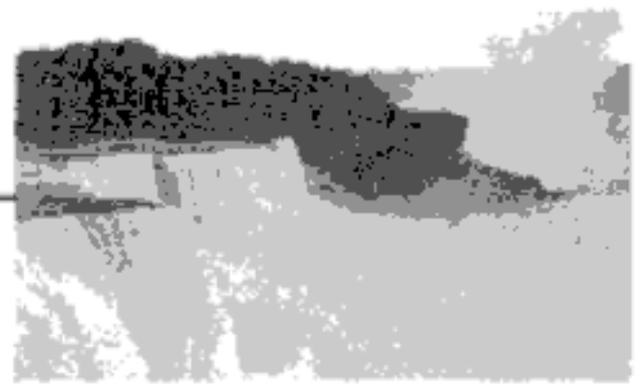
Chapter 33

DRAINAGE



THE DRAINAGE SYSTEM

The drainage system is an integrated system of tributaries and a trunk stream which collect and funnel surface water to the sea, lake or some other body of water. The total area that contributes water to a single drainage system is known as a drainage basin. This is a basic spatial geomorphic unit of a river system, distinguished from a neighbouring basin by ridges and highlands that form divides. Thus, river basins are natural units of land. They are regarded as the fundamental geomorphic as well as hydrological units for a systematic study of the river basins, mainly due to the following three reasons:

(i) They can be placed in an orderly hierarchy,
(ii) They are areal units whose geomorphological and hydroloical characteristics can be measured quantitatively, and
(iii) They can be treated as working systems with energy inputs of climatological variables like temperature and rainfall and output of river discharge as runoff.

The Committee on Runoff of the American Geophysical Union treats the micro-unit within a river basin as the *watershed,* while the sum of all the micro, meso and macro tributaries of a river is known as a *river basin.*

DRAINAGE PATTERN

A geometric arrangement of streams in a region; determined by slope, differing rock resistance to weathering and erosion, climate, hydrologic variability, and structural controls of the landscape is known as a drainage pattern. In other words, drainage pattern refers to a design which a river and its tributaries form together, from its source to its mouth. The factors controlling the pattern of drainage in a region include the topography, slope, structural control, nature of rocks, tectonic activities, supply of water, and above all, the geological history of that region. In India, the following type of drainage patterns are found:

RIVER BASINS OF INDIA

The area drained by the main river including all its tributaries is known as its drainage basin. On the basis of the area drained, the river basins of India have been classified into three categories: (i) river basins with catchment area of more than 20,000 sq km known as large river basins; (ii) river basins having a catchment area between 2000 to 20,000 sq km known as the medium basins, and (iii) the rivers having a catchment area less than 2000 sq km known as minor river basins. India has one hundred and thirteen river basins, of which 14 are large, 44 medium and 55 minor river basins. The major river basins of India in descending order of area are: the Ganga, Indus, Brahmaputra, Godavari, Krishna, Luni, Mahanadi, Narmada, Kaveri, Tapi, Mahi, Sabarmati, Barak, and Subarnarekha. The major river basins form about 84 per cent of the total drainage area of the country **(Fig. 3.4).**

The three major river systems (Ganga, Indus, and Brahmaputra) are international rivers. The Indus and some of its important tributaries traverse Tibet (China), India, and Pakistan, while the Ganga and Brahmaputra, and their tributaries cross Tibet, Nepal, Bhutan, and Bangladesh. The main river basins, their basin area, and annual discharge has been shown in Table 3.1.

On the basis of mode of origin, the drainage of India may be divided into (i) Himalayan or the Extra-Peninsular Drainage, and (ii) the Peninsular Drainage.

There is no clearcut line of demarcation between these two drainage systems, as many of the Peninsular rivers like the Chambal, Betwa, Sind, Ken, and Son are much older in age and origin than the Himalayan rivers.

Table 3.1 *Major Rivers of India and their Surface Flow*

River Basin	*Basin Area**	*Percentage area*	*Annual Discharge* (M^3/km^2)	*%*
Ganga	861,404	26.2	468,700	25.2
Yamuna	366,233	11.0	—	—
Indus	321,284	9.8	79,500	4.3
Godavari	312,800	9.5	118,000	6.4
Krishna	259,000	7.9	62,800	3.4
Brahmaputra	258,008	7.8	627,000	33.8
Mahanadi	141,600	4.3	66,640	3.6
Narmada	98,800	3.0	54,600	2.9
Kaveri	87,900	2.7	20,950	1.1
Tapi	66,900	2.0	17,982	0.9
Penner	55,213	1.7	3,238	0.2
Brahmani	39,033	1.2	18310	1.0
Mahi	34,481	1.0	11,800	0.6
Subarnarekha	19,296	0.6	7,940	0.4
Sabarmati	21,895	0.7	3,800	0.2

*Area means basin area in India.
Source: S.P. Das Gupta, 1989.

RIVER SYSTEMS OF THE HIMALAYAN DRAINAGE

The rivers originating from the Himalayan and Trans-Himalayan regions consist of three river systems, namely: (i) the Indus System, (ii) the Ganga System, and (iii) the Brahmaputra System (**Fig. 3.6**).

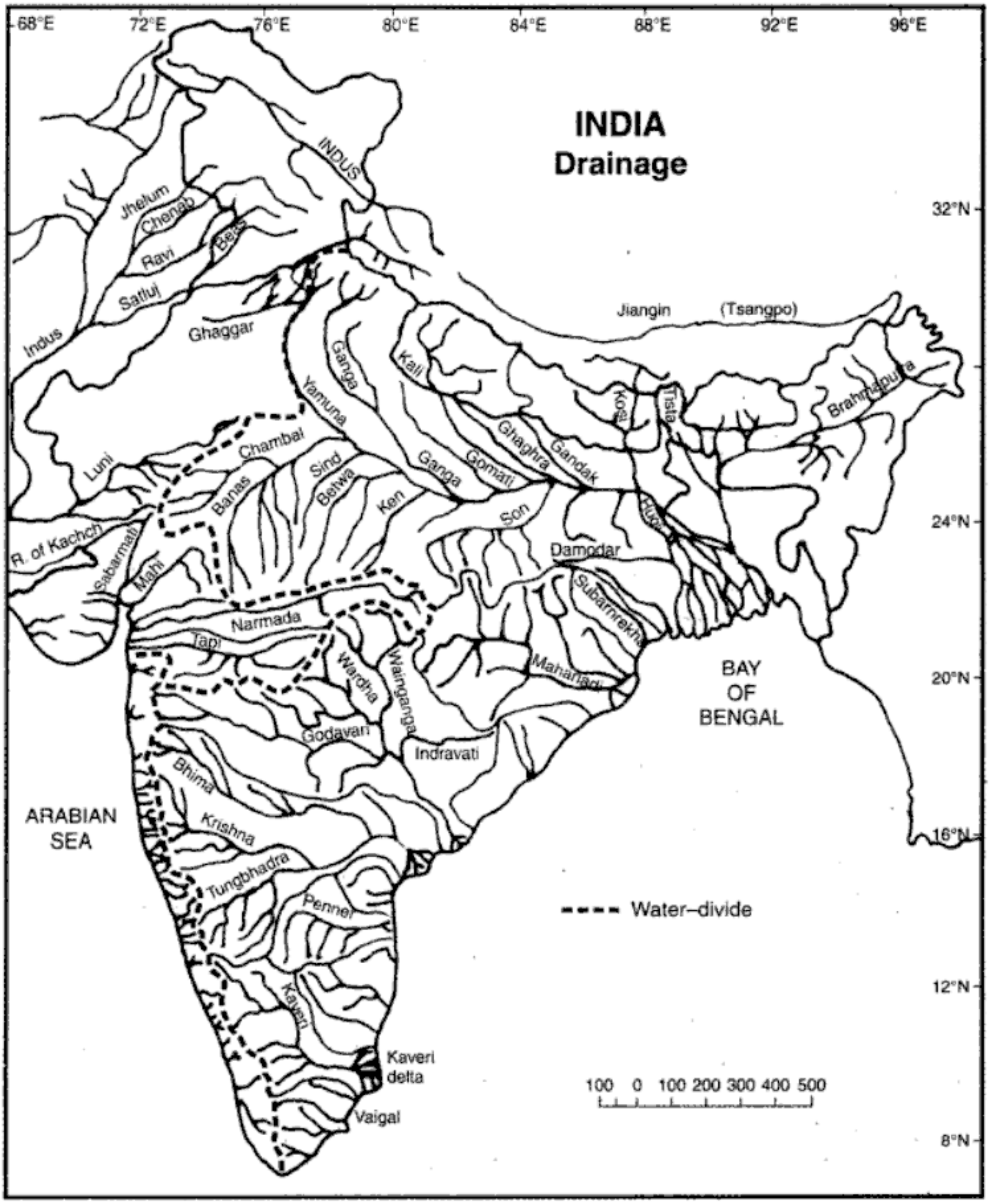


Fig. 3.6 River Systems of India

many great cities on its banks. The maintenance of this sacred river is imperative from socio-cultural and ecological point of view.

The Yamuna River (length 1380 km.)

This is the longest and the western-most tributary of the Ganga. Its source lies in the Yamunotri Glacier on the western slopes of Banderpunch (6316 m). Downwards, it is joined by Tons river behind the Mussoorie Range (Uttarakhand). From the Mussoorie Range, it debouches into the plains where it flows in a broad curve. Making a boundary between Haryana and Uttar Pradesh, it passes Delhi, Mathura, Agra and flows southward until it joins the Ganga at Allahabad. The important tributaries of the Yamuna are mostly the right bank tributaries, originating from the Aravallis (Rajasthan), Vindhyan Range, and the Malwa Plateau of Madhya Pradesh. The Chambal, Sind, Betwa, Ken and Tons are the main righthand tributaries of the Yamuna River.

It is believed that during the Vedic period, the River Yamuna might have flowed towards south and southwest through Bikaner in Rajasthan, and shared its water with the legendary River Saraswati.

The Chambal (length 960 km)

The Chambal River rises near Mhow—south-west of Indore in Malwa Plateau from the Vindhyan Range—and flows towards the north in a gorge upto the city of Kota. Below Kota, it turns to the north-east, and after passing Bundi, Sawai-Madhopur and Dholpur, it finally joins the Yamuna about 40 km to the west of Etawah. The Banas river, rising from the Aravalli Range is its main left bank tributary. Kali Sind and Parbati originating from the Malwa Plateau are the right bank tributaries of Chambal. The Chambal River is famous for its extensive ravines which it has carved all along in the Lower Chambal Valley. The ravines of the Chambal Basin are attributed to a slight uplift during the recent geological times, and they merge into the Yamuna alluvial plain where the landscape is extensively etched out by other tributaries of the Yamuna to the east and west of Chambal. Multipurpose projects have been constructed across the river. The main dams across the river are Gandhi Sagar, Rana Pratap Sagar (Rawatbhata) and Jawahar Sagar.

Chambal Ravines

A maze of ravines, valleys and saw-toothed ridges dissect the plateau. These ravines are found in Rajasthan, Madhya Pradesh and Uttar Pradesh in the lower course of the Chambal River. Infested with dacoits, the ravines are being reclaimed for agriculture, pastures, and social forestry.

The Ramganga

This is a comparatively small river which rises in the Kumaun Himalayas. The river is deflected to the south-west by the Shiwalik, which it cuts through, before emerging at the Ganga Plain in Najibabad. It joins the River Ganga in Hardoi district opposite to Kannauj.

The Sharda

This river rises from the Milam Glacier in the Nepal Himalayas where it is known as the Goriganga. It is known by various names, such as the Kali, when it turns along the Indo-Nepal border, and the Chauka, before it joins the right bank of Ghagra near Barabanki.

The Karnali

The Karnali is known as Kauriala in the Nepal Himalayas and as Ghagra in the Ganga Plain. The

Narmada (Length 1300 km, drainage basin 98,800 sq km)

The Narmada River rises from the plateau of Amarkantak of the Maikal Hills of Chhattisgarh. Moving north-westward, it passes through a complex course near Jabalpur, through some impressive marble gorges, the most spectular being Dhunwadhar Waterfalls (10m high) near Jabalpur. Moving westward from Jabalpur, it flows through a rift valley between the Vindhyan and the Satpura ranges. It has rich alluvial deposits in its valley. Finally, it widens below Bharuch and makes a 27 km wide estuary to enter the Gulf of Khambat (Arabian Sea).

Tapi

Having a length of 700 km. and a basin area of 66,900 sq km, the river Tapi rises from the Satpura Range and flows westward almost parallel to Satpura. At Khandwa-Burhanpur Gap, the Narmada and Tapi come close to each other. Below Jalgaon , the river, like the Narmada, flows in a rift valley but in a much constricted form between the Satpura Range to the north and the Ajanta Range to the south. Below the city of Surat, it makes an estuary and merges into the Gulf of Khambat.

EASTERLY RIVERS OF THE PENINSULAR REGION

There are a number of rivers originating from the Chotanagpur Plateau and merging into the Bay of Bengal, of which the Brahmani is the most important.

Subernrekha (length 400 km, basin 28,000 sq km)

The Subernrekha rises a little to the southwest of Ranchi where it has a number of waterfalls. In a general easterly direction, it passes through Jamshedpur and flows to the Bay of Bengal near Balasore.

The Brahmani (Length 420 km)

The Brahmani river is formed by the confluence of the Kosi and Sankh rivers. They join together at Rourkela and drain the western parts of the Garhjat Hills. Flowing through Bonai, Talcher and Balsore districts, it merges into the Bay of Bengal above the Paradwip-port. With the Baitarani river to its north, a delta complex forms below Bhadrak.

The Mahanadi (length 885 km, basin 141,600 sq km)

The Mahanadi is the most important river of Orissa as well as that of Chhattisgarh. This river rises in the Chhattisgarh basin, draining the western and eastern parts of Raipur. In the initial stage, it flows towards the north-east, and after receiving a number of streams such as Seonath and Sandur on both its flanks at heights between 200 m and 700 m, the combined water gets a natural exit towards the east through a gorge which has been impounded to create the Hirakud Dam. A little below the dam at Sambalpur, the river turns eastward and flows through the Eastern Ghats

the tendencies of river capturing. River capturing is mainly caused by the headward erosion of the river. In the plain areas, generally, the rivers form meanders in their courses. During floods, due to increased quantity of water, the streams try to straigthen their courses. Earth movements do have their role in affecting these processes. Some of the important river captures are as under:

The ancient Saraswati River, which provided an abode for early Aryan settlers, presents a typical example of shifting courses and river capturing. Descending from the Himalayan ranges, its initial course during the pre-historic period was passing near Churu (about 2000 to 3000 BC), and the Luni river was one of its tributaries. It gradually shifted towards west till it joined the Satluj near Ahmadpur. Later on, the water of its upper course was captured by a tributary of the Ganga River as a result of which its lower course became dry. This gave birth to Yamuna River, an important tributary of the Ganga System. Even today the dry valley of the Saraswati River is found in Rajasthan area in the form of Ghaggar valley. Similar shifting has also been observed in the rivers of the Punjab during the historical past. The records of the third century BC show that the Indus flowed more than 130 km east of its present course, through the now practically dry beds of the deserted channel, to the Rann of Kachchh which was then a gulf of the Arabian Sea. Later on, it gradually shifted towards the west and occupied its present position. During the reign of Akbar the Great, the Chenab and Jhelum rivers joined the Indus near Uch (Pakistan), but their present confluence lies near Mithankot about 100 km downstream of the old place of confluence. Similarly, Multan was formerly located along the Ravi River, but today it is situated about 60 km south of its confluence with the Chenab. About 250 years ago the Beas river changed its old course, traces of which are still found between Montgomery and Multan, and joined the Satluj river near Sultanpur. In the early part of the Christian Era the Satluj had more easterly course and independently discharged its water into the Arabian Sea.

About 250 years ago, the Brahmaputra flowing through Mymensingh was discharging its waters into the Meghna River. In due course of time, it straightened its course and joined the Ganga (Padma) River forming a new stream called Jamuna. A feeble channel of the Brahmaputra is still flowing along the same old course and retains the old name. This change in the course was associated with 30 m rise in Madhopur forest area between 1720-1830 A.D. Even the entry of the Brahmaputra to the plains of Assam is also the outcome of the process of river capturing. According to geologists, during early days, the Tsangpo river of Tibet taking an easterly course used to join the Irrawaddy River (Myanmar) through the Chindwin, which was then a large river, transporting huge quantity of water. Later on, a small river flowing along the southern slopes of the Himalayas through its headward erosion captured the water of the Tsangpo River and, thus, helped in the evolution of the stream of Brahmaputra.

Similarly, Kapili, a tributary of the Brahmaputra, has captured the waters of the Meghna river of Bangladesh. In old days, the Meghna originated from the Brail Ranges (between Meghalaya and Manipur) and flowing southward, emptied its waters in the eastern part of the Bay of Bengal. But Kapili, through headward erosion, captured its northern course. The Lumding-Halflong Pass is an evidence of this abandoned valley. In a similar way, the Dhansiri River capturing the water of a tributary, Kapili River has helped in the formation of a new river called Jumna.

There can be numerous causes responsible for the shifting of river courses. These include the shifting gentle slope of the Great Plains of India, meandering courses of the rivers, straightening of the river courses during floods, upliftment of the Potwar Plateau (Delhi-Sirhind Plateau), downwarping of the Malda Gap, rise in the Madhopur forest area and uplift of the Barind area.

when a dam was built across the headwaters of the Luni River. Thousands of pilgrims come to bathe in the waters of the lake during the festival of Kartika Poornima in November.

Renuka Lake

Situated in the Siarmaur District of Himachal Pradesh, this lake has been named after the goddess Renuka. A Lion Safari and a zoo are major attractions at Renuka. It is a site for the annual fair in the month of November.

Roopkund

Situated in Uttarakhand, it is a lake around which 600 skeletons were found at the edge of the lake. The location is uninhabited and is located at an altitude of about 5030 m. The skeletons were discovered in 1942. Radio-carbon dating suggest that these people died in an epidemic.

Sambhar Lake

Situated about 70 km to the west of Jaipur city, it is the largest salt lake of India. On the eastern end, the lake is divided by a 5 km long dam made of stones. To the east of the dam are salt evaporation ponds where salt is being produced for more than a thousand years. The water depth varies from a few cm during the dry season to about 3 m after the monsoon rains. Sambhar has been designated a Ramsar site (recognised wetland) of international importance. Thousands of Siberian birds reach the lake during the winter season.

Sasthamkotta Lake

It is a large fresh water lake in Kerala state. It is located near Sasthamkotta in Kollam District, about 30 km from Kollam. It is a great attraction for the tourists.

Satta or Sat Tal

It is the calm, quiet group of seven lakes near Bhimtal town of the Kumaun Division of Uttarakhand. These lakes are situated at an altitude of 1370 m above mean sea level. These lakes are a paradise for migratory birds.

Suraj Tal

Located below the summit of the Baralacha Pass, it is a high altitude lake, 4980 m above sea level. This lake is the source of the Bhaga River, one of the main branches of the Chenab River.

Tawa Reservoir

Located in Hoshingabad on the River Narmada (M.P.), it was created as a result of the Tawa Dam. It forms the western boundary of Satpura National Park and Bori Wild Life Sanctuary.

Tsongmo Lake

Situated in the state of Sikkim, about 40 km away from Gangtok, it is a glaciated tarn lake. It is oval shaped. Being situated at an altitude of about 3780 m, it remains frozen during the winter season. It is a sacred lake for the Buddhists and the Hindus.

Government Strategy

The total renewable water resources of India are estimated at about 1900 sq km per annum. It is predicted that by 2025 large parts of India will join countries or regions having absolute water scarcity.

The following steps have been taken by the government to implement the water harvesting programme:

1. Since sustainability of drinking water-source is of paramount importance for smooth functioning of rural water supply, 25 per cent out of 20 per cent of the allocation under Accelerated Rural Water Supply Programme (ARWSP) has been earmarked exclusively for water harvesting schemes to make implementation of such schemes mandatory.
2. Similarly, 25 per cent out of the allocation under Prime Minister's *Gramodaya Yojana* has also been earmarked for funding schemes under submission on sustainability.
3. MPs are requested to utilise Local Area Development Fund in their respective constituencies to take up water harvesting schemes.
4. Preparation of pilot projects on water harvesting in selected states have already been undertaken.
5. Further, preparation of user-friendly atlas type of document on traditional water-harvesting structures in various parts of the country has been initiated for popularising the concept of water harvesting amongst all concerned, including the community.

By adopting watershed as a unit, different location-specific measures are adopted and executed carefully in each of the topo-sequences according to capability. Considering the fact that the rainfed area in India is about 60 per cent of the country's net sown area, and the vast area should not suffer from neglect and poverty, investment in watershed management for water-scarce regions (receiving rainfall below 75 cm) of India is an appropriate development intervention which warrants top priority from the point of social justice and containing the widening spatial imbalance between irrigated wet farming and dryland farming systems.

In brief, watershed development approach being an intensive one, appears to be infinitely expensive in a relative sense over the seed and fertilizer approach, but economic evaluation conducted at the *Central Soil and Water Conservation Research Institute* at Dehra Dun shows that this is not so. On the other hand, the realisation that a crop-based approach, or an approach which treats the country as a single unit, would not address the major issue for agricultural development in different location-specific conditions, watershed management (or alternative drainage, flood control and conjunctive uses of water of different sources, or again, a more appropriate management of hill and forest-based agriculture) are alternative regimes, each having a different investment and policy support strategy.

There are a number of successful watershed management experiences like *Sukhomajri*, near Kalka and *Pani-Panchayats* (water collectives) at Ralegaon Sidhi in Maharashtra, where the basic problems of food and fuelwood requirements of poor rural communities have been largely solved by water harvesting.

It is being suggested that in many rural or agricultural situations in our country, we require community participation interfaced with institutional support at the level of, say, 'watershed' land and water managements in difficult ecological regimes to develop the slender resource base of the areas. The replication of successes like *Sukhomajri* would be for the better.

Studies to develop a baseline data for better understanding of the existing and emerging situations need to be undertaken. Recycling of water and water conservation will be a critical component of our daily lives in the new millennium. As far as possible, the technologies should be indigenously developed so as to make them socially acceptable and economically viable.

months. Hence, the diversion of excess water from the Brahmaputra to the Ganga may meet this water deficit, which shall help in the economic development of the region.

The Brahmaputra-Ganga Link Canal Project involves the construction of a diversion barrage at Dhubri (Lower Assam), and a 320 km long feeder canal linking the Dhubri Barrage to the Farakka Barrage. A portion of this feeder canal will lie in Bangladesh for which an interenational agreement between India and Bangladesh has to be signed. This canal will provide irrigatioin water to Bangladesh also. The canal may augment the flow of level in the Padma River (Ganga in Bangladesh) during the lean months of the year. Besides, the link canal would provide cheap inland navigation facility to both the countries. Due to lack of concurrence from Bangladesh and involvement of huge financial expenditure, the scheme has not yet been started.

3. The Narmada Link Canal to Gujarat and Rajasthan

Under the Sardar Sarovar Project, there is a proposal to build a terminal storage dam across the Narmada River near Navagam, and a diversion canal linking the place to regions of Kachchh (Gujarat) and western Rajasthan. This link canal will be of immense help to the drought prone areas of Gujarat and western Rajasthan.

4. The Chambal Link Canal

A canal of about 500 km connecting the Chambal River with the Indira Gandhi Canal has also been proposed. The canal would provide water to the central parts of Rajasthan. It will involve a lift of 200 to 250 m.

5. Links between the Rivers of the Western Ghats to the East

The rivers of the Western Ghats carry enormous quantity of water during the rainy season. Due to steep gradient and the narrow coastal plains much of the water goes to the Arabian Sea as waste. This water may be diverted to the rain-shadow areas of the Western Ghats through the diversion canals where it can be utilised for irrigation. The Periyar Diversion Scheme, constructed several years ago, is such a type of model scheme where the surplus water of the west-flowing Periyar river has been collected in a barrage and diverted through a tunnel across the Sayadri, so as to meet the water needs of the drought prone areas of Tamil Nadu in the east. Similar schemes may also be executed in case of other rivers of the Western Ghats.

GROUND WATER RESOURCES OF INDIA

India is rich in underground water. Its spatial distribution, however, is most uneven. For example, the average annual rainfall in India is about 110 cm. While Mawsynram and Cherrapunji receive more than 1000 cm rainfall annually, the average annual rainfall in Ganganagar is only about 20 cm.

The underground water resource is a function of geological structure, topography, slope, precipitation, runoff, soils and hydrological conditions of a region. In the opinion of Prof. R.L. Singh (1971), India may be divided into eight ground water provinces (**Fig. 3.12**). A brief account of these provinces has been given in the following section:

Siruvani Waterfall

It is situated at the Siruvani River at a distance of about 40 km from Coimbatore in the Western Ghats. It is one of the main water sources of Coimbatore city. The panoramic view of the dam and the falls is enchanting.

Thalaiyar Waterfall (Rattail)

Also known as Rat-tail, it is located near Kodaikanal in Tamil Nadu. With an elevation of 297 m, it is the highest waterfall in Tamil Nadu State. The waterfall is, however, not connected by road and the approach is tiresome.

Vattaparai Waterfall

Located at the Pazhayar River in the Kanyakumari District of Tamil Nadu, it is a great attraction for tourists. The surrounding area is proposed to be developed into a Wildlife Sanctuary.

Vazhachal Falls

Located in the Thrissur District of Kerala, these are one of the best waterfalls in India. They are a great attraction for the domestic and international tourists.

Some of the other important Waterfalls in India

Chhattisgarh

Teerathgarh.

Madhya Pradesh

Dhunwadhar (Narmada River, near Jabalpur).

Himachal Pradesh

Bundla and *Palani* falls.

Jharkhand

Ghaghri, Hundru and *Johna* falls.

Karnataka

Abbey Falls, Arisina Gundi Falls, Hebbe Falls, Irupu Falls, Kalhatti Falls, Keppa Falls, Koosalli Falls, Kudumari Falls Kunchikal Falls, Magod Falls, Mekedaatu Falls, Muthyala Falls, Sathodi Falls, Simsa Falls, Chunchi Falls, Unchalli Falls.

Kerala

Athirappilly Falls, Meenmutty Falls, Palaruvi Falls, Soochipara Falls, Thusharagiri Falls.

Maharashtra

Chchai Falls, Gatha Falls, Keoti Falls, Rajat Pratap Falls (M.P.), Kune Falls, Marleshwar Falls, Pandavgat Fall.