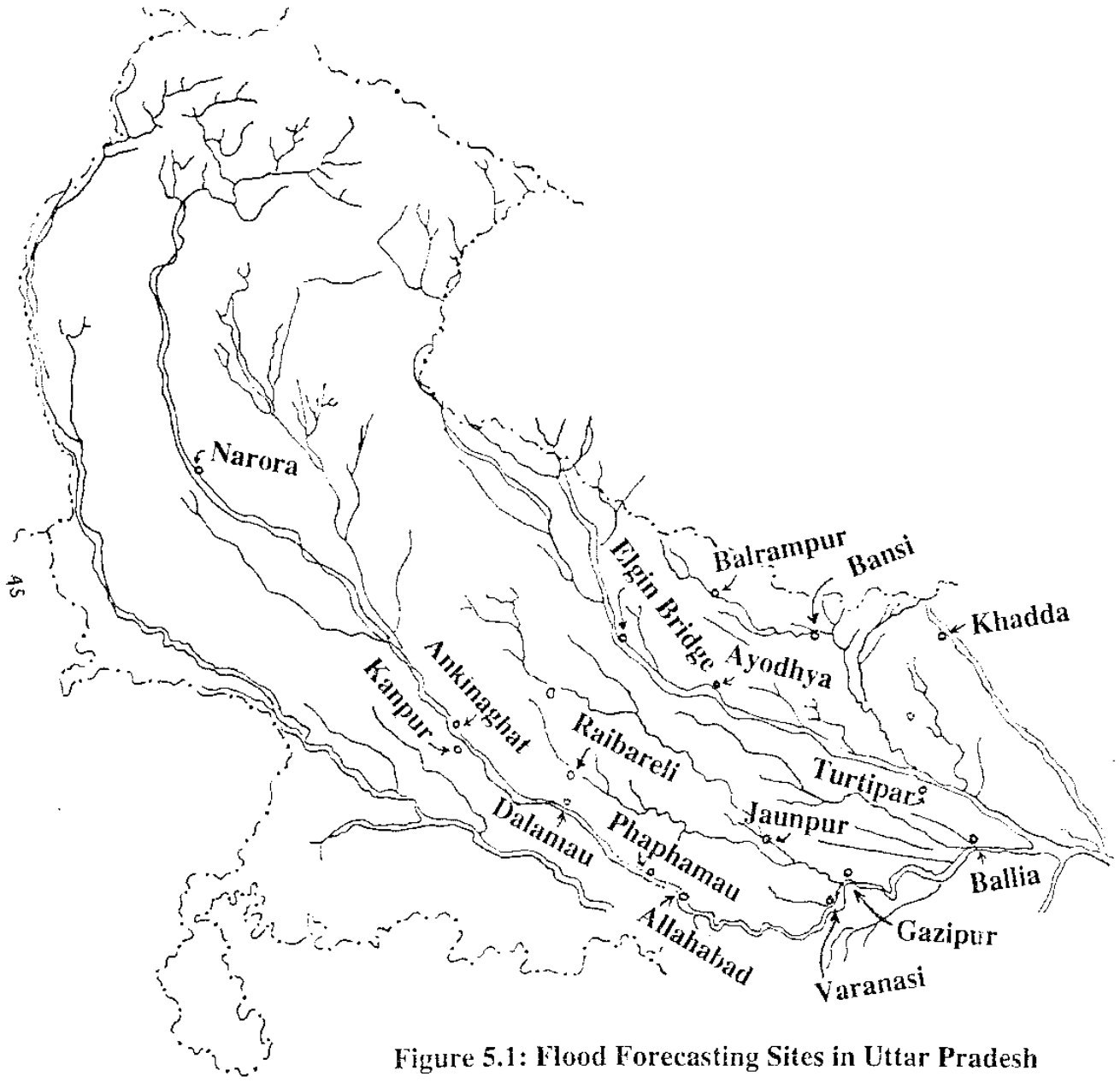


Figure 5.1: Flood Forecasting Sites in Uttar Pradesh

Sl. No.	Name of River	Name of G&D Sites	District	State	Concerned Agency
12.	"	Allahabad (Phaphamau)	Allahabad	"	CWC(MGD-III). Varanasi
13.	"	Allaahabad (Chhatnag)	Allahabad	"	"
14.	"	Mirzapur	Mirzapur	"	"
15.	"	Varanasi	Varanasi	"	"
16.	"	Gazipur	Gazipur	"	"
17.	"	Ballia	Ballia	"	"
18.	Yamuna	Mathura	Mathura	"	
19.	"	Agra	Agra	"	
20.	"	Etawah	Etawah	"	
21.	"	Auraiya		"	
22.	"	Kalpi		"	
23.	"	Hamirpur		"	
24.	"	Chillaghat		"	
25.	"	Allahabad (Naini)	Allahabad	"	
26.	Ramganga	Bareilly		"	
27.	"	Dabri		"	
28.	Betwa	Mohana		"	
29.	"	Shahjina		"	
30.	Ken	Banda		"	
31.	Chambal	Dhulpur		"	
32.	Gomti	Neemsar	Sitapur	"	
33.	"	Bhatpurwa Ghat	Sitapur	"	

Sl. No.	Name of River	Name of G&D Sites	District	State	Concerned Agency
34.	"	Lucknow (H.S)	Lucknow	"	CWC(MGD-I) Lucknow
35.	"	Sultanpur	Sultanpur	"	
36.	"	Jaunpur	Jaunpur	"	CWC(HGD-III) Varanasi
37.	"	Bani		"	
38.	"	Rai Barelly	Rai Barelly	"	CWC(MGD-I) Lucknow
39.	Sharda	Banbasa	Nainital	"	
40.	"	Palia Kalan	Lakhimpur	"	
41.	"	Sharda Nagar	"	"	
42.	Ghaghra	Katernia Ghat	Bharaich	"	
43.	"	Elgin Bridge	Barabanki	"	
44.	"	Ayodhya	Faizabad	"	
45.	"	Turtipar	Ballia	"	
46.	Rapti	Kakardhari		"	CWC(MGD-I) Lucknow
47.	"	Balarampur	Gonda	"	"
48.	"	Bansi	Basti	"	"
49.	"	Rigauli		"	
50.	"	Gorakhpur (Birdghat)	Gorakhpur	"	"
51.	Kauna	Chanderdweep Ghat		"	
52.	"	Basti		"	
53.	"	Muklishpur		"	

Sl. No.	Name of River	Name of G&D Sites	District	State	Concerned Agency
54.	Burhi Rapti	Kakrahi		"	
55.	Gandak	Khadda	Deoria	"	CWC(MGD-IV Patna

HYDROLOGICAL PROBLEMS OF STUDY AREA

6.1 Flood Problem in Ganga Basin

Occurrence of flood is a natural phenomenon associated with complexes of the hydrological cycle. Ganga basin is no exception to it. Every year floods cause hardship, misery and damage to crops, life and property in one or the other part of the basin. The major tributaries of the Ganga take their origins in the Himalayas extending beyond India's geographical boundary. Flood problem is mostly confined to the areas on the northern bank of the river Ganga. The damage is mostly caused by spilling over of the banks of the tributaries and erosion caused by change of river courses. During severe storm, many drainage channels are unable to carry the storm water quickly, causing inundation in parts of the basin. When the Ganga is in spate, the storm in the catchment of any of its tributaries would create drainage congestion leading to flooding. The main flood problems of the State of Uttar Pradesh can be broadly categorized as under:

i. Inundation of the countryside due to inadequacy of drainage system.

ii. Inundation of villages situated within the flood zone of the rivers.

iii. Inundation of agricultural areas by spilling of the rivers.

iv. Inundation and erosion of banks and adjacent areas by the rivers in floods.

6.1.1 Flood problem in the main Ganga

The river Ganga spills over its banks at several places. The major problem of flooding along Ganga occurs below the confluence of Yamuna at Allahabad. Below Allahabad, the river also erodes its banks near Varanasi, Ballia, Mirzapur and Gaighat.

6.1.2 Flood problem in the Yamuna

The bank erosion problem has been experienced on the left bank in the district of Shaharanpur, Muzaffar Nagar and Meerut. The Banganga and the Gambhir flow through the flood plain of Bharatpur district and cause drainage congestion in that area. The Yamuna in the lower reach in Uttar Pradesh spills during high floods, in the districts of Bands and Allahabad. Important towns like Agra, Mathura, Itawah, Hamirpur and Allahabad also experience floods during high stages in the river. Banda town also gets affected by floods from the river Ken. Drainage congestion problem occurs in Bulandshahar, Aligarh, Mathura, and Agra and Etawah districts.

6.1.3 Flood problem in the Ramganga

The flood in this river system is limited to its lower reach near its confluence with Gang. The districts affected Bijnor, Moradabad, Bareilly, Rampur, Badaun, Shahjahanpur, Hardoi and Farukhabad. Bank erosion has been noticed near the townships of Pilibhit, Shahjahanpur and Moradabad, by its tributary 'Kosi'. In plains the course of the river Ram-Ganga uncertain. During floods, the river overflows its banks, opening out new channels and destroys the fertility of the land by depositing coarse land on it. The river Kosi, which is a tributary of the Ramganga, is constantly changing its course and spills over its bank in the upper reaches near Rampur district. In the year 1974 a dam was constructed on the river Ramganga at Kalagarh in the district of Bijnore. To some extent, it has reduced the flood problem in the catchment of river Ramganga.

6.1.4 Flood problem in the Gomti

The flood problem in this river system is mainly caused by river Gomti and its tributary Sai. The flooding from Gomti is mainly caused in Lucknow, Sultanpur, and Jaunpur districts while from river Sai in Unnao, Lucknow, Raeibareli, Pratapgarh and Jaunpur districts. Lucknow and Jaunpur towns remain under threat by river Gomti. The middle reach of the river is severely affected due to drainage congestion.

6.1.5 Flood problem in the Ghaghra

The eastern part of Uttar Pradesh which lies in the river system is the worst affected. During high flood, large areas of the districts of Bahraich, Gonda, Basti, Deoria, Gorakhpur, Faizabad, Azamgarh, and Ballia get inundated. Bank erosion problem exists in the districts of Azamgarh and Ballia. In Bihar, the flood waters inundated large areas in Siwan, Gopalganj, & Chapra districts. The river spills through the gaps in the left embankment and causes flooding in vast areas.

6.2 Erosion and Sediment Problem

There are six major factors which contribute to high rates of run-off and sediment discharge from the Himalayan catchments (Rastriya Barh Ayough). These are classified as:

1. Shifting cultivation
2. Grazing
3. People's right and privileges
4. Forest fires
5. Surface mining
6. Land slides and slips

Above factors are directly or indirectly connected with the human activities or the human interference with the nature. There are several other causes for excessive silt content in these rivers. These are given below:

1. Geologically younger and more friable nature of the Himalayas
2. Hilly catchment being prone to earthquake.
3. High intensity of rainfall
4. Steep slope in the hilly reaches of the rivers
5. Picking up of silt during the passage of the rivers through the alluvial plains.

The river Ganga and most of its tributaries originate from the Himalaya. These Himalayan rivers traverse through unconsolidated sedimentary rocks and drain the geologically unstable steep slopes where the rainfall is very heavy. This results in excessive sediment load in these rivers particularly during the monsoon. Numerous landslides and slips in the region further accelerate it. The other contributory factors for the land erosion are deforestation, over grazing and lack of vegetation cover. The streams and rivers, which originate from such degraded watersheds, experience flash floods, carry heavy sediment load and aggrade their beds, thereby reducing their bankful capacity. In the study area the river Ghaghra, the Rapti, the Gomti and the Sarda carry heavy silt load and the catchment areas of Alakananda and Bhagirathi are prone to soil erosion. The average annual, average monsoon and the maximum monsoon value of the silt data (Comprehensive Plan of Flood Control for the Ganga Sub-basin, Part-I) at various sites in the study area are given in the **Table 6.1**.

Table 6.1: Average Annual, Maximum Annual, Average Monsoon and the Maximum Monsoon Value of Silt Load.

Sl. No	Name of River	Gauge Site	Average Annual Silt Load in Th.H.M.	Maximum Annual Silt Load in Th.H.M.	Average Monsoon Silt Load in Th.H.M	Maximum Monsoon Silt Load in Th.H.M.
1	Yamuna	Etawah	1,636.058	4,672.07	1,625.181	3,002.56
2	Ramganga	Zira Rahimpur	3,248.444	8,338.667	3,139.847	7,449.317

Sl. No	Name of River	Gauge Site	Average Annual Silt Load in Th.H.M.	Maximum Annual Silt Load in Th.H.M.	Average Monsoon Silt Load in Th.H.M	Maximum Monsoon Silt Load in Th.H.M.
3.	Ghaghra	Katamiaghat	3,165.032	5,994.537	3,043.984	5,779.08
4.	Ghaghra	Elgin Bridge	7,664.632	11,670.740	7,347.938	10,379.624
5.	Ghaghra	Turtipar	7,524.07	11,104.839	7,310.227	10,877.401
6.	Sarda	Palia Kalan	3,023.817	4,629.691	3,008.927	4,597.231
7.	Rapti	Bridghat	1,127.894	1,705.606	1,118.388	1,695.553
8.	Ganga	Buxar	13,516.304	24,647.864	13,487.73	24.636.434

6.3 Waterlogging and Drainage

Large areas in Uttar Pradesh are affected by waterlogging (**Fig. 6.1**). **Figure 6.2** shows the area where usar land has increased a most. There has been a very rapid increase in tubewell irrigation in Uttar Pradesh. Portion of the irrigated land irrigated by the tubewells are shown in **Figure 6.3**. In Uttar Pradesh, a considerable area is also affected by Salt (**Figure 6.4**). The problem of waterlogging and siltation in river beds is acute particularly in the command areas of the two major irrigation systems of Sharda Sahayak and Gandak. In these canal systems, recharge of sub-surface water in the absence of proper drainage facilitates and low utilisation of ground water has led to a rise in sub-soil water table. Sharda canal command falls in 118 blocks of districts Pilibhit, Shahjahanpur, Hardoi, Unnao, Lucknow, Bareilly, Barabanki, Pratapgarh, Raibareli, Sitapur, Lakhimpur Kheri and Nainital. Waterlogging and soil alkalinisation are much serious in central and eastern command, such as in Hardoi, Unnao and Lucknow, due to low surface gradient (<0.3 m/km) and predominance of impervious thick clay layers upto the depth range of 10 m to 30 m. with thin intercalation of lenticular sandy strata. In this area, the critical water table is at the depth range of 1.50m to 2.0 m. in varying lithological setup above which complete soil profile is saturated and waterlogged.

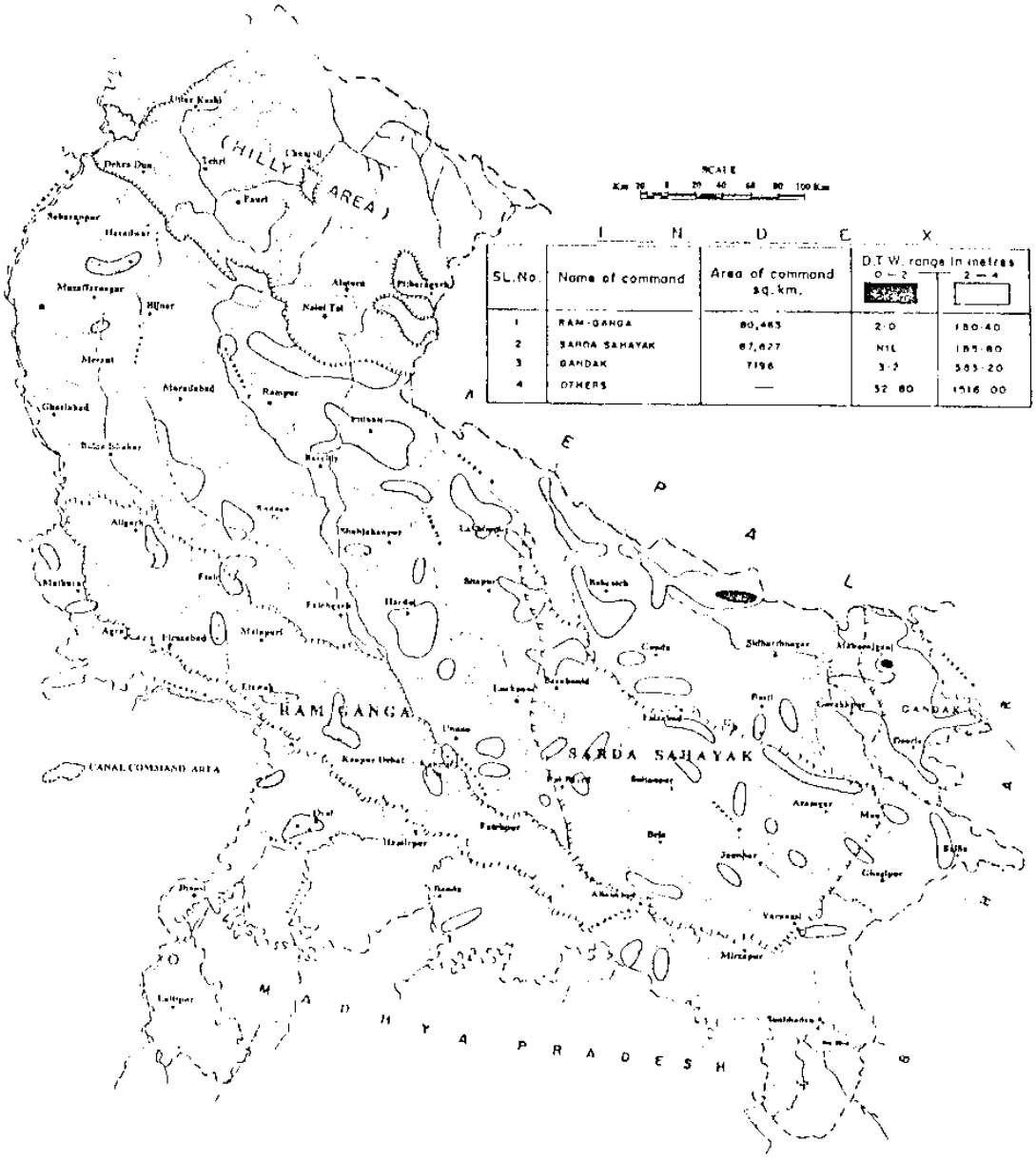


Fig 6.1: Map Showing Commandwise Area of Water logging and Pron to Water logging in U.P.

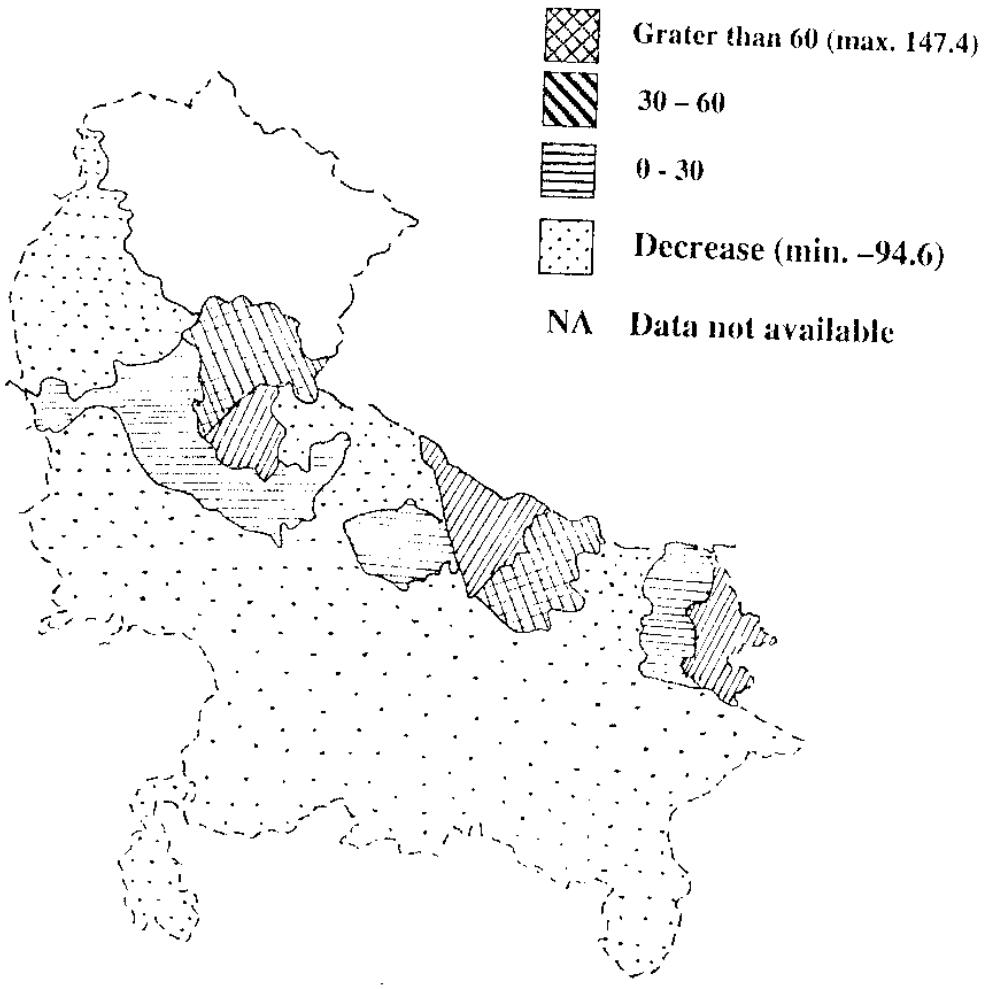


Figure 6.2: Increase in Usar land in Uttar Pradesh, 1950-1980

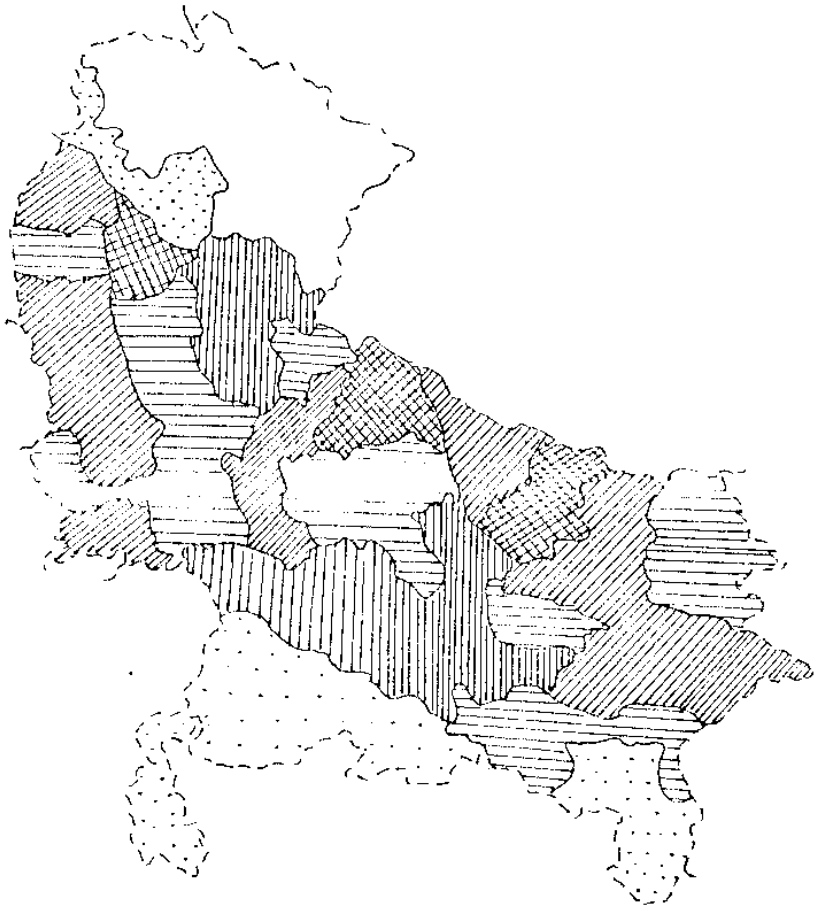


Figure 6.3 : Proportion of irrigated land irrigated by tubewells in Uttar Pradesh, 1980.

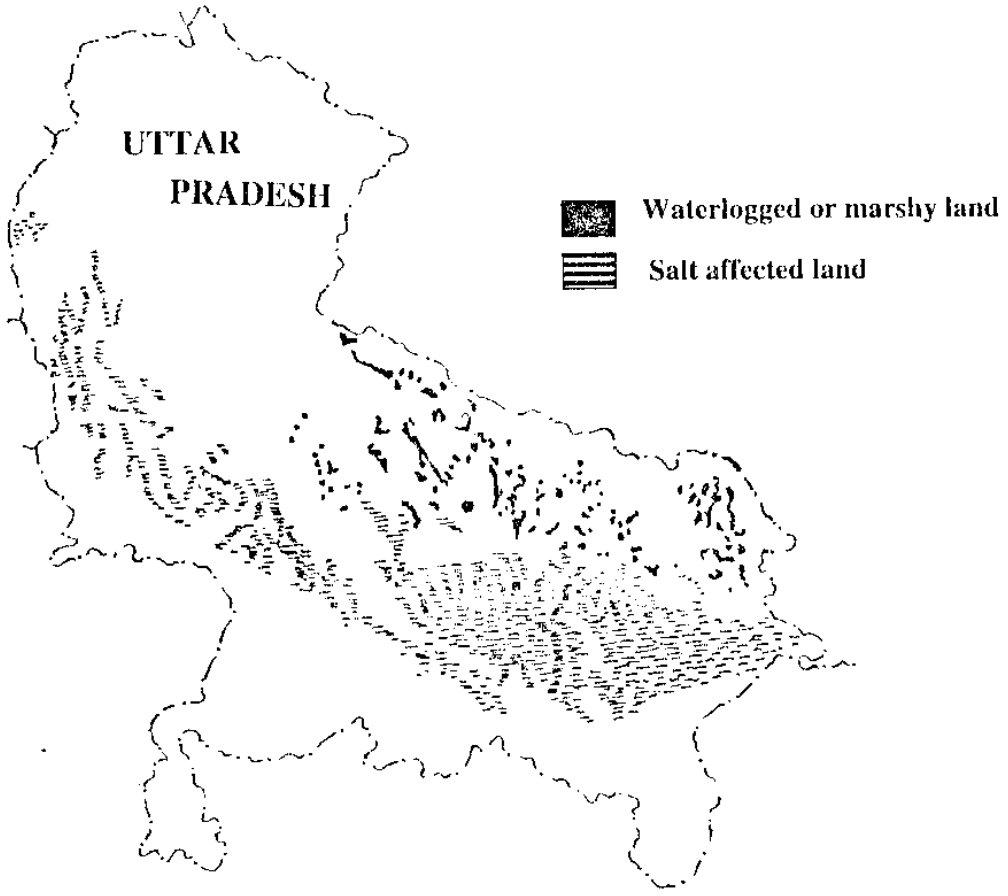


Figure 6.4 : Salt affected and waterlogged areas of Uttar Pradesh

It is estimated that about 0.45 million ha in Sharda Sahayak and about 0.25 million ha in Gandak command area are affected by waterlogging. Seepage from canals, over irrigation of fields by farmers and obstruction of natural drainage by roads, railways and canals have created the problem of waterlogging resulting in salinity and alkalinity.

In Sharda canal command water logging and usar land is increasing, worst affected districts are: Hardoi, Unnao, Lucknow, Raebareli, Sitapur, Pratapgarh and Barabanki. The actual extent of waterlogged and usar land is not recorded for complete command, but in some districts is spread area is recorded by Aerial photo-interpretations and other sources (Rai et. al., 1990) as given in **Table 6.2.**

Table 6.2 : Extent of Waterlogged and Usar Land in Sharda Canal Command Districts

Sl No.	Districts	Usar Land	Ponded Water and Marshy Land
1	Bareilly	18.59	N.A.
2	Hardoi	33.54	N.A.
3	Shahjahanpur	21.79	N.A.
4	Pilibhit	0.53	N.A.
5	Lakhimpur Kheri	24.06	N.A.
6	Nainital	0.03	N.A.
7	Unnao	54.04	12.78
8	Lucknow	22.50	4.63
9	Barabanki	23.97	N.A.
10	Raebareli	49.91	6.19
11	Sitapur	19.93	N.A.
12	Pratapgarh	52.48	7.11
	Total	323.39	N.A.

6.4 Surface and Groundwater Pollution

Degradation of water quality of the river Ganga are due to community sewage, partially cremated and unburnt human bodies thrown in the river. The share of industries to total pollution load is also significant (15-20%). In addition, agricultural pollution is increasing. According a report of the Central Water Pollution Prevention and Control Board, about 0.6 million tons of chemical fertilizers (34% of the countries annual consumption) and 1300 tons of pesticides are being applied in the Ganga basin every year. This contaminates the surface and ground water by toxic substances.

6.3.1 Pollution level along Ganga

According to an estimate the total urban domestic and industrial wastes generated in the Ganga basin is about 2000 tons of biological oxygen demand (BOD) per day. Uttar Pradesh, the single state contributes the maximum pollution load of 1000 tons of BOD per day. Deforestation in the Himalayas greatly increases erosion and sedimentation. The estimated annual soil erosion rate from fields is also high (270 t/ha) in comparison to Congo (3 t/ha), Amazon (13 t/ha), and Nile (8 t/ha). Because of these sediments contains organic matters, a high load also depletes dissolve oxygen (DO) in water and thus affects the self purifying capacity of the river. Diversion of flow in the lean season (**Table 6.3**) for irrigation is further causing a slower rate of dilution of pollutants.

Table 6.3: Low seasons flow of the Ganga at selected stations.

Sl. No.	Locations	Rate of flow (cumecs)
1	Narora	321
2	Kannauj	1542
3	Kanpur	1679
4	Fatepur	1725
5	Allahabad	1870
6	Varanasi	4120
7	Patna	5693
8	Munger	7248

(Source: Environmental Research Laboratory, Aligarh Muslim University, UP)

Before it descends into the plains, the Ganga water is relatively clean. Disposal of sewage water starts from Rishikesh. BOD and other indicators of river Ganga at the selected places are furnished (Comprehensive Plan of Flood Control for the Ganga Sub-basin Part I, 1986) in **Table 6.4**.

Table 6.4: BOD, DO, COD and Other Indicators of River Ganga at Selected Places.

Monitoring Stations	BOD (mg/l)	DO (mg/l)	COD (mg/l)	Total coliform (MPL/100ml)	BOD generation in catchment areas (kg/day)
Haridwar	2.0	5.7	8.6	2400	100 430
Gamukteswar	5.1	6.8	11.4	1430	195 599
Kannauj	7.3	6.2	13.4	NA	343 815
Kanpur	15.3	6.5	28.4	NA	171 440
Allahabad	9.3	7.4	22.0	31250	105 923
Varanasi	9.3	6.4	20.0	12075	111 963
Patna	1.3	7.4	16.2	125500	354 926
Munger	2.2	6.4	22.3	24200	179 386

(Source: State water pollution Control and Prevention Board of UP and Bihar)

At Haridwar although the concentration of BOD (2.0 mg/l) is below the prescribed standards (3.0 mg/l), the DO content is not sufficiently high(5.7 mg/l) to restore the water quality. Further downstream from Haridwar, at Narora, it is least polluted as the concentration of DO is significantly high (Narora, 8.7 mg/l). At Kanpur, the situation becomes worse. The total sewage generation is about 275 million litre per day (Kumra, 1981). Analysis shows BOD is considerably (270 mg/l) above the prescribed limit. In addition, about 150 industrial units discharge their untreated toxic wastes into the river, resulting in severe damage of water quality (DO, 3 mg/l at Jajmau near Kanpur).

The river is highly polluted at Kanpur, Allahabad and Varanasi; moderately polluted at Fatepur, Patna and Munger; and less polluted at Narora and Kannauj as far as organic pollution is concerned. At hot summer and low flow, BOD of introduced wastes

exceeds available oxygen. DO level also reduced because warm water holds less oxygen and speeds up bacterial decay.

6.3.2 Ground water Pollution

The health hazard due to intake of fluoride through drinking water has been found in some patches in Uttar Pradesh, where the level of fluoride has crossed the recommended permissible limit of 1.5 mg/litre (**Figure 6.5**). A study carried out by Mukherjee et. al. (1995) indicates that the sporadic occurrence of high concentration of fluoride in the top aquifer system is causing phenomenal health hazard to the habitants of Nawabganj and Asoha blocks of Unnao district. **Figure 6.6** shows the distribution of chloride in shallow ground water.

The eastern parts of Uttar Pradesh encompasses the eastern end of the vast brackish/saline water aquifer occurring in between fresh water aquifers, occupying the entire 7000 sq. kms. of the southern and western parts of the Ganga plain. Besides this, in parts of Jaunpur district another deeper aquifer in the depth range of 500 to 650 m also holds poor quality groundwater. The eastern part of the Ganga Plain has also recorded groundwater pollution in parts of Varanasi, Bhadohi, Jaunpur Sultanpur and Padrauna districts. Around Bhadohi while the groundwater pollution is due to the effluent from Carpet industries. Higher concentrations of NO_3 (maximum permissible limit: 45 mg/l) is measured in the shallow groundwater zones upto a depth of 40 m within the cities of the Varanasi (59 to 342 mg/l), Jaunpur (65 to 1110 mg/l) and surroundings. The magnitude of the groundwater quality problem can best be indicated by the fact that about 30 percent of the area of Ganga alluvial plain is in the grip of poor quality groundwater.

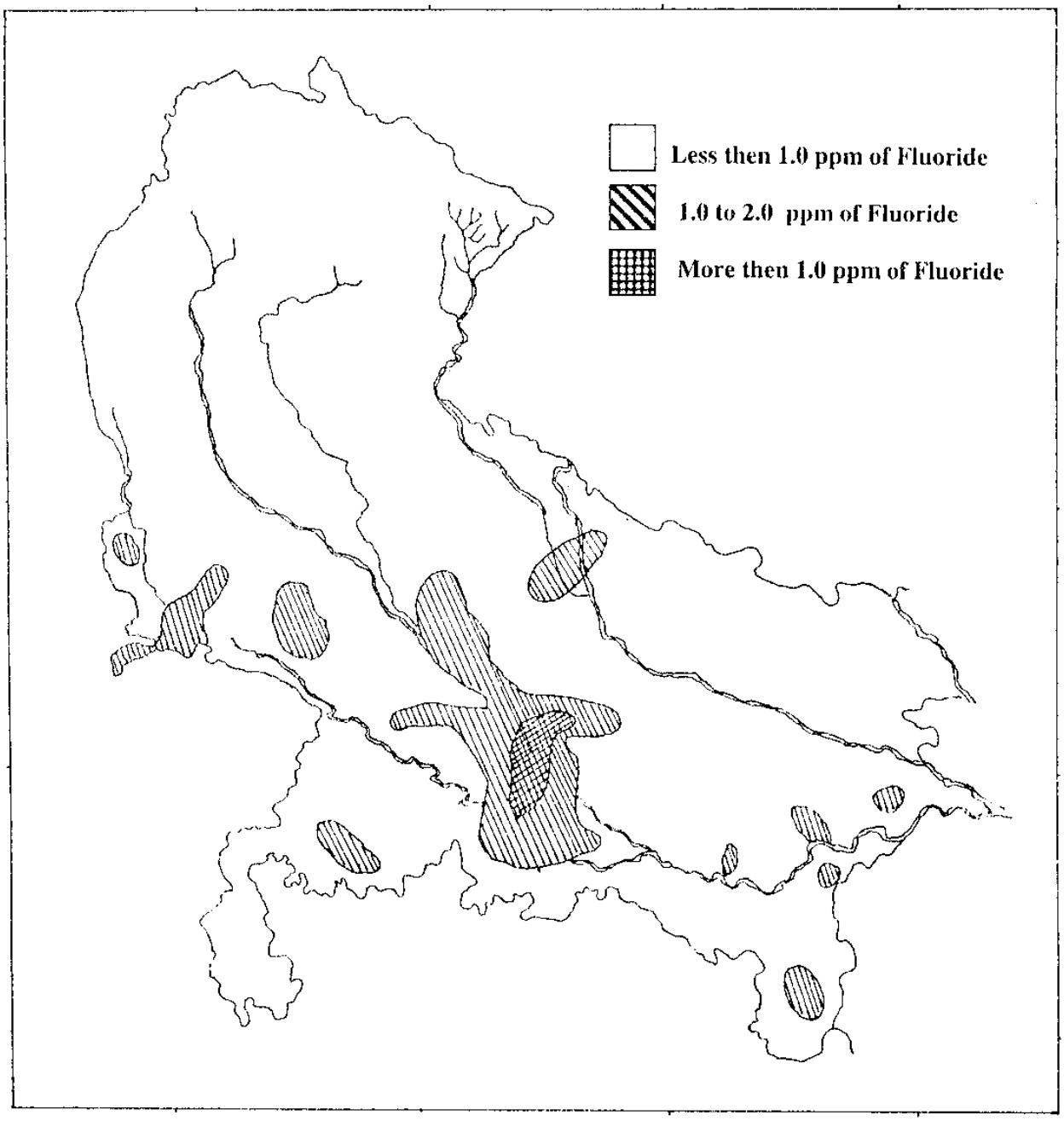


Figure 6.5 : Distribution of Fluoride in shallow ground water

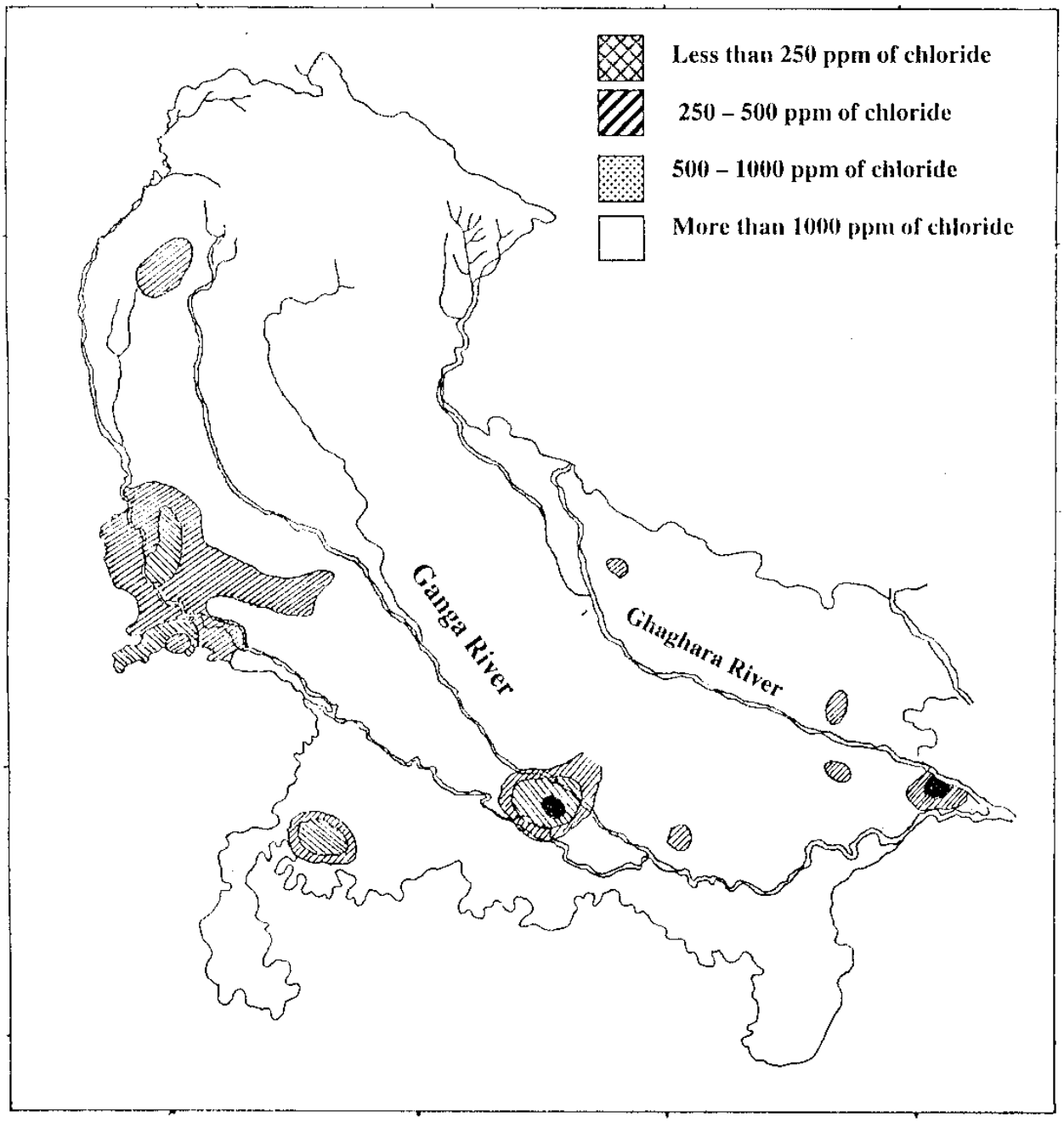


Figure 6.6 : Distribution of Chloride in shallow ground water

CONCLUSIONS

The river Ganga, which originates from the glaciers of Grater Himalayas travels down from the Himalayas and enters the plains of Uttar Pradesh, Bihar, West Bengal finally emptying into the sea, has tremendous potential for various water resources activities. The surface water resources of the basin are immense when regarded in terms of total annual volumes, but the flow patterns show extremely high annual variations reflecting the varying rainfall pattern in the basin. Rainfall pattern, geomorphology, and topography of the basin represent a unique feature of typical hydrological problems.

The plains of Uttar Pradesh, which is known as Gangetic Alluvial Plains, stretches about 800 km. from east to west and 500 km. from north to south between the Peninsular Plateau and the Himalayan mountain chain. This low land includes almost level to gently sloping alluvial plain with local depression of the river Ganga and its tributaries. The major portion of the land in the area is utilized for agricultural purpose. In the Gangetic plains, problems of floods and water logging are important issues besides droughts in some pockets. Disposal of sewage and industrial affluent in Ganga and its tributaries is a cause of increasing pollution of Ganga water. Over exploitation of ground water is also having an impact on the hydrological problems of the basin. In the present study, such hydrological problems of Gangetic plains are discussed independently for each sub-basin. In order to deal with the problems it is important to have a first hand information about the availability of hydrological data. A number of State and Central Government Organisations are having a wide network of various gauging sites for the collection and monitoring of various hydrological parameters. In this context, availability of various hydrological data is also discussed.

REFRENCES

1. Comprehensive Plan of Flood Control for the Ganga Sub-basin-Part I-Volume I, 1986, Ganga Flood Control Commission, Patna.
2. Drainage Aspects of Eastern Region and the Eastern Coastal Areas of India, 1991, Technical Report No.-38, Water Resources Management and Training Project, Louis Berger International, Inc. and Water and Power Consultancy Services (India) Ltd.
3. Flood Report of Ganga Sub-basin-1989, Ganga Flood Control Commission, Patna.
4. Rai, D., Singh, G.R., Sharma, D.K., Singh, S.C., 1990, A Prevention and Reclamation Methodology of Water Logged and User Soil in Sharda Canal Command, All India Seminar on Water Logging and Drainage, Roorkee.
5. Report: Rashtriya Barh Ayog (National Commission on Floods).
6. Water and the Quest for Sustainable Development in the Ganga Valley, 1995, Mansell Publishing Ltd, London WC2N5JE, England.
7. Mukherjee, S., Pal, O.P., Pandey, A.K., 1995, Case Studies on Sporadic Fluoride Contamination in Ground Water, District Unnao, Uttar Pradesh, BHU-Jal News, Quarterly Journal of Central Ground Water Board, Vol.10, No. 1, pp1-6.

DIRECTOR : DR. S.M. SETH

TECHNICAL COORDINATOR : DR. K.K.S. BHATIA

HEAD : N.C. GHOSH

STYDY GROUP

SCIENTISTS : A.K. LOHANI

N.G. PANDEY

ASSISTANCE : A. PRAKASH

A.K. SIVADAS