REPORT OF THE IRRIGATION COMMISSION

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IRRIGATION COMMISSION
1972

VOLUME III (Part 2)

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PREFACE

In Volume I of the Report, we emphasised the need for planned development of water resources. Large schemes for water storage involve processes which are often irreversible, and leave little opportunity for subsequent correctives except at a prohibitive cost. Besides, there is also a limit to the total number of available dam sites. The absence of a co-ordinated strategy and planning can lead to a waste of resources, and impose severe limitations on the benefits which might otherwise have accrued from them.

2. An integrated water policy calls for attention to irrigation, drainage, navigation, flood control, hydroelectric power generation, water-supply for industrial and domestic use, soil conservation, land reclamation, control of water pollution from human, animal and industrial wastes, pisciculture, recreation, and control of ground water levels. If any one of these factors is dealt with in an isolated manner, serious conflicts and losses may result.

3. We also indicated that planning for the development of water resources cannot be rigid. The demand for water and its availability, change with the time and conditions and it is necessary to maintain an intelligent flexibility in planning, to keep pace, not only with changing circumstances, but also with the latest development in technology.

4. The planning of water resources has to be related to a defined area or region, with due regard to inter-regional needs. A river basin, and in the case of large rivers, a sub-basin, is a natural unit. It has a defined watershed boundary, and within it there is a certain physical homogeneity and an inter-relationship between the surface and ground water resources. A river basin, therefore, becomes a suitable unit for planning. An overall plan for the development of water resources requires not only full knowledge of the quantity, quality, and distribution of water resources, but also an evaluation of land uses and their effects on stream flows and the production and movement of sediments.

5. We have, therefore, made an attempt to collect, collate and compile the data available for each river basin or a sub-basin in the case of a big river like the Ganga. This Volume is the result of that effort. It has been split into two Parts for easy handling.

6. The figures of area proposed to be irrigated by new schemes or the water utilisation given in this Volume should not be construed to convey any acceptance of the schemes either by the Irrigation Commission, the Ministry of Irrigation & Power or the State Governments. Most of the rivers are inter-State and the final shape of new schemes will, therefore, depend upon inter-State agreements or accord. Where Tribunals have been constituted the schemes have to fit in with the award.

7. In compiling the statistics for each basin, the Commission has been somewhat handicapped. The agricultural statistics give information only by districts. In order to get an idea of the land use and area irrigated within each basin, the figures of districts which lie partially in the basin, have had to be worked out on the basis of proportional statistics (the ratio of the area in the basin to the total area of the district). The figures for each basin are therefore only approximate.

8. The water use or water utilisation and the reservoir losses in each basin have been worked out on a rough basis. Actual quantities of water diverted by the various projects have not always been available and in the absence of such information, the utilisation has been worked out on the basis of '*duties*' and '*delta*' prevalent in the area.

9. As observed by me in the preface to the second volume of the Report, the third volume on the River Basins had to be completed under the same limitations as the second volume. We had to race against time and if there are shortcomings left they were beyond our control.

New Delhi
30th June 1972

(AJIT PRASAD JAIN)

CONTENT

SALIENT FEATURES OF THE BASIN OF EAST FLOWING RIVERS BETWEEN THE GANGA AND THE BAITARANI

(i) Source	The Subarnarekha	Near Nagri village in Ranchi district (Latitude 23°18′N, Longitude 85°11′E).	
	Two small streams between the Subarnarekha and the Burhabalang	1. (Northern) West of Lakshman Nath village Balasore district. (Latitude 21°51′N, Longitude 87°7′E).	
		2. South-west of Gopiballabhpur village in Midnapur district. (Latitude 22°7′N, Longitude 86°50′E).	
	The Burhabalang	South of Simhpalgarh village in Mayurbhanj district (Latitude 21°47′ N, Longitude 86°22′E).	
	Two small streams between the Burhabalang and the Baitarani	1. (Northern) Near Nilgiri village in Balasore district. (Latitude 21°27′ N, Longitude 86°45′E).	
		2. North of Dantur village in Balasore district (Latitude 21°24′N, Longitude 86°34′E).	
		Km	Miles
(ii) Length	The Subarnarekha	395	245
	Two small streams between the Subarnarekha and the Burhabalang (1)	38	24
	(2)	77	48
	The Burhabalang	164	102
	Two small streams between the Burhabalang and the Baitarani (1)	22	14
	(2)	54	33
		Sq.km.	Sq. miles
(iii) Drainage area	The Subarnarekha (including the Resulpur and Piehabani streams)	19,296	7,450
	Two small streams between the Subarnarekha and the Burhabalang	2,418	933

	The Burhabalang	4,837	1,868
	Two small streams between the Burhabalang and the Baitarani	2,645	1,021
	Total	29,196	11,273

(iv) Population (1971 Census)		5.93 millions.	
(v) Density of population	203 per sq. km.	526 per sq. mile	
(vi) Miximum discharge		Cumecs	Cusecs
	The Subarnarekha	16,990	6,00,000
	The Burhabalang	5,663	2,00,000
(vii) Minimum discharge	The Subarnarekha	2.8	100
	The Burhabalang	1.4	50
(viii) Average annual runoff		m.cu.m,	MAF
	The Subarnarekha at Rajghat	7,941	6.44
	The Burhabalang at Kuliana Dam Site	637	0.52

	Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)	1,898	4,690
(x) Net area sown (1967-68)	1,292	3,193
(xi) Gross area sown (1967-68)	1,413	3,492
(xii) Net area irrigated (1967-68)	157	388
(xiii) Gross area irrigated (1967-68)	196	484
(xiv) Area irrigated after completion and full development of Fourth Plan projects	233	576
(xv) Probable additional irrigation by future projects	N.A	

(xvi) Water utilisation including reservoir losses

		m.cu.m.	MAF
(a) On completion and full development of major, medium and minor projects under construction and operation at the end of 1968-69	Surface water	1858	1.51
	Ground water	58	0.04
	Total	1916	1.55
(b) On completion and full development of Fourth Plan projects	Surface water	3004	2.44
	Ground water	104	0.08
	Total	3108	2.52

CHAPTER I

BASIN OF EAST FLOWING RIVERS BETWEEN THE GANGA AND THE BAITARANI

The basin of the east-flowing rivers between the Ganga and the Baitarani extends over an area of 29,196 sq. km. and lies between east longitude 85°10′ to 87°25′ and north latitudes 20°45′ to 23°30′. Lying in the north-east corner of the peninsular India, the basin covers large areas in the States of Bihar and Orissa and a somewhat smaller area in West Bengal. The State-wise distribution of the drainage area is given below:

State	*Drainage area* Sq. km.
Bihar	13,685
Orissa	11,964
West Bengal	3,547
Total	29,196

1.2 The basin is bounded on the north and the west by the Chhotanagpur plateau, on the south by the ridges separating it from the Baitarani basin, on the south-east by the Bay of Bengal and on the east by the ridge separating it from the Kasai valley. The basin has a rectangular shape with a maximum length of 305 km. in a north-west-south-east direction and a maximum width of 123 km. in a north-east-south-west direction.

1.3 There are two major topographical divisions in the basin, namely (i) the northern plateau and (ii) the coastal plains. The plateau region covers the district of Purulia in West Bengal and the Ranchi and Singhbhum districts in Bihar. Part of the Mayurbhanj district of Orissa lying in the basin, is hilly and well-forested. The coastal plains cover parts of Balasore district in Orissa and of the Midnapur district of West Bengal lying in the basin. The general slope of the basin is from north-west to south-east. There are four sub-basins of which those of the Subarnarekha and the Burhabalang are more important. The Subarnarekha basin has a long sausage shape, while the Burhabalang basin is triangular in shape with the main river as the base and the apex near Kalamgadia village in the Mayurbhanj district.

THE RIVER SYSTEMS

1.4 The various river systems in the basin from north to south are:

(1) The Subarnarekha (including the Rasulpur and Piehabani streams).
(2) Two small streams between the Subarnarekha and the Burhabalang.
(3) The Burhabalang.
(4) Two small streams between the Burhabalang and the Baitarani.

These river systems are described briefly in the following paragraphs.

The Subarnarekha

The Subarnarekha rises near Nagri village in the Ranchi district at an elevation of about 600 m. at north latitude 23°18′ and east longitude 85°11′ and flows in generally easterly and north-easterly direction for a length of 56 km. in the Ranchi district.

It then forms the boundary between the Ranchi and Hazaribagh districts for a length of 24 km. Thereafter, the river turns to the right and after flowing for a further distance of 20 km. along the Bihar-West Bengal border, it is met by a major tributary, the Kanchi, from the right. The river continues to flow for another 14 km. along the Bihar-West Bengal border to enter the Singhbhum district. Flowing in a generally south-easterly direction for a further distance of 16 km. the river receives from its right another major tributary, the Karkari. 30 km. downstream of this confluence, the Subarnarekha is joined by its biggest tributary, the Kharkai, from the right. After flowing for another 98 km. in the Singhbhum district, the river turns to the left and forms the common boundary between Bihar and Orissa States for a length of 11 km. It then enters the Midnapur district and after flowing for a length of 27 km. in a generally easterly direction, turns to the right and flows for another 37 km. in the Midnapur district and crosses the inter-State border between the West Bengal and Orissa States. The river thereafter flows in a generally south-easterly direction for a length of 62 km. to outfall into the Bay of Bengal.

Of its total length of 395 km, 269 km. are in Bihar, 64 km. in West Bengal and 62 km. in Orissa. The river including the Rasulpur and Piehabani streams drains a total area of 19,296 sq. km.

The Kanchi, the Karkari and the Kharkai are its important right bank tributaries. These tributaries are briefly described below.

The Kanchi

The Kanchi rises near Lodhma village in the Ranchi district at an elevation of 600 m. at north latitude 23°12′ and flows in a generally easterly direction for a total length of 76 km. to join the Subarnarekha from its right, north-west of Suisa village in the Purulia district. The Kanchi drains a total area of 1,096 sq. km.

The Karkari

The Karkari also rises near Lodhma village in the Ranchi district at an elevation of 600 m. at north latitude 23°16′ and east longitude 85°11′ and flows for a total length of 110 km. in a generally easterly direction to meet the Subarnarekha from the right, just north-west of Chandil village in the Singhbhum district. The Karkari drains a total area of 1,341 sq. km.

The Kharkai

The Kharkai rises north of Talbandh village in the Mayurbhanj district at an elevation of 600 m. at north latitude 22°4′ and east longitude 86°21′ and flows first in a north-west direction and then in a north-east direction for a total length of 136 km. to join the Subarnarekha from the right, near Jamshedpur in the Singhbhum district. The Sanjai is its important left bank tributary. The Kharkai drains a total area of 6,611 sq. km.

Two Small Streams between the Subarnarekha and the Burhabalang

The northern stream rises west of Lakshman Nath village in the Balasore district at an elevation of 45 m. at north latitude 21°51′ and east longitude 87°7′ and flows in a generally south-easterly direction for a total length of 38 km. to join the Bay of Bengal. The second stream rises south-west of Gopiballabhpur village in the Midnapur district at an elevation of 100 m. at north latitude 22°7′ and east longitude 86°50′ and runs in a generally south-easterly direction for a total of 77 km. to join the Bay of Bengal. The total area drained by these two streams is 2,418 sq. km.

The Burhabalang

The Burhabalang rises south of Simhpalgarh village in the Mayurbhanj district at an elevation of about 800 m. at north latitude 21°47′ and east longitude 86°22′ and flows first in a northerly and then in a south-easterly direction for a total length of 164 km. to join the Bay of Bengal. The Burhabalang drains a total area of 4,837 sq. km.

Two small streams between the Burhabalang and the Baitarani

The northern stream rises near Nilgiri village in the Balasore district at an elevation of 150 m. at north latitude 21°27′ and east longitude 86°45′ and runs in a generally south-easterly direction for a total length of 22 km. to join the Bay of Bengal. The second stream rises north of Dantur village in the Balasore district at an elevation of 300 m. at north latitude 21°24′ and east longitude 86°34′ and runs in a generally south-easterly direction for a total length of 54 km. to join the Bay of Bengal. These two streams together drain a total area of 2,645 sq. km.

CLIMATE

1.5 Three distinct seasons occur in the basin. They are (i) the cool weather, (ii) the hot weather and (iii) the rainy season. The cool weather extends from about the middle of October to the middle of February. There is very little rainfall in the months of December, January and February. In the hot weather, extending from the middle of February to the middle of June, the basin gets some rainfall due to thunder storms and is hot. The south-west monsoon season, which follows the hot weather, extends from the middle of June to the middle of October.

Rainfall

1.6 There are at present 121 reporting raingauge stations inside the basin. The distribution of the stations is fairly even and their number is also sufficient.

The rainfall in the basin varies from region to region. The rainfall increases from about 1,258 mm. at the northern extremity of the basin to about 1,483 mm. in the Ranchi district and then again falls to about 1,435 mm. in the Kharkai sub-basin in the Singhbhum district. Further south the rainfall increases to 1,648 mm. in the Mayurbhanj district and tails off to 1,568 mm. at the end of the basin in the Balasore district. Nearly 90% of the annual rainfall occurs during the monsoon period from June to October. The monthly and annual normals of rainfall in the districts lying in the basin are shown in Appendix 1.1.

Temperature

1.7 The basin enjoys a tropical climate. In the northern plateau of the basin, the variation of temperature during the year is less marked than in the plains. In the month of January, the mean temperature over the basin varies from 17.5°C to 20°C. In April, the mean temperature is about 30°C, whereas in the month of July it is between 27.5°C and 30°C. In the month of October, the basin experiences temperatures between 25°C and 27.5°C. The annual maximum and minimum normals of temperature at Ranchi in the basin are 28.9°C and 18.5°C respectively.

Evaporation

1.8 Data on evaporation is not available for the basin. One departmental observatory of the India Meteorological Department is located at Jamshedpur. No agro-meteorological observatories are located in the basin.*

SOILS

1.9 Detailed soil survey of the area covered by the basin has not been made. However, the general data regarding the soils of India indicate that mainly red yellow soils, red sandy soils, mixed red and black soils, lateritic soils and deltaic alluvium occur in the basin.

The basin partly covers the districts of Ranchi, Singhbhum and Hazaribagh in Bihar; Mayurbhanj and Balasore in Orissa; and Purulia and Midnapur in West Bengal.

1.10. The principal soil types found in the various districts lying in the basin are given below: †

Hazaribagh and Ranchi: Gravelly soils, sandy loams, alluvium soils and black clays. The soils on the uplands are reddish and porous, while those in lowlands are heavier and darker.

Singhbhum: Red loams on the uplands and heavy black clays on the lowlands.

Mayurbhanj: Red soils which are generally open in texture and well-drained.

Balasore: Mainly sandy loams.

Purulia: Mainly gravelly soils. Soils vary from sands, loams to stiff clays.

Midnapur: Laterites, red soils, alluvial and coastal soils.

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*Evaporation Data (India), India Meteorological Department (April, 1970).

†Soils of India by S. P. Ray Chaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

LAND USE AND AGRICULTURAL PRACTICES

1.11 State-wise land use details in the basin as in 1967–68, the latest year for which the statistics are available, are given below:

Table 1.1

Land Use Details

(Thousand hectares)

Sl. No.	Item	Name of State			Total
		Bihar	Orissa	West Bengal	
1	2	3	4	5	6
1.	Gross area	1,369	1,196	355	2,920
2.	Reporting area	1,367	1,105	354	2,916
3.	Area under forests	386	183	41	610
4.	Area not available for cultivation	183	183	42	408
5.	Culturable area	798	829	271	1,898
6.	Uncultivated culturable area	350	200	56	606
7.	Net area sown	448	620	215	1,292
8.	Area sown more than once	32	70	19	121
9.	Total cropped area	480	690	234	1,413
10.	Net area irrigated	16.4	77.8	63.2	157.4
11.	Gross area irrigated	19.3	112.4	64.2	195.9
12.	Percentage of net area sown to culturable area	56.1	75.9	79.3	68.1
13.	Percentage of net area irrigated to culturable area	2.1	9.4	23.3	8.3
14.	Percentage of net area irrigated to net sown area	3.7	12.4	29.4	12.2

The cultivated area in the basin constitutes 74.5% of the culturable area, which shows that agriculture has been practised quite extensively in the basin. The culturable area in the basin is about 0.97% of the total culturable area of the country. The total cropped area in the basin is about 0.87% of the total cropped area in the country. The land use details indicate that the resources in the basin have not been put to full use.

1.12 The general cropping pattern, State-wise in the irrigated area is described below:

Bihar

Of the total irrigated area of 19,300 hectares, 75.1% is under paddy, 1.6% under other pulses, 4.2% under wheat and the balance under other crops. The other crops grown in the irrigated area are maize, ragi, barley, gram, tur, condiments, spices, fruits, vegetables, etc. Food crops represent about 99.0% of the irrigated area and the balance of 1.0% is under non-food crops.

Orissa

The latest crop-wise irrigation statistics are available for the year 1956–57 only. According to these out of the total irrigated area of 111,900 hectares, 97.8% is under paddy, 1.4% under other pulses, 0.5% under other sugarcane and the balance under other crops. The other crops grown in the irrigated area are jowar, bajra, ragi, gram, rapeseed, mustard, linseed, cotton, tobacco and fodder crops. Practically the entire irrigated area is under food crops.

West Bengal

Out of the total irrigated area of 64,200 hectares, 88.3% is under paddy, 2.1% under pulses, 0.3% under sugarcane and the balance under other crops. The other crops grown in the irrigated area are maize, cereals, pulses, etc. Almost the entire irrigated area is under food crops.

Summing up, of the total irrigated area in the basin, 89.7% is under paddy, 4.7% under other pulses, 0.4% under sugarcane, 0.6% under wheat and the balance under miscellaneous crops. Food crops cover about 99.8% of the irrigated area and the balance of 0.2% is under non-food crops.

1.13 There are mainly three crop seasons in the basin. They are (i) the kharif, (ii) the rabi and (iii) the hot weather. The important kharif crops are paddy, maize, ragi, millets, cotton, jute, mesta, sunn-hemp, ginger, and chillies. The important rabi crops are paddy, rape, mustard, jute and tobacco. The principal hot weather crop is paddy.

1.14 The sowing and harvesting seasons of the principal crops in the various States are shown below:*

Table 1.2

Sowing and Harvesting Periods

Name of crop	Period of	
	Sowing	Harvesting
1	2	3
Bihar		
Autumn Rice	June	September-October
Winter Rice	Mid-June-Mid-September	Mid-Setember-January
Summer Rice	February-March	May-June
Maize	June-July	August-November
Ragi	Mid-May-July	August-November
Small Millets (Kharif)	June	September
Rape and Mustard	September-November	January-March
Orissa		
Autumn Rice	May-June	August-September
Winter Rice	September-October	November-December
Summer Rice	November-December	March-April
Potatoes (Hills)	October-November	Mid-January-March
Cotton	May-June	November-December
Jute	May-June	November-December
Mesta	Mid-May-Mid-June	August-Mid-September
Tobacco	Mid-October-Mid-November	August-Mid-September
Sunn-hemp	May-June	September

*Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, C. D. and Cooperation (1967).

Table 1.2—Contd.

1	2	3
West Bengal		
Autumn Rice	June-July (T)	August-November
Winter Rice	July-August (T)	November-December
Summer Rice	December-February (T)	April-May
Tur (Kharif)	May-August	December-April
Potatoes (Plains)	September-November	January-March
Ginger	May-June	November-December
Chillies	May-December	August-March
Jute	April-May	August-October
Mesta	May-June	November-December
Tobacco	October-November	February-March

(T)—Transplanting

REGIONAL ECONOMY

Population

1.15 On the basis of the 1971 census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 5.93 millions. The State-wise distribution is shown below:

State		*Population*
Bihar		2.30 millions
Orissa		2.36 millions
West Bengal		1.27 millions
	Total	5.93 millions

There are two cities in the basin, namely Ranchi and Jamshedpur, which have a population of more than one lakh according to the 1971 census. The average density of population in the basin is 203 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. Whereas the Midnapur district has the highest density of 405 persons per sq. km., the lowest density of 137 persons per sq. km. occurs in Mayurbhanj district.

*Census Paper 1 of 1971 (Supplementary), Registrar-General, India.

1.16 Out of the total population in the basin, nearly 90.1% live in rural areas, while the balance of 9.9% live in urban areas. The working force constitutes nearly 30.6% of the total population. Nearly 40.0% of the working forces is engaged as cultivators and 32.0% as agricultural labourers. The balance of 28.0% of the working force is employed in manufacturing, mining and other tertiary activities.

Forests & Agriculture

1.17 In the basin, forests occupy 20.9% of the total area and the culturable area constitutes 65.1%. Out of the total culturable area of 1.90 million hectares, nearly 1.41 million hectares are annually cultivated. An area of 0.20 million hectares constituting 13.9% of the cultivated area is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 89.7% of the total irrigated area.

Power

1.18 The hydro-power potential of this basin has been assessed as 35 MW at a 60% load factor by the Central Water and Power Commission. At present, there are no major hydro-power stations under operation. There are two thermal power stations at Jamshedpur and Ghatsila. A major hydro-electric project, namely the Subarnarekha Project is under construction in the basin. This project will have an installed capacity of 130 MW. Work on the project was started in 1965-66. The first unit of 65 MW is expected to be commissioned during the Fourth Plan and the second unit, also of 65 MW, during the Fifth Plan.

Mineral Wealth

1.19 The basin has got rich mineral resources spread over vast areas. The principal minerals found in the basin are:*

Iron Ore, in the Singhbhum, Mayurbhanj and Purulia districts;
Copper, in the Ranchi, Hazaribagh and Singhbhum districts;
Coal, in the Purulia district;
Bauxite, in the Ranchi district;
Chromite, in the Singhbhum district;
China Clay, in the Singhbhum district, and Mayurbhanj districts;
Fire Clay, in the Hazaribagh district;
Limestone, in the Ranchi, Hazaribagh and Singhbhum districts;
Steatite, in the Singhbhum, Hazaribagh, Balasore and Mayurbhanj districts;

*Techno-Economic Surveys of Bihar, Orissa and West Bengal. NCAER.

Apatite, in the Singhbhum district;
Asbestos, in the Singhbhum and Purulia districts;
Manganese, in the Singhbhum district;
Atomic Minerals, in the Singhbhum district;
Vanadium, in the Mayurbhanj district;
Barytes, in the Purulia district;
Mica, in the Purulia district.

Industries

1.20 The important industries in the basin are:
Tobacco products in Chakradharpur.
Cement, Asbestos Sheets, Glass and Ceramics in Chaibasa.
Locomotives and coaches, Automobiles, Agricultural Equipment, Wires and Cables, Iron and Steel, Machinery, Metal Tubes and Conduits, Copper and Brass, Chemicals (Acids & Caustics), Fertilisers and Soaps in Jamshedpur.

Communications

1.21 The basin is served by the South-Eastern Railway. The system is mainly on broad-gauge. There is also a narrow-gauge line. There are a few important lines connecting different places in the basin among which are the Madras-Howrah line, the Howrah-Bombay line, the Tatanagar-Gorumahisani line, the Rajkharswan-Gua line, the Purulia-Lohardaga line, the Tatanagar-Muri-Barkakana line and the Adra-Chakradharpur line. The National Highways connecting Calcutta with Madras and Bombay pass through the basin. In addition, there is a network of State Highways, district and village roads. The rivers in the basin are not navigable though the Orissa Coast Canal, lying partly in the basin, is. This canal is a continuation of the Hijli Tidal Canal, Rang II and tails into the Subarnarekha at Bhograi in Orissa. It is navigable throughout the year by launches and country boats up to 0.9 m. draft.*

The basin is fairly well served with communications.

Dependence on rainfall and water resources

1.22 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence except in parts of the basin where irrigation has been provided and where major industries have developed. There is a keen demand for the development of water resources in the basin.

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*Navigable Waterways of India CW & PC (1961).

WATER RESOURCES

Surface Water

1.23 In 1949, when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's formula, the total annual runoff of the river systems in the basin was estimated to be 20,328 m. cu. m.*

In 1960 the Central Water & Power Commission, while conducting irrigation potential studies, assessed the total annual runoff of the river systems in the basin to be 14,814 m. cu. m. on the basis of Strange's rainfall-runoff coefficients for average catchments.†

Gauges and discharges are being observed on the Subarnarekha and the Burhabalang at the following sites by the State Governments of Bihar and Orissa:

Table 1.3

Gauge and Discharge Sites

Sl. No.	Name of Site	Location Longitude	Location Latitude	Type	Year of start of observations
1	2	3	4	5	6
	Subarnarekha‡				
1.	Hatia	85°34′E	22°38′N	GD	1957
2.	Gatalsood	85°33′E	23°26′N	GD	1957
3.	Domohani upstream	86°9′E	22°50′N	GD	1958
4.	Domohani downstream	86°10′E	22°50′N	GD	1958
5.	Jamshedpur	86°12′E	22°49′N	GD	1957
6.	Ghatsila	86°29′E	22°35′N	G	1954
7.	Rajghat	87°9′E	21°46′N	G	1955
8.	Navgudi (Tidal Gauge)	86°18′E	21°36′N	G	1950
	Burhabalang				
9.	Dam site	—	—	GD	1964

G = Gauge site; GD = Gauge & Discharge site.

*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

†Report of technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

‡Report on the Subarnarekha basin, Central Water and Power Commission (unpublished).

In addition, some *ad hoc* and irregular observations, in connection with proposed projects, have been made on some tributaries of the Subarnarekha.

Systematic and continuous discharge observations should be made on the main rivers and their tributaries in the basin to assess correctly the water resources of the basin. The ungauged rivers and tributaries in the basin need also to be gauged systematically, at suitable locations.

Under the programme of establishing and maintaining centrally sponsored key hydrological stations in the country, the Central Water & Power Commission has proposed the inclusion of the following sites:

Table 1.4

Centrally Sponsored Sites

Sl. No.	Name of the river	Location of site
1	2	3
1.	Subarnarekha	At West Bengal-Bihar border.
2.	,,	Below the confluence of the Sanjai.
3.	,,	At Bihar-Orissa border.

The average annual flows at the various sites on the different rivers as per the data furnished by the Orissa State Government are given below:

Table 1.5

Average Annual Flows

Sl. No.	Name of the river	Catchment area sq. km.	Normal rainfall in mm.	Average flow in m.cu.m.				
				June-Sept.	Oct-Dec.	Jan-Mar.	April-May	Total
1	2	3	4	5	6	7	8	9
1.	Subarnarekha at Rajghat	18,252	1,374	6,796	943	118	84	7,941
2.	Burhabalang at Kuliana Dam site	1,049	1,367	503	112	15	7	637

Remarks: 1. Average for 1964-69.
2. Average for 1964

Ground Water

1.24 Systematic investigations and studies of the ground water potential of the basin have not been made so far. Only in some parts of the basin, in the districts of Hazaribagh, Ranchi, Singhbhum, Mayurbhanj and Balasore, have some investigations and studies been made recently.* The area studied in the districts of Hazaribagh, Ranchi and Singhbhum are in hard rock formations. In these areas, ground water occurs under water-table conditions, in the weathered residium of various precambrian metamorphites and circulates through weak structural planes. At places narrow and shallow alluvial channel fills in river valleys form promising repositories of ground water. The water has a uniformly good quality and is mainly used for domestic and small-scale irrigation. In these areas, only large diameter open wells are possible for limited consumption. In many areas, perennial springs supply considerable quantities of water. The springs can be harnessed wherever dependable and perennial supplies are assured.

In the Mayurbhanj district covering the Lower Subarnarekha and the Burhabalang basins, ground water occurs under water-table condition in weathered Archaean crystalline rocks like gneisses, schists, amphibolites, quartzites and other sedimentary rocks. Ground water is tapped through large diameter open wells and is used for domestic purposes and, to a very limited extent, for small-scale farming. The water is suitable for all types of use.

In the Balasore district, in the area investigated, productive water bearing formations are of the upper tertiary-quarternary age. Good aquifer zones occur in the Balasore-Agarpara areas. In the coastal fringe, granular zones contain saline water but a distinct improvement in the quality of water is observed at greater depths. Large-scale development of ground water resources appear feasible in the Balasore and Agarpara areas.

In the Midnapur district, a number of tubewells have been constructed in recent years where many aquifers have been encountered in the recent alluvium. The aquifer materials consist mostly of fine and very coarse sand. The water-table in the tubewells tapping these aquifers rises very close to the surface and in favourable topographic depressions, the wells actually overflow in the post-monsoon season.

In the Purulia district, ground water occurs under water-table conditions and is tapped by open wells. There, development of ground water by tubewells is not considered feasible. Small-scale develonment can.

*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (Aug. 1970).

however, take place by means of large diameter open wells. Generally, the water is of good quality.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, quantitative and qualitative assessment of the ground water resources. A correct assessment of the ground water resources in the basin, which will help in framing a rational plan of development for various needs can only be made when full investigations are carried out.

EXISTING DEVELOPMENT

1.25 The First Irrigation Commission had not recommended any specific projects by name to be taken up for construction in the basin.*

However, two medium projects were constructed in the basin thereafter, in the pre-Independence period. Both these projects are in Orissa State and are described below.

Baldiha Project

The project consists of an anicut across the Palpala Nala, a tributary of the Burhabalang in the Mayurbhanj district. Constructed in 1912, at a cost of Rs. 3.00 million, it irrigates an area of 3,688 hectares.

Haldia Project

It is a storage scheme located across the Chipat Nalla, a tributary of the Burhabalang for irrigation of 3,643 hectares in the Mayurbhanj district. It was constructed in 1912 at a cost of Rs. 4.00 million.

During the Plan periods, one multipurpose and six medium projects have been taken up for construction in the basin. All these projects lie in Bihar State and are described below.

Torlow Project

The project consists of a weir with 0.8 m. high automatic crest shutters across the river Torlow, a tributary of the Kharkai in the Subarnarekha basin, near the village of Torlow and a canal system on the left bank for irrigating 2,200 hectares in the Singhbhum district. It was started in 1957 and completed in the year 1962–63 at a cost of Rs. 1.62 million.

Roro Project

The project, costing Rs. 13.61 million, provides for a 73 m. long,

*Report of the First Irrigation Commission.

5.93 m. high cement concrete weir across the Roro river, a tributary of the Kharkai and a canal system on the left bank for irrigating 10,927 hectares in the Singhbhum district. It was taken up for construction in 1957 and is likely to be completed during the Fifth Plan.

Kanchi Weir Scheme

Located in the Ranchi district the project comprises a 229 m. long, 1.98 m. high diversion weir across the Kanchi river, a tributary of the Subarnarekha and canal system on either bank. It will irrigate 18,212 hectares at a cost of Rs. 15.21 million. Started in 1958, the project is likely to be completed during the Fifth Plan.

Sona Weir Scheme

The scheme comprises a diversion weir across the river Sona in the Subarnarekha basin near the village of Korkate and a canal on the right bank for irrigating an area of 6,516 hectares. The project costing Rs. 6.33 million, was starterd in 1962 and is likely to be completed during the Fourth Plan.

Kokro Project

The project, costing Rs. 3.50 million, consists of a weir across the river Kokro in the Subarnarekha basin about 1.6 km. north-west of the village of Fulwe and Behra and a canal system on the right flank to irrigate 3,837 hectares in the Ranchi district. It was started in 1962 and is likely to be completed during the Fifth Plan.

Bijoy Project

The project provides for the construction of a weir across the river Bijoy in the Subarnarekha basin near the village of Subansari and a canal on the right bank to irrigate 2,024 hectares in the Singhbhum district. The project costing Rs. 3.33 million was started in 1962 and is likely to be completed during the Fourth Plan.

Subarnarekha Multipurpose Project

The project comprises a 2,270.7 m. long, 35.4 m. high composite dam across the river Subarnarekha at Getalsud, 30 km. from Ranchi City. It will have an installed capacity of 130 MW—two units of 65 MW each. In addition to the generation of power, the project will also meet the water supply requirements of Ranchi City. The project, costing Rs. 129.00

million, was taken up for construction in the year 1965–66. The dam has been completed. The first unit of 65 MW is likely to be commissioned during the Fourth Plan and the second unit, also of 65 MW, during the Fifth Plan.

Some particulars of the major and medium projects in operation and under construction in the basin are given in the Appendices 1.2 and 1.3.

Besides the major and medium projects, a number of minor schemes, comprising tanks and wells, irrigate a large area in the basin. In many villages, there are more tanks than one which irrigate the adjoining agricultural lands. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, in the basin, are shown below:

Table 1.6

Source-wise Irrigation

(Thousand hectares)

Sl. No.	Source of irrigation	Area irrigated in Bihar	Orissa*	West Bengal*	Total area irrigated
1	2	3	4	5	6
1.	Canals	5.0	33.0	31.9	69.9
2.	Tanks	4.2	8.7	19.9	32.8
3.	Tubewells	—	—	0.6	0.6
4.	Wells	3.2	0.9	—	4.1
5.	Other sources	4.0	35.2	10.8	50.0
	Total	16.4	77.8	63.2	157.4

*Pertains to 1964-65

By the end of 1968–69 the area under minor schemes increased by about 13,600 hectares.

1.26 Data with regard to the average annual quantum of water diverted by the major and medium projects in operation in the basin has been supplied by the Orissa State for the projects lying in its territory. However, for the projects located in the Bihar State no such data is available. On the basis of the data supplied by the Orissa State, a rough assessment of the average annual quantum of water diverted by the major and medium projects in operation and under construction in the basin works out to 361 m. cu. m.

1.27 Details of the large number of minor schemes comprising tanks, wells and other diversions are not available. Based on the area irrigated from these sources and on rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been made. The approximate annual diversion by the minor schemes may be of the order of 1,079 m. cu. m., excluding reservoir losses.

Reservoir Losses

1.28 In the absence of data on the reservoir losses for the major and medium schemes in the basin, an approximate estimate of the losses has been made by the Commission, assuming that this would be of the order of 20 per cent of the annual diversion by these projects. On this basis, the reservoir losses work out to approximately 72 m. cu. m.

For minor schemes, in the absence of observed statistics, it is extremely difficult to estimate the losses. Assuming that the waterspread of a tank to be about 87.5 per cent of the area irrigated from it, as estimated for the Krishna-Godavari basins,* and that the total loss is of the order of 1.22 m. over the water surface area, the total reservoir losses for the tanks in the basin work out approximately 404 m.cu.m.

1.29 Thus, on completion and full development major, medium and minor projects under operation and construction as in 1968–69 in the basin would use about 1,916 m. cu. m., of which 1,858 m. cu. m. is from surface water and 58 m. cu. m. from ground water. Additional utilisation for the water supply to Ranchi City from the Subarnarekha Multi-purpose Project would be of the order of 8 m. cu. m.

1.30 There are a number of industries located in the basin around Chaibasa and Jamshedpur. Details of the water requirements of these industries are not available. The industries located in the basin in Orissa are expected to utilise 0.83 m. cu. m. as estimated by the State Government. The details are given below:

Table 1.7

Water Requirements of Industries

Sl. No.	Group	Name of the industry	Location	Annual water requirments in m.cu.m.
1	2	3	4	5
1.	Mineral based Industries—Metallurgical and metal based	Ferro Manganese Plant	Joda	0.83

*Report of the Krishna-Godavari Commission (July, 1962).

The industrial needs are expected to grow.

The problem of water pollution in the basin due to the discharge of industrial wastes has not been reported so far. However, the problem may arise in the future, and will have to be guarded against.

FUTURE DEVELOPMENT

1.31 No project is proposed to be taken up in the basin in the Fourth Five Year Plan period by any of the concerned State Governments.

By the end of the Fourth Plan, the area under minor schemes is expected to increase by about 80,690 hectares requiring nearly 1,184 m.cu.m. of water including reservoir losses.

On completion and full development of Fourth Plan projects, about 3,108 m. cu. m. of the waters (surface 3,004 m. cu. m. and ground 104 m. cu. m.) in the basin would have been used for irrigating a total area of 232,837 hectares.

The Governments of Bihar and West Bengal have not indicated the projects proposed to be taken up by them in the future in the basin beyond the Fourth Plan period.

The Orissa Government has in view two major projects to be taken up in the future in the basin. Some details of these projects are given below.

Burhabalang Project

The project envisages a storage dam across the Burhabalang at Bansabouhri and a diversion weir at Nischinta in the Mayurbhanj district. A dam across the Katia, a tributary of the Burhabalang at Mundakata and diversion weir lower down at Dori Kanta in the Mayurbhanj district are also envisaged. The project will irrigate a total area of 34,200 hectares in the kharif and rabi seasons, and is estimated to cost Rs. 110 million.

Burhabalang-Subarnarekha Project

This project is expected to cost Rs. 1,450 million and to irrigate a total area of 360,000 hectares. Other details of the project are not available.

Available particulars and locations of these projects are given in Appendix 1.4.

The supplies proposed to be utilised by these new projects are given in Table 1.8.

Table 1.8

Water Utilisation by New Projects

Name of the Project	Supplies proposed to be utilised (m.cu.m.)
1	2
Burhabalang	204
Burhabalang-Subarnarekha	2,860
Total	3,064

FLOODS, WATERLOGGING & DRAINAGE

1.32 The flood problem in the basin is more or less confined to the lower reaches of the Subarnarekha. The Subarnarekha carries considerable discharges during the flood season. The peak floods revealed are of the order of 16,990 cumecs and 5,663 cumecs in the Subarnarekha and the Burhabalang respectively. In this area, there is widespread inundation by the Subarnarekha owing to the incapacity of its natural section to carry the discharge. The condition gets worse when heavy rainfall occurs simultaneously with high tides. The river spills over both its banks in the Orissa/Bengal delta inundating an area of about 518 sq. km. The other rivers in the basin also spill over their banks during floods on account of inadequate carrying capacity. Collectively they present a flood problem because they submerge areas in the lower reaches.

The problem of the Subarnarekha was specifically referred to the Orissa Flood Committee of 1928. The latter were of the view that the alignment of Bhograi and Joki embankments being radically defective interfered with the natural drainage in the delta. The Committee recommended:

(i) Provision of a new embankment across the angle formed by the Bhograi and Joki embankments and abandoning of the Joki embankment;

(ii) bunds near the mouth of the river in the coastal area to be removed or lowered to improve drainage;

(iii) a portion of the Orissa Coastal Canal lying on west of the Subarnarekha to be adandoned to improve drainage.

No action was taken on the above recommendations partly on account of financial considerations and partly due to opposition from West Bengal to (i) and from local people to (ii) and (iii). Subsequent enquiry committees, while suggesting the systematic collection of hydrological data, did not recommend any specific solution for the problems of this river.

1.33 The following flood control works have been undertaken:

(i) Straightening of the Chittai nallah.

(ii) Construction of a direct outfall from the Kaljori nallah into the Subarnarekha and closing of its present connection with the Chittai nallah.

(iii) Construction of a non-return sluice across the mouth of the Chittai nallah with small flank embankments for its drainage into the Subarnarekha.

(iv) Direct cut in the Subarnarekha at Amchua to hasten the flood discharge into the sea. This work has been suspended due to some legal difficulty in obtaining possession of land.

1.34 The High Level Committee on Floods, in their report dated 1958, made the following recommendations in regard to the control of floods in the Subarnarekha:

(i) The entire coastal area of the Subarnarekha needs to be surveyed by the Survey of India so as to locate the drainage lines. These drainage lines should be resusciated and cross-drainage works across the canal provided wherever necessary;

(ii) the plinth levels of important villages in the flood area should be raised or ring bunds should be provided around them;

(iii) investigations should be carried out to drain off the area expeditiously by:

(a) providing more sluices on the roads and railway lines, if necessary, or

(b) increasing waterway of the existing bridges and culverts under the roads and the railway lines need to be increased;

(iv) for the reduction of the depth of submergence between the Subarnarekha and the road above Jaleshwar railway station, the waterways of existing bridges and culverts under the roads and the railway lines;

(v) the waters of low pockets should also be drained either into the Chittai nallah or directly into the Subarnarekha;

(vi) the area situated in the low-lying corner formed by the coastal canal and the Joki embankment should be drained into the coastal canal by non-returnable sluices;

(vii) the Agriculture Department should look into the possibility of adjusting the crop pattern in the spill area suitably so as to withstand prolonged flooding.

1.35 The Ministers' Committee on Flood Control, in their report dated December, 1964, made the following recommendations in regard to the control of floods in the basin:

(i) New embankments, cuts, escapes and other works recommended by the Flood Enquiry Committee (1962) should be taken up according to a phased programme,

(ii) Old embankments should be raised and strengthened wherever necessary.

The action taken on these recommendations by the State Government is not known.

1.36 The problem of waterlogging in the basin is mostly confined to the coastal region. In this area, natural drainage systems exist in the doabs between two rivers. These drainage systems drain the rainwater of the doab and also the flood spills from the main rivers and do not often freely discharge leading to the temporary submergence of vast areas. Effective drainage to prevent waterlogging, and salinity control are necessary in this area.

1.37 In the upper regions, there has been practically no waterlogging due to flow irrigation.

SOIL CONSERVATION

1.38 The problem of soil erosion in the basin is particularly serious in the region covering parts of the Singhbhum and Mayurbhanj districts. In these areas, extensive shifting cultivation which destroys forests and creates conditions of severe soil erosion, is practised by the tribals. Soil erosion also occurs due to faulty agricultural practices like ploughing through the contours of unbunded fields. In the forests, there is large-scale unplanned felling and thining of trees and uncontrolled grazing, which also result in soil erosion.

1.39 For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures should be taken up in the cultivated areas in the basin and in the areas under forests.

1.40 The soil conservation measures to be taken may be classified under the following heads:

(i) Afforestation in the new areas as well as in existing forests, which have been either denuded or where replacement is needed;

(ii) terracing and contour bunding and construction of field bunds on agricultural lands, which require treatment;

(iii) pasture development and protection of marginal and sub-marginal lands;

(iv) fringe afforestation and stream bank control; and
(v) construction of check dams, gully plugging etc.

No project in the basin has been included under the centrally sponsored programme of soil conservation in catchments of major river valley projects.

GENERAL

1.41 The Subarnarekha is an inter-State river system, in the State of Bihar, West Bengal and Orissa. An agreement has been reached between the concerned States regarding the utilisation of the waters of the river. The allocation of water among the various States is shown below:

Bihar	3,947 m. cu. m.
Orissa	1,480 ,,
West Bengal	123 ,,
Total	5,550 m. cu. m.

1.42 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs should be established.

1.43 Gauge and discharge sites at representative points on the main rivers and their tributaries need to be established to assess correctly the water resources of the basin. The observations at the various sites should be continued on a permanent basis to obtain data essential not only for the preparation of individual projects but also for the regulation of available river water.

1.44 Systematic and scientific exploratory work is needed for a qualitative and quantitative assessment of the ground water resources so that these resources are developed in a rational way, for use either independently or in conjunction with surface waters.

1.45 There is need for inter-State co-operation and agreement in respect of soil conservation measures and conserving the storage capacities of existing and proposed reservoirs.

1.46 Data collected with regard to the sediment carried by the rivers would be of considerable use in working out the dead storages and lives of reservoirs. It will also reflect the effect of soil conservation carried out in the basin. Sediment data needs to be collected regularly.

SALIENT FEATURES OF THE BRAHMANI-BAITARANI BASIN

(i) Source	The Brahmani:	Near Nagri village in Ranchi District (Latitude 23° 20′N, Longitude 85°12′E).	
	The Baitarani	Near Mankarnacha village in Keonjhar district (Latitude 21°49′N, Longitude 85°17′E).	
(ii) Length	The Brahmani	799 km.	496 miles
	The Baitarani	355 km.	220 miles
(iii) Drainage area	The Brahmani	39,033 sq.km.	15,071 sq.miles
	The Baitarani	12,789 ,,	4,938 ,,
	Total	51, 822 ,,	20,009 ,,
(iv) Population (1971 Census)		7.77 millions	
(v) Density of Population		150 per sq.km.	389 per sq.mile
		Cumecs	Cusecs
(vi) Maximum discharge at the head of the delta	The Brahmani	22,654	8,00,000
	The Baitarani	14,158	5,00,000
(vii) Minimum discharge at the head of delta	The Brahmani	8.5	300
	The Baitarani	2.8	100
		m.cu.m.	MAF
(viii) Average annual runoff	The Brahmani at Jenapur	18,311	14.84
	The Baitarani at Akhuapada	5,452	4.42
		Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)		3,201	7,910
(x) Net area sown (1967-68)		2,029	5,014
(xi) Gross area sown (1967-68)		2,403	5,938
(xii) Net area irrigated (1967-68)		310	766
(xiii) Gross area irrigated (1967-68)		447	1,105
(xiv) Area irrigated after completion and full development of Fourth Plan projects		592	1,464
(xv) Probable additional irrigation by future projects		N.A.	
(xvi) Water utilisation, including reservoir losses		m.cu.m.	MAF

(a) On completion and full development of major, medium and minor projects under operation and construction at the end of 1968-69	Surface water	4,320	3.50
	Ground water	136	0.11
	Total	4,456	3.61
(b) On completion and full development of Fourth Plan Projects	Surface water	6,764	5.45
	Ground water	200	0.16
	Total	6,964	5.64

CHAPTER II

THE BRAHMANI-BAITARANI BASIN

The Brahmani-Baitarani basin extends over an area of 51,822 sq. km., and lies between east longitudes 83°55′ and 87°3′ and north latitudes 20°35′ and 23°35′. Lying in the north-east of the Deccan Plateau, the basin covers large areas in the States of Orissa and Bihar and a small area in Madhya Pradesh. The Statewise distribution of the drainage basin is given below:

State	*Drainage area* sq. km.
Orissa	34,749
Bihar	15,757
Madhya Pradesh	1,316
Total	51,822

2.2 The basin is bounded on the north by the Chhotanagpur Plateau on the west and south by the ridge separating it from the Mahanadi basin, and on the east by the Bay of Bengal. The Brahmani sub-basin covering 39,033 sq. km. has a long sausage shape. The Baitarani sub-basin covering 12,789 sq. km. is roughly circular in shape. The basin, as a whole, has a maximum length of 423 km. in the north-west-south-east direction and a maximum width of 193 km. in north-east-south-west direction.

2.3 The basin has four well-defined physical regions: (i) the northern plateau, (ii) the Eastern Ghats, (iii) the coastal plains and (iv) the erosional plains of the central table-land. The northern plateau and the Eastern Ghats are well-forested hilly regions. The coastal plain stretching over the districts of Cuttack and Balasore, covers the delta formed by the two rivers and is a fertile area well suited for intensive cultivation. The erosional plains of the central table-land are traversed by the Brahmani, the Baitarani and their tributaries.

THE RIVER SYSTEMS

2.4 The major river systems in the basin are the Brahmani and the Baitarani. These river systems are described briefly in the following paragraphs.

2.5 The Brahmani, known as the South Koel, in the upper reaches, rises near Nagri village in the Ranchi district of Bihar State at an elevation of about 600 m. at north latitude 23°20′ and east longitude 85°12′ and flows initially in a north-westerly direction for a length of 47 km. Thereafter, it takes a turn to the left and flows in a generally southern direction for a length of 96 km. Changing direction towards the south and south-east, the river continues to flow for a length of 121 km. up to Manoharpur, receiving many small tributaries on both banks. In this reach, the Karo, a major left bank tributary, joins the South Koel, at the 218th km. of the latter's run from the source, just south of Gudri in Singhbhum district. Beyond Manoharpur, the river turns to the right and flows in a south-westerly direction for a distance of 55 km. up to Rourkela. At the 306th km. of its run from the source, the river receives the Sankh, a major right bank tributary, near Rourkela. Below the confluence of the Sankh and the South Koel, the river is known as the Brahmani. Beyond Rourkela, taking a turn to the left, the river flows in a generally south-easterly direction for a length of 260 km. In this reach, another major tributary, the Tikra, joins the Brahmani from the right at the 497th km. of the latter's run, north-west of Samal. Flowing in a generally easterly direction for a further length of 220 km. and receiving several small tributaries from both banks, the Brahmani falls into the Bay of Bengal, opposite Wheeler island. The river, in its tail reach, is known as the Maipura. The total length of the river from the head to its outfall into the sea is 799 km., of which 258 km. are in Bihar and the balance in Orissa.

2.6 The Karo, the Sankh and the Tikra are the principal tributaries and are described briefly in the following paragraphs.

The Karo rises near Nagri in Ranchi district at an elevation of 600 m. above sea level at north latitude 23°17′ and east longitude 85°8′ and flows in a generally southern direction for a total length of 112 km. to join the South Koel, from the left, near Gudri village in Singhbhum district. The Karo drains a total area of 2,741 sq. km.

The Sankh river rises north-east of Raja Dera village in Ranchi district at an elevation of about 900 m. at north latitude 23°17′ and east longitude 84°11′ and flows generally in a south and south-easterly direction for a total length of 196 km. to join the South Koel from the right near Rourkela, in Sundargarh district. The Sankh drains a total area of 6,933 sq. km.

The Tikra rises south of Jamunkira village in Sambalpur district at an elevation of about 450 m. at north latitude 21°27′ and east longitude 84°22′ and flows in a generally easterly direction for a total length of 101 km. to join the Brahmani, north-west of Samal in Dhenkanal district. The Tikra drains a total area of 2,528 sq. km.

2.7 The Baitarani rises in the hill ranges of Keonjhar district near Mankarnacha village at an elevation of about 900 m. at north latitude 21°49′ and east longitude 85°17′. The river flows initially in a generally northerly and north-easterly direction for a total length of 80 km. up to Jaintgarh. Thereafter, it takes an almost right angle turn and flows in a generally south-easterly direction up to Jajpur for a length of 194 km. Changing direction again towards the east, the river continues to flow for another 81 km. and joins the Bay of Bengal near Palmyras Point. The Salandi joins the Baitarani from the left at the 314th km. of its run, north-west of Rajkalika. The Matai, another left bank tributary, joins the Baitarani at the 343rd km. of the latter's run near Dhamra. The Baitarani, in its lower reaches, is known by the name of Dhamra. The total length of the river from the head to its outfall into the sea is 355 km. and lies entirely in the State of Orissa.

2.8 The Salandi and the Matai are the principal tributaries and are described briefly in the following paragraphs.

The Salandi rises near Megasini village in Mayurbhanj district at an elevation of about 900 m. above sea level at north latitude 21°35′ and east longitude 86°18′ and flows in a generally south-easterly direction for a total length of 144 km. to join the Baitarani from the left. The Salandi drains a total area of 1,793 km.

The Matai rises near Bhadrakh in Balasore district at an elevation of about 50 m. above sea level at north latitude 21°4′ and 86°32′ and flows in a generally southerly direction for a total length of 63 km. to join the Baitarani from the left.

CLIMATE

2.9 In the year, four distinct seasons occur in the basin. They are (i) cold weather, (ii) hot weather, (iii) south-west monsoon and (iv) post-monsoon. In the cold weather, the winds are generally light, and blow either from the north or the north-east and the atmosphere is bright. During December and January, very little precipitation occurs, but during February, there is some precipitation in association with passing western disturbances. It is mostly confined to the hilly parts of the catchment. The winter is pleasant and not severe.

2.10 The hot season commencing in March lasts till the middle of June by which time the south-west monsoon sets in. Thunderstorms are quite frequent during the hot season and some of them result in rain, the intensity of such rainfall being comparatively more in the hills than in the plains.

The south-west monsoon sets in by the middle of June over the basin and continues to be active till the first week of October. During this period, the basin receives over 90% of its total annual rainfall. The monsoon withdraws by the first week of October.

After the withdrawal of the south-west monsoon, a few thunderstorms continue to occur. The weather clears up by November and it is cool thereafter.

Rainfall

2.11 There are at present 59 reporting raingauge stations inside the basin. The distribution of the stations is not even, and they are insufficient in number. More raingauges to obtain a balanced distribution over the entire basin should be established. In selecting the locations for new gauges, care should be taken that all areas in the basin are suitably represented. The monthly and annual normals of rainfall in the districts lying in the basin are given in Appendix 2.1.

Temperature

2.12 The basin has a tropical climate. In the hilly parts of the basin the variations of temperature during the year are less marked than in the plains. In the month of January, the mean temperature over the basin is between 17.5°C and 20°C. In April, the mean temperature varies from 30°C to 32.5°C whereas in the month of July, it ranges from 27.5°C to 30°C. In the month of October, the basin experiences temperatures between 25°C and 27.5°C. Generally, late December and early January are the coldest part of the year. The annual normals of temperature at some stations in and around the basin are given below:

Station	*Annual normals of temperature*	
	Maximum (°C)	*Minimum (°C)*
Angul	32.3	21.0
Balasore	31.5	21.5
Cuttack	31.0	22.3
Sambalpur	32.5	20.9

Evaporation

2.13 The data on evaporation is not available for the basin. There are no departmental or agro-meteorological observatories of the India Meteorological Department within the basin.* The monthly evaporation losses from the reservoir assumed in the Salandi Project are as under:

Table 2.1

Monthly Evaporation Losses—Salandi Project

Sl. No.	Name of the Project	Evaporation (cm.)												
		J	F	M	A	M	J	J	A	S	O	N	D	Annual
1.	Salandi*	9	11	12	14	17	12	5	5	5	12	11	9	122

*Report on the Salandi Irrigation Project, Government of Orissa (1955).

SOILS

2.14 No systematic soil survey of the Brahmani-Baitarani basin has been carried out so far. The general data regarding the soils of India, however, indicate that the basin consists mainly of red and yellow soils, red sandy and loamy soils, mixed red and black soils and coastal alluvium. The largest area is covered by the red and yellow soils. Red and yellow soils differ greatly in fertility, produce a number of crops under irrigation and are suitable for paddy cultivation. Red sandy and loamy soils are suitable for the cultivation of paddy and other crops. With irrigation, a large variety of crops can be grown on them. Mixed red and black soils are of medium fertility suitable for a wide variety of crops depending upon climatic conditions.

2.15 The basin covers, in full, the district of Keonjhar and parts of the districts of Sundargarh, Sambalpur, Dhenkanal, Cuttack, Balasore and Mayurbhanj in Orissa; Ranchi and Singhbhum districts in Bihar and Raigarh district in Madhya Pradesh. The principal soil types found in the various districts in the basin are given below: †

Keonjhar: Red soils which are generally open in texture and well-drained.

Sundargarh: Red soils which are generally open in texture and well-drained.

*Evaporation Data (India), India Meteorological Department (April, 1970).

†Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Sambalpur: The cultivated soils are loamy in texture and have low nutrient contents.

Dhenkanal: Black soil or 'regur' and old alluvium. In general, they have a higher content of clay.

Cuttack: The soils vary from clays to clayey loams, the latter being more common.

Balasore: Mainly sandy loams.

Mayurbhanj: Red soils which are generally open in texture and well-drained.

Ranchi: Gravelly soils, sandy loams, alluvial soils and black clays. The soils on the uplands are reddish and porous while those in the low-lands are heavier and darker.

Singhbhum: Red loams on the uplands and heavy black clays in the lowlands are the main soil types.

Rajgarh: The main soils are kankar, matasi, dorsa, and bhata. Kankar is generally black in colour, but reddish and lighter varieties are also found. Matasi is a yellow soil with many varieties. Dorsa is a mixture of kankar and matasi. Bhata is a poor red soil full of stones, and without any consistency.

LAND USE AND AGRICULTURAL PRACTICES

2.16 State-wise land use details in the basin in 1967–68, the latest year for which the statistics are available are given below:

The cultivated area in the basin constitutes 75.1% of the culturable area, which shows that agriculture has been practised quite extensively in the basin. The culturable area in the basin is about 1.64% of the total culturable area of the country. The total cropped area in the basin is about 1.47% of the total cropped area in the country. The land use details indicate that the resources in the basin have not been put to intensive use.

2.17 The general cropping pattern, State-wise, in the irrigated area is given below:

Bihar

2.18 Of the total irrigated area of 19,100 hectares, 62.8% is under rice, 2.1% under other pulses, 5.2% under wheat and the balance under other crops. The other crops grown in the irrigated area are maize, ragi, barley, gram, tur, condiments and spices, fruits, vegetables, etc. The food crops represent about 99.5% of the irrigated area and the balance 0.5% is under non-food crops.

Table 2.2

Land Use Details

(Thousand hectares)

Sl. No.	Item	Name of the State			Total
		Bihar	Madhya Pradesh	Orissa	
1.	Gross area	1,576	132	3,475	5,183
2.	Reporting area	1,574	130	3,469	5,173
3.	Area under forests	407	42	776	1,225
4.	Area not available for cultivation	179	18	550	747
5.	Culturable area	988	70	2,143	3,201
6.	Uncultivated culturable area	408	20	744	1,172
7.	Net area sown	580	50	1,399	2,029
8.	Area sown more than once	51	3	320	374
9.	Total cropped area	631	53	1,719	2,403
10.	Net area irrigated	16	0.8	292.8	309.6
11.	Gross area irrigated	19.1	0.8	426.8	446.7
12.	Percentage of net area sown to culturable area	58.7	71.4	65.3	63.4
13.	Percentage of net area irrigated to culturable area	1.6	1.1	13.7	9.7
14.	Percentage of net area irrigated to net sown area	2.8	1.6	20.9	15.3

Madhya Pradesh

2.19 Of the total irrigated area of 800 hectares, 25.1% is under sugarcane, 37.5% under rice and the balance of 37.4% under other food crops. The other crops grown in the irrigated area are barley, gram, fruits, vegetables, rapeseed, mustard, tobacco, etc. Practically, the entire irrigated area is under food crops.

Orissa

2.20 The latest crop-wise statistics of the irrigated area are available only for 1956–57, which indicate that out of the total irrigated area of 165,200 hectares, nearly 83.4% is under rice, 3.1% under sugarcane, 2.1% under pulses and 0.3% under wheat. Other crops grown in the irrigated area are jowar, bajra, ragi, gram, rapeseed, mustard, linseed, cotton, jute, tobacco, fodder crops, etc. The food crops cover nearly 97.1% of the irrigated area and the balance 2.9% is under non-food crops.

Summing up, of the total irrigated area in the basin, 81.1% is under rice, 3.0% under sugarcane, 2.6% under other pulses, 0.8% under wheat and the rest under miscellaneous crops. Food crops cover 97.4% of the irrigated area and the balance of 2.6% is under non-food crops.

2.21 The main two crop seasons in the part of the basin lying in Madhya Pradesh State, are the kharif and the rabi. The kharif crops are paddy, jowar, maize, ragi, bajra and small millets. The important rabi crops are jowar, millets, wheat, barley, gram and other pulses. In addition to these seasonal crops, garden crops like sugarcane, plantains etc. are also grown throughout the year.

Three crop seasons prevail in the part of the basin lying in the Bihar and Orissa States. They are (i) the kharif, (ii) the rabi and (iii) the hot weather. The important kharif crops are paddy, jowar, bajra, maize, ragi and millets. During the rabi season, the main crops grown are paddy, jowar, barley, wheat, and pulses. The hot weather crops, generally, are paddy and chillies. In addition, cash crops like cotton and jute are also grown for a major part of the year in the Orissa area.

2.22 The sowing and harvesting months of the principal crops in the various States are given below:*

Table 2.3
Sowing and Harvesting Periods

Name of crop	Period of	
	Sowing	Harvesting
Madhya Pradesh		
Kharif Paddy	June-August	September-December
Kharif Jowar	June-August	November-January
Rabi Jowar	September-October	January-March
Kharif Millets	June-August	September-December
Rabi Millets	September-November	December-March
Maize	June-July	August-September
Ragi	June-July	September-November
Bajra	June-August	October-December
Small millets	June-August	September-December
Wheat	October-November	February-April
Bihar		
Autumn Paddy	May-July	September-October
Winter Paddy	July-September	November-December
Summer Paddy	January-February	May-June

*Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 2.3—Contd.
Sowing and Harvesting Periods

Name of crop	Period of	
	Sowing	Harvesting
Kharif Jowar	April-August	September-December
Kharif Bajra	April-August	September-December
Maize	June-July	September-October
Ragi	June-July	September-October
Millets	June-August	October-November
Wheat	October-December	February-May
Barley	October-December	February-May
Gram	October-December	February-May
Orissa		
Autumn Paddy	May-June	September-October
Winter Paddy	June-August	December-January
Summer Paddy	December-January	May-June
Kharif Jowar	June-July	September-October
Bajra	June-July	September-October
Maize	June-July	September-October
Wheat	October-November	March-April
Barley	October-November	March-April
Millets	June-July	September-October
Jute	May-June	December-January
Cotton	June-July	January-February

REGIONAL ECONOMY

Population

2.23 On the basis of the 1971 Census* and the percentage of the area of each district within the basin, to the district as a whole, the total population in the basin is about 7.77 millions. The State-wise distribution is given below:

State	*Population* (Millions)
Bihar	2.41
Madhya Pradesh	0.13
Orissa	5.23
Total	7.77

*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

No city in the basin has a population of more than one lakh. The average density of population in the basin is 150 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. The coastal plain is the most densely populated while the hilly areas have relatively low density. The most densely populated district of Cuttack has 349 people per sq. km. while the district of Raigarh has only 99 people per sq. km. The population in the districts of Sundargarh, Mayurbhanj, Keonjhar, Dhenkanal and Singhbhum has a relatively large component of persons belonging to the scheduled tribes. They are economically backward and depend for their livelihood mainly on forest produce and on shifting cultivation or on a primitive form of settled agriculture. They have little industrial activity even on a cottage scale.

2.24 Out of the total population in the basin, nearly 88.4% of the people live in rural areas while the balance of 11.6% live in urban areas. The working force constitutes nearly 33.8% of the total population. 47.2% of the working force is engaged as cultivators and 31.8% as agricultural labourers. The balance of 21.0% of the working force is employed in manufacturing and other tertiary activities.

Forests and Agriculture

2.25 In the basin, forests occupy 23.7% of the total area and the culturable area occupies 61.9%. Out of the total culturable area of 3.20 million hectares, nearly 2.40 million hectares are annually cultivated. An area of 0.45 million hectares constituting 18.6% of the cultivated area is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 81.1% of the total irrigated area.

Power

2.26 There are no major hydro-power stations in the basin. The hydroelectric power potential of this basin has been assessed as 1,154.5 MW at a 60% load factor by the Central Water & Power Commission. At present, there are two major thermal power stations in the basin, at Rajgangpur and Talcher respectively. The Rajagangpur Station has an installed capacity of 6.5 MW and is located close to Rourkela. The Talcher Station is located 3.2 km. from the Talcher Railway Station and about 7 km. from the main Cuttack-Sambalpur Road in Orissa. The installed capacity of this station is 250 MW. This project costing Rs. 348 million, was started in 1961 and one unit of 62.5 MW was commissioned in 1967. The second and the third units of 62.5 MW each were commissioned in 1968 and the fourth unit of 62.5 MW was commissioned in

1969. The power generated is fed into the State grid. The basin also gets power from the Hirakud Project.

Mineral Wealth

2.27 The basin has a rich variety of mineral wealth spread over vast areas. The principal minerals found are: *

Iron ore, in the Singhbhum, Keonjhar, Sundargarh, Cuttack, Mayurbhanj and Sambalpur districts;

Copper, in the Singhbhum and Ranchi districts;

Bauxite, in the Ranchi, Sambalpur and Raigarh districts;

Chromite, in the Singhbhum, Keonjhar, Cuttack and Dhenkanal districts;

Limestone, in the Singhbhum, Ranchi, Sambalpur, Sundargarh and Raigarh districts;

Asbestos, in the Singhbhum district;

Manganese, in the Singhbhum, Keonjhar and Sundargarh districts;

Atomic Minerals, in the Singhbhum district;

Dolomite, in the Sundargarh and Sambalpur districts;

Coal, in the Sambalpur and Dhenkanal districts;

Fireclay, in the Dhenkanal and Sambalpur districts;

China Clay, in the Singhbhum, Mayurbhanj, Keonjhar, Sambalpur and Sundargarh districts;

Soapstone, in the Singhbhum district.

Industries

2.28 Rich in forests, agricultural and mineral resources, the industrial potential of the basin is much higher than that of many other parts of India. There is also a large hydro-power potential awaiting development. The present development of the large potential is only a modest beginning and much remains to be done in the area. Important industries are located in Rourkela, among them being iron and steel, fertilizers, DDT and insecticides. At Kusunda are located chemical industries (acids and caustics), fertilisers, DDT and insecticides, soaps etc.

Communications

2.29 The basin is served by the South-Eastern Railway. The entire system is on the broad-gauge. There are a few important lines connecting different places in the basin, among them being the Madras-Howrah line, the Talcher-Nergundi line, the Rourkela-Gua line etc. The National

*Techno-Economic Surveys of Bihar, Madhya Pradesh and Orissa, NCAER.

Highway connecting Madras and Calcutta passes through the basin in its lower reaches. The National Highways connecting Calcutta with Bombay and Sambalpur with Cuttack also pass through the basin. In addition, there is a network of State Highways and district and village roads in the basin. The Brahmani and Baitarani are navigable in their lower reaches as they are inter-linked with the Mahanadi delta canal system. The Kendrapara Canal is linked with the deltas of the Brahmani and the Baitarani through its branch, the Gobri Canal. Cuttack is thus connected with Chandbali Port situated on the left bank of the Baitarani. Goods and passengers are carried between Cuttack and the deltas of the Mahanadi, the Brahmani and the Baitarani rivers, which are also inter-connected in their tidal reaches, by numerous tidal creeks. At present, boats up to 60 tonnes capacity, drawing 0.9 metre draft, ply on some of the reaches mainly for transporting jute and iron ore.*

The basin is fairly well served with communications.

Dependence on Rainfall and Water Resources

2.30 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence except in parts of the basin where irrigation facilities have been provided and where major industries have developed. There is a keen demand for the development of the water resources of the basin.

WATER RESOURCES

Surface Water

2.31 In 1949 when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's empirical formula, the annual runoff of the Brahmani-Baitarani System was estimated as 39,225 m. cu. m.**

In 1960 the Central Water & Power Commission, while conducting irrigation potential studies, assessed the total annual runoff of the Brahmani-Baitarani river system as 28,691 m. cu. m. on the basis of Strange's rainfall runoff co-efficients for 'average' catchments.†

2.32 Prior to 1964, there seems to have been no planned and systematic observation of discharges on the Brahmani, the Baitarani and their

*Navigable Waterways of India, Central Water and Power Commission (1961).

**An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

†Report of technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

tributaries. Some *ad hoc* and irregular observations had been made on the rivers, and on some tributaries. Since 1964, systematic and regular observations on the Brahmani at the Jenapur weir and on the Baitarani at the Akhuapada weir have been made by the Orissa State Government. The Madhya Pradesh State Government is not making any gauge and discharge observations in this basin. Details of gauge and discharge observations, if any, made by the Bihar Government in the basin have not been furnished by the State. The major tributaries like the Karo, the Sankh, the Tikra and the Matai do not seem to have been gauged at all. Some gauge and discharge observations have been done on the Salandi in connection with the Salandi Project. The details of the existing gauge and discharge sites, as furnished by the Orissa State Government are given below:

Table 2.4

Existing Gauge and Discharge Sites

Sl. No.	Name of river/ tributary	Name of site	Catchment area up to the site (sq. km.)	Year of start of observations
1.	Brahmani	Jenapur anicut	36,260	1964
2.	Baitarani	Akhuapada anicut	13,360	1964
3.	Salandi	Hadgarh dam site	673	1950

It will be seen that there are only three sites in the basin where systematic and continuous discharge observations are being conducted. The number of gauge and discharge sites in the basin is far below the minimum requirements. The main rivers in their upper reaches and many of the important tributaries are not being gauged at present. It will be necessary to establish sufficient gauge and discharge sites at representative points on the main rivers and the main tributaries in order to assess correctly the water resources of the basin.

2.33 Under the programme of establishing and maintaining centrally sponsored key hydrological stations in the country, the Central Water & Power Commission has proposed the inclusion of the following sites:

Table 2.5

Centrally Sponsored Sites

Sl. No.	Name of the river	Location of site
1.	Brahmani	Below the confluence of the South Koel and the Karo
2.	-do-	Below the confluence of the Sankh and the Brahmani
3.	-do-	52 km. below Khankenai
4.	Baitarani	3.2 km. above Koirobanlam

In addition, it has been recommended that a gauge and discharge site on the Baitarani near the railway bridge may be maintained by the Orissa State Government.

2.34 The average annual flows at the various sites on the different rivers according to the data furnished by the Orissa State Government are given below:

Table 2.6

Average Annual Flows

Sl. No.	Name of river and site	Catchment area in sq. km	Mean runoff in m.cu.m.							Remarks
			Normal anual rainfull in cm	June-Sept.	Oct.-Dec.	Jan.-March	April-May	Total		
1.	Brahmani at Jenapur	36,260	157.55	15,036	2,529	249	497	18,311		Average from 1965 to 1969
2.	Baitarani at Akhuapada	13,360	153.78	4,517	685	151	99	5,452		-do-
3.	Salandi at dam site	673	—	—	—	—	—	565		-do-

Ground Water

2.35 Systematic investigations and studies of the ground water potential of the Brahmani-Baitarani basin have not been made so far. Only in some parts of the basin like the Sundargarh, Dhenkanal, Cuttack, and Balasore districts, have some investigations and studies been made recently.*

In Sundargarh and Dhenkanal districts, ground water occurs in the regolithic mantle and soil cover of older rocks like archaeans, schists, gneisses etc. along the joints and fissures under water-table conditions. It also occurs in the Gondwana sedimentaries and in the narrow and shallow alluvial valley fills of recent age. Shallow, small-diameter tube-wells have been in use recently in Sundargarh district, particularly in the Rourkela area. The quality of water is suitable for all purposes.

The coastal alluvial plain in Cuttack and Balasore districts has also been investigated for ground water development. In the Balasore and Bhadrak sub-divisions, productive water bearing formations are of upper tertiary-quarternary age. Good aquifer zones have been located in the Balasore and Agarpara areas. Large-scale development of ground water resources appears feasible in the area. In the Basta and Chandbali areas in Balasore district, fresh water-bearing formations occur below depths of 135 to 160 m. The Chandbali artesian basin appears to have great potentialities for ground water development. In the Jajpur sub-division of Cuttack district, ground water development on a large-scale, particularly in the Panikoili-Pada-Govindpur sector appears feasible. The coastal regions of Balasore and Cuttack districts, which are underlain by alluvium are suitable for ground water development on a large scale. Exploration for ground water has to be extended in these districts. However, the presence of brackish or saline waters at shallow depths in these tracts often pose serious problems. Deeper aquifers will have to be exploited cautiously to prevent any saline encroachment. The re-charge of deeper aquifers is from the landward side and the development of ground water has to be properly oriented and extended towards the sea-coast, keeping in view the hazards.

The investigations carried out so far point to the urgency and the importance of carrying out further systematic exploratory work in the basin for a scientific, quantitative and qualitative assessment of the ground water resources. A correct assessment of the ground water resources of the basin, which will help in framing a rational plan of development for various needs can only be made when full investigations have been carried out.

EXISTING DEVELOPMENT

2.36 Irrigation has been practised in the basin from historical times. The Orissa Canal System is the only important irrigation system cons-

*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

tructed in the basin in the pre-Independence period. The project is more than a century old and utilises the waters of the Mahanadi, Brahmani and Baitarani rivers for irrigation and navigation purposes. The project is described briefly, in so far as it pertains to this basin, in the following paragraphs.

Orissa Canal System

2.37 The Birupa Weir, across the Birupa, a branch of the Mahanadi, which was constructed during the period 1864–1869, supplies water to the Kendrapara and Patamundi Canals on its right and to the first range of the High level Canal on its left. The High Level Canal crosses the Brahmani by means of two weirs, the Brahmani and Pattia Weirs, 1,219 m. and 218 m. long respectively, over its two branches; the former feeds the Dudhai Canal, which was constructed some forty years later than the original system to irrigate the island which separates the branches, and the latter, the second range of the High Level Canal. Both these weirs were constructed in 1875. The High Level Canal also crosses the Baitarani river, by two weirs, 313 m. and 160 m. long respectively, which supply the Jajpur Canal and the third and last range of the High Level Canal, which tails into the Salandi river at Bhadrak. The project irrigates an area of 53,900 hectares in the Brahmani-Baitarani basin.

The First Irrigation Commission had not recommended any specific projects by name, to be taken up for construction in the basin.

During the Plan periods, one major and two medium projects have been taken up for construction. These are described briefly in the following paragraphs.

Salandi Project

2.38 The project provides for a composite dam 818 m. long and 51.8 m. high across the Salandi, at Hadgarh and a 204.3 m. long barrage 5.6 km. downstream of the dam at Bidyadharpur, with a 80.5 km. long canal taking off from the head regulator on the left flank of the barrage. The project costing Rs. 130.77 million, will irrigate 61,920 hectares in Balasore district. The project was taken up for construction in 1960 and is likely to be completed during the Fourth Plan.

Derjang Project

2.39 The project envisages an earthen dam of a maximum height of 27 m. across the rivers Hingra and Metalia about 9.7 km. from Angul town. A canal will take off from the left flank to irrigate 9,712 hectares in the Dhenkanal district. The project costing Rs. 37.24 million was started in 1960 and is likely to be completed during the Fourth Plan.

Pitamahal Project

2.40 The project provides for an earthen dam of a maximum height of 9.7 m. across the Pitamahal river and two canals taking off from the reservoir for irrigating 4,856 hectares in the Sundargarh district. The total cost of the project is Rs. 8.3 million. The project was started in 1968 and is likely to be completed during the Fourth Plan.

2.41 Some particulars of the major and medium projects under operation and construction in the basin are given in Appendices 2.2 and 2.3.

2.42 Besides the major and medium projects, a number of minor schemes, comprising tanks and wells, irrigate a very large area in the basin. In many villages, there are more tanks than one. The adjoining agricultural lands receive water from them. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, in the basin, are as under:

Table 2.7

Source-wise Irrigation

Sl. No.	Source of irrigation	Area irrigated ('000 hectares)			Total area irrigated ('000 hectares)
		Bihar	Madhya Pradesh	Orissa*	
1.	Canals	5.8	—	112.7	118.5
2.	Tanks	2.6	0.3	81.7	84.6
3.	Wells	4.2	0.1	7.5	11.8
4.	Other sources	3.4	0.4	90.9	94.7
	Total	16.0	0.8	292.8	309.6

*Data pertains to 1964-65.

By the end of 1968–69, the area under minor schemes increased by about 15,730 hectares.

2.43 Based on the data supplied by the Orissa State Government regarding the average annual quantum of water diverted by the major and medium projects under operation and construction in the basin, the utilisation by these projects works out to 1,042 m.cu.m., excluding reservoir losses.

Details of the large number of minor schemes comprising tanks, wells and other diversions are not available. Based on the area irrigated from these sources and on rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been made. The approximate annual diversion by the minor schemes may be of the order of 2,206 m.cu.m., excluding reservoir losses.

Reservoir Losses

2.44 On the basis of assumptions detailed in para 1.28 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium schemes	109 m.cu.m.
(ii) Minor schemes (tanks)	1,099 ,,
Total:	1,208 ,,

2.45 Thus, on completion and full development the major, medium and minor projects under operation and construction in 1968–69 in the basin would use about 4,456 m.cu.m. of which 4,320 m.cu.m. is from surface waters and 136 m.cu.m. from ground waters.

2.46 There are a number of industries located in the basin, especially round about Rourkela. The water requirements of the industries located in the basin in the Orissa State have been assessed as 93 m.cu.m. by the Orissa State Government. Details are given in Table 2.8.

Water pollution in the basin due to the discharge of industrial wastes has not been reported so far. However, the problem of pollution may arise in future, and will have to be guarded against.

FUTURE DEVELOPMENT

2.47 One major project, namely the Anandpur Barrage Project, is proposed to be taken up in the basin in the Fourth Five Year Plan period. The details of this project are given below:

Anandpur Barrage Project

2.48 The project envisages a 490.7 m. long barrage across the Baitarani river near Anandpur village in Keonjhar district with a canal

Table 2.8

Water Requirements of Industries—Orissa

Sl. No.	Group	Name of the industry	Location	Annual requirement of water (m.cu.m.)
1.	Mineral based industries —Metallurgical & Metal based	Hirakud Steel Ltd.	Rourkela	0.33
		Utkal Machinery	Kans Bahal	0.50
		Kalinga Iron Works	Barbil	1.66
		National Coal Development Corpn., Talcher (3 points of supply)	—	8.30
		Paradeep Port Project	—	8.30
		Ferro-Chrome Project	Jajpur Road	65.20
2.	Mineral based non-metallurgical	Orissa Cement Ltd.	Rajgangpur	3.32
3.	Forest & Agricultural based industry	Orient Paper Mills	Rajgangpur	3.32
4.	Chemical & Allied Industries	Orissa Fertilisers & Chemicals	Rourkela	1.66
		Indian Detonators	Rourkela	0.33
				92.92
			Say	93 m.cu.m.

system on either side for irrigating 158,620 hectares in the Keonjhar, Balasore and Cuttack districts. The project costing Rs. 214.90 million, is proposed to be integrated with the Salandi project, which is under construction in the basin. The project is likely to utilise 965 m.cu.m. of water. Some particulars of the Anandpur Barrage are shown in Appendix 2.4.

2.49 By the end of Fourth Plan, the area under minor schemes is expected to increase by about 96,640 hectares, requiring nearly 1,543 m.cu.m. of water, including reservoir losses.

Thus, the additional utilisation by the Fourth Plan major, medium and minor schemes would be of the order of 2,508 m.cu.m. benefiting an area of 255,260 hectares. On completion and full development of Fourth Plan projects, about 6,964 m.cu.m. of the waters in the basin would have been used for irrigating a total area of 592,480 hectares.

2.50 The Orissa Government has in view two multipurpose and nine major and medium projects to be taken up in future in the basin. Some details of these projects are given below:

Bhimkund Multi-purpose Project

2.51 The project envisages a masonry straight gravity dam across the Baitarani river in Keonjhar district. Costing Rs. 800.00 million, it will provide irrigation to an area of 32,000 hectares annually. In addition, it will generate 380 MW of hydro-power at a 60 per cent load factor and provide flood control benefits. A major part of the tail race water will be utilised for rabi irrigation under the Anandpur Barrage Project.

Kusai Project

2.52 It is a storage-cum-diversion scheme and will utilise the waters of the Kusai river, a tributary of the Baitarani. Located in the Keonjhar district, it will provide irrigation to 12,950 hectares and cost Rs. 20.00 million.

Upper Baitarani Multipurpose Project

2.53 The project provides for four dams, namely the Jharpara dam and the Kanpur dam across the Baitarani, the Ordai dam across the Ordai river, a tributary of the Baitarani, and the Kanjhari dam across the Kanjhari river, another tributary of the Baitarani. The Jharpara dam will be a rolled earthfill dam, 2,286 m. long and 36 m. high and the Kanpur dam, a masonry gravity dam, 548 m. long and 55 m. high. The Ordai dam and the Kanjhari dam will both be rolled earthfill dams. The Ordai dam will be 762 m. long and 24.3 m. high and the Kanjhari dam, 762 m. long and 45.7 m. high. The project will provide irrigation to an area of 84,050 hectares, and will supply water to the proposed steel plant near Nayagarh. It will cost Rs. 194.30 million.

Aunli Project

2.54 Located in the Dhenkanal district, the project provides for the construction of a 94.49 m. long, 3.05 m. high diversion weir across the Aunli river, a tributary of the Brahmani. The project costing Rs. 4.80 million will provide irrigation to an area of 3,803 hectares.

Dadaraghati Project

2.55 The project provides for a 208.8 m. long, 27.75 m. high masonry gravity dam across the Gambharia Jore river, a tributary of the Brahmani for irrigating an area of 4,014 hectares annually. The project will cost Rs. 23.30 million.

Mankara Project

2.56 Located in Dhenkanal district, the project envisages a dam across the Mankara river, a tributary of the Brahmani. Costing Rs. 12.00 million, the project will irrigate 4,020 hectares annually.

Tikra Project

2.57 The project provides for a storage dam across the Tikra river, a major tributary of the Brahmani, in Dhenkanal district. The project will cost Rs. 150.00 million and irrigate 69,000 hectares annually.

Extension of Distributary 2 of Jajpur Canal

2.58 Located in Cuttack district, the project will provide irrigation to an additional area of 8,450 hectares under the existing Jajpur Canal system.

Kansbahal Project

2.59 The project, costing Rs. 7.50 million, provides for a storage dam across the Badjore river, a tributary of the Sankh, in Sundargarh district for irrigating an area of 5,180 hectares annually.

Lodani Project

2.60 The project envisages a 402.3 m. long, 33.5 m. high dam across the Brahmani in Sundargarh district. The project will cost Rs. 101.00 million and will irrigate 86,576 hectares annually.

Upper Brahmani (Barkot) Project

2.61 The project, costing Rs. 300.90 million, provides for a 1,256 m. long, 51.5 m. high dam across the Brahmani in Sundargarh district. The project will extend irrigation in an area of 242,700 hectares.

2.62 Some particulars of the above projects are shown in Appendix 2.5.

2.63 The supplies proposed to be utilised by the various new projects proposed by the Orissa Government are given in Table 2.9.

Table 2.9

Utilisation by New Projects

Sl. No.	Name of the Project	Supplies proposed to be utilised in m. cu. m.
1	2	3
1.	Bhimkund Multipurpose Project	2,407
2.	Kusai	48
4.	Upper Baitarani Multipurpose Project	691
4.	Aunli	30
5.	Dadaraghati	36
6.	Mankara	31
7.	Tikra	528
8.	Extension of Distributary 2 of Jajpur Canal	N.A.
9.	Kansbahal	34
10.	Lodani	663
11.	Upper Brahmani (Barkot)	3,851
	Total	8,319 m. cu. m.

FLOODS, WATERLOGGING & DRAINAGE

2.64 The flood problems of the Brahmani and Baitarani are mainly confined to their lower reaches. Since the Mahanadi, the Brahmani and the Baitarani have their channels inter-connected in their deltas, the worst floods in the delta areas occur when there is heavy rainfall simultaneously in the catchment areas of more than one of these rivers. The spill from one river flows into the other and there is intermingling of water leading to the flooding of most of the delta areas. There are also occasions when, due to storms of high intensity, some local flooding takes place in the upper reaches of these two rivers.

2.65 The flood problems of the Brahmani and the Baitarani can be characterised as: *

(a) Prolonged submersion of vast agricultural lands in the middle and lower deltas as the river channels cannot carry the flood dis-

*Report of the Ministers Committee on Flood Control, Ministry of Irrigation and Power (1964).

charge within their banks and a major part of the flood flows spill the banks;

(b) fertile land becoming permanently unfit for cultivation by sand castings;

(c) severe scour of river banks washing away villages and land;

(d) the formation of sand bars across the mouths of the rivers from the south-west to the north-east due to littoral drift; and

(e) breaches in the flood embankments during high floods.

Some flood embankments have been built along these rivers in the past. Many of them are private embankments and have been constructed in isolated places to prevent the river spill from damaging the land. They have been built in inadequate sections and maintained indifferently, with the result that they provide poor protection in times of need.

2.66 The flood control measures undertaken in the pre-Independence period were confined to the construction of embankments. The recent flood control works carried out so far on the Brahmani consist mainly of raising and strengthening old embankments. The Orissa Government has a proposal for the construction of a multipurpose storage reservoir across the Brahmani at Rengali about 122 km. north-west of Cuttack.* In addition, the construction of marginal embankments along both banks in the delta area for the main branches of the river, is envisaged. The Rengali dam is expected to moderate the floods to safe limits in the deltaic areas downstream. Due to the silting up of the existing weir at Jenapur, the distribution of flood waters into the various channels of the Brahmani downstream of Jenapur is not effective. A proper distribution of flood waters into the various channels will go a long way to reduce the flood problem.

2.67 The recent flood control works carried out on the Baitarani consist also mostly of raising and strengthening existing embankments. The Orissa Government has proposed a multipurpose dam at Bhimkund across the Baitarani, which will cater for flood moderation also. In addition, some embankments in the lower reaches near the sea-coast are envisaged.

The Brahmani and the Baitarani carry very high discharges during floods. The high flood discharges of these rivers at the heads of their deltas are 22,654 cumecs and 14,158 cumecs respectively.† The minimum dry weather discharges at these places are 8.5 cumecs and 2.8 cumecs

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*Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

†Orissa Decade of Destiny (1963-1973)—A Plan for integrated development of river basins of Orissa (1963), by Dr. A. N. Khosla.

respectively. These figures are indicative of the wide seasonal variations in discharges in the rivers.

2.68 The problem of waterlogging in the basin is mostly confined to the delta areas in Orissa. In the deltaic region, the main rivers, namely the Mahanadi, the Brahmani and the Baitarani open out into several branches and sub-branches, which either join the main rivers downstream or discharge directly into the sea. In the course of delta formation, the banks of the main rivers have gradually become higher than the surrounding land. Due to the topography, a natural drainage system exists in the doab between the two rivers. These drainage systems drain the rainwater of the doab and also the flood spills from the main rivers, but where they do not freely discharge, they temporarily submerge vast lands in the doabs. Floods in the main rivers, obstruct the drainage particularly when the flood stage of the rivers confined by embankments is considerably higher than the adjoining lands. The discharge of drainage is also held back by tidal flows from the sea. Thus, waterlogging conditions are created, which result in the formation of lagoons and low lying swampy lands. Effective drainage is, therefore, necessary in the coastal plains to prevent waterlogging.

Due to flow irrigation in the upper reaches, there has been practically no waterlogging there.

SOIL CONSERVATION

2.69 The problem of soil erosion in the Brahmani-Baitarani basin is particularly serious in the plateau region covering parts of the Sambalpur, Dhenkanal, Keonjhar, Sundargarh, Mayurbhanj and Singhbhum districts. In these areas, shifting cultivation is practised by the tribals on an extensive scale, which destroys forests, and creates conditions of severe soil erosion. Soil erosion also occurs due to faulty agricultural practices such as ploughing through the contours of unbunded fields. There is large-scale unplanned felling and thinning of trees and uncontrolled grazing in the forests, which also result in soil erosion.

For the conservation of river supplies, and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures should be taken up in the cultivated areas and in the culturable, but not yet cultivated, areas of the basin, and in the areas under forests.

Soil conservation work has been taken up in the catchments of the Brahmani and the Baitarani by the Orissa State Government. The area covered so far under the Brahmani scheme is 4,339 hectares and under the Baitarani, 6,503 hectares. Land development measures are also being executed in the catchment areas of both rivers.

Studies of the rise in the water table in the bunded areas are being carried out in Madhya Pradesh, whereas no such studies have been done in Orissa. Studies made by Madhya Pradesh indicate that there is a rise in the water table in the bunded areas.

High priority for soil and water conservation measures in drought affected areas has been accorded by the State Governments. The Agriculture & Forest Departments are entrusted with the work of soil conservation.

GENERAL

2.70 The Brahmani and its tributaries form an inter-State river system, flowing through the States of Bihar, Madhya Pradesh and Orissa. The Orissa Canal System is under operation and two others, namely the Derjang and the Pitamahal Projects are under execution on the Brahmani and its tributaries. The States have all along been planning projects for their individual benefit. Preparation of a master plan for the development of the basin is essential to make the optimum use of the available resources.

2.71 As stated in para 2.11 the distribution of the existing raingauge stations in the basin is not even and the number is inadequate. New raingauge stations to fill up the existing gaps should be established.

2.72 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs needs to be established.

2.73 The number of gauge and discharge sites in the basin is far below the minimum requirements. An adequate number of gauge and discharge sites at representative points on the main rivers and the main tributaries should be established to assess correctly the water resources of the basin. Gauge and discharge observations at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects, but also for the regulation of available river water.

2.74 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with surface water.

2.75 There is need for inter-State co-operation and agreement in respect of soil conservation measures and for conserving the storage capacities of existing and proposed reservoirs in the basin.

2.76 It is necessary for systematic data to be collected of the sediment carried by the rivers, which would be of considerable use in working out dead storage and the life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE MAHANADI BASIN

(i) Source: Near Nagri town in the Raipur district of Madhya Pradesh (Latitude 20°21′N, Longitude 81°58′E)		
(ii) Length of the Mahanadi river	Km.	Miles
In Madhya Pradesh	357	222
In Orissa	494	307
Total	851	529
(iii) Drainage area	Sq. km.	Sq. miles
Bihar	635	245
Madhya Pradesh	75,136	29,010
Maharashtra	238	92
Orissa	65,580	25,322
Total	141,589	54,669
(iv) Population (1971 Census) 17.80 millions.		
(v) Density of population 126 per sq. km.	326 per sq. mile	
(vi) Maximum discharge at Naraj, 739 km. (459 miles) from source	44,741 cumecs	1,580,000 cusecs
(vii) Minimum discharge at Naraj	42 cumecs	1,500 cusecs
(viii) Annual runoff at Kaimundi, 723 km. (449 miles) from source	m.cu.m.	MAF
(a) at 50% dependability	66,644	54.03
(b) at 75% ,,	53,763	43.59
(c) at 90% ,,	42,170	34.19
(ix) Maximum annual runoff recorded todate at Kaimundi in 1961-62	140,216	113.68
(x) Minimum annual runoff recorded todate at Kaimundi in 1954-55	35,827	29.05
	Thousand hectares	Thousand acres
(xi) Culturable area (1967-68)	7,994	19,754
(xii) Net area sown (1967-68)	5,624	13,897
(xiii) Gross area sown (1967-68)	7,028	17,367
(xiv) Net area irrigated (1967-68)	1,044	2,580
(xv) Gross area irrigated (1967-68)	1,282	3,168
(xvi) Area irrigated after completion and full development of Fourth Plan projects	2,218	5,481
(xvii) Probable additional irrigation by future projects	3,000	7,413
(xviii) Water utilisation including reservoir losses	m.cu.m.	MAF
(a) On completion and full development of major, medium and minor projects under operation and construction at the end of 1968-69 — Surface water	21,287	17.26
Ground water	277	0.22
Total	21,564	17.48
(b) On completion and full development of Fourth Plan projects — Surface water	25,452	20.63
Ground water	371	0.30
Total	25,823	20.93

CHAPTER III

THE MAHANADI BASIN

The Mahanadi basin extends over an area of 141 thousand sq. km. and lies between east longitudes 80°30′ and 84°50′ and north latitudes 19°20′ and 23°35′ Lying in the north-east of the Deccan plateau, the basin covers large areas in the States of Madhya Pradesh and Orissa, and only small areas in Bihar and Maharashtra. The State-wise distribution of the drainage basin of the river is given below:

State	*Drainage area* (Sq. km.)
Bihar	635
Madhya Pradesh	75,136
Orissa	65,580
Maharashtra	238
Total	141,589

The Mahanadi basin is bounded on the north by the Central India hills, on the south and east by the Eastern Ghats and on the west by the Maikala range. The upper basin is a saucer-shaped depression known as the Chhatisgarh. The basin is circular in shape with a diameter of about 400 km. and an exit passage of about 160 km. length and 60 km. breadth.

There are four well-defined physical regions in the basin, namely, (i) the Northern Plateau, (ii) the Eastern Ghats, (iii) the Coastal Plain and (iv) the erosional plains of the Central Table Land. The Northern Plateau and the Eastern Ghats are well-forested hilly regions. The Coastal Plain stretching over the districts of Cuttack and Puri covers the large delta formed by the Mahanadi and is a fertile area well suited for intensive cultivation. The erosional Plains of the Central Table Land are traversed by the Mahanadi and its tributaries.

THE MAHANADI RIVER SYSTEM

3.2 The Mahanadi is one of the major rivers of the country flowing east and draining into the Bay of Bengal. Among the peninsular rivers, in water potential and flood producing capacity, it ranks second to the Godavari.

The Mahanadi rises in a pool, 6 km. from Pharsiya village near Nagri town in Raipur district of Madhya Pradesh. Initially, for about 56 km. the river flows west in a shallow valley between low, scattered hills. Near Kanker, it takes a sharp turn to the north-west. Four small tributaries join this point. 31 km. below (near Charama) the river turns north-east and continues to flow in this direction for about 113 km. On the way, at Rajim, the Pairi river joins from the right. About 13 km. above Sheorinarayan, near Khargahni, in Bilaspur district, the first great affluent, the Seonath joins from the left. Beyond this confluence, the Mahanadi takes an easterly course for a length of about 138 km. It receives the tributary Jonk from its right, near Sheorinarayan. The Hasdo joins from the left, about 17 km. further lower down near Mahuadih. It forms a braided course, about 21 km. long while receiving the Barai river on its left. Further down, it is joined by the Mand at Chandarpur from the left. Traversing a further length of 28 km., the Mahanadi leaves Madhya Pradesh and enters Orissa. The Ib river joins from the left near Bagra, now flowing into the reservoir created by the Hirakud Dam. The Hirakud Dam is located across the Mahanadi, 9.7 km. from the Sambalpur railway station. Below Sambalpur the river turns south and splits near Charpali into two channels which unite again near Dhamn. Between Hirakud and Chiplima, a distance of about 27 km., the bed is rocky with a number of rapids. About 11 km. below Dhamn, the Mahanadi enters the district of Bolangir and flowing in a southerly and south-easterly direction for a length of about 45 km. it reaches Sonepur. About 11 km. upstream of Sonepur, the Ong falls into the Mahanadi from the right. Near Sonepur, the river takes a gradual turn to the south-east, and is joined on its right by the second biggest tributary, the Tel. The Eastern Ghats start from here. At Baudh, the river again splits into two arms. Beyond Athmallik, the valley narrows down sharply and between Jamudeli and Baramul, for a distance of about 23 km., the river flows through the extremely narrow Satkosia gorge. Tikarpara village is about 6 km. below the start of this gorge. This gorge ends at Baramul and the river crosses the Eastern Ghats. The valley of the Mahanadi between Baramul and Baideswar is flat with scattered hillocks here and there. Below Baramul, the river widens again, attaining a width of about 1.6 km. At Kantilo, it turns east-north east. Near Pathpur, it flows through the Kaimundi gorge. Below this gorge, the river widens again and takes a sharp turn to the left, finally to emerge into the delta at Naraj, 11 km. west of Cuttack. Below Naraj the river splits into two channels, the Katjuri and the Birupa. The Katjuri on the right side splitting and uniting, flows in the Puri district under the name of the Devi, which finally falls into the Bay of Bengal. Sixteen km. below the off-take of the Birupa on the left, the Chitartala takes off and rejoins the parent stream after flowing for about 64 km. Another important branch, taking off on the left near Jaipur below Chitartala, is the Paiki river which rejoins the river after flowing for 32 km. Throwing off numerous branches, the Mahanadi falls into the Bay of Bengal, near False point about 16 km. below the confluence of the Chitartala and the Mahanadi.

The total length of the river from the head to its outfall into the sea is 851 km., of which 357 km. are in Madhya Pradesh and the balance of 494 km. are in Orissa.

The Seonath, the Jonk, the Hasdo, the Mand, the Ib, the Ong and the Tel are the principal tributaries and are described briefly in the following paras.

The Seonath: This river, the longest tributary of the Mahanadi, rises in the midst of undulating country with numerous small groups of hills at an elevation of about 533 m. near Kotgal and flows for about 383 km. to join the Mahanadi on its left near Kharghand. The main sub-tributaries joining the Seonath are the Kharkhara, the Tandula and the Kharun on the right bank and the Surhi, the Hanp, the Agar and the Arpa on the left bank. The Seonath drains an area of about 30,761 sq. km. which is nearly 25 per cent of the total area of the Mahanadi basin.

The Jonk: Rising in the Khariar hills, in the Kalahandi district of Orissa State at an elevation of about 762 m., the Jonk flows for a length of about 196 km. to join the Mahanadi on its right at Sheorinarayan. It drains an area of about 3,673 sq. km.

The Hasdo: Rising at an elevation of about 915 m. at a place nearly 10 km. north of Sonhat in the Sarguja district of Madhya Pradesh, the Hasdo flows for about 333 km. to join the Mahanadi on its left, near village Mahuadih. It drains an area of about 9,803 sq. km. Its principal sub-tributary is the Gej nadi.

The Mand: The Mand rises in the Sarguja district of Madhya Pradesh at an elevation of about 686 m. and flows for about 241.50 km. to its confluence with the Mahanadi on its left near Chandarpur. The river has a catchment area of about 5,237 sq. km.

The Ib: The Ib rises in the hills near Pandrapat, at an elevation of about 762 m. in the Raigarh district of Madhya Pradesh. It is about 251 km. long and falls now into the Hirakud Reservoir on its left. The total area drained by the Ib is 12,447 sq. km. For about 40 km. in the lower reaches, a part of the catchment is submerged by the Hirakud Reservoir.

The Ong: Rising at an elevation of 457 m. on a hill in the northern outskirts of the south-north running range of mountains situated to the right of the Jonk river, the Ong flows for a total length of about 204 km. to join the Mahanadi on its right about 11 km. above Sonepur. The Ong drains an area of 5,128 sq. km. lying in the interior of the main basin.

The Tel: The Tel rises in plain and open country in the Koraput district of Orissa, about 32 km. to the west of Jorigam. It flows for a total length of 296 km. to join the Mahanadi on the right bank, 1.6 km. below Sonepur. The Tel drains an area of about 22,818 sq. km.

CLIMATE

3.3 In the year, four distinct seasons occur in the basin. They are (i) the cold weather (ii) the hot weather (iii) the south-west monsoon and (iv) the post-monsoon.

In the cold weather the winds are generally light and blow either from the north or the north-east and the atmosphere is bright. During December and January, very little precipitation occurs, but during February, 25 mm. to 50 mm. of rainfall occurs in association with passing western disturbances. The precipitation is mostly confined to the northern half of the catchment, especially the hilly region. The winter is not severe, but pleasant.

The hot season commencing in March lasts till the middle of June by which time the south-west monsoon sets in. Thunderstorms are quite frequent during the hot season and some of them result in rain, the intensity of such rainfall being comparatively more in the hills than in the plains. The rains of this season are of great importance to agricultural operations in view of the soil preparation needed for the kharif crops.

The south-west monsoon setting in by the middle of June over the entire basin, continues to be active till the first week of October. During this period the basin receives over 90 per cent of its total annual rainfall. The rainfall is not continuous, but occurs in spells of varying durations and intensities. In certain areas the rains stop during the season resulting in serious drought. On the other hand, very heavy rains occurring in association with the formation of monsoon depressions in the Bay of Bengal and their movement inland in the westerly and north-westerly direction are also common. These rains cause severe floods and heavy damage. The monsoon withdraws by the first week of October.

After the withdrawal of the south-west monsoon, a few thunderstorms continue to occur. The weather clears up by November and it is cool thereafter.

Rainfall

3.4 There are at present 212 rain-gauge stations inside the Mahanadi basin up to Kaimundi. The distribution of the stations is fairly even and their number is also sufficient.

The rainfall data of all the existing raingauge stations are being observed and printed by the Rainfall Registration Authorities of the concerned States. This data appears in the annual volumes of the 'Daily Rainfall of India' compiled and issued by the India Meteorological Department. Such volumes are available since 1891. The annual rainfall varies from 1,143 mm. to 2,032 mm. over the entire basin. The rainfall in Durg district in the western extremity of the basin is of the order of 1,140 mm. which gradually increases to 1,620 mm. in the north-east in Sambalpur district and to 2,030 mm. around Balandapara in the Phulbani district. Further east the rainfall is about 1,380 mm. around Nayagarh in Puri district and increases to 1,500 mm. towards the tail end of the basin. The monthly distribution or normal annual rainfall for the basin as a whole is shown in Table 3.1.*

Table 3.1

Monthly Distribution of Normal Annual Rainfall

Month	Rainfall (mm)	Percentage of annual total
January	14.9	1.0
February	23.4	1.8
March	17.8	1.4
April	20.1	1.4
May	28.9	2.0
June	214.9	14.9
July	404.9	28.2
August	390.0	27.1
September	227.8	15.8
October	70.6	4.9
November	16.8	1.2
December	4.3	0.3
Monsoon	1,308.1	91.0
Annual	1,438.1	100.0

*Mahanadi basin—Assessment of surface water resources—CW & PC (Unpublished).

It will be seen that in the basin 91 per cent of the annual rainfall is received during the five monsoon months from June to October. The rainfall in July and August alone accounts for about 55 per cent of the annual total.

Temperature

3.5 Generally, December is the coldest month, with the mean minimum temperature ranging between 10°C and 13.7°C inland whereas near the coast, it usually does not fall below 15.8°C. The lowest temperature on record in the hilly region is 3.3°C whereas in the plains, it is 5°C and in the coastal areas it is 10.6°C. May is generally the hottest month of the year, when the mean maximum temperature ranges from 38°C over the hills to 43°C in the plains. A maximum temperature of 47.2°C has been recorded in the plains at Sambalpur and Raipur, whereas at Pendra Road, in a comparatively hilly area, the maximum temperature of only 43.9°C has been recorded. Coastal areas have not experienced temperatures above 39.4°C.

Evaporation

3.6 Evaporation is an important climatic factor bearing on agriculture and water resource development. Unfortunately in the Mahanadi basin, little or no data on evaporation is available. The India Meteorological Department has compiled the evaporation data in respect of 30 departmental and 48 agro-meteorological observatories having data for more than five years, scattered all over the country. Observations at all these stations are taken with the standard U.S. Evaporation Pan (Class A) covered with wire mesh. No departmental observatory is located in the basin. Two agro-meteorological observatories are in the basin at Cuttack and Bhubaneswar.* The monthly evaporation losses from reservoirs as assumed in the different parts of the Mahanadi basin are given in Table 3.2.

SOILS

3.7 No systematic soil survey of the Mahanadi basin has been carried out so far. The general data regarding soils of India, however, indicate that the basin consists mainly of red and yellow soils. Mixed red and black soils occur in parts of the Bolangir Patna, Sambalpur and Sundargarh districts of Orissa. Laterite soil is found in the lower part of the

*Evaporation Data (India), India Meterological Department, (April, 1970).

Table 3.2

Evaporation Losses Assumed in Selected Reservoirs

(*cm.*)

Project	Evaporation (Monthwise)												Annual
	J	F	M	A	M	J	J	A	S	O	N	D	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Madhya Pradesh													
1. Dudhwa*	Monthwise break-up not available												183
2. Mahanadi** reservoir project (Satiara)	10	10	23	33	43	18	5	5	8	10	10	8	183
Orissa													
3. Hirakud†	9	7	14	15	24	20	22	22	23	13	8	6	183

*Dudhwa Tank Project, Vol. I, Govt. of Madhya Pradesh (1963).
**Mahanadi Reservoir Project, Govt of Madhya Pradesh (1969).
†Report of the Advisory Committee on Hirakud Dam (March 1952).

basin lying in the Cuttack and Puri districts of Orissa. The coastal plains of the Mahanadi are composed of saline and deltaic soils.

The basin covers in full the district of Bolangir Patna and partly the districts of Raipur, Shahdol, Bastar, Bilaspur, Durg, Raigarh and Sarguja in Madhya Pradesh, Cuttack, Dhenkanal, Kalahandi, Koraput, Phulbani, Puri, Sambalpur and Sundargarh in Orissa. Small portions of Ranchi district in Bihar and Chanda district in Maharashtra also fall in the basin. The principal soil types found in the various districts lying in the basin are as under*:

Madhya Pradesh

Bastar and Durg: The best soils of the districts are 'Kankar' and 'Dorsa I', both black and deep. 'Dorsa II' and 'Matasi' also occur. 'Kankar' is a clayey soil containing about 43.4 to 56.5 per cent clay and 16 to 20 per cent sand. 'Dorsa I and II' contain 37 to 44 per cent clay; 25 to 29 per cent of silt and nearly 24 to 31 per cent of sand. 'Dorsa II' is

*Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

inferior to 'Dorsa I'. 'Matasi' is a sandy loam containing about 40 to 41 per cent sand and 18 to 29 per cent clay. Of the total area, 36 per cent is covered by 'Kankar', 46 per cent by 'Dorsa' and 13 per cent by 'Matasi'.

Bilaspur: The black soils prevail mainly in Mugeli tehsil where they cover 59 per cent of the area and the rest is entirely 'Dorsa'. In Bilaspur tehsil, 'Dorsa' is nearly 71 per cent. Next come 'Matasi' and 'Dorsa II'

Raigarh and Raipur: The main soils are 'Kankar', 'Dorsa', 'Matasi' and 'Bhata'. 'Kankar' is black in colour but reddish and lighter varieties are also found. 'Dorsa' is a mixture of 'Kankar' and 'Matasi'. 'Matasi' is a yellow soil with many varieties. 'Bhata' is the poorest soil of the districts. It is red and full of stones and has no consistency. 'Pal kachhar' and 'Palpar kachhar' are silts found on the banks of rivers. 'Pal kachhar' is a garden soil and 'Palpar kachhar' is a sandy soil.

Sarguja: A mixture of red and yellow soils occurs.

Orissa

Bolangir Patna: The cultivated soils are loamy in texture, generally deficient in nitrogen and their nutrient contents are low.

Cuttack: The soils vary from clays to clay loams, the latter being found to a larger extent.

Dhenkanal: Black soil or regur and old alluvium occur. In general, they have a higher content of clay.

Ganjam: Lateritic soils are found.

Kalahandi: Mixed red and black soils occur.

Koraput: The soils are highly sandy (fine & coarse). The water-holding capacity is low but the moisture equivalent appears to be too high in relation to the sandy nature of soil.

Phulbani: Laterite, red and brown forest soils occur.

Puri: The soils are of sandy nature and are poor in plant nutrients.

Sambalpur: The cultivated soils are loamy in texture and nutrient contents are low.

Sundargarh: Red soils occur which are generally open in texture and well drained.

LAND USE AND AGRICULTURAL PRACTICES

3.8 State-wise land use details in the basin, as in 1967-68, the latest year for which the statistics are available, are given in Table 3.3.

Except in the Chhatisgarh and coastal plains, the basin has an extensive area under forests. This is mainly due to the hilly nature of the terrain and the lack of transport facilities. The Chhatisgarh and coastal plains, with high incidence of rainfall are predominantly rice growing areas. The land

Table 3.3

Land Use Details—Mahanadi Basin

(Thousand hectares)

Item	Name of the State				Total
	Bihar	Madhya Pradesh	Mahara-shtra	Orissa*	
1	2	3	4	5	6
Gross area	63	7,514	24	6,558	14,159
Reporting area	63	7,474	24	6,410	13,971
Area under forest	15	2,817	15	1,653	4,500
Area not available for cultivation	6	579	2	880	1,477
Culturable area	42	4,078	7	3,867	7,994
Uncultivated culturable area	17	1,005	—	1,348	2,370
Net area sown	25	3,073	7	2,519	5,624
Area sown more than once	2	663	—	739	1,404
Total cropped area	27	3,736	7	3,258	7,028
Net area irrigated	0.5	380.1	1.1	662.3	1,044.0
Gross area irrigated	0.7	382.4	1.1	898.2	1,282.4
Percentage of net area irrigated to culturable area	1.19	9.32	15.7	17.13	13.06
Percentage of net area sown to culturable area	59.52	75.36	100.00	65.14	70.35
Percentage of net area irrigated to net area sown	2.00	12.37	15.71	26.29	18.56

*Relates to the year 1964-65.

use details indicate that the resources in the basin have not been put to intensive use.

3.9 The general cropping pattern, State-wise is given below:

Bihar

Of the total irrigated area of nearly 700 hectares, about 42.9 per cent is under paddy. Other crops grown in the irrigated area are sugarcane, maize, barley, gram, tur, other pulses, condiments, spices, fruits, vegetables, rape, mustard, linseed, cotton, tobacco and fodder crops.

Food crops represent almost 100.00 per cent of the irrigated cropped area.

Madhya Pradesh

Of the gross irrigated area of 382,400 hectares, about 94.6 per cent is under paddy. Other crops grown in the irrigated area are wheat, sugarcane, barley, gram, fruits, vegetables, groundnut, rape, mustard, linseed, cotton, tobacco and fodder crops.

Food crops represent about 99.97 per cent of the irrigated cropped area; the balance of 0.03 per cent being under non-food crops.

Maharashtra

Of the gross irrigated area of 1,100 hectares, about 90.9 per cent is under paddy. Other crops grown in the irrigated area are sugarcane, gram, condiments, spices, cotton, tobacco and fodder crops.

Food crops cover almost 100 per cent of the irrigated cropped area.

Orissa

The latest crop-wise statistics of the irrigated area are available only for the year 1956-57, which indicate that out of 497,900 hectares, about 83.75 per cent is under paddy, 0.45 per cent is under wheat and 2.30 per cent under sugarcane. Other crops grown in the irrigated area are jowar, bajra, ragi, gram and other pulses.

Food crops represent about 97.12 per cent of the irrigated cropped area; the balance of 2.88 per cent being under non-food crops.

Summing up, of the total irrigated area in the basin, 88.44 per cent is under paddy, 0.45 per cent under wheat, 1.7 per cent under sugarcane and the rest under miscellaneous crops.

There are mainly two crop seasons, the kharif and the rabi. The kharif crop is mainly rice. Except for small areas which are irrigated, this crop is mostly dependent on rain. Three types of paddy, namely, the autumn, the winter and the summer paddy, are grown in the basin. Autumn paddy is prevalent mostly in the upper reaches of the basin lying in Madhya Pradesh. The crop is sown between the 10th June and the 15th August and is harvested from the 15th September to the 15th December. In Orissa State, Sarad or winter paddy is the most important crop and the major portion of the area is covered by it. Sarad paddy is also sub-divided into two varieties, namely, the 'Laghu' and 'Guri' (early and late), according to the amount of water required. Winter paddy is sown between June and August and is harvested in December-January.

Summer paddy is cultivated only in a few places in the delta. It is raised on low ground, locally called 'Pats', where enough moisture for the crop exists long after the monsoon. Summer paddy is sown or transplanted sometime in December or January and is harvested in May-June. Other kharif crops grown in the basin are jowar, bajra, maize, ragi, groundnut and fodder crops.

Wheat is sown in October or November and harvested between 15th February and April. Other rabi crops, barley, gram, bajra, ragi, linseed, rape and mustard are generally sown in October and harvested in February or March.

Fibre crops like cotton are sown both in Madhya Pradesh and Orissa during 20th May-July and harvested during 15th October-February. In Orissa, another variety of cotton is sown in November-December and harvested in May.

REGIONAL ECONOMY

Population

3.10 On the basis of the 1971 Census,* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 17.80 millions. The State-wise distribution is given in Table 3.4.

Table 3.4

Population in the Mahanadi Basin—State-wise

State	Population (Million)
1	2
Orissa	9.21
Madhya Pradesh	8.48
Maharashtra	0.02
Bihar	0.09
Total	17.80

There are only three main cities in the basin which have a population of more than one lakh each. They are Raipur and Durg in Madhya Pradesh and Cuttack in Orissa. The average density of population in the basin is 126 persons per sq. km. It varies from region to region within the basin. The Coastal Plain is the most densely populated while the hilly areas have a relatively low density. The most densely populated district of

*Census Paper I of 1971 (Supplement), Registrar General, India.

Cuttack has 349 people per sq. km. while the hilly district of Bastar with 39 persons per sq. km. is at the other extreme. The population in parts of the basin lying in the Northern Plateau and hilly areas has a relatively large component of scheduled tribes. The tribal people form a distinct group and have lived for centuries in forests isolated from the main stream of social and economic life. They are economically backward and depend for livelihood mainly on forest produce and shifting cultivation. They have little industrial activity even on a cottage scale. They are strongly attached to their own culture and traditions, which has made them less responsive to changes taking place around.

Ninety per cent of the population in the basin live in rural areas and the balance of ten per cent in cities and towns. The working force constitutes about 35 per cent of the population. Nearly 43 per cent of it is engaged as cultivators, 31 per cent as agricultural labourers and the balance 26 per cent employed in mining, manufacturing and tertiary activities.

Forests and Agriculture

3.11 A large part of the basin consists of forests. Forest and agriculture are the mainstay of the people. The area annually cropped is about seven million hectares. Agriculture is generally rain-fed with relatively low yields, except for about 1.28 million hectares of irrigated area under paddy.

Power

3.12 The Central Water and Power Commission has assessed the total hydro-potential of the Mahanadi basin at 947.5 MW. At present, the development of hydro-power has not taken place on a large scale. The installed capacities of existing Hirakud hydroelectric and Korba thermal generating plants as in 1970 were 270 MW and 300 MW respectively.

Mineral Wealth

3.13 The basin has a rich variety of mineral wealth spread over vast areas. The principle minerals found are*:

Iron Ore: In Bastar, Durg, Sundargarh, Cuttack and Sambalpur districts. The deposits in Bastar district alone are estimated to be in excess of 4,300 million tonnes. The quality of the ore is good and the iron content, in some mines, is as high as 68 per cent.

*Techno-Economic Survey of Orissa and Madhya Pradesh, NCAER

Coal: In Raigarh, Sarguja and Bilaspur districts. Practically all the coal is of the non-coking type and therefore not suitable for metallurgical purposes. New coal fields such as Korba have been opened up recently to feed the large thermal stations nearby.

Manganese: In Sundargarh district. Scattered deposits also occur in Bilaspur, Bastar and Bolangir Patna districts.

Bauxite: In Sarguja, Bilaspur, Bastar and Raigarh districts. It also occurs at great heights on the top and slopes of mountains in Kalahandi and Sambalpur districts. The quality of the ore is good and has 28 to 60 per cent of aluminimum oxide.

Limestone: In Durg, Raigarh, Bilaspur, Bastar, Sundargarh and Sambalpur districts. The limestone has a reputation for quality for use in the chemical and paper industries. The best known occurrences of dolomite in India are in Sundargarh district. The Sambalpur dolomites are siliceous.

China Clays: In districts of Durg, Bilaspur, Sambalpur and Sundargarh. These clays are suitable for the ceramic and paper industries.

Fire Clays: Mainly in Durg, Bilaspur and Sambalpur districts and to a lesser extent in Dhenkanal and Puri districts. The Sambalpur clay is considered suitable for the manufacture of refractories.

Copper: In Bastar district.

Salt: In the coastal districts of Cuttack and Puri, but the production costs are high and the quality not satisfactory for industrial use.

Other minerals like lead, talc and soapstone, mica, graphite, gold, diamonds, ochres, etc. also occur in different parts of the basin, but the prospects of developing them depend upon further geological investigations.

Industries

3.14 Rich in forest, agricultural and mineral resources, the industrial potential of the Mahanadi basin is much better than that of many other parts of India. There is also a large hydro-power potential awaiting development. Present developments are only modest and large potential remains to be developed.

Only a small part of the enormous forest wealth is at present being exploited, as timber and for the manufacturing paper and other products.

Among agricultural based industries, mention may be made of processing industries like rice-milling, manufacture of sugar and of textiles, extraction of oil from groundnut and other oilseeds, etc. Mining of coal, iron, manganese, etc. are the other important activities in mineral-rich districts.

Iron and steel are manufactured at Bhilai. Other small engineering industries are spread all over the basin.

Cement is manufactured at Sundargarh. Another important industry is that of aluminium at Hirakud.

Communications

3.15 There are two main trunk lines, the Madras-Calcutta and Bombay-Calcutta running through the basin. The first line crosses a little to the north of the delta and the second for about 280 km. The Vijayanagaram-Raipur railway line runs in the south-west part of the basin for about 260 km. There are some branch lines partly or wholly in the basin viz. Nergemdi-Talcher, the Jharsuguda-Sambalpur, the Raipur-Dhamtari, the Raipur-Rajim, the Bilaspur-Katni, the Khurda Road-Peni and the Champa-Korba. These lines serve the important industrial and coal belts.

Three important National Highways pass through the basin, namely, (i) National Highway No. 5 connecting Madras with Calcutta, (ii) National Highway No. 6 connecting Calcutta with Nagpur and (iii) National Highway No. 42 connecting Cuttack to Sambalpur. In addition, the basin is covered with a network of State highways and major district and village roads.

The Mahanadi is navigable during the rainy season, even in the upper reaches.

In its lower reaches enough draft is available for navigation by country boats. During the dry season, as the course of the river is broken at several places by rock out-crops, navigation becomes difficult. Boats can, however, ascend from the Hirakud Reservoir to Arang in Raipur district. The reach of 179 km. from Dholpur to Cuttack in the lower course of the river has been considerably improved for navigation as regular flows are now available from the Hirakud Project. Recent investigations have shown that navigation in this reach would be possible by shallow power draft.

It would be seen that a major part of the basin is not well served with communications.

Dependence on Rainfall and Water Resources

3.16 The economy of the basin largely depends on agriculture. Due to the uneven incidence of the rainfall, the area provides a low level of subsistence, except in small parts of the basin where facilities for irrigation exist. There is a keen demand for the development of water resources.

WATER RESOURCES

Surface Water

3.17 The water potential of the Mahanadi river system has been assessed by different authorities at different times. The first assessment was made by the First Irrigation Commission. As the daily discharge records of the river flow were then available only for one year, the Commission had to place reliance on the rainfall-runoff relationship based on observed discharge data of other similar catchments. The Commission was careful to caution that the estimates so arrived must be regarded as mere rough approximations. The total annual surface flow of the system was assessed at 148,947 m. cu. m.

In 1949 when a basin-wise assessment of the water resources of the country was made on the basis of the Khosla's Formula, the annual runoff of the system was estimated at 92,819* m. cu. m.

In 1960, the Central Water & Power Commission assessed the total annual runoff of the Mahanadi river system as 70,678† m. cu. m. on the basis of Strange's co-efficient for average catchments.

Prior to 1946, no planned or systematic observations of discharge on the Mahanadi and its tributaries were made. Some observations made on the main river and some of its tributaries were ad hoc. The Central Waterways, Irrigation & Navigation Commission started observing gauges and discharges in 1946 at Hirakud, Tikerpara and Kaimundi on the main river. On some of the tributaries like the Hasdo, the Ib and the Tel and at other sites on the main river, namely, Saradih and Sonepur, the State Government have been conducting discharge observations. A few years ago the sites at Hirakud, Tikerpara and Kaimundi also have been transferred to the State Government.

The discharge observations by the CWINC and the Central Water & Power Commission have been conducted mostly with current meters. In the floods when the current remains steady, current meters have been used for measuring the surface velocity and a correction factor, varying from 0.80 to 0.89 has been used to derive the mean velocity. When boats could not be held steady in high velocity floods, surface floats were used and the correction factor applied to get at the mean velocity. In dry months when the flows are low, the river is dammed with sand bags with a notched opening and the discharge passing through the notch is calculated by adding 10 per cent extra flows to account for the leakage through the bags. Current meters are used at 0.6 depth in summer and cold

*An appraisal of water resources by Dr. A. N. Khosla. UNESCO.

†Report of the technological possibilities of irrigation projects in India, CW&PC (Unpublished)

weather and floats in high floods. The method of observation employed by the States is not known. The discharge observations at Sambalpur have been discontinued after the completion of the Hirakud dam. The gauge and discharge sites for which reasonable correct and consistent data is available are listed in Table 3.5.

Table 3.5*

Gauge and Discharge Sites

Sl. No.	Name of gauge and discharge sites	Name of river or tributary	Year of start of observations	Remarks
1	2	3	4	5
1.	Bango	Hasdo	1957-58	
2.	Saradih	Mahanadi	-do-	
3.	Deogaon	Ib	-do-	
4.	Sambalpur	Mahanadi	1950-51	Observations discontinued after 1961-62
5.	Sonepur (Tel)	Tel	1957-58	
6.	Sonepur (Main)	Mahanadi	-do-	
7.	Baramul	-do-	1950-51	
8.	Kaimundi	-do-	-do-	

*Mahanadi basin—assessment of surface water resources—CW&PC (Unpublished).

The main river in the upper reaches and many important tributaries are not being at present gauged. The CW&PC, after studying the distribution of the existing gauging sites, has suggested 18 new gauge and discharge sites listed in Table 3.6.*

On the establishment of these new sites, the gauge and discharge sites will be evenly spread.

The CW&PC has recently conducted studies to assess the water resources of the Mahanadi river system. The precipitation data in the catchment which is available for a long period and the stream-flow data available for a short period has been used to arrive at a rainfall-runoff relationship.

Dependable runoff data are available from 1950–51 in respect of three gauge-discharge sites on the main stream viz. (i) Sambalpur (ii) Baramul and (iii) Kaimundi. Similar data is available for Saradih and Sonepur

*Mahanadi basin—assessment of surface water resources, CW&PC (Unpublished).

Table 3.6

New Gauge-Discharge Sites Proposed by the Central Water & Power Commission

Sl. No.	Name of rivers	Location of Gauge-Discharge Sites
1	2	3
1.	Mahanadi	Near Rajim in Raipur district.
2.	-do-	Near Sheorinarayan in Bilaspur district.
3.	Seonath	Near Durg City.
4.	-do-	Near Tilda in Durg district.
5.	-do-	About 10 km. upstream of its confluence with the Mahanadi.
6.	Kharun	About 10 km. upstream of its confluence with the Seonath.
7.	Pairi	About 6 km. upstream of its confluence with the Mahanadi.
8.	Jonk	About 6 km. upstream of its confluence with the Mahanadi.
9.	Hasdo	Near Champa in Bilaspur district.
10.	Mand	Near Kotra in Raigarh district.
11.	Ib	Near Loakara in Raigarh district.
12.	Local stream	Near Rampur in Bolangir-Patna district.
13.	Ong	About 25 km. upstream of Agalpur in Sambalpur district.
14.	-do-	About 8 km. upstream of its confluence with the Mahanadi.
15.	Tel	Near Titlagarh in Kalahandi district.
16.	-do-	About 10 km. upstream of Ghantapara in Bolangir-Patna district.
17.	Kodago	About 5 km. upstream of its confluence with the Tel river.
18.	Local stream	Near Kantilo in Puri district.

sites, on the main river and discharge sites on the Ib, the Hasdo and the Tel from 1958–59. The weighted catchment rainfalls for 35 years (1930–31 to 1964–65) for all the gauging sites have been computed and the run-off series, from 1930–31 to 1964-65, constructed from the rainfall-runoff curves for all sites. The runoff series for the gauge-discharge sites on the main river are shown in Appendix 3.1.

The annual runoffs on 50, 75 and 90 per cent dependabilities for all the gauge and discharge sites on the main river are given in Table 3.7.

Table 3.7

Annual Runoffs of the Mahanadi System at Various Sites

Sl. No.	River	Site	Area Sq.km.	Stream flow (m.cu.m.) available for % time or % dependability		
				90%	75%	50%
1.	Mahanadi	Saradih	61,626	21,802	26,641	32,018
2.	-do-	Sambalpur	84,245	30,891	38,163	46,243
3.	-do-	Sonepur	116,961	40,712	48,939	58,081
4.	-do-	Baramul	125,918	43,252	53,425	64,727
5.	-do-	Kaimundi	131,696	42,170	53,763	66,644

Ground Water

3.18 Systematic investigations and studies of the ground water potential of the Mahanadi basin have not been made so far. Only in some parts of the basin like Raipur, Bastar, Puri and Cuttack districts, have some investigations and studies been done recently. The predominant rock groups found in the basin are:* (i) Archeans covering parts of Raipur, Bilaspur, Raigarh, Sarguja, Ganjam, Koraput, Dhenkanal, Phulbani, Bastar, Puri and Cuttack districts; (ii) Cuddapahs covering parts of Durg, Raipur, Bilaspur, Raigarh, Sundargarh, Bolangir Patna, Kalahandi and other districts; (iii) Gondwanas partly covering Raigarh, Bilaspur, Sarguja, Sambalpur, Ganjam, Puri and Cuttack districts; (iv) Shallow alluvial beds in the district of Raipur and (v) Coastal alluvial tracts in the Mahanadi delta area.

Amongst the Archeans, granites and gneisses are by far the most important crystalline rocks in which ground water occurs, mostly in the weathered mantle and very insignificantly along the rift and grain and horizontal joints. The thicker the weathered mantle and the coarser the underlying boulder horizon of sheared gneisses, the richer will be the ground water. Phyllites and schists contain some ground water along their plains of schistosity, as also the slates; but granulites and quartzites are almost devoid of water. Marbles, along with calciphyres, contain some water depending upon the limitation in thickness of the weathered mantle and the possibility of solution channels in them. In the rock groups, equivalent to the Dharwars of the Bailadila range in Bastar district, development of ground water in any considerable quantity even by open wells is

*Groundwater Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

not possible, but the springs that issue from steep slopes form good local sources of ground water that can be utilised for both domestic and industrial purposes.

Amidst the Cuddapahs in Chhatisgarh the weathered mantle of hard and compact Chandarpur sandstones has ground water only in the zone of weathering. The bottom-most zone with pebbly and gravel material is the most productive horizon. These zones need careful exploration and assessment as with inadequate planning or improper development, they may get depleted in a very short time. The limestone belt of Nandini in Drug district has been reported to have caverns of an anastomosing pattern. It is likely that these caverns are filled with water. Wells piercing the limestones have recorded higher yields than wells in the shales.

The lower Gondwanas in Sarguja, Bilaspur and Raigarh districts have been explored for their coal resources. The exploration has been hitherto confined to the individual coal-field areas with no data whatsoever on the intervening tracts. In respect of coal-fields also, authentic data is limited mostly to daily static water levels and of internal flooding of the coal mines, with practically no factual data on the ground water potential of the entire coal-field or parts of it or even of individual bore or open wells. Ground water occurs in them under both water table and confined conditions in the granular zones of sand-stones, grits and occasionally in conglomeratic zones. The thickness of the confined granular zones in depth and their porosities needs to be systematically explored to assess the ground water possibilities. The upper Gondwana tract covering part of Sarguja district is another possible potential belt which remains to be explored.

The shallow alluvial pocket around Dhamtari in Raipur district has some ground water possibilities. In this area the alluvium is limited to 25 m. in depth. The alluvial deposits comprise alternating beds of sands and clays with a soil cap and lateritic cover.

In the coastal alluvial plains of Cuttack and Puri districts, the ground water has generally south-easterly slope. The near-surface aquifer zones have generally fresh water suitable for irrigation. Fresh water-bearing formations also occur below depths of 135 to 225 m. The aquifer zones within 152 m. of the land surface are saline and the better quality of ground water is found at greater depths. In Cuttack district, in Panikoili-Bada-Govindpur sector of Jajpur sub-division, ground water development on a large scale appears feasible. In the Kendrapara sub-division fresh water-bearing zones occur below a depth of 150 m. under artesian/sub-artesian conditions, the shallower zones having saline water. Systematic exploration is necessary to determine the extent of feasible development. In the Jagatsinghpur sub-division 40 to 60 m. thick aquifers under artesian conditions are available within a depth range of 180 to 210 m.

In Puri district and in Pipli-Nimapara-Gop area fresh-water-bearing zones of 10 to 50 m. thickness within a depth of 35 to 85 m. have been located. In the upland region of the district covered by Khondalites-Charnokites and Atgarh sand-stones capped by laterites at places, ground water suitable for all uses has been located at average depths of 6 to 8 m.

In general, the Upper Tertiary sandstones and Quarternary alluvium in the coastal districts have productive aquifers. The coastal regions underlain by alluvium are suitable for ground water development on a large scale. However, the presence of brackish or saline waters at shallow depths in these tracts often poses a serious problem. Deeper aquifers have to be exploited cautiously to prevent any saline encroachments.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the Mahanadi basin for a scientific quantitative assessment of the ground water resources. A correct assessment of the ground water resources which will help in framing a rational plan of development for various needs, can be made only after full investigations have been completed.

EXISTING DEVELOPMENT

3.19 Our predecessor Commission had made the following observations on the irrigation development in the Mahanadi basin:

"The most promising field for the extension of irrigation by Government works may be said to comprise the rice tracts of Chhatisgarh districts."

"There is, however, reason to believe that small canals taking off from streams and rivers will afford a much cheaper form of protection for such areas as they can be made to command than any other form of irrigation works."

"Moreover, from the few projects which have been laid before us for small canals from the Mahanadi, it would appear that the cost per acre protected will be less than one-third that of works depending entirely upon storage. We think, therefore, that works for this class should be the first to receive our attention, storage works being provided for them hereafter when found necessary."

Regarding the scope for further extension of irrigation in the Mahanadi delta, the Commission had made the following observations:

"There is no urgent need for further famine protection to the plains of Orissa; and indeed that there are few parts of India more secure, or in which the value of irrigation bears so small a proportion to its cost. We think that good might be effected by multiplying the number of irrigation sluices in the great flood embankments that line the rivers, in order that the land protected from destructive inundation may not be deprived of the beneficial inundation. Should it be considered necessary still further to protect Orissa, the volume of its rivers has not been exhausted, and irrigation might be carried into Puri and extended in Balasore for probably a not unreasonable sum. But we do not recommend these extensions in the face of the far more important projects on which capital may be better expended."

The Commission had not recommended any specific projects by name for construction in the basin.

As a result of the above recommendations, the Mahanadi Canal System benefiting the rice growing districts in Chhatisgarh came into existence.

The salient features of projects completed in the Mahanadi basin in the pre-Plan and Plan periods are shown in Appendix 3.2. Details of the schemes, which are under construction are shown in Appendix 3.3. The major projects in the basin in Madhya Pradesh and Orissa are briefly described below:

Madhya Pradesh

The Mahanadi Canal System constructed in the upper reaches of the river in 1923 is the only pre-Plan major scheme. It consists of a 405 m. long weir at Rudri near Dhamtari in Raipur district with 1.2 m. high falling shutters on the crest and a canal system on its left bank. The supplies at the weir site are supplemented by the waters of the Muramsilli Reservoir, constructed in 1923 across the Silari nadi, a tributary of the Mahanadi joining it a little upstream of the weir. The Muramsilli dam is an earth dam with a concrete core, 2,591 m. long and 25.5 m. high. The reservoir has a gross storage of 165 m. cu. m. of which 162 m. cu. m. is the live capacity. The Mahanadi Canal System together with the Muramsilli Reservoir cost Rs. 15.650 million and irrigates an area of 35,000 hectares.

Seven medium/minor schemes were also constructed in the pre-Plan period.

The Dudhwa Reservoir Project taken up for construction in the First Plan period on the Mahanadi is likely to be completed in 1973. Costing Rs. 33.4 million, the project will supplement the supplies of the Mahanadi Canal System, and irrigate an additional area of 56,665 hectares. The Mahanadi Canal System has been remodelled at a cost of Rs. 28.3 million to distribute the bigger discharges from the Dudhwa reservoir.

In 1961 the Hasdeo Project (Phase I) was taken up for construction. The project is a major one and consists of a masonry barrage 283.77 m. long across the river Hasdeo at village Dari in Bilaspur district. It has a 3.55 km. long canal taking off on the left bank, to supply water to Korba Thermal Power Station for cooling. The estimated cost of the project is Rs. 98.6 million and is likely to be completed during the Fourth Plan.

The following medium projects have been completed in the various Plan periods.

Table 3.8

Details of Medium Projects Completed in Madhya Pradesh

Sl. No.	Name of the project	Estimated cost (Rs. million)	Ultimate irrigation (hectares)
1	2	3	4
1.	Saroda	15.673	7,350
2.	Gondli	3.995	3,080
3.	Kedar Nala	8.472	4,650
4.	Development of Maniari	3.705	9,710
5.	Keswa Nalla	5.992	3,848

Orissa

The Mahanadi Delta Irrigation Scheme is the most important project of the pre-Plan period. It comprises two weirs, one across the Mahanadi and the other across the Birupa, with canal systems. The Jobra Weir across the Mahanadi in Cuttack district, 1,935 m. long, 4 m. high was completed in 1877 at a cost of Rs. 1.01 million. The canal system irrigates lands between the Katjuri and the Mahanadi. The weir across the Birupa, at Chaudwar, 604 m. long, 1.5 m. high was completed in 1869 at a cost of Rs. 0.226 million. Three canals take off from the weir to irrigate the delta area. Total irrigable area under the Mahanadi Delta Irrigation Scheme is 189 thousand hectares, of which 83 thousand hectares are being irrigated.

The scheme for the unified development of the Mahanadi river in Orissa consists of three dams on the main river viz. Hirakud, Tikerpara (Baramul) and Naraj. It has been planned to be executed in stages, so that each stage may be an independent project and yet become an integral part of the unified plan.

In 1948, the Hirakud Dam, which is the upper-most of the three, was taken up for construction. Its features are (i) a dam across the river at Hirakud, near Sambalpur; (ii) canals from the dam to irrigate the upper areas in Sambalpur district and (iii) power generation at two sites, one at the dam and the other about 27.4 km. downstream. The main dam is 4,801 m. long with about 20,661 m. of dykes on either side. It is an earth dam with spillways and dykes to close the gaps between hills on both flanks. The total storage of the reservoir is 8,100 m. cu. m., of which the live storage is 5,822 m. cu. m. The main canal system including branches is 147 km. long. An area of 2,53,747 hectares is expected to be irrigated annually on full development. The power development had been planned in two stages. Stage I, 2 units of 37,500 KW each and 2 units of 24,000 KW each; Stage II—3 units each of 24,000 KW and 2 units each of 37,500 KW. The total cost of the project is Rs. 678.1 million for Stage I and Rs. 149.5 million for Stage II. The dam was completed in the year 1957 and full power potential was achieved in 1963–64.

In 1955, the Mahanadi Delta Irrigation Project (Mundali Weir) was taken up for construction. The project comprises a weir across the river Mahanadi at Mundali, 4.8 km. upstream of Naraj in the Cuttack district and a canal system. The weir will be 1,353 m. and the main canal 386.34 km. long. The estimated cost of the project is Rs. 686.81 million. It will extend irrigation benefits to an area of 680,710 hectares and is likely to be completed during the Fourth Five Year Plan.

Four medium projects under construction are expected to be completed during the Fourth Five Year Plan. Their details are given in Table 3.9.

Table 3.9

Medium Projects Under Construction in Orissa

Sl. No.	Name of Project	Cost (Rs. million)	Ultimate irrigation (hectares)
1	2	3	4
1.	Budhabudhiani	14.865	3,720
2.	Salki	16.600	21,890
3.	Uttei	9.020	11,830
4.	Dahuka	5.605	4,650

A number of minor schemes consisting of tanks, dug wells and tube-wells have also brought a sizeable area under irrigation. In many villages, there are more than one tank which irrigate adjoining agricultural lands. Details of the area irrigated from various sources in the year 1967–68, State-wise, in Mahanadi basin are given in Table 3.10
By the end of 1968–69, the area under minor schemes increased by about 21,660 hectares.

Most of the important information relating to water resources development in the basin is either non-existent or has not been compiled and

Table 3.10

Source-wise Irrigation—Mahanadi Basin

(Thousand hectares)

Source of irrigation	Area irrigated				
	Bihar	Madhya Pradesh	Maharashtra	Orissa*	Total
1	2	3	4	5	6
Canals	0.2	308.5	0.2	316.2	625.1
Tanks	Neg.	44.8	0.9	131.6	177.3
Wells	0.2	9.5	—	14.9	24.6
Other sources	0.1	17.3	Neg.	199.6	217.0
Total	0.5	380.1	1.1	662.3	1,044.0

*Relates to the year 1964-65.

analysed. Working statistics of canals and reservoirs have neither been compiled nor published. As per the data supplied by the States of Madhya Pradesh and Orissa, the average annual diversion on full development of major and medium projects in operation and under construction as in 1968–69 is likely to be of the order of 13,926 m. cu. m.

No information about the large number of minor schemes that is tanks, wells and other diversion works is available. No observation seems to have been made or records maintained of the quantity of water used through them. Based on approximate duties and the rough figures of the area irrigated, attempts have been made to estimate the quantities of water used from the minor works. The approximate diversion through these works in 1968–69 may have been of the order of 4,700 m. cu. m.

Reservoir Losses

On the basis of assumptions detailed in para 1.28 the reservoir losses from the various scheme in the basin will be as under:

(i) Major and medium schemes	1,196 m. cu. m.
(ii) Minor schemes (tanks)	1,738 ,,
Total	2,934 ,,

Thus, on the full development the major, medium and minor projects in operation and under construction in the basin as in 1968–69 would use about 21,564 m. cu. m. (including reservoir losses). Of this 21,287 m. cu. m. would come from the surface waters and 277 m. cu. m. from the ground waters.

The major and medium projects in operation and under construction in the basin would on full development irrigate 1.48 million hectares. The up-to-date data in respect of minor schemes is not available. However, as the area irrigated by the minor schemes in 1968–69 was of the order of 0.44 million hectares, the total area irrigated in the basin from all sources would be of the order of 1.92 million hectares.

There are quite a few industries located in the basin, which are utilising the Mahanadi water. Of these, the Bhilai Steel Plant, the Aluminium Plant at Hirakud, Paper and other factories near Chaudwar (Cuttack) etc. deserve mention. Data on the present industrial water needs is not available. In future, it is certain that such demands would grow.

The problem of water pollution in the Mahanadi arising from the discharge of industrial wastes has not assumed serious proportion so far, However, with the rapid expansion of industries in future, this problem may get aggravated and should be kept in mind in future planning.

FUTURE DEVELOPMENT

3.20 Six major and medium projects are proposed to be taken up for construction in the basin in the Fourth Five Year Plan. Some details of these projects are given in Appendix 3.4. These projects would irrigate a total area of 0.149 million hectares on full development. Project reports for many of these projects are not yet ready. An approximate estimate of the quantity of water likely to be diverted through these projects has, on the basis of rough duties, been put at roughly 2,060 m. cu. m. including the reservoir losses.

The utilisation by minor schemes is expected to increase by about 2,199 m. cu. m. by the end of Fourth Plan. Thus, the additional utilisation by major, medium and minor projects at the end of the Fourth Plan would be of the order of 4,259 m. cu. m. irrigating about 0.299 million hectares. On the completion and full development of Fourth Plan projects, about 25,823 m. cu. m. of the waters (25,452 m. cu. m. of surface and 371 m. cu. m. of ground waters) would have been used for irrigating a total area of 2.218 million hectares.

Among the Fourth Plan projects, special mention needs to be made of the Upper Mahanadi Project (Satiara), which deserves priority from various considerations. The water requirements of Bhilai Steel Plant were originally being met by the Tandula and Gondli reservoirs. The capacity of the Steel Plant was increased from 1.01 million tonnes to 2.54 million tonnes and the Kharkhara Reservoir was constructed to meet the additional water requirements. Both the Gondli and Kharkhara reservoirs were originally planned as irrigation projects. Subsequently, they have practically been reserved to supply water to the Bhilai Steel Plant. During lean years (like 1965–66–67) when the storage in these two reservoirs proved insufficient, water to the Steel Plant had to be supplied from the Tandula Reservoir at the cost of irrigation. There are proposals for increasing the capacity of the Steel Plant from the present 2.54 million tonnes to 3.25 million tonnes and finally to 5.08 million tonnes.

To meet the additional water requirements of the enlarged plant, a reservoir across the Mahanadi has become necessary and the Madhya Pradesh State Government has proposed to construct one across the river about 5 km. upstream of the existing Rudri Weir. The project envisages the construction of a composite dam 1,830 m. long, of which 570 m. will be masonry and the remaining earthen. It will be 30 m. high and will have a capacity to store 766 m. cu. m. The project will also provide irrigation to 80,940 hectares in the kharif and 40,470 hectares in the rabi seasons under the Mahanadi and Tandula Canal Systems. For making up water deficiencies existing at present in the Mahanadi and Tandula Canal Systems, particularly for rabi irrigation and for meeting the water requirements of the Bhilai Steel Plant, it is of the utmost importance that the Upper Mahanadi Project be taken up immediately.

The Madhya Pradesh Government* has proposed 11 multipurpose and 38 major and medium irrigation schemes for future development in the basin. These projects, on completion, are expected to provide irrigation facilities to 0.86 million hectares.

The Orissa Government† have indicated five future projects of which three schemes, on completion, would provide irrigation facilities to 2.58 million hectares. Information for the other two schemes is not available.

Some details of the new projects proposed by the two States are given in Appendix 3.5. All these projects have not been investigated and project reports for none of them is available. It is quite possible that some of them may not prove feasible. The balance of 28,311 m. cu. m. available at 75 per cent dependability disclose very large water resources still available for utilisation by future projects. Considerable extension of irrigation in the basin, probably three million hectares, may be possible.

Of the new projects, special mention may be made of Hasdo and Jonk Multipurpose Projects in Madhya Pradesh and Tikerpara-Gania Project in Orissa. Brief particulars of these projects are as follows:

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*Irrigation and Power Potential of Madhya Pradesh Rivers, Government of Madhya Pradesh (PWD)—1963.

†Orissa's Decade of Destiny (1963-73)—A plan for the integrated development of the river basins of Orissa 1963 by Dr. A. N. Khosla.

The Hasdo Multipurpose Project in the Bilaspur district provides for the construction of a 457 m. long straight gravity type dam, with an earth dyke of 1,524 m. length on the right, across the river Hasdo. The power output from the power house at the foot of the dam will be 50 MW at 60 per cent load factor. A gross area of 0.19 million hectares would be commanded by the project, out of which the annual irrigation will be 0.24 million hectares. The estimated cost of the project is Rs. 22.5 million.

The Jonk Multipurpose Project provides for the construction of a 37 m. high concrete dam across the river Jonk near village Porra in Raipur district. The project will irrigate an area of 0.04 million hectares and generate 9 MW of firm power.

The Tikerpara-Gania Project envisages the construction of the Tikerpara Dam across the river Mahanadi, 161 km. downstream of Hirakud, and the Gania Barrage, 35 km. further downstream. The right and left bank irrigation-cum-navigation canals will take off from the Gania Barrage and terminate at Visakhapatnam and Haldia ports respectively. Both these canals will have power plants and locks at the various falls and pumping stations for lift irrigation. The Tikerpara Dam will create a reservoir with a gross storage of 57,974 m. cu. m. of which the live storage would be 46,872 m. cu. m. The water spread of the reservoir will extend over 2,590 sq. km. This ambitious project is proposed to be treated as two separate projects, namely (i) the dam project with the power part and (ii) the barrage project as an irrigation, navigation and power project. It is also proposed to implement the two projects in stages. The estimated costs of the two projects are Rs. 1,750 million and Rs. 2,462 million respectively.

Ecological Balance

3.21 Since the construction of the Hirakud Dam, the releases of large volumes of silt-free water from the reservoir have caused excessive erosion of river banks downstream. The construction of giant dams like the Tikerpara will result in larger changes in the ecosystem, which cannot be treated as an isolated matter. The whole system will have to be taken into account and failure to do this may eventually cost heavily. The adverse effects of its construction on the lower reaches of the river and especially the delta, need to be carefully considered in all respects. It would be of interest to recall the problems encountered in Egypt after the construction of the mighty Aswan High Dam on the Upper Nile. The dam was designed around the goals of power production, irrigation and flood control. But, the dam has greatly restricted the flow of silt down the Nile, which in the past used to provide annual fertilization of the lands along the banks and offset the effects of natural erosion of the delta.

The downstream erosion now threatens to wash away as much of productive farmland as has been opened by new irrigation works near Lake Nasser. Silt full of nutrients formerly found its way to the Mediterranean and made possible the growth of organisms which supported fish, including sardines. This silt no longer reaches the Mediterranean; and as a result the Egyptian sardine catch has declined from 18,000 tonnes in 1965 to 500 in 1968.

Another problem, created by the introduction of irrigation in the delta plains of the Nile is the growth of snails, which carry the virtually incurable and seriously debilitating disease, schistosomiasis. The constant flow of water in the irrigation systems encourages the growth of these snails, which could not formerly multiply or spread in great numbers because the flood waters of the Nile could fill only the ditches. The power production at Aswan dam is also threatened due to the clogging of the shore lines of Lake Nasser by the water weeds and higher water transpiration loss.

The construction of the Tikerpara Dam may also create similar harmful conditions in the delta. The evils attendant on the construction of large reservoirs underline the necessity to maintain the ecological balance.

FLOODS, WATERLOGGING AND DRAINAGE

3.22 The flood problems of the Mahanadi are mainly confined to its lower reaches in Orissa. The main rivers of Orissa, namely, the Mahanadi, the Brahmani and the Baitarani are inter-connected in the delta, the worst floods in the delta area occur when there is a heavy downpour simultaneously in the catchment areas of more than one of these rivers. The spill from one river flows into the other leading to flooding of most of the delta area. There are also occasions when due to high-intensity storms, some local flooding occurs in the upper reaches of the river in Madhya Pradesh.

The flood problems of the Mahanadi can be characterised as:

(a) prolonged submersion of vast agricultural lands in the middle and lower delta because of the failure of the river channels to contain the high flood discharge within their banks;

(b) fertile land being rendered unfit for cultivation by sand casting, and scouring of river banks;

(c) excessive scouring of river banks downstream due to the release of large volumes of silt-free water from the Hirakud Dam; and

(d) the formation of sand bars from south-west to north-east across the mouth of the river due to littoral drift.

Some flood embankments in Orissa built over a century ago, were privately owned. They were constructed in isolated places to prevent the river from spilling and damaging the lands. They were in inadequate sections and were maintained indifferently. They provided poor protection when it was most needed.

The Hirakud Dam Project was the first to confer any appreciable flood control benefits to the delta. Other measures undertaken included construction of new embankments, strengthening of existing embankments, town protection and raising of village sites, cuts for quick drainage etc. By 1969 a total expenditure of Rs. 60.65 million had been incurred on flood-control works during the planning period.* In the Fourth Plan, Orissa has provided an outlay of Rs. 200 million. Statistics of flood damage to different river basins are not available. But for the State as a whole, the flood-affected area has been varying from 0.03 million hectares in 1958 to 1.40 million hectares in 1960. The average works out to 0.49† million hectares per year. An area of 0.54 million hectares is protected now.

The Orissa Government appointed a Committee to make a review of the flood situation which made recommendations about embankments, beels etc. But for the effective control of floods, it is necessary to construct at least one more reservoir across the Mahanadi. This with the Tikkerpara project, when it is constructed, will free the delta from the scourge of floods.

3.23 In the course of delta formation, the river beds rise gradually and become higher than the adjoining lands. Whenever the rivers are in flood and the water level rises, the drainage of the area gets affected. These conditions result in the formation of small lagoons and swamps in the doabs towards the sea-coast.

Waterlogging due to flow irrigation from the major projects like the Hirakud Project, is negligible. After more than ten years of flow irrigation from the Hirakud, no waterlogging problem has arisen. Even the low lands affected by seepage from higher fields, yield two paddy crops a year. Similarly, no waterlogging problem has arisen in the Mahanadi and the Tandula Canal Systems area of Madhya Pradesh.

SOIL CONSERVATION

3.24 The problem of soil erosion in the Mahanadi exists in an acute form in the eastern hills covering parts of Phulbani, Kalahandi, Koraput and Ganjam districts and in the northern plateau covering parts of

*India, Irrigation and Power Projects (Five Year Plans), CW&PC (April, 1970).

†Report of the Ministers Committee on Flood Control, Ministry of Irrigation & Power (December, 1964).

Sambalpur and Dhenkanal districts. The tribals of these areas practise shifting cultivation extensively, which means destruction of forests and creation of conditions for intense soil erosion. The population pressure on land is increasing and conditions worsening. In Orissa about 3.31 million hectares of land is estimated to be under shifting cultivation.

We have dealt with problems of soil conservation in the later portion of Chapter XIV of the first volume. The Hirakud project has been included in the centrally sponsored programme for soil conservation.

For the construction of reservoirs, it is important that soil conservation works are taken up. They are afforestation of new areas, upgrading of existing forest areas, terracing and contour bunding of agricultural fields, development of pastures, fringe afforestation and streambank control and construction of check dams, gully plugging, etc.

They comprise works like contour bunding, bench terracing, pasture development, gully control, afforestation, construction of silt detention tanks engineering structures and other measures. Priorities in soil conservation measures have been fixed on the basis of silt load data, extent of erosion, slope percentage, etc. Up to the end of the Third Plan, at a cost of Rs. 18.562 million, an area of 88,000 hectares was treated. During the Annual Plans period (1966–69) soil conservation measures were undertaken on an area of 52,000 hectares at a cost of Rs. 14.607 million.*

The capacity survey of the Hirakund reservoir to determine the rate of its silting is in progress. Meantime, the CW&PC has conducted some studies regarding siltation of the reservoir, by the inflow-outflow method. The gross storage capacity of the reservoir is 8,100 m. cu. m., of which 5,822 m. cu. m. is the live storage and the balance of 2,278 m. cu. m. the dead storage. The data of inflow and suspended silt load at Hirakud are available from 1947 but the firm data of silt outflow from the reservoir are available from only 1957.** The silt inflow and outflow data since 1957 is tabulated in Table 3.11.†

The total suspended silt retained in the reservoir from 1957 to 1967 is of the order of 320.49 m. cu. m. i.e. 27.50 m. cu. m. on an average per year. Adding 10% of suspended load as deposition per annum, this total works out to 30.25 m. cu. m. against the assumed annual siltation rate of 20.84 m. cu. m.

The rate of silt is higher, about one and a half times the rate of siltation assumed in the project estimates. It may not be possible to predict accurately the life of the reservoir, but the higher siltation rate highlights urgency of the soil conservation measures.

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*India, Irrigation and Power Projects (Five Year Plans), CW&PC (April, 1970).

**Data for 1956 is available but it is incomplete.

†Sedimentation data on selected reservoirs in India (Revised Edition), Soil Conservation Directorate, CW&PC, March, 1969 (Unpublished).

Table 3.11

Siltation in Hirakud Reservoir

Year	Suspended silt inflow into the reservoir (m.cu.m.)	Suspended silt outflow from the reservoir (m.cu.m.)	Suspended silt retained in the reservoir (m.cu.m.)
1	2	3	4
1957	19.80	3.41	16.39
1958	39.64	10.69	28.95
1959	43.83	11.33	32.50
1960	33.46	11.51	21.96
1961	103.46	26.53	76.93
1962	13.81	4.12	9.69
1963	37.75	6.03	30.72
1964	45.90	12.14	33.76
1965	16.17	1.42	14.75
1966	15.97	3.79	12.18
1967	34.27	9.60	24.67

The Fourth Plan provides an outlay of Rs. 50.0 million to cover an additional area of 130,850 hectares in the Hirakund catchment by soil conservation measures.

An inter-State agreement to carry out soil conservation measures to conserve the storage capacities of existing and proposed reservoirs is necessary.

Studies in the rise of the water-table in the bunded areas of Madhya Pradesh are being carried out but no such studies have been undertaken in Orissa. In Madhya Pradesh, there is a rise in water-table in the bunded areas. Both the States have accorded high priority to soil and water conservation measures in drought-affected areas. In both the States the Agriculture and Forest Departments have been entrusted with soil conservation works.

GENERAL

3.25 The Mahanadi and its tributaries are an inter-State river system, flowing through the States of Madhya Pradesh, Maharashtra, Bihar and Orissa. Several small and large projects have already been constructed in its basin. Some are under execution in Madhya Pradesh and Orissa. But the approach all through has been to look at the projects from the interest of the concerned State.

For the optimum utilisation, it is essential that a comprehensive basin-wise plan for the development of the Mahanadi basin is prepared. It should comprise the construction of a series of dams on the main river and its major tributaries and allied irrigation, power and navigation works. The implementation of the overall plan would involve time and heavy capital investment. The plan should be implemented by constructing projects which can function independently and yet become an integral part of the unified basin plan.

A network of evaporation-measuring stations particularly at the sites of existing and proposed reservoirs needs to be established.

Daily discharge and sediment observations at the existing eight sites and at the new eighteen sites suggested under section 3.17 need to be conducted.

Systematic and scientific exploratory work for a quantitative and qualitative assessment of the ground water resources in the basin is another necessity.

The inter-State co-operation and agreement to carry out soil conservation measures to preserve the storage capacities of existing and proposed reservoirs is a welcome feature.

SALIENT FEATURES OF THE BASIN OF EAST FLOWING RIVERS BETWEEN THE MAHANADI AND THE GODAVARI

(*i*) Six small streams between the Mahanadi and the Rushikulya draining into the Chilka lake	(1) (Northern-most) North-west of Tangi village in Puri district. (Latitude 19°15′N, Longitude 85°15′E) (2) Near Survakhala village in Puri district. (Latitude 19°52′N, Longitude 85°13′E) (3) Near Dhuauuali village in Puri district. (Latitude 19°50′N, Longitude 85°7′E) (4) Near Sankhjeri village in Puri district. (Latitude 19°58′N, Longitude 85°12′E) (5) East of Sumondola village in Ganjam district. (Latitude 19°42′N, Longitude 85°6′E) (6) West of Rambha village in Ganjam district (Latitude 15°32′ N, Longitude 85°3′E)
The Rushikulya	Near Digi village in Phulbani (Baudh Khondmals) district (Latitude 19°59′N, Longitude 84°13′E)
Small stream between the Rushikulya and the Bahuda	South-west of Berhampur in Ganjam district. (Latitude 19°15′N, Longitude 84°40′E)
The Bahuda	Near Ramagiri village in Ganjam district. (Latitude 19°3′N, Longitude 84°20′E)
Five small streams between the Bahuda and the Vamsadhara	(1) (Northern-most) near Audanda village in Ganjam district. (Latitude 19°0′N, Longitude 84°22′E) (2) North-west of Tarlakota village in Srikakulam district. (Latitude 18° 51′N, Longitude 84°20′E) (3) East of Ganduveda village in Srikakulam district. (Latitude 18°40′N, Longitude 84°11′E) (4) East of Ganduveda village in Srikakulam district. (Latitude 18°40′N, Longitude 84°9′E) (5) East of Ganduveda village in Srikakulam. (Latitude 18°40′N, Longitude 84°7′E)
The Vamsadhara	South-west of Belagad in Phulbani (Baudh Khondmals) district. (Latitude 19°50′N, Longitude 83°33′E)
The Nagavali	Near Gunupur village in Kalahandi district. (Latitude 19°38′N, Longitude 83°5′E)

Eight small streams between the Nagavali and the Sarada	(1) Northern-most—Near Chipurupalle village in Srikakulam district. (Latitude 18°20′N, Longitude 93°35′E) (2) Near Chipurupalle village in Srikakulam district. (Latitude 18°19′N, Longitude 83°34′E) (3) South of Salur village in Srikakulam district. (Latitude 18°25′N, Longitude 83°10′E) (4) North of Anantagiri village in Visakhapatnam district. (Latitude 18°17′N, Longitude 82°57′E) (5) Near Kottavalasa village in Visakhapatnam district. (Latitude 17°52′ N, Longitude 83°17′E) (6) Near Chanduvada village in Visakapatnam district. (Latitude 17°50′N, Longitude 83°3′E) (7) Near Duvvada village in Visakhapatnam district. (Latitude 17°42′N, Longitude 83°7′E) (8) North-east of Anakapalle village in Visakhapatnam district. (Latitude 17°45′N, Longitude 83°3′E)
The Sarada	Near Anantagiri village in Visakhapatnam district. (Latitude 18°13′N, Longitude 82°55′E)
The Varaha	Near Lammasingi village in Visakhapatnam district. (Latitude 17°52′N, Longitude 82°32′E)
The Tandava	South-west of Chintapalle village in Visakhapatnam district. (Latitude 17° 48′N, Longitude 82°17′E)
The Eluru	South of Gudem village in Visakhapatnam district (Latitude 17°48′N, Longitude 82°12′E)
Small stream between the Eluru and the Godavari	West of Somavaram in East Godavari district. (Latitude 17°14′N, Longitude 82°1′E)

(*ii*) Length:

		Km.	Miles
Six small streams between the Mahanadi and the Rushikulya draining into the Chilka lake	(1)	19	12
	(2)	10	6
	(3)	21	13
	(4)	42	26
	(5)	10	6
	(6)	8	5
The Rushikulya		146	91
Small stream between the Rushikulya and the the Bahuda		24	15
The Bahuda		73	45

Five small streams between the Bahuda and			
the Vamsadhara	(1)	33	20
	(2)	26	16
	(3)	20	12
	(4)	20	12
	(5)	48	30
The Vamsadhara		221	137
The Nagavali		217	135
Eight small streams between the Nagavali and the Sarada	(1)	36	22
	(2)	32	20
	(3)	71	44
	(4)	80	50
	(5)	22	14
	(6)	36	22
	(7)	16	10
	(8)	30	19
The Sarada		104	64
The Varaha		66	41
The Tandava		73	45
The Eluru		125	78
Small stream between the Eluru and the Godavari		48	30

		Sq. km.	Sq. miles
(*iii*) Drainage area:	Six small streams between the Mahanadi and the Rushikulya draining into the Chilka Lake	2,709	1,046
	The Rushikulya	7,753	2,993
	Small stream between the Rushikulya and the Bahuda	919	355
	The Bahuda	1,248	482
	Five small streams between the Bahuda and the Vamsadhara	1,758	679
	The Vamsadhara	10,830	4,181
	The Nagavali	9,410	3,633
	Eight small streams between the Nagavali and the Sarada	5,296	2,045
	The Sarada	2,725	1,052
	The Varaha	1,177	454
	The Tandava	1,545	597
	The Eluru	3,809	1,471
	Small stream between the Eluru and the Godavari	506	195
	Total	49,685	19,183

(*iv*) Population (1971 Census)		9.44 millions
(*v*) Density of population	190 per sq. km.	492 per sq. mile.

(*vi*)	Maximum discharge		Cumecs	Cusecs
	Of the Rushikulya		8,495	3,00,000
	Of the Vamsadhara		4,701	1,66,000
(*vii*)	Minimum discharge	Nil		
(*viii*)	Average annual runoff		m.cu.m.	MAF
	The Rushikulya		1,762	1.45
	The Bahuda		222	0.18
	The Vamsadhara		3,460	2.81
	The Nagavali		2,430	1.97
			Thousand hectares	Thousand acres
(*ix*)	Culturable area (1967-68)		2,705	6,684
(*x*)	Net area sown (1967-68)		1,805	4,460
(*xi*)	Gross area sown (1967-68)		2,244	5,545
(*xii*)	Net area irrigated (1967-68)		683	1,688
(*xiii*)	Gross area irrigated (1967-68)		787	1,945
(*xiv*)	Area irrigated after completion and full development of Fourth Plan projects		669	1,653
(*xv*)	Probable additional irrigation by future projects		N.A.	
(*xvi*)	Water utilisation, including reservoir losses		m.cu.m.	MAF
	(*a*) On completion and full development of major, medium and minor projects under operation and construction at the end of Annual Plan (1968-69)	Surface water	8,752	7.09
		Ground water	195	0.16
		Total	8,947	7.25
			m.cu.m.	MAF
	(*b*) On completion and full development of Fourth Plan projects	Surface water	10,221	8.29
		Ground water	223	0.18
		Total	10,444	8.47

CHAPTER IV

BASIN OF EAST FLOWING RIVERS BETWEEN THE MAHANADI AND GODAVARI

The basin of the east-flowing rivers between the Mahanadi and the Godavari extends over an area of 49,685 sq. km. and lies between east longitudes 81°15′ to 85°30′ and north latitudes 16°55′ to 20°18′. Lying in the north-east corner of the peninsular India, the basin covers large areas in the States of Orissa and Andhra Pradesh. The State-wise distribution of the drainage areas is shown below:

Table 4.1

Drainage Area—State-wise

Name of State	Drainage area Sq. km.
Orissa	25,780
Andhra Pradesh	23,905
Total	49,685

4.2 The basin is bounded on the north, the west and the south by the various ranges of the Eastern Ghats and on the east by the Bay of Bengal. The basin which is irregular in shape, has a maximum length of about 182 km. in the north-west-south-east direction and a maximum width of 476 km. in the north-east-south-west direction.

4.3 There are two major topographical divisions in the basin, namely (i) the hill ranges of the Eastern Ghats and (ii) the coastal plains. The hill ranges are well-forested. The plains extending from the eastern slopes of the Ghats slope gently towards the Bay of Bengal. There are 13 sub-basins, of which the Rushikulya, the Vamsadhara, the Nagavali and the Sarada are the more important. The Rushikulya basin is circular in shape, while the Vamsadhara and the Nagavali basins are fan shaped.

THE RIVER SYSTEMS

4.4 The various river systems in the basin, from the north to the south, are:

(1) Six small streams between the Mahanadi and the Rushikulya draining into the Chilka Lake.
(2) The Rushikulya.
(3) Small stream between the Rushikulya and the Bahuda.
(4) The Bahuda.
(5) Five small streams between the Bahuda and the Vamsadhara.
(6) The Vamsadhara.
(7) The Nagavali.
(8) Eight small streams between the Nagavali and the Sarada.
(9) The Sarada.
(10) The Varaha.
(11) The Tandava.
(12) The Eluru.
(13) Small stream between the Eluru and the Godavari.

These river systems are described briefly in the following paragraphs.

Six Small Streams between the Mahanadi and the Rushikulya draining into the Chilka Lake

4.5 The northern-most stream rises north-west of Tangi village in Puri district at an elevation of about 500 m. at north latitude 19°57′ and east longitude 85°15′ and flows for a total length of 19 km. The second stream rises near Survakhala village in Puri district at an elevation of 100 m. at north latitude 19°52′ and east longitude 85°13′ and flows for a total length of 10 km. The third stream rises near Dhuauuali village in Puri district at an elevation of 100 m. at north latitude 19°52′ and east longitude 85°7′ and flows for a total length of 21 km. The fourth stream known as the Sutia, rises near Sankhjori village in Puri district at an elevation of 300 m. at north latitude 19°57′ and east longitude 85°12′ and flows for a total length of 42 km. The fifth stream rises east of Sumondolo village in Ganjam district at an elevation of 100 m. at north latitude 19°42′ and east longitude 85°6′ and flows for a total length of 10 km. The sixth stream rises west of Rambha village in Ganjam district at an elevation of 100 m. at north latitude 19°32′ and east longitude 85°3′ and flows for a short distance of 8 km. All the streams flow in a generally south-easterly direction and drain into the Chilka lake. The area drained jointly by all the six streams (including the Chilka Lake area) is 2,709 sq. km.

The Rushikulya

The Rushikulya rises near Digi village on the eastern slopes of the Eastern Ghats in Phulbani (Baudh-Khondmals) district at an elevation of about 1000 m. at north latitude 19°59′ and east longitude 84°13′ and flows in a generally south-easterly direction for a total length of 146 km. to drain into the Bay of Bengal. The total area drained by this river is 7,753 sq. km. The Dhana, the Bhaguva, the Mahanadi on the left and the Patama, the Ghodohada on the right are its major tributaries.

Small Stream between the Rushikulya and the Bahuda

This stream rises south-west of Berhampur in Ganjam district at an elevation of 300 m. at north latitude 19°15′ and east longitude 84°40′ and flows for a total distance of 24 km., in a south-easterly direction, to join the Bay of Bengal. The area drained by this stream is 919 sq. km.

The Bahuda

The Bahuda rises near Ramagiri village in Ganjam district at an elevation of 600 m. at north latitude 19°3′ and east longitude 84°20′ and runs first in a north-easterly and then in a south-easterly direction, for a total length of 73 km. to join the Bay of Bengal. The total area drained by this river is 1,248 sq. km.

Five Small Streams between the Bahuda and the Vamsadhara

The northern-most stream rises near Audanda village in Ganjam district at an elevation of 1,500 m. at north latitude 19°0′ and east longitude 84°22′ and runs for a total length of 33 km. The second stream rises north-west of Tarlakota village in Srikakulam district at an elevation of 450 m. at north latitude 18°51′ and east longitude 84°20′ and runs for a total distance of 26 km. The third stream rises east of Ganduveda village in Srikakulam district at an elevation of 300 m. at north latitude 18°40′ and east longitude 84°11′ and flows for a total length of 20 km. The fourth stream rises east of Ganduveda village in Srikakulam district at an elevation of 200 m. at north latitude 18°40′ and east longitude 84°9′ and runs for a total length of 20 km. The last stream also rises east of Ganduveda village in Srikakulam district at an elevation of 200 m. at north latitude 18°40′ and each longitude 84°7′ and runs for a total length of 48 km. All five streams flow in a generally south-easterly direction and join the Bay of Bengal. The total area drained jointly by all these streams is 1,758 sq. km.

The Vamsadhara

The Vamsadhara rises south-west of Belaged village in Phulbani (Baudh Khondmals) district at an elevation of 600 m. at north latitude 19°50′ and east longitude 83°33′ and flows in a generally south-easterly direction for a total length of 221 km. to empty into the Bay of Bengal. It drains a total area of 10,830 sq. km. lying both in Orissa and Andhra Pradesh States.

The Nagavali

The Nagavali rises near Gunupur village in Kalahandi district at an elevation of 900 m. from the eastern slopes of the Eastern Ghats, at north latitude 19°38′ and east longitude 83°5′ and runs in a south-easterly direction for a total length of 217 km. to join the Bay of Bengal. The Nagavali drains a total area of 9,410 sq. km., lying both in Orissa and Andhra Pradesh States. The Janjhavati, the Suvarnamukhi and the Vegavati are its important right bank tributaries.

Eight Small Stream between the Nagavali and the Sarada

The details of these eight small streams are given below:

Table 4.2

Details of Eight Small Streams between the Nagavali and Sarada

Sl. No.	Stream	Source					Total length in km.
		Village	District	Elevation in m. above MSL	North Latitude	East Longitude	
1.	First or the Northern-most stream	Near Chipurupalle	Srikakulam	120	18°20′	93°35′	36
2.	Second stream	-do-	-do-	120	18°19′	83°34′	32
3.	Third stream	South of Salur	-do-	300	18°25′	83°10′	71
4.	Fourth stream	North of Anantagiri	Visakhapatnam	900	18°17′	82°57′	80
5.	Fifth stream	Near Kotavalasa	-do-	140	17°52′	83°17′	22
6.	Sixth stream	Near Chanduvada	-do-	300	17°50′	83°3′	36
7.	Seventh stream	Near Duvvada	-do-	150	17°42′	83°7′	16
8.	Eighth stream	North-east of Anakapalle	-do-	120	17°45′	83°3′	30

The total area drained jointly by all the above eight streams is 5,296 sq. km. All of them flow generally south-east and join the Bay of Bengal.

The Sarada

The Sarada rises near Anatagiri village in Visakhapatnam district at an elevation of 1,200 m., at north latitude 18°13′ and east longitude 82°55′ and runs for a total length of 104 km. in a generally south-east direction to join the Bay of Bengal. It drains a total area of 2,725 sq. km.

The Varaha

The Varaha rises near Lammasingi village in Visakhapatnam district at an elevation of 800 m, at north latitude 17°52′ and east longitude 82°32′ and runs in a generally south-easterly direction for a total length of 66 km. to join the Bay of Bengal. It drains an area of 1,177 sq. km.

The Tandava

The Tandava rises south-west of Chintapalle village in Visakhapatnam district at an elevation of 1,200 m., at north latitude 17°48′ and east longitude 82°17′ and flows in a south-easterly direction for a total length of 73 km. to join the Bay of Bengal. The river drains an area of 1,545 sq. km.

The Eluru

The Eluru rises south of Gudem village in Visakhapatnam district at an elevation of 1,290 m. at north latitude 17°48′ and east longitude 82°12′ and runs for a total length of 125 km. in a south-easterly direction to join the Bay of Bengal. It drains an area of 3,809 sq. km.

Small Stream between the Eluru and the Godavari

This stream rises west of Somavaram in East Godavari district at an elevation of 140 m. at north latitdue 17°14′ and east longitude 82°1′ and runs for a total length of 48 km. in a south-easterly direction to join the Bay of Bengal. It drains an area of 506 sq. km.

CLIMATE

4.6 Three distinct seasons occur in the basin. They are (i) cool weather, (ii) hot weather and (iii) rainy season. The cool weather extends from about the middle of October to the middle of February. On the eastern slopes of the Eastern Ghats, some showers occur up to the end of November. Usually, there is very little rainfall in the months of December, January and February. In the hot weather extending from the middle of February to the middle of June, the entire basin is hot and practically dry. The south-west monsoon season, which follows the hot weather, extends from June to the end of October.

Rainfall

4.7 There are at present 141 reporting raingauge stations inside the basin. The distribution of the stations is fairly even and their number is also sufficient.

4.8 The rainfall in the basin varies from region to region. The rainfall decreases from 1,270 mm. at the north-east corner of the basin to about 1,016 mm. at the south-east extremity of the basin. More than 90% of the annual rainfall occurs during the monsoon period, from June to October. The monthly and annual normals of rainfall in the districts lying in the basin are given in Appendix 4.1.

Temperature

4.9 The basin enjoys a tropical climate. In the hilly western part of the basin, the variation of temperature during the year is less marked than in the plains.

In the month of January, the mean temperature over the basin is between 22.5°C and 25°C. In April, the mean temperature varies from 30°C to 32.5°C whereas in the month of July, the mean temperature is between 27.5°C and 30°C. In the month of October, the basin experiences temperatures above 27.5°C. The annual maximum and minimum normals of temperature at Kakinada in the basin are 31.9°C and 23.9°C respectively.

Evaporation

4.10 Data on evaporation is not available for the basin. One departmental observatory and one agro-meteorological observatory of the India Meteorological Department are located in the basin.* They are at Visakhapatnam and Samalkot respectively. The monthly evaporation losses from the reservoir assumed in the Joro-Harbhangi Project are as in Table 4.3.

*Evaporation Data (India), India Meteorological Department (April, 1970).

Table 4.3

Monthly Evaporation Losses-Joro-Harbhangi Project

Sl. No.	Name of the project	Evaporation (cm.)												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1.	Joro-Harbhangi	10	10	18	23	26	18	15	15	15	13	10	10	183

SOILS

4.11 A detailed soil survey of the area covered by the basin has not been made. However, the general data regarding the soils of India indicates that mainly red sandy soils, red loamy soils and coastal alluvium occur in the basin. Laterite soils are also found to a smaller extent.

The basin covers the districts of Srikakulam and Ganjam and parts of the districts of Visakhapatnam, East Godavari, Puri, Koraput, Phulbani and Kalahandi.

The principal soil types found in the various districts lying in the basin are described below.*

Srikakulam: Red soils, alluvium developed by the Vamsadhara and the Nagavali and coastal alluvium.

Visakhapatnam: Soils which are mostly loamy to sandy loam in texture. These are well drained.

East Godavari: Loamy or clayey soils.

Ganjam: Lateritic soils.

Puri: The soils are sandy and poor in plant nutrients.

Koraput: Soils are very sandy (fine and coarse). The water-holding capacity is low but the moisture equivalent appears to be too high in relation to the sandy nature of the soil.

Phulbani: Laterite, red and brown forest soils.

Kalahandi: Mixed red and black soils.

LAND USE AND AGRICULTURAL PRACTICES

4.12 State-wise land use details in the basin in 1967–68, the latest year for which the statistics are available, are given in Table 4.4.

Agriculture has been practised extensively in the basin. The cultivated area for the basin as a whole constitutes 83.0% of the culturable area. The culturable area in the basin is about 1.39% of the total culturable

*Soils of India by S. P. Ray Chaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Table 4.4

Land Use Details

(Thousand hectares)

Sl. No.	Item	Name of State: Andhra Pradesh	Name of State: Orissa	Total
1.	Gross area	2,391	2,578	4,969
2.	Reporting area	2,383	2,531	4,914
3.	Area under forests	671	577	1,248
4.	Area not available for cultivation	461	500	961
5.	Culturable area	1,251	1,454	2,705
6.	Uncultivated culturable area	294	606	900
7.	Net area sown	957	848	1,805
8.	Area sown more than once	165	274	439
9.	Total cropped area	1,122	1,122	2,244
10.	Net area irrigated	450	233	683
11.	Gross area irrigated	508	279	787
12.	Percentage of net area sown to culturable area	76.5	58.3	66.7
13.	Percentage of net area irrigated to culturable area	36.0	16.0	25.2
14.	Percentage of net area irrigated to net sown area	47.1	27.4	37.8

area of India. The total cropped area in the basin is about 1.38% of the total cropped area in the country.

4.13 The general cropping pattern in the irrigated area in the States is as under:

Andhra Pradesh

Of the total irrigated area of 508,400 hectares, about 89.1% is under paddy, 4.1% under sugarcane, 3.3% under ragi, 0.7% under sesamum and the balance under other crops. The other crops grown in the irrigated area are jowar, bajra, maize, pulses, condiments, spices, groundnut, cotton, tobacco and fodder crops. Food crops represent about 98.2% of the irrigated area, the balance 1.8% being under non-food crops.

Orissa

The latest crop-wise statistics available pertain to the year 1956–57. The cropping pattern, as per this data, is as under:

Out of the total irrigated area of 179,400 hectares 93.4% is under paddy, 1.7% under ragi, 0.8% under sugarcane and the balance under other crops. The other crops grown in the irrigated area are jowar, wheat and pulses. Food crops cover 97.4% of the total irrigated area, the balance of 2.6% being under non-food crops.

For the basin as a whole, of the total irrigated area, 90.2% is under paddy, 3.3% under sugarcane, 2.9% under ragi, 0.5% under sesamum and the rest under other crops. Food crops cover 98.0% of the irrigated area, the balance of 2.0% being under non-food crops.

4.14 There are three main crop seasons in the basin (i) autumn (kharif), (ii) winter (rabi) and (iii) summer (hot weather). The kharif crops are paddy, bajra, jowar, maize, ragi etc. The rabi crops are jowar, barley, millets, gram, other pulses etc. The main summer crop is paddy. Besides the seasonal crops, garden crops like sugarcane, betel leaves, turmeric etc. are also grown throughout the year. The sowing and harvesting seasons of the principal crops are given below*:

Table 4.5

Sowing and Harvesting Periods

Name of crop	Period of	
	Sowing	Harvesting
Andhra Pradesh		
Autumn Paddy	March-April	June-July
Winter Paddy	June-August	September-December
Summer Paddy	January-February	April-May
Kharif Jowar	September-October	February
Bajra	June-July	September-October

*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 4.5—Contd.
Sowing and Harvesting Periods

Name of crop	Period of	
	Sowing	Harvesting
Orissa		
Autumn Paddy	May-June	August-October
Winter Paddy	June-July	September-December
Summer Paddy	December-February	March-June
Maize	June-October	August-January
Ragi	May-August	July-December

REGIONAL ECONOMY

Population

4.15 On the basis of the 1971 Census* and the percentage of the area of each district within the basin to the district as a whole, the total population in the basin is about 9.44 millions. The State-wise distribution is shown below:

State	*Population*
Andhra Pradesh	5.74 millions
Orissa	3.70 millions
Total	9.44 millions

According to the 1971 Census only one city in the basin, Visakhapatnam in Andhra Pradesh, has a population of more than one lakh. The average density of the population in the basin is 190 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. Whereas the East Godavari district has the highest density of 281 persons per sq. km., the lowest density of 56 persons per sq. km. occurs in Phulbani (Baudh Khondmals) district. The population in the districts of Koraput, Phulbani and Kalahandi has a relatively large component of persons belonging to the scheduled tribes. They are economically backward and depend for their livelihood mainly on forest produce and on shifting cultivation or a primitive form of settled agriculture. They have little industrial activity even on a cottage scale.

*Census Paper I of 1971 (Supplementary), Registrar-General (India).

4.16 Out of the total population in the basin, nearly 85% live in rural areas, while the balance of 15% live in urban areas. The working force constitutes nearly 38.3% of the total population. Nearly 36.8% of the working force is engaged as cultivators and 34.7% as agricultural labourers. The balance of 28.5% of the working force is employed in manufacturing, mining and other tertiary activities.

Forests & Agriculture

4.17 Forests occupy 25.4% of the total area in the basin and the culturable area constitutes 55.1%. Out of the total culturable area of 2.71 million hectares, nearly 2.24 million hectares are annually cultivated. An area of 0.79 million hectares constituting 35.1% of the cultivated area is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 90.2% of the total irrigated area.

Power

4.18 There are no major hydro-power stations in the basin. The hydroelectric power potential of this basin has been assessed as nil by the Central Water & Power Commission. At present, there is a thermal power station at Visakhapatnam. The power generated is fed into the State grid. The basin gets power from the Machkund, Sileru and Hirakud projects.

Mineral Wealth

4.19 The principal minerals found in the basin are: *

Iron Ore: In the East Godavari, Visakhapatnam, Koraput, Kalahandi and Puri districts.

Manganese: In the Srikakulam, Koraput, Puri, Kalahandi and Ganjam districts.

Limestone and Dolomite: In the Koraput, Puri, Phulbani and Kalahandi districts.

Bauxite: In the Kalahandi and Koraput districts.

Monazite: In the Visakhapatnam district.

China Clay: In the Koraput, Phulbani, Kalahandi and Ganjam districts.

Fire Clay: In the Puri, Kalahandi and Koraput districts.

Graphite: In the Puri, Kalahandi and Koraput districts.

Mica: In the East Godavari, Visakhapatnam, Srikakulam, Ganjam, Phulbani, Kalahandi and Koraput districts.

Gold: In the Kalahandi and Koraput districts.

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*Techno-Economic Surveys of Bihar and Orissa States, NCAER.

Industries

4.20 The important industries in the basin are:
Jute: In Visakhapatnam.
Silk and other fabrics: In Kakinada.
Sugar: In Rayagada, Visakhapatnam and Pithapuram.
Tobacco products: In Pithapuram.
Matches: In Visakhapatnam.
Ship-building & Dockyards: In Visakhapatnam.
Automobile parts: In Kakinada.
Agricultural equipment: In Kakinada.
Petroleum and its by-products: In Visakhapatnam.
Drugs & Pharmaceuticals: In Rayagada, Srikakulam, Visakhapatnam and Kakinada.
Leather & Leather goods: In Berhampur and Vizianagaram.
Inks, Paints & Varnishes, etc: In Visakhapatnam and Kakinada.
Chemicals (Acids & Caustics): In Kakinada.
Fertilisers: In Visakhapatnam.
Iron & Steel: A steel plant is being set up in Visakhapatnam in the near future.

Communications

4.21 The basin is served by the network of the South-Eastern Railway. The entire system is on broadgauge. There are a few important lines connecting different places in the basin. Some of these are the Madras-Howrah line, Samalkot-Kakinada line and Vizianagaram-Raipur line. The National Highway connecting Madras with Calcutta passes through the basin for a considerable distance. The National Highway connecting Vizianagaram with Jagdalpur also passes through the basin. In addition, there is a network of State Highways, district and village roads in the basin. The rivers in the basin are not navigable. The Godavari Canal System connecting Kakinada lies partly in the basin and is navigable.* It is connected through the Krishna Delta Canals to the Buckingham Canal.

The basin is fairly well served with communications.

Dependence on Rainfall and Water Resources

4.22 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence except in parts of the basin where facilities of

*Navigable Waterways of India, Central Water and Power Commission (1961).

irrigation have been provided and where major industries have developed. There is a keen demand for the development of water resources in the basin.

WATER RESOURCES

Surface Water

4.23 When the basin-wise assessment of the water resources of the country was made on the basis of Khosla's formula, the annual runoff of the basin of the east-flowing rivers between the Mahanadi and Godavari was estimated as 16,072 m. cu. m.*

In 1960, the Central Water & Power Commission, while conducting irrigation potential studies, assessed the total annual runoff of the basin as 17,210 m. cu. m.** based on the available observed data and Strange's rainfall runoff co-efficients.

Planned and systematic observations of discharges on the various rivers in the basin does not seem to have been done. Some *ad hoc* and irregular observations have been made on the rivers and on some tributaries mainly in connection with proposed projects. Full data in respect of discharge sites, especially in Andhra Pradesh State, have not been made available by the State Government.

Systematic and regular observations on the Rushikulya and Vamsadhara have been done by the Orissa State Government in recent years.

Under the programme of establishing and maintenance of centrally sponsored key hydrological stations in the country, the Central Water & Power Commission has proposed the inclusion of a site on the Vamsadhara, just 48 km above its outfall into the sea.

The number of sites in the basin where systematic and continuous discharge observations are being conducted is far below the minimum requirements. Many of the rivers and their important tributaries are not being gauged at present. It will be necessary to establish sufficient gauge and discharge sites at representative points on the main rivers and their tributaries to assess correctly the water resources of the basin.

The average annual flows of the different rivers as per the data furnished by the Orissa State Government are given in Table 4.6.†

Ground Water

4.24 Systematic investigations and studies of the ground water poten-

*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

**Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

†Replies of Orissa State to the Questionnaire issued by the Irrigation Commission.

Table 4.6

Average Annual Flow

Sl. No.	Name of the river	Normal rainfall in cm	Average flow in m.cu.m. June-Sept.	Oct.-Dec.	Jan.-March	Apr.-May	Total	Remarks
1	2	3	4	5	6	7	8	9
1.	Rushikulya	120.00	1,444	318	—	—	1,762	
2.	Bahuda	—	—	—	—	—	222	
3.	Vamsadhara	119.38	2,014	1,313	85	48	3,460	Average for 1951 to 58
4.	Nagavali	—	—	—	—	—	2,430	

tial of the basin have not been made so far. Only in some parts of the Vamsadhara basin, have some investigations and studies been done recently.* In the area investigated in the Vamsadhara basin, in the districts of Koraput and Ganjam, ground water occurs under water table conditions in the weathered mantle of older crystalline rocks and in the shallow alluvial valley fill which has a maximum thickness of 15 to 20 m. The quality of water is good and it is used for domestic and minor irrigation purposes. In the Srikakulam district, the area studied is underlain by granites, gneisses, khondalites, charnokites, river alluvia and coastal sands. Ground water occurs in wells at depths of 2.5 to 15 m. In Visakhapatnam district, the open wells tap the weathered portions of the granite, gneiss and khondalite. Ground water can be developed by large open wells piercing the full thickness of weathered rock.

Occurrences of hot springs in Ganjam and Puri districts have been reported. In Ganjam district, a spring occurs about 40 km. from Berhampur on the road to Lohagudi at Taptapani, from which issues a copious and constant flow of hot water (temperature about 44°C) along with sulphurous vapour. In Puri district, hot springs occur at Atari and Tarabala. The temperature of the water is 59°C to 60°C.

The Orissa State has carried out some exploratory work in the Rushikulya and Vamsadhara sub-basins in connection with the programme of introducing tubewells to give assured irrigation in the coastal alluvial area. They have explored further extensions of acquifers in shallow fringe areas beyond the areas probed by the Exploratory Tubewells Organisation, for medium to low duty tubewells. Ground water survey and aquifer mapping and assessment for the entire State has been envisaged under the

*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

co-ordinated programme of the Geological Survey of India, the Exploratory Tubewells Organisation and the State Cell.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, qualitative and quantitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development for various needs can only be made when full investigations are carried out.

EXISTING DEVELOPMENT

4.25 Irrigation has been practised in the basin from historical times and many projects have been constructed, the most important of these being the Rushikulya Canal System, the details of which are given below.

The Rushikulya Canal System

The Rushikulya Canal System is an integrated system comprising two reservoirs, one at Bhanjanagar called the Russelkonda Reservoir and the second at Saroda, and three anicuts, namely the Janivilli Anicut, the Ghumsur Anicut and the Gallery Anicut. The Russelkonda Reservoir has been formed by damming the valley of the Boringa Nalla, an affluent of the Loharkhandi, which joins the Mahanadi above the Ghumsur Anicut. It is situated 1.6 km north of the town of Bhanjanagar in Ganjam district. The Saroda Reservoir has been formed by damming the Padma, an affluent of the Joro, which falls into the Rushikulya near Saroda. The Russelkonda Reservoir forms the most important component of the project. It draws its supply from its own catchment and from the Gallery Anicut across the Badanadi through the Gallery Channel, connecting the anicut with the reservoir. Water from the Russelkonda reservoir is first let down into the Loharkhandi river and is picked up at Ghumsur Anicut below the junction of the Loharkhandi, Budhanadi and Badanadi rivers. The Mahanadi canal, taking off from the right of the Ghumsur Anicut falls into the Rushikulya just above the Janivilli Anicut and, besides irrigating its own ayacut, feeds the Rushikulya Canal, which takes off from the Janivilli Anicut on the right bank. The other channel, which takes off from the Ghumsur Anicut is the Girisola Channel, which runs on its left. The Rushikulya Canal, which takes off from the Janivilli Anicut, forms the life line of the project and commands a block of nearly 37,231 hectares. It depends to a very great extent on supplementary supplies direct from the Saroda Reservoir and indirectly from the Russelkonda reservoir and the free flow at the Ghumsur Anicut, through the Mahanadi Canal. Work on the project commenced in 1884 and was completed in 1898 at a cost of Rs. 5.62 million. A total area of 49,340 hectares is irrigated by the project.

The First Irrigation Commission had not recommended any specific projects by name, to be taken up for construction in the basin. However, a number of projects were constructed in the basin thereafter, in the pre-Independence period, the more important of which are described below.

Thotapalli Regulator

The project consists of a regulator across the Nagavali river constructed at a cost of Rs. 1.36 million, for irrigating an area of 1,174 hectares in Srikakulam district. The project was completed in 1910.

Nagavali Regulator

Constructed across the Nagavali river at a cost of Rs. 1.95 million, this regulator irrigates an area of 14,650 hectares in Srikulam district. The project was completed in 1913.

4.26 During the Plan periods, a number of projects have been taken up for construction in the basin, both in Andhra Pradesh and Orissa States, which are described briefly in the following paragraphs.

Andhra Pradesh

Gambhiramgedda Reservoir Project: The project consists of a 411 m long, 16 m high dam across the river Gambhiramgedda for irrigating 240 hectares in Visakhapatnam district. It was completed in 1957 at a cost of Rs. 1.41 million.

Vegavathi Anicut: The project consits of a 91 m. long anicut across the river Vegavathi. It irrigates an area of 2,350 hectares in Srikakulam district and was completed in 1958, at a cost of Rs. 2.33 million.

Narayanapuram Anicut: The project comprises a 356.6 m. long, 13.3 m high anicut across the river Nagavali for irrigating an area of 14,910 hectares in Srikakulam district. It was completed in 1959 at a cost of Rs. 9.69 million.

Seethanagaram Anicut: Located in Srikakulam district, the project consists of an anicut across the Suvarnamukhi river, a tributary of the Nagavali, for irrigating an area of 1,620 hectares. Costing Rs. 1.25 million, it was completed in 1960.

Nagavali Right Side Channel: This project costing Rs. 2.69 million, was completed in 1960 and irrigates an area of 3,640 hectares in the Nagavali sub-basin in Srikakulam district.

Paidigam Project: The project consists of a 42.4 m. long, 1.4 m. high weir across the river Mahendratanaya for irrigating 2,000 hectares, in Srikakulam district. It was completed in 1963 at a cost of Rs. 2.42 million.

Tandava Reservoir: The project comprises a 201.2 m long, 32 m high earthen dam across the Tandava river, near the village of Gantavari Kothagudem in Visakhapatnam district. Costing Rs. 40.37 million, it will irrigate 18,576 hectares. Started in 1965, it is likely to be completed during the Fourth Plan.

Pampa Reservoir: The project envisages an earthen dam across the river Pampa at Annavaram in East Godavari district to provide irrigation facilities to an area of 4,860 hectares, including the existing ayacut of 3,797 hectares. Taken up for construction in 1965, it is likely to be completed during the Fourth Plan at a cost of Rs. 9.92 million.

Varaha Reservoir: The project consists of an earthen dam, 215.4 m long, 25 m high, across the Varaha river near Kalyanapulva in Visakhapatnam district. A channel will take off from the head sluice on the left flank to irrigate 3,262 hectares. Work on the project costing Rs. 11.19 million was started in 1965 and is likely to be completed during the Fourth Plan.

Vottigedda Project: The project provides for a 2,849.9 m long earthen dam across the Vottigedda, a tributary of the Nagavali near the village of Ravada in the Srikakulam district, and a canal system on either bank to irrigate an area of 6,750 hectares. Taken up for construction in 1966, it is likely to be completed during the Fourth Plan at a cost of Rs. 20.22 million.

Orissa

Dhanei Project: The project, costing Rs. 13.21 million, provides for a 17.7 m high earthen dam across the Dhanei river, a tributary of the Rushikulya, about 1.6 km downstream of the village of Barasingi in the Ganjam district. Canals take off on both banks to irrigate 5,261 hectares. Started in 1959, the project is likely to be completed during the Fourth Plan.

Salia Project: The project envisages an earthen dam 445 m long, 28.2 m high with a chute spillway across the Salia river at Panesudihi in Puri district with canals on either side to irrigate 10,830 hectares in the districts of Puri and Ganjam. The cost of the project is estimated to be Rs. 29.40 million. Taken up for construction in 1960, it is likely to be completed during the Fourth Plan.

Godahado Reservoir Project: The project provides for a 1,667 m long, 29 m. high earthen dam with a masonry spillway across the Godahado river at Bijayanagargarh and a pick-up weir across the Kantaikoli Nalla at Snukra Kholi for irrigating an area of 6,475 hectares annually. The project costing Rs. 19.73 million was taken up for construction in 1960 and is likely to be completed during the Fourth Plan.

Bahuda Project—Stage I: The projects of five diversion weirs, namely (i) at Tarubidi across the Bahuda, (ii) at Kalingadela across the Bahuda, (iii) at Budagoda across the Poichodia, (iv) at Badulia across the Barteda and (v) at Kalna across the Badinala. An inter-connecting canal system will irrigate an area of 9,109 hectares. Taken up for construction in 1962, it is likely to be completed during the Fourth Plan at a cost of Rs. 15.89 million.

Hiradarbhati Project: The project, costing Rs. 3.45 million, envisages an anicut across the river Rushikulya near Athagada in Ganjam district for irrigating an area of 5,307 hectares. Started in 1963, it is expected to be completed during the Fourth Plan.

Baghua Project: The project provides for a 99 m long diversion weir across the river Baghua, a tributary of the Rushikulya river and a left bank canal to irrigate an area of 4,050 hectares in Ganjam district. Costing Rs. 6.80 million, it is likely to be completed during the Fourth Plan.

Some particulars of the major and medium projects under operation and construction in the basin are given in Appendices 4.1 and 4.2.

4.27 Besides the major and medium projects, a number of minor schemes, comprising tanks and wells, irrigate a very large area in the basin. In many villages, there are more tanks than one irrigating adjoining agricultural lands. The details of the area irrigated by the various sources like canals, tanks, tubewells, wells etc. during the year 1967-68, in the basin, are shown in Table 4.7. By the end of the Annual Plan 1968–69, the area under minor schemes increased by about 8,830 hectares.

Data with regard to the average annual quantum of water diverted by the major and medium projects under operation and construction in the basin has been supplied by the Orissa State for the projects lying in its territory. However, for the projects located in the Andhra Pradesh State, no such data is available. On the basis of the data supplied by the Orissa State, a rough assessment of the average annual quantum of water diverted by the major and medium projects under operation and construction in the basin, in Andhra Pradesh has also been made. On completion and full development the major and medium projects under operation and construction in the basin as in 1968-69, utilise about 1,757 m. cu. m.

Table 4.7

Source-wise Irrigation

Sl. No.	Source of irrigation	Area irrigated in thousand hectares		Total area irrigated in thousand hectares
		Andhra Pradesh	Orissa	
1.	Canals	179.1	157.3	336.4
2.	Tanks	243.0	19.3	262.3
3.	Tubewells	3.2	—	3.2
4.	Wells	12.4	2.2	14.6
5.	Other sources	12.6	53.7	66.3
	Total	450.3	232.5	682.8

4.28 Details of the large number of minor schemes comprising tanks, wells and other diversions are not available. Based on the area irrigated from these sources and on rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been made. On completion and full development the minor schemes under operation and construction as in 1968–69 would utilise about 3,788 m. cu. m., excluding reservoir losses.

Reservoir Losses

On the basis of assumptions detailed in para 1.28 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and medium schemes	175 m. cu. m.
(ii) Minor schemes (tanks)	3,227 m. cu. m.
Total	3,402 m. cu. m.

4.30 Thus, on completion and full development, the major, medium and minor projects under operation and construction as in 1968-69 in the basin would use about 8,947 m. cu. m. (including reservoir losses) of which 8,752 m. cu. m. is from surface water and 195 m. cu. m. from ground water.

4.31 There are a number of industries located in the basin round about Kakinada and Visakhapatnam. Details of the water requirements of these industries are not available. The industries located in the basin in the Orissa State are expected to utilise 19 m. cu. m. as estimated by the State Government. The details are given below: *

Table 4.8

Water Requirements of Industries—Orissa

Sl. No.	Group	Name of the industry	Location	Annual requirement of water (m.cu.m.)
1.	Mineral based industries—Metallurgical and Metal based	Ferro Silicon Plant	Rayagada	0.33
		Ferro Manganese Plant	-do-	0.83
2.	Forest & Agricultural based industry	Straw Products Ltd. (Paper Mill)	-do-	8.30
3.	Chemical & Allied industries	Yayasri Chemicals	Ganjam	8.30
			Total	17.76
				Say 18 m.cu.m.

The problem of water pollution in the basin due to discharge of industrial wastes has not been reported so far. However, the problem may arise in the future, and will have to be guarded against.

FUTURE DEVELOPMENT

4.32 Two medium projects, namely the Yeleru Reservoir Project and the Neradi Barrage Project, are proposed to be taken up in the basin in the Fourth Five Year Plan period. Both these projects are in Andhra Pradesh. The available details of these projects are given below.

Yeleru Reservoir Project

The project provides for a dam across the Eluru river in East Godavari district, to irrigate an area of 40,468 hectares. It is expected to cost Rs. 30.00 million.

Neradi Barrage Project

Located in the Vamsadhara basin, the project will irrigate 10,117 hectares at a cost of Rs. 19.40 million.

*Replies of the Orissa State to the Questionnaire issued by the Irrigation Commission.

Some particulars of the projects (p. 110) are given in Appendix 4.3.

On completion and full development, the above projects will utilise about 486 m. cu. m. of water including the reservoir losses.

By the end of Fourth Plan, the area under minor scheme is expected to increase by about 51,260 hectares requiring nearly 1,011 m. cu. m. of water, including reservoir losses.

Thus, the additional utilisation by the Fourth Plan, major, medium and minor schemes would be of the order of 1,497 m. cu. m. benefiting an area of 101,845 hectares. On completion and full development of Fourth Plan projects, about 10.444 m. cu. m. of the water (10,221 m. cu. m. of surface water and 223 m. cu. m. of ground water) in the basin would have been used for irrigating a total area of 669,079 hectares.

The Andhra Pradesh Government has not indicated the projects proposed to be taken up by them in the future in the basin.

The Orissa Government has in view one major and three medium projects to be taken up in the future in the basin. Some details of these projects are given below.

Joro Harbhangi Project

The project envisages a 1,347 m long, 39.6 m high dam across the river Harbhangi in Ganjam district and a canal 28.97 km long. The water stored in the reservoir will be diverted to the Rushikulya valley to irrigate an area of 29,100 hectares. The estimated cost is Rs. 52.70 million.

Ramanadi Project

The project provides for a dam across the Ramanadi river in Ganjam district. Costing Rs. 13.0 million, it will irrigate an area of 5,150 hectares.

Machaghat Project

Located in the Ganjam district, the project provides for a dam across the Dadanala, a tributary of the Laharakhandi. It will irrigate 7,000 hectares annually at a cost of Rs. 18.00 million.

Pipalpankha Project

The project costing Rs. 22.70 million aims at providing irrigation to 18,400 hectares in Ganjam district.

Some particulars of the above projects are given in Appendix 4.4.

The supplies to be utilised by the various new projects proposed by the Orissa Government are given in Table 4.9.

Table 4.9

Utilisation by New Projects—Orissa

Sl. No.	Name of the Project	Supplies proposed to be utilised (m.cu.m.)
1.	Joro Harbhangi	170
2.	Ramanadi	40
3.	Machaghat	54
4.	Pipalpankha	71
	Total	335 m.cu.m.

FLOODS, WATERLOGGING & DRAINAGE

4.33 The occurrence of heavy floods is not a regular feature in the basin. There are, however, occasions when floods do occur and cause some damage to life and property. Large-scale flood control measures neither exist nor seem necessary in the basin.*

Floods in the rivers of the basin are rare, sudden and short-lived.

The highest flood discharges recorded in the Rushikulya and Vamsadhara rivers are 8,495 cumecs and 4,701 cumecs respectively.** In the Rushikulya basin, the deltaic plain is not so wide-spread and the irrigated area is mostly in the erosional plain rather than in the deltaic plain. Here, the marginal lands on either bank of the river are liable to flood and have been protected by embankments.

The rivers in the basin mainly spill over their banks during floods on account of inadequate carrying capacity. Collectively, the rivers present some flood problem by flooding considerable areas in the lower reaches, damaging the existing sources of irrigation, inundating villages and large tracts of cultivated areas and causing damage to roads and bridges.

4.34 So far, waterlogging has not been reported in the irrigated areas in the basin. The coastal region is, however, likely to be affected by salinity and drainage problems for which necessary measures may have to be undertaken.

*Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

**Orissa Decade of Destiny (1963-73)—A plan for integrated development of river basins of Orissa by Dr. A. N. Khosla (1963).

SOIL CONSERVATION

4.35 The problem of soil erosion in the basin is particularly serious in the eastern hills covering parts of Phulbani, Kalahandi, Koraput and Ganjam districts. The tribals in these areas practise shifting cultivation on an extenive scale, which destroys forests and creates conditions of intense soil erosion. Soil erosion also occurs due to certain faulty agricultral practices like ploughing through the contours of unbunded fields. Large-scale unplanned felling and thinning of trees and uncontrolled grazing in the forests also result in soil erosion.

In the basin, a fairly high percentage of area 25.4% is under forests. The soil conservation measures to be taken may be classified under the following heads:

(i) Afforestation in the new areas as well as in existing forests, which have been either denuded or where replacement is needed;
(ii) Terracing and contour bunding and construction of field bunds on agricultural lands, which require treatment;
(iii) Pasture development and protection of marginal and sub-marginal lands;
(iv) Fringe afforestation and stream bank control; and
(v) Construction of check dams, gully plugging etc.

No project in the basin has been included under the centrally sponsored programme of soil conservation in catchments of major river valley projects.

4.36 Data on the silting of reservoirs and tanks in the basin is not available. To conserve the storage capacities of existing and proposed reservoirs, soil conservation measures are necessary and have to be undertaken.

GENERAL

4.37 Some of the river systems in the basin have their catchment areas in more than one State. Of these, the more important are the Vamsadhara and the Nagavali river systems flowing through the States of Orissa and Andhra Pradesh. The two State Governments have entered into an agreement for sharing the waters of the Vamsadhara river. As regards the Nagavali, although a number of projects have already been constructed and many more are under construction on this river system, no agreement exists between the concerned States for the distribution and utilisation of its water.

4.38 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs needs to be established.

4.39 The number of gauge and discharge sites in the basin is far below the minimum requirements. A sufficient number of gauge and discharge sites at representative points on the main rivers and the main tributaries need to be established to assess correctly the water resources of the basin. Gauge and discharge observations at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects but also for the regulation of available river water in any year.

4.40 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with the surface water.

4.41 There is need for inter-State co-operation and agreement in respect of soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

4.42 It is necessary for data to be collected of the sediment carried by the rivers, which would be of considerable use in working out dead storage and life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE GODAVARI BASIN

(*i*) Source: At Trimbak, near Nasik about 80 km. (50 miles) from Arabian Sea.

(*ii*) Length of Godavari river:	Km.	Miles
In Maharashtra	694	431
In Andhra Pradesh	771	479
Total	1,465	910
(*iii*) Drainage area:	Sq. km.	Sq. miles
Andhra Pradesh	73,201	28,263
Madhya Pradesh	65,255	25,195
Mysore	4,405	1,701
Maharashtra	152,199	58,764
Orissa	17,752	6,854
Total	312,812	120,777
(*iv*) Population (1971 Census)		35.46 millions.
(*v*) Density of population	113 per sq. km.	293 per sq. mile.
(*vi*) Maximum discharge	Cumecs	Cusecs
At Dowleiswaram, 1,375 km. (854 miles) from source, on 15th August, 1953	80,137	2,830,000
(*vii*) Minimum discharge: At Dowleiswaram	42	1,500
	m.cu.m.	MAF
(*viii*) Average annual runoff: At Dowleiswaram (As assessed by Krishna-Godavari Commission.)	117,997	95.66
(*ix*) Maximum annual runoff recorded to-date at Dowleiswaram in 1907-1908	165,570	134.23
(*x*) Minimum annual runoff recorded to-date at Dowleiswaram in 1899-1900	12,409	10.06
	Thousand hectares	Thousand acres
(*xi*) Culturable area (1967-68)	18,931	46,780
(*xii*) Net area sown (1967-68)	14,435	35,670
(*xiii*) Gross area sown (1967-68)	15,460	38,203
(*xiv*) Net area irrigated (1967-68)	1,618	3,998
(*xv*) Gross area irrigated (1967-68)	2,005	4,955
(*xvi*) Area irrigated after completion and full development of Fourth Plan projects	4,383	10,831
(*xvii*) Probable additional irrigation by future projects	N.A.	
(*xviii*) Water utilisation including reservoir losses	m.cu.m.	MAF

(*a*) On completion & full development of major, medium & minor projects under operation and construction, in 1968-69	Surface water	32,732	26.53
	Ground water	5,389	4.37
	Total	38,121	30.90
(*b*) On completion and full development of Fourth Plan projects	Surface water	51,477	41.73
	Ground water	7,590	6.15
	Total	59,067	47.88

CHAPTER V

GODAVARI

The Godavari basin extends over an area of 312,812 sq. km. which is nearly 10 per cent of the total geographical area of the country. The basin lies between east longitudes 73°26′ and 83°7′ and north latitudes 16°16′ and 22°36′. The basin lies in the Deccan plateau, and covers large areas in the States of Andhra Pradesh, Madhya Pradesh and Maharashtra, in addition to smaller areas in Mysore and Orissa. The State-wise distribution of the areas is given below:

Table 5.1

Drainage Area—State-wise

Sl. No.	Name of State	Drainage area sq.km.
1	2	3
1.	Andhra Pradesh	73,201
2.	Madhya Pradesh	65,255
3.	Maharashtra	152,199
4.	Mysore	4,405
5.	Orissa	17,752
	TOTAL	312,812

5.2 The Godavari basin is bounded on the north by the Satmala Hills, the Ajanta Range and the Mahadeo Hills, on the south and east by the Eastern Ghats and on the west by the Western Ghats. It is roughly triangular in shape and the main river itself runs practically along the base of the triangle.

Except for the hills forming the watershed around the basin, the entire drainage basin of the river comprises rolling and undulating country—a series of ridges and valley interspersed with low hill ranges. Large flat areas of the type characteristic of the Indo-Gangetic plains are scarce, except in the delta.

The western edge of the basin is an almost unbroken line formed by the Sahyadri range of the Western Ghats, from 600 to 2,100 m. height. It has the heaviest rainfall and the dampest climate in the basin. Hardly 50 to 60 km. east of the ghats lie the sparsely cultivated and undulating plains of the Deccan, with a dry climate.

The interior of the basin is a plateau, the greater part of which is at an elevation of 300 to 600 metre. Its general slope is eastwards. Great undulating plains, divided from each other by flat topped ranges of hills, are the chief characteristics of this plateau. The hill-sides are marked by conspicuous wide terraces except in the southern part where the hills are frequently crowned with great 'tors' or rounded hummocks of bare rock, the result of ages of weathering.

The Eastern Ghats which form the eastern boundary of the peninsula are by no means so well-defined or continuous as the Sahyadri range on the West. They rise from the plains of east Godavari and Visakhapatnam to the level of the table land of Jeypore and are fairly well-defined.

The northern boundary of the basin comprises a series of table-lands varying from 600 to 1,200 metres in elevation, which have withstood the effect of ages of denudation better than the terrain to the north and south of them. To the south, lie great stretches of plain at an elevation of more than 300 m., interspersed with and surrounded by hill ranges, some bare and rocky, but generally covered with forests or scrub jungle.

The delta of the Godavari, formed by deposits at the mouth of the river over the ages, consists of a wide belt of river borne alluvium. The process of silting at the mouth of the river is still continuing and the delta is gradually extending into the sea.

GODAVARI RIVER SYSTEM

5.3 The river Godavari rises in the Nasik district of Maharashtra, about 80 km. from the Arabian Sea, at an elevation of 1,067 m. After flowing for about 1,465 km. in a generally south-east direction, through the Maharashtra and Andhra Pradesh, it falls into the Bay of Bengal.

About 64 km. from its source, the Godavari receives the waters of the Darna, on its right bank and a short distance lower down the Kadwa joins it from the left. The combined waters of the Pravara and the Mula which rise in the hills of Akola join the river about 217 km. from its source. About 338 km. lower down, while still in Maharashtra, the river receives the combined waters of the Purna and Dudna rivers and after a further

138 km. at the border of Maharashtra and Andhra Pradesh the waters of the Manjra river join it from the south. At this point, the Godavari flows at an elevation of about 329 m.

The river Pranhita, conveying the combined waters of the Penganga, the Wardha and the Wainganga, which drain Nagpur and the southern slopes of the Satpura Range, falls into the Godavari about 306 km. below its confluence with the Manjra. Forty-eight km. lower, the waters of the Indravati river from the erstwhile Bastar State join the river. Both the Pranhita and the Indravati are major rivers in their own right. The last major tributary is the Sabari from Orissa which falls into the Godavari, 100 km. above Rajahmundry.

The Godavari drains an area of about 313,000 sq. km. The main catchments are in its upper reaches with relatively smaller catchment in the Western Ghats, the Mahadeo Hills, the Maikal Range and the hills in the south of Orissa.

5.4 The Pravara, the Purna, the Manjra, the Pranhita, the Indravati and the Sabari are Godavari's principal tributaries.

The Pravara rises in the Western Ghats at an altitude of about 1,067 m. and flowing in an easterly direction for about 200 km., the Pravara falls into the Godavari, about 10 km. north of Newasa, at an altitude of about 457 m. About 177 km. from its source, it receives the waters of the Mula river from its right. The Mula also rises in the Western Ghats south of the Pravara. The Pravara has a drainage area of 6,537 sq. km. lying entirely in Maharashtra, but its principal source of supply is only about 32 km. length of the Western Ghats.

The Purna rises in the Ajanta Range of hills at an altitude of 838 m. and flows in a south-easterly direction for a length of 373 km. before joining the Godavari at an elevation of about 351 m., 64 km. upstream of Nanded. Of its tributaries, the longest is the Dudna. The total catchment area of 15,579 sq. km. of the Purna and its tributaries lies in a relatively low rainfall zone which gets 711 mm. to 889 mm. of rain in the year.

The Manjra rises in the Balaghat Range of hills in the Bhir district of Maharashtra at an altitude of about 823 m. and flows in a general east-south-east direction for 515 km. through Maharashtra, Mysore and Andhra Pradesh. Beyond Sangareddipet, it continues to flow northward, to join the Godavari. The total length of the river from the source to its confluence with the Godavari at an altitude of 323 m., is about 724 km.

The principal tributaries of the Manjra are the Tirna, the Karanga and the Haldi which join it from the right, and the Lendi and the Maner which join it from the left. The Manjra and its tributaries have a total catchment area of 30,844 sq. km. lying in a zone which gets about 635 mm. of rain annually in the upper and of about 1,916 mm. in the lower reaches.

The Pranhita with its three principal branches, the Penganga, the Wardha and the Wainganga, is the most important tributary of the Godavari.

The Penganga rises at an altitude of 686 m. in the Buldana Range in Maharashtra and, after flowing for a length of 676 km. in a generally east-south-east direction, joins the river Wardha at an elevation of 174 m. Except in its uppermost reaches covering about 161 km. in which the terrain is barren and hilly, the river passes through the dense forests of Yeotmal and Nanded districts. The Kiadoh joins the Penganga from the right and the Pus, the Arna, the Aran and the Waghari join from the left. The total area drained by the Penganga and its tributaries is 23,898 sq. km.

The Wardha rises at an altitude of 777 m. in the Betul district of Madhya Pradesh and enters Maharashtra about 32 km. from its source. After flowing for a distance of 483 km., in a generally south-easterly direction, it joins the Wainganga at an elevation of 146 m. The major tributaries of the Wardha are the Wunna from the left and the Bembla and the Penganga from the right. The Wardha drains an area of 24,087 sq. km. and throughout its course the river flows through dense forests.

The Wainganga, rising at an altitude of 640 m. in the Seoni district of Madhya Pradesh, flows north for a short distance, then east and finally south to form a great loop. After flowing for a total length of 274 km. in Madhya Pradesh, it forms the boundary between Madhya Pradesh and Maharashtra for about 32 km. It then flows due south for another 303 km. to join the Wardha. The major tributaries of the Wainganga are the Pench and the Kanhar from the right and the Bagh and the Andhari from the left. The Wainganga and its tributaries drain an area of 61,093 sq. km.

The combined waters of the Wainganga and the Wardha, called the Pranhita, flow for 113 km. along the border between Maharashtra and Andhra Pradesh before falling into the Godavari at an elevation of 107 m.

The catchment area of the Pranhita and of all its branches is 109,077 sq. km. and lies in a medium rainfall zone of 889 mm. to 1,600 mm. (annual).

The Indravati rises at an altitude of 914 m. in the Kalahandi distrct of Orissa on the western slopes of the Eastern Ghats. It flows westward through the Koraput district of Orissa and the Bastar district of Madhya Pradesh, turns south at about 531 km. from its source and joins the Godavari, at an elevation of about 82 m. Its important tributaries are the Narangi, the Baordhig, the Kotri and the Bandia on the right and the Nandira (Berudi) on the left. The Indravati and its tributaries drain an area of 41,665 sq. km., lying in a relatively high rainfall zone with about 1,524 mm. of rain annually.

The Sabari or the Kolab, is the last major tributary of the Godavari. It rises at an altitude of 1,372 m. in the Sinkaram hill range of the Eatern Ghats and flows for short distances in a north, north-westerly and westerly direction to turn south and join the Godavari, about 418 km. from its source, at an altitude of 25 m. The Sileru also called the Machkund, its most important tributary, rises at an elevation of 1,219 m. and flows for a length of about 306 km. before joining the Sabari, at an elevation of 41 m, 34 km. above the confluence of the Sabari with the Godavari. The total catchment area of the Sabari and its tributaries is 20,427 sq. km. lying in a relatively high rainfall zone with about 1,397 mm. to 1,778 mm. of rain annually.

5.5 Areas in the sub-basins and of the tributaries, their percentage to the total area of the Godavari basin are given in Table 5.2.

Table 5.2

Drainage Area of the Godavari and Its Tributaries

Sl. No.	Name of the sub-basin	Area (sq.km.)	Percentage of Godavari basin
1	2	3	4
1.	Upper Godavari (from the source to its confluence with the Manjra)	33,502	10.71
2.	Pravara	6,537	2.09
3.	Purna	15,579	4.98
4.	Manjra	30,844	9.86
5.	Middle Godavari (from its confluence with the Manjra to its confluence with the Pranhita)	17,205	5.50
6.	Maner	13,106	4.19
7.	Penganga	23,898	7.64
8.	Wardha	24,087	7.70
9.	Pranhita	61,093	19.53
10.	Lower Godavari (from its confluence with the Pranhita to the sea)	24,869	7.95
11.	Indravati	41,665	13.32
12.	Sabari	20,427	6.53
	Total	312,812	100.00

CLIMATE

5.6 Four distinct seasons occur in the Godavari basin, viz: (i) the cold weather; (ii) the hot weather; (iii) the south-west monsoon and (iv) the post-monsoon.

The cold weather season in the entire basin, from mid-October to mid-February is generally pleasant, the western and the north-eastern regions being colder than the rest of the basin.

In the hot weather, the heat is unbearable in the central, northern and eastern regions. The weather is comparatively hotter in the westernmost parts of the basin.

The south-west monsoon sets in by mid-June and ends by mid-October. During this period, the basin receives about 88% of its total annual rainfall.

After the withdrawal of the south-west monsoon in the middle of October, the weather gradually improves and becomes cool and pleasant.

Rainfall

5.7 The Godavari basin receives its maximum rainfall during the south-west monsoon. The monsoon currents strike the west coast of the peninsula from the west and south-west, meet the Western Ghats or Sahyadri Range which present almost an uninterrupted barrier ranging from 610 m. to 2,134 m. in height. Before surmounting this barrier the currents deposit most of their moisture on its windward side, and then sweep across the interior of the peninsula on a westerly course. Rainfall is governed largely by the orography of the area, which leads to variations in the amount of precipitation. In crossing the Ghats, the monsoon winds lose a large part of their moisture. The monsoon currents follow the eastward slope of the country from the crest of the Ghats which form the water shed. Conditions in the interior are therefore somewhat unfavourable for heavy precipitation except in association with the depressions from the Bay of Bengal. The north-east part of the Godavari basin also receives some rain in association with monsoon depressions, which move west-north-west across the Orissa coast.

The Godavari river receives the drainage from a length of about 129 km. of the high rainfall zone in the Western Ghats. The annual rainfall varies from 3,000 mm. to 1,000 mm. in this reach.

East of the Western Ghats, the annual rainfall decreases rapidly to less than 600 mm. along a line running approximately from Chitradurga through Sangli and Poona to a point north-east of the line connecting Kurnool, Raichur, Bijapur and Ahmednagar. East of this line the rainfall again gradually increases to about 900 mm. in and around Guntur.

There is a belt, some distance east of the Western Ghats and in width varying from about 80 km. in the south to about 97 km. in the north, with less than 600 mm., the normal annual rainfall. This belt which is about 10,360 sq. km. in area, includes portions of the Aurangabad and Ahmednagar districts of Maharashtra.

January and February are almost entirely dry in the Godavari basin, the rainfall during these two months being less than 15 mm. During the next three months, up to end of May, it varies from 20 mm. to about 50 mm., in most parts of the basin.

5.8 All parts of the basin receive the maximum rainfall in the period from June to September. The annual average rainfall in the various sub-basins of the Godavari basin are given in Table 5.3 seasonwise.*

Table 5.3

Average Annual Rainfall in the Godavari Basin Sub-basinwise

Sl. No.	Name of sub-basin	Rainfall in mm.				
		Jan.-Feb.	Mar.-May	June-Sep.	Oct.-Dec.	Annual
1	2	3	4	5	6	7
1.	Upper Godavari (from the source to its confluence with the Manjra)	12	28	645	85	770
2.	Pravara	6	26	476	98	606
3.	Purna	15	32	660	90	797
4.	Manjra	16	47	696	87	846
5.	Middle Godavari (from its confluence with Manjra to its confluence with the Pranhita)	25	45	809	76	955
6.	Maner	24	56	762	90	932
7.	Penganga	25	39	819	77	960
8.	Wardha	31	40	907	77	1,055
9.	Pranhita	41	45	1,196	81	1,363
10.	Lower Godavari (from its confluence with the Pranhita to the sea)	20	88	929	171	1,208
11.	Indravati	27	85	1,366	110	1,588
12.	Sabari	14	125	1,137	157	1,433
	Godavari basin	25	56	953	98	11,32

*Report of the Krishna-Godavari Commission (July, 1962).

The actual rainfall varies widely from year to year. There are also variations in the incidence and distribution of rainfall in time and space. These variations have an important bearing on river flows and agricultural operations. Studies carried out by the India Meteorological Department indicate that there is considerable variation not only in the dates of the onset and withdrawal of the monsoon but also in the speed with which the monsoon currents move from Kerala towards Bombay and across the peninsula. The normal deviation for the west coast is about five to six days. In some particular years, however, the monsoon has been known to break on the west coast as many as 19 days earlier or 13 days later than the mean date.

The rainfall variations in different months and different years are as important as the dates of the onset of the south-west monsoon. This variation is generally denoted by calculating the 'co-efficient of variability' for any given area and given period. The formula expressing the co-efficient of variability is $\frac{S.D.}{X} \times 100$, where S.D. is standard deviation and x is the arithmetic mean. The standard deviation of a given set of values is the mean square root of the deviations of individual values from their arithmetic mean. If S.D. denotes standard deviation for n values of x and $\bar{x}$ is their arithmetic mean, then

$$S.D. = \sqrt{\frac{(x-\bar{x})^2}{n}}$$

In other words, standard deviation is an overall measure of the dispersion of individual values on both sides of the arithmetic mean, the more compact the cluster, the smaller the standard deviation and the more frequent the deviations of a large magnitude, the larger the standard deviation.

5.9 The co-efficients of variability of monthly rainfall for different meteorological sub-divisions as worked out by the IMD are shown in Table 5.4.*

Table 5.4

Co-efficient of Variability

Sl. No.	Name of sub-division	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Bombay Deccan	215	175	144	71	76	33	30	37	39	61	101	200
2.	Berar	173	170	203	169	143	43	34	46	53	108	140	267
3.	Central Provinces (East)	111	99	138	137	110	73	38	37	58	126	161	191
4.	Hyderabad (North)	251	167	163	61	97	35	25	41	40	71	120	204

A co-efficient of variability of 267 during the month of December for Berar indicates that the magnitude of standard deviation would be one-fourth of the mean rainfall of the month.

*Report of the Krishna-Godavari Commission (July, 1962).

A closer examination of the figures in the above table would show that the co-efficient of variability for the north-east monsoon (October to December) is considerably larger than that for the south-west monsoon (June to September). This lends support to the view that the north-east monsoon is much less dependable than the south-west monsoon and that agriculture and river flows dependent on the former would be more precarious than those dependent on the latter. It will be noticed, also, that the rainfall from December to May cannot be generally depended on for agricultural operations.

Temperature

5.10 The Godavari basin has a tropical climate. The mean annual surface temperature in the Western Ghat area is about 24°C; it increases gradually towards the east and attains a maximum of 29.4°C on the east coast.

During January, which may be taken as a typical winter month, the mean daily minimum temperature going from west to east, increases from 15°C, on the Western Ghats to about 18°C on the east coast; the mean daily maximum temperature generally exceeds 30°C in the western part of the Godavari basin and is only slightly less than 30°C in the eastern part. The daily maximum and the daily minimum temperatures are considerably higher than in North India.

Maximum and minimum temperatures in the basin gradually increase as we move from west to east. They are highest in April, which is a typical summer month. The maximum increases from 35°C in the west to 40°C in the middle of the plateau, though it goes down again to 35°C on the east coast. The minimum increases from 22°C in the west to 26°C in the east coast.

During July, which is a typical monsoon month, the minimum increases from 20°C in the Western Ghats to 26°C near the east coast and the maximum increases from 27°C in the Western Ghats to 33°C near the east coast. During October, which is a typical post-monsoon month, the minimum temperature is 20°C in most parts of the basin though it increases to about 23°C near the coast. The mean daily maximum temperature is a little above 39°C over the entire basin.

Evaporation

5.11 Unfortunately very meagre data on evaporation is available for the Godavari basin. The IMD has compiled the evaporation data in respect of 30 departmental and 42 agro-meteorological observatories spread all over India and having data for more than five years. Observations at all these observatories are taken with the standard U.S. Evaporation Pan (Class A) covered with wire-mesh. Of these observatories, three departmental and 12 agro-meteorological observatories are located in the Godavari basin and adjoining areas.* For the departmental observatories the data pertains to the period 1959–1968 and is available month-wise, whereas the data for the agro-meteorological observatories pertains to the period 1961–1968 and has been presented for the 12 periods into which the calendar year is divided for agro-meteorological purposes. The monthly evaporation losses from reservoirs as assumed in the different parts of the Godavari basin are given in Table 5.5.†

Table 5.5

Monthly Evaporation Losses Assumed in the Godavari Basin

Sl. No.	Particulars	Evaporation (cm)												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Andhra Pradesh													
1.	Small reservoirs in Andhra region	10	10	18	23	25	18	15	15	15	13	10	10	182
2.	Nizamsagar	13	10	13	15	20	15	18	18	20	15	15	8	180
3.	Pochampad—Stage I	10	10	23	31	31	23	15	15	15	15	10	10	208
4.	Ippur (Proposed)	10	10	23	31	31	23	15	15	15	15	10	10	208
5.	Inchampalli (Proposed)	10	10	18	23	26	18	15	15	15	15	10	10	185
	Madhya Pradesh													
6.	All works	13	15	18	25	30	25	5	5	5	15	13	13	182
	Maharashtra													
7.	Itiadoh	Month-wise break-up not available												244
8.	Bagh		"		"	"	"							244
9.	Jayakwadi—Stage I	13	15	28	36	33	25	20	18	18	15	13	10	244
10.	Upper Penganga—Stage I	Month-wise break-up not available												229
					Hot-weather			Kharif			Rabi			
11.	Upper Godavari				122			76			46			244
12.	Lendi				112			71			46			229
13.	Manjra				112			71			46			229
	Orissa													
14.	All works	10	10	18	23	25	18	15	15	15	13	10	10	182

SOILS

5.12 No systematic soil survey of the Godavari basin has been carried out so far. The general data regarding soils of India, however, indicate that the basin consists mainly of (i) black soils (regur), (ii) red soils, (iii) laterites and lateritic soils, (iv) alluvium, (v) mixed soils and (vi) saline and alkaline soils.

*Evaporation Data (India), India Meteorological Department (April, 1970).
†Report of the Krishna-Godavari Commission (July, 1962).

The principal soil types found in the various districts in the basin are shown in Table 5.6.*

Table 5.6

Soils in the Godavari Basin—Districtwise

Sl. No.	Name of State/District	Type of Soil
1	2	3
	Andhra Pradesh	
1.	Adilabad	Medium and deep black and mixed red and black.
2.	East Godavari	Red loamy, red sandy, laterite and deltaic alluvium.
3.	Hyderabad	Red and shallow black.
4.	Karimnagar	Red sandy and deep black.
5.	Khammam	Sandy loam, clayey loam and loam.
6.	Medak	Shallow black, and red.
7.	Nizamabad	Medium and deep black.
8.	Vishkhapatnam	Red loamy, red sandy and coastal alluvium.
9.	Warangal	Red sandy, red loamy and deep black.
10.	West Godavari	Red sandy, mixed red and black and coastal alluvium.
	Madhya Pradesh	
11.	Balaghat	Red loamy, red and yellow and shallow black.
12.	Bastar	Red loamy and red and yellow.
13.	Chhindwara	Shallow black and skeletal.
14.	Durg	Red loamy and red and yellow.
15.	Mandla	Red and yellow, shallow black and skeletal.
16.	Raipur	Red and yellow.
17.	Seoni	Shallow black and skeletal.
	Maharashtra	
18.	Ahmednagar	Black, red and grey or white.
19.	Akola	Medium black.
20.	Amravati	Medium black.
21.	Aurangabad	Medium and deep black.
22.	Bhandara	Red loamy.
23.	Bhir	Shallow and medium black.
24.	Buldana	Medium black.

*Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, Community Development & Cooperation (1967).

Table 5.6—Contd.

1	2	3
25.	Chanda	Red loamy and medium black.
26.	Jalgaon	Medium and deep black.
27.	Nanded	Medium and deep black
28.	Nasik	Medium and deep black.
29.	Osmanabad	Medium black and shallow reddish brown soils.
30.	Parbhani	Medium and deep black.
31.	Poona	Black or medium black, red and coarse grey.
32.	Nagpur	Shallow and medium black.
33.	Sholapur	Medium and deep black.
34.	Wardha	Medium black.
35.	Yeotmal	Medium black and mixed red and black.
	Mysore	
36.	Bidar	Red, sandy, laterite and medium black.
	Orissa	
37.	Kalahandi	Red loamy and red and yellow.
38.	Koraput	Red loamy.

LAND USE AND AGRICULTURAL PRACTICES

5.13 State-wise land use details in the basin, as in 1967–68, the latest year for which the statistics are available, are given in Table 5.7.

Table 5.7

Land Use Details in the Godavari Basin

(Thousand hectares)

Sl. No.	Classification	Name of the State					
		Andhra Pradesh	Madhya Pradesh	Maha-rashtra	Mysore	Orissa	Total
1	2	3	4	5	6	7	8
1.	Gross area	7,320	6,525	15,220	441	1,775	31,281
2.	Reporting area	7,107	6,519	14,964	438	1,756	30,784
3.	Area under forests	2,087	3,723	2,899	7	403	9,119
4.	Area not available for cultivation	981	357	947	29	420	2,734

Table 5.7—Contd.

1	2	3	4	5	6	7	8
5.	Culturable area	4,039	2,439	11,118	402	933	18,931
6.	Uncultivated culturable area	1,297	712	2,041	106	340	4,496
7.	Net area sown	2,742	1,727	9,077	296	953	14,435
8.	Area sown more than once	264	184	491	33	53	1,025
9.	Total cropped area	3,006	1,911	9,568	329	646	15,460
10.	Net area irrigated	758	133	671	8	48	1,618
11.	Gross area irrigated	932	133	918	9	13	2,005
12.	Percentage of net area sown to culturable area	67.9	70.8	81.6	73.6	63.6	76.3
13.	Percentage of net area irrigated to culturable area	18.8	5.4	6.0	2.1	5.1	8.6
14.	Percentage of net area irrigated to net area sown	27.6	7.7	7.4	2.8	8.1	11.2

The area shown under forests is not necessarily all wooded as some areas classed as forests were denuded and have not been re-planted. The original classification, however, continues.

The culturable area in the basin is about 9.7% of the total culturable area of the country, but the total cropped area in the basin is about 9.5% of the total cropped area in the country.

Area under irrigated crops is about 11.2% of the cropped area. Its classification in 1967–68 is shown in Table 5.8.

Table 5.8

Area Irrigated—Source-wise

(Thousand hectares)

Sl. No.	Source of irrigation	Area in the State of					Total area
		Andhra Pradesh	Madhya Pradesh	Maha-rashtra	Mysore	Orissa	
1	2	3	4	5	6	7	8
1.	Canals	289.3	62.2	104.6	—	14.5	470.6
2.	Tanks	350.2	42.7	211.2	0.7	4.0	608.8
3.	Tubewells	9.1	—	—	—	—	9.1
4.	Wells	83.2	19.6	344.2	7.1	0.8	454.9
5.	Other sources	25.9	8.2	11.1	0.5	28.7	74.4
	Total	757.7	132.7	671.1	8.3	48.0	1,617.8

A large portion of the irrigated area is irrigated by tanks, wells and other sources, canal irrigation being largely confined to the delta.

5.13 The general cropping pattern, State-wise is described below:

Andhra Pradesh

Of the gross irrigated area of nearly 932 thousand hectares about 84.2% is under paddy and about 3.6% under maize. On 46,200 hectares, sugarcane is grown. Other irrigated crops are jowar, bajra, wheat, ragi, millets, condiments, spices, groundnut, sesamum, cotton, tobacco and fodder crops.

Food and non-food crops cover about 97.2% and 2.8% of the irrigated cropped area respectively.

Madhya Pradesh

Of the gross irrigated area of 133 thousand hectares, about 82.2% is under paddy and 5.3% under wheat. On 4,200 hectares sugarcane is grown. Other irrigated crops are maize, barley, gram, tur, fruits, vegetables, rape, mustard, linseed, cotton, tobacco and fodder crops.

Food and non-food crops cover about 99.7% and 0.3% of the irrigated cropped area respectively.

Maharashtra

Of the gross irrigated area of 918 thousand hectares, nearly 27.5% is under paddy, 12.3% under jowar, 7.7% under wheat and 1.1% under bajra. On 51,800 hectares sugarcane is grown. Other irrigated crops are maize, barley, gram, tur, condiments, spices, groundnut, sesamum, cotton, tobacco and fodder crops.

Food and non-food crops cover about 92.2% and 7.8% of the irrigated area respectively.

Mysore

Of the gross irrigated area of 8,800 hectares, nearly 12.5% is under paddy, 11.4% under wheat and 3.4% under jowar. About 4,100 hectares of sugarcane is grown. Other irrigated crops are maize and millets.

Food crops cover the entire irrigated area.

Orissa

The latest crop-wise statistics of the irrigated area are available only for the year 1956–57, which indicate that about 60.8% is under paddy, 1.6% under sugarcane and 0.8% under wheat.

Food crops represent about 64.8% of the irrigated cropped area; the balance of 35.2% being under non-food crops.

Summing up, of the total irrigated area in the basin, 57.7% is under paddy, 5.3% under sugarcane, 5.7% under jowar, 3.9% under wheat and the rest under miscellaneous crops.

Because of the relatively equable temperatures in the basin, crop seasons are not so well defined as in north India. By and large, the sowing of crops and other agricultural operations are determined by the timing of rainfall and the availability of river water which, in turn, also depend on the incidence of rainfall.

In western Maharashtra, there are three official irrigation seasons, namely (i) kharif, from the 15th June to the 14th October, (ii) rabi, from the 15th October to the 14th February and (iii) hot weather from the 15th February to the 14th June. The growth of many crops, however, covers more than one season; jowar is grown both in kharif and rabi and cotton and groundnut can be grown in all the three seasons, if irrigation supplies are available.

In Vidarbha, Madhya Pradesh and Orissa, there is generally only one crop which is sown about the beginning of July immediately after the rains begin. The un-irrigated areas generally bear a short-term crop which is harvested by October, and the irrigated areas a long-term crop which is harvested in November-December. In some areas, a rabi crop follows.

In Andhra Pradesh and most of Mysore, the crop season begins with the advent of the rains in June. The unirrigated crops are harvested in October but the irrigated paddy is not harvested until about December. If irrigation waters are available, another paddy crop follows which is sown in January-February and harvested in April-May. Paddy can, however, be grown almost the year round. Paddy, in all stages of growth, can be seen at the same time in the same locality. Such fields as cannot be sown in July and August, are sown during the September rains.

In general, paddy, cotton and groundnut can be grown throughout the year in the basin, provided irrigation supplies are available. Cotton is almost entirely an unirrigated crop; the variety grown is short-staple cotton requires sufficient moisture during the early stages of its growth and comparatively drier conditions during the flowering and maturing stages; rainfall during the ball opening and harvesting period is definitely harmful. Long-staple variety of cotton takes a relatively longer crop period and, therefore, needs some irrigation supplies in addition to rainfall. These varieties give a relatively large yield and, in suitable soil with sufficient drainage, long-staple cotton can be a good cash crop. Like cotton, groundnut is also grown mainly as a rainfed crop. The average yield of the 'spreading' varieties grown under these conditions is 1,344–

1,569 kg. per hectare and that of the 'bunch' varieties 896–1,120 kg. per hectare. With a relatively small quantity of irrigation water, groundnut, a valuable cash crop, can be made to give 3,361 kg. or more per hectare.

REGIONAL ECONOMY

Population

5.14 On the basis of the 1971 Census,* and the percentage of the area of each district, within the basin, to the district as a whole, the total population in the basin works out to about 35.46 millions. State-wise distribution is given in Table 5.9.

Table 5.9

Population in the Godavari Basin

Sl. No.	State	Population (million)
1	2	3
1.	Andhra Pradesh	10.83
2.	Madhya Pradesh	3.98
3.	Maharashtra	18.56
4.	Mysore	0.66
5.	Orissa	1.43
	Total	35.46

5.15 There are only seven cities in the basin with a population of more than one lakh each. They are, Rajahmundry and Warangal in Andhra Pradesh and Ahmednagar, Akola, Amravati, Nagpur and Nasik in Maharashtra. The density of population varies from region to region. For the basin as a whole it is 113 persons per sq. km. The coastal plain is the most densely populated while the hilly areas have a low density. In 1971 the district of Hyderabad, the most densely populated area, had 362 persons per sq. km. while the hilly district of Bastar with 39 persons per sq. km. stood at the other extremity. The composition of the population in hilly areas is somewhat different from that in other areas of the basin. It has a relatively larger component of persons belonging to the scheduled tribes. The tribal people, who form a distinct ethnic group, have lived for centuries in forests isolated from the main stream of social and economic life. They are economically backward and depend for

*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

their livelihood mainly on forests and shifting cultivation or a primitive form of settled agriculture in the forests. They have little of industrial activity even on a cottage scale. They are strongly attached to their own culture and traditions, which has made them less responsive to the change taking place around them.

85.5 per cent of the population in the basin live in rural areas and the balance of 14.5 per cent in cities and towns. The working force (comprising the Census categories of self-supporting persons and earning dependents), constitutes about 37.3 per cent of the population. Nearly 40.2 per cent of the working force is engaged as cultivators, 30.0 per cent as agricultural labourers and the balance of 29.8 per cent in mining, manufacturing and tertiary activities.

Forests and Agriculture

5.16 Forests and agriculture are the main stay of the people. A large part of the basin covering 9.12 million hectares out of a total area of about 31 consists of forests. The north-eastern part of the basin in Andhra Pradesh, Madhya Pradesh and Orissa is particularly rich in forests, but this potential is largely undeveloped. Lack of communications in the area is one reason for the low level of exploitation of forest wealth. The area annually cropped in the Godavari basin is about 15 million hectares. Agriculture is generally rain-fed with relatively low yields, except for about 2.0 million hectares of irrigated area of which 1.16 million hectares grow paddy.

Power

5.17 The development of power in the basin has not so far taken place on a large scale. The hydroelectric survey conducted by the Central Water and Power Commission indicates the total hydro potential of the Godavari basin as 6,210.4 MW at 60 per cent load factor. Against this, the installed capacity of the hydroelectric stations in operation and under construction in the basin is 1,329.75 MW. The installed capacity of the thermal generating plants in operation and under construction is 1,662.50 MW. Project-wise details are given in Table 5.10.

Mineral Wealth

5.18 The basin has a rich variety of mineral wealth spread over vast areas. The occurrence of minerals is intimately connected with the geologic formations of the areas. The principal minerals found are listed below: *

*Techno-Economic Surveys of Orissa, Madhya Pradesh and Mysore, NCAER.

Table 5.10

Power Projects in the Godavari Basin

Sl. No.	Name of State/Project	Installed capacity in MW	
		Hydro	Thermal
1	2	3	4
	Andhra Pradesh		
1.	Machkund	114.75	—
2.	Balimela (jointly with Orissa)	480.00	—
3.	Upper Sileru	120.00	—
4.	Lower Sileru	600.00	—
5.	Nizamsagar	15.00	—
6.	Ramagundam	—	100.00
7.	Kothagudam	—	460.00
	Maharashtra		
8.	Balharshah	—	52.50
9.	Khaperkheda	—	120.00
10.	Nagpur	—	480.00
11.	Nasik	—	390.00
12.	Parli	—	60.00
	Total	1,329.75	1,662.50

Bauxite: In Balaghat district of Madhya Pradesh.

Manganese: In Visakhapatnam district of Andhra Pradesh, the Bhandara district of Maharashtra and the Koraput district of Orissa.

Iron Ore: In the Khammam district of Andhra Pradesh.

Coal: In the Khammam district of Andhra Pradesh, the Chhindwara district of Madhya Pradesh and the Chanda district of Maharashtra.

Other minerals like lead, zinc, corundum, ilmenites refractory minerals and kaolin are also found in small quantities in different parts of the basin.

Industries

5.19 Rich in forests, agricultural and mineral resources, the industrial potential of the Godavari basin is high. There is also a large undeveloped hydro-power potential. Present development is only a modest utilisation of the large potential awaiting development in the area.

A small part of the enormous forest wealth of the basin is at present utilised as timber and in the manufacture of paper and other timber products in the districts of Adilabad and East Godavari of Andhra Pradesh, Bastar of Madhya Pradesh and Chanda of Maharashtra.

Industries based on agricultural produce are the processing of agricultural commodities like rice milling, cotton ginning, pressing, spinning and weaving, manufacture of sugar, manufacture of textiles, extraction of oil from groundnut and other oil seeds.

Mining of manganese, coal and other ores are important activities in the districts rich in minerals. Most of the ores are at present being exported. Small engineering industries are spread all over the area.

Cement is manufactured in the Adilabad district.

Communications

5.20 Generally speaking a major portion of the basin has poor communications. The basin is served by the Central and South-Eastern Railways. The main line connecting Bombay and Calcutta passes through its upper reaches, and the main Madras-Calcutta line passes through it just above the delta. There are some branch lines partly or wholly in the basin viz., the Itarsi-Nagpur line, the Jalgaon-Wardha line, the Wardha-Warangal line, the Warangal-Hyderabad line and the Nagpur-Wardha line, which serve towns in the important industrial and coal belts. Some of the prominent towns served are, Akola, Bhandara, Chanda, Nagpur, Nasik, Warangal and Wardha.

Six National Highways, namely (i) Varanasi-Kanniyakumari, (ii) Madras-Calcutta, (iii) Bombay-Nagpur, (iv) Nagpur-Calcutta, (v) Bombay-Hyderabad and (vi) Bombay-Agra, traverse the basin. In addition, there is a network of road communications connecting important towns and villages. The Indravati and Sabari sub-basins have poor communication facilities.

The navigable waterway of the Godavari system comprises the Godavari river and its tributary, the Sabari, the delta arms, namely the Gowtami, the Vasista, the Vynatheyam and a network of irrigation-cum-navigation canals in the delta.

The Godavari is navigable throughout the year by country boats of a maximum capacity of 40.6 tonnes, up to Venkatapuram and by small streamers up to Bhadrachallam.* There is a by-pass canal 3.6 km. long, with locks on either end at the Dumagodam anicut located about 177 km. above the Dowlaiswaram anicut to avoid dangerous rapids. At Dowlaiswaram there is no lock in the anicut for the passage of boats. Navigation from the upper reaches of the Dowlaiswaram anicut is routed through

*Navigable waterways of India, CW & PC (1961) the delta canals, which are connected with the tidal reaches of the Godavari and its tributaries. The total length of these canals is about 789 km.

After the Dowlaiswaram anicut, the Godavari bifurcates into the Gowtami and the Vasista channels which are navigable by large boats and power craft in their tidal reaches. The Gowtami is navigable for about 27 km. from the sea to a point 37 km. below the Dowlaiswaram anicut. The Vasista is navigable for about 43 km. from the sea up to a point about 45 km. below the Dowlaiswaram anicut. The Vynatheyam, a branch of the Vasista is navigable by large boats and power craft for 26 km. from the sea up to the Gannavaram aqueduct located about 5 km. below the point where it branches off from the Vasista.

The Sabari is navigable by small boats up to Konta only during the period from July to February.

Dependence on Rainfall and Water Resources

5.21 The economy of the basin at present largely depends on agriculture which, in view of the uneven incidence of the rainfall, provides a low level of subsistence, except for small parts of the basin where irrigation has been provided. These areas are also the seat of industries based on agricultural produce. For these reasons, there is a keen demand in the basin for the development of water resources.

WATER RESOURCES

Surface Water

5.22 The water potential of the Godavari river system has been assessed at different times by different authorities. The very first assessment was made by the First Irrigation Commission. This Commission used past records of the surface flow of the Godavari from the greater part of its catchment covering a number of years to estimate the average flow. It assessed the total annual surface flow in the Godavari river system to be 1,16,665 m. cu. m.*

In 1949 when the assessment of the basin-wise water resources of the country was worked out on the basis of Khosla's formula, the annual run-off of the Godavari river system was estimated to be 1,25,519 m. cu. m.**

In 1960 when the irrigation potential studies of the country were com-

*Report of the First Irrigation Commission

**An appraisal of water resources by Dr. A.N, Khosla, UNESCO.

pleted by the Central Water & Power Commission, the total annual run-off of the Godavari system was assessed at 1,15,355 m. cu. m.*

The Krishna-Godavari Commission set up by the Government of India, estimated the average annual yields for sub-basins, and reported in July/August 1962 that the aggregate yield of the Godavari system is 1,31,108 m. cu. m. Out of this a deduction of 10 per cent was made for losses in the reach below the Manjra confluence, which gave a figure of 1,17,997 m. cu. m. as the total yield from the catchment.†

5.23 Until 1964 no planned or systematic observation of discharges was done on the Godavari and its tributaries. Some ad hoc observations were being made on the main river and on a number of tributaries. The only systematic records pertain to existing anicuts or reservoirs where river flows were generally calculated on the basis of gauge readings observed from different parts of the works. The Krishna-Godavari Commission went into this question in great detail. After a study of the available data of the 44 sites in the Godavari system, the Commission concluded that regular observations were being done at 29 sites only. Observations at the remaining sites had either been discontinuous or had been made irregularly. Of the 29 sites where regular observations were being made, the data for a period of 10 years or more was available for 18 sites and for a period of 20 years or more, for only 7 sites, namely, Nandur Madhmeshwar and Dowlaishwaram on the Godavari, Lake Beale on the Darna, Palkhed on the Kadwa, Waghad on the Kolwan, Ozer on the Pravara and Nizamsagar on the Manjra.

Based on the data of 44 sites before them, the Krishna-Godavari Commission made the following observations regarding the general features of the flows in the Godavari and its tributaries.

"The Godavari and its tributaries generally start rising after the onset of the south-west monsoon in the month of June. The river flow is maximum during the months of July and August. The volume of flow in these two months is 40 to 75 per cent of the annual flow. In September, the flow varies from 15 to 35 per cent of the annual flow. The flow declines sharply in the month of October and varies from 5 to 15 per cent of the annual flow.

In general, the volume of flow during the months June to November is about 90 to 100 per cent of the annual flow."

5.24 The Commission found that the method of gauging flows was faulty and in particular, the defects were:

*Report of Technological possibilities of Irrigation projects in India, CW & PC (unpublished).

†Report of the Krishna-Godavari Commission (July, 1962).

(i) that in most cases, outdated, rough and ready methods were still in use and no advantage appeared to have been taken of modern standards for discharge observations and the estimation of river-flows;

(ii) that the records of observations had not, in many cases, been properly maintained which added to the difficulty of assessing their reliability;

(iii) that at some sites, with erodible beds, river discharges were computed on the basis of daily, or even more frequent, velocity observations by floats, but the cross-section was taken only once a year or even once in 3–5 years. At other places, the slope-area method was used, but a uniform slope was assumed once a year or less frequently and the results of such observations could not be considered reliable;

(iv) that on most weirs or anicuts, State Governments were applying formulae or co-efficients which required to be re-examined in the light of latest research findings;

(v) that the discharge sites were very unevenly distributed over the catchment area.

5.25 The Commission recommended a list of sites for systematic and regular gauging of flows. They numbered 38; out of which 9 sites were on the main river, 5 on Indravati, 3 each on Manjra, Penganga and Sabari, 2 each on Wardha, Wainganga and Sileru and one each on Pravara, Sindhphana, Purna, Maner, Pranhita, Kiadoh, Nibra, Kotri and Talperu. A complete table giving the name of sites and the river and the location of site is given in the Table 5.11.

Table 5.11

Sites Recommended by the Krishna-Godavari Commission

Sl. No.	Name of site	Name of river or tributary	Location
1	2	3	4
1.	Nandur-Madhmeshwar	Godavari	—
2.	Toka	,,	Below the confluence with the Pravara
3.	Nathrah	,,	Upstream of the confluence with the Sindhpana
4.	Barbara	,,	Upstream of the confluence with the Purna
5.	Dharmabad	,,	,, ,, ,, Manjra
6.	Chinnur	,,	,, ,, ,, Pranhita
7.	Inchampalli	,,	Below the confluence with the Indravati
8.	Ippur	,,	,, ,, ,, Sabari
9.	Dawlaishwaram	,,	

Table 5.11—Contd.

1	2	3	4
10.	Ozar	Pravara	Below the weir
11.	Depegaon	Sindhphana	Upstream of the confluence with the Godavari
12.	Purna	Purna	Upstream of the confluence with the Godavari
13.	Nadiwari	Manjra	Upstream of the confluence with the Maharashtra-Mysore border
14.	Devnoor	,,	—
15.	Machinur	,,	Upstream of the confluence with the Godavari
16.	Damarkunta	Maner	,, ,, ,, ,,
17.	Sironcha	Pranhatia	,, ,, ,, ,,
18.	Wedi	Wardha	Upstream of the confluence with the Penganga
19.	Adegaon	,,	Upstream of the confluence with the Wainganga
20.	Kaveri	Penganga	Upstream of the confluence with the Kiadoh
21.	Savangi	,,	Below the confluence with the Waghari
22.	Baragaon	,,	Upstream of the confluence with the Wardha
23.	Bhanegaon	Kiadoh	Upstream of the confluence with the Penganga
24.	Ambhorah	Wainganga	Below the confluence with the Kanhan
25.	Ashti	,,	Upstream of the confluence with the Wardha
26.	Nowrangapur	Indravati	—
27.	Jagdalpur	Indravati	—
28.	Kudurgaon	,,	Below the confluence with the Baordhig
29.	Darba	,,	Upstream of the confluence with the Nibra
30.	Regalgudem	,,	Upstream of the confluence with the Godavari
31.	Gurgura Tola	Nibra	Upstream of the confluence with the Indravati
32.	Bhamragarh	Kotri	Upstream of the confluence with the Indravati
33.	Cherla	Talperu	—
34.	Pakki	Sabari	Near proposed dam site of Upper Kolab H. E. Project
35.	Karimati	,,	Upstream of the Orissa-Madhya Pradesh border
36.	Motu	,,	Upstream of the confluence with the Sileru
37.	Jalaput (Machkund) Dam	Sileru	—
38.	Kottagudem	,,	Upstream of the confluence with the Sabari

These sites recommended were considered to be key sites necessary for determining the important elements relating to the hydrology of the Godavari river system. The data to be obtained at these sites was considered essential for the preparation of individual projects, an integrated basin-wise plan and for the subsequent operation of such a plan and the regulation, to best advantage, of the available river waters in any year.

5.26 The recommendation of the Commission was accepted by the Government of India and a special Circle was established within the Central Water & Power Commission for carrying out the work. The Central Gauging Circle established in 1964 is at present observing gauges and discharges on the Godavari and its tributaries. The method of observation at each site is based on local topographic considerations and the entire work is reviewed by a Committee of Chief Engineers of the States concerned, with the Chairman, CW&PC as the Chairman of the reviewing body.

Out of the 38 sites recommended by the Krishna-Godavari Commission, 34 sites have been established by the Central Gauging Circle. The remaining 4 sites namely, site No. 1 (Nandur), site No. 10 (Ozar), site No. 12 (Purna) and site No. 28 (Chitrakot) continue to be with the respective State Governments. It has since been decided that independent stations will be set up by the CW&PC at these 4 sites.

Of the 34 sites set up by the Central Gauging Circle on the Godavari river, current meter gauging are being carried out at 29 sites and only gauge observations at the remaining 5 sites. These five sites were in the process of conversion to discharge sites during 1969–70.

Owing to foreign exchange difficulties the procurement of navigational and other hydrological equipment such as motor launches, out-board engines and echo sounders etc. was delayed and the current meter discharge observations could not be continued throughout the year on all the sites. The observations had to be restricted to the low water season only. The number of sites where discharges have been measured by the current meter and computed by floats during the period 1965–69 are shown below:

	1965–66	*1966–67*	*1967–68*	*1968–69*
No. of sites for which discharges have been measured or computed for the full year	10	16	22	29

At all gauge and discharge sites gauge readings are recorded thrice daily during the non-monsoon period, and hourly during the monsoon period. Discharge measurements are taken only on working days, and not on holidays. However, for holidays discharges are computed from the stage discharge curves established on the basis of actual gauge discharge observations made during the period and other relevant information. Attempts are being made to take discharge observations on holidays also.

For the water year from 1st June to 31st May, the observed discharge data is scrutinised and after computing the discharges for the day when actual discharge observations could not be made, on the basis of the stage discharge relation curves, the daily discharge data is supplied to the States of Andhra Pradesh, Maharashtra, Mysore, Madhya Pradesh and Orissa.

Flows at Polavaram, the terminal site on the Godavari, as observed by the current meter and estimated for the period 1967–69 are given in Table 5.12.*

Table 5.12

Flows at Polavaram

Flow at Polavaram in TMC	For the year	
	1967-68	1968-69
(*i*) By current meter observations	1,452.8 (43)	1,879.2 (78)
(*ii*) By estimation from stage/discharge curves for the year	750.0 (22)	532.8 (22)
(*iii*) By estimation from extrapolated stage/discharge curve	1,169.9 (35)	—
Total observed and estimated at Polavaram	3,371.8	2,412.0

Note: Figures in brackets show the percentage with respect to the total observed and estimated flow.

Generally discharges have been based only on current meter observations from 1968–69, and that data can be taken to be reliable. However, this data is inadequate and the continuance of discharge observations for a number of years is essential.

*Collection of Gauge and Discharge Data at sites set up by CW&PC in the Godavari basin, CW&PC (October, 1969).

Ground Water

5.27 A study of the map showing the distribution of hard and soft rocks in the Godavari basin indicates that a large part of the basin lies over ancient crystallines and metamorphics which have 'very poor' water bearing capacity. The Deccan trap which extends under the rest of the basin, has been stated to have 'poor' water bearing characteristics.

The major part of the basin has not been surveyed and explored for assessing the groundwater resources in detail. Recently, however, systematic geohydrological studies of some parts of the Godavari basin have been made. The extent of the area covered by such studies in the various sub-basins/districts is shown in Table 5.13.*

Table 5.13

Area Covered by Geohydrological Studies in the Godavari Basin

Sl. No.	Sub-basin/district	Area sq. km.
1	2	3
1.	Wardha sub-basin	2,300
2.	Indravati sub-basin	2,700
3.	Ahmednagar & Aurangabad	1,300
4.	Bidar	4,900
5.	Medak	600
6.	Nizamabad	2,170
7.	Adilabad	700
8.	Karim Nagar	1,030
9.	Warangal	2,000
10.	Khammam	1,795
11.	West Godavari	1,800

5.28 The results of these studies are summarised in the following paragraphs.

The prevalent rock types in the area studied in the Wardha sub-basin are Deccan lava flows, underlain by older sedimentaries like the Vindhayans and the Kamthis. Ground water occurs under water table condition in the weathered zone of massive trap units as well as in the interflow zones. Ground water development by open wells on a moderate scale is possible in the Aurangpur-Kasuroa, Jhadgaon, Savangi and Wadhona areas.

*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

In the Indravati sub-basin, the Archeans, Puranas, and alluvium along the river and its major tributaries, are the predominant geological formations. In all the formations groundwater occurs under water table conditions, and development on a moderate scale for irrigation is possible along the river and its tributaries. For small scale groundwater development, collector wells and large open wells will be suitable in the alluvium and topographic depressions, respectively.

In the Ahmednagar and Aurangabad districts different flows of Deccan basalt have been identified. Groundwater occurs both under the water table and confined conditions in different units of the basaltic flows. Wells located in topographical depressions like nalas will be suitable for utilising groundwater. Dug-cum-bore wells will prove suitable for tapping the confined zones for higher yields.

In Bidar district the area investigated is underlain mostly by Deccan trap formations. Open wells in the area generally yield water fit for irrigation.

In Medak district, the area studied is underlain by laterites and Deccan traps which overlie the Archaean Crystalline rocks. Groundwater has been extensively developed by means of open wells in the laterites.

In Nizamabad district, the Nizamsagar command area has been studied. This is a strip bounded by the river Manjra on the west and north, the Nizamsagar main canal on the south and the Peddavagu on the east. It is underlain by crystalline rocks of Peninsular gneissic complex and alluvial fills of 10 to 12 metres thickness, consisting of clays and sands and occupying the natural water courses. Groundwater occurs under the water-table conditions in the weathered mantle extending down to 20 metres, and in joints, fractures, crevices etc. in the fresh rock below. Groundwater in the area is extensively developed for irrigation and domestic purposes by means of dug wells. The quality of water is generally good and fit for irrigation both in the crystalline and the alluvial sediments. The groundwater storage could be augmented by constructing check dams and weirs at suitable locations across the Manjra river and its tributaries.

In Adilabad district, Gondwanas, Cuddapahs, Deccan traps and gneisses occur. Bore wells in the Vindhayan formations are not likely to be successful. There are good possibilities for developing groundwater in sandstones to the south-east of Asifabad by means of tubewells. The quality of water is good and fit for irrigation.

In Karimnagar district the area investigated is underlain by the Peninsular gneissic complex. Open wells of large dimensions located in lowlands towards the valleys might yield limited supplies.

In Khammam district, the area studied is underlain by granites, gneisses, phillites, schists, biotites and river alluvium occupying low lands. Groundwater development is possible by large diameter open wells in specific areas. In the small alluvial patch in the flood plains of the Wira river, limited ground water development is possible.

During the period 1959 to 1962, systematic groundwater surveys, extending over the sedimentary tracts of East and West Godavari districts were carried out by the Southern Groundwater Division of the Geological Survey of India. In 1958, exploratory drilling was done by the Exploratory Tubewells Organisation at 12 sites in the two districts, nine out of twelve wells were converted into production wells. These exploratory tubewells have revealed the occurrence of good underground resources in the area explored. Relevant particulars of the nine production tubewells built by the Exploratory Tubewells Organisation are given in Table 5.14.

Table 5.14

Details of Production Tubewells Built by ETO in the Godavari Basin

Sl. No.	Location of tubewell	Depth of tube-well in feet	Yield in G.P.H in 1000	Pumping level in feet	Ayacut area irrigated acres	Cost of each tubewell in Rs.	Estimated cost of pumping for irrigating 1 acre of paddy in kharif season
1	2	3	4	5	6	7	8
	West Godavari District						
1.	Gunnampalli	509	53	37	140	65,716	57.72(D)
2.	Nallamadu	186	22	69	58.52	51,879	107.64(D)
3.	Nallajerla	400	20	33	51.37	68,630	51.48(D)
4.	Venkataramannagudem	407	38	85	70	63,985	—
	East Godavari District						
5.	Punyakshetram	727	37	58	72.03	100,612	90.48(D)
6.	Balavaram	536	31	94	52.00	77,354	65.00(E)
7.	Pera Ramachandrapuram	760	44	50	108.64	87,555	34.84(E)
8.	Razole	512	33	34	81.25	67,657	23.40(E)
9.	Dowlaishwaram	669	40	67	—	85,035	46.28(E)

Note: 'E' stands for electrically operated tubewell and 'D' for diesel operated tubewell.

Based on the study of the geology of the region, the groundwater investigations and exploratory drilling so far carried out as well as the performance of tubewells and filter-point wells in both the deltaic and upland tracts of the two districts, the occurrence and development of groundwater in the various geological formations are given below:

Pre-Cambrian Crystalline Rocks and Metamorphosed Sedimentary Rocks

The Archean crystalline rocks and the older sedimentary rocks occupy a large area in the East Godavari district and smaller areas in the West Godavari district. In view of absence of any granular zones in these rocks, large scale development of groundwater through tubewells is not generally considered feasible.

Lower Gondwana Sediments

Overlying the above rocks, are the Chintalapudi sandstones, which occur in parts of the Chintalapudi and Kovvur taluks of West Godavari district. Future development of groundwater is possible in this formation. As the formations are of hard sandstone, deep tubewells fitted with deep well pumps would be necessary.

Upper Gondwana Sediments

These consist of Gollapalli sandstones, Raghavapuram shales and Tirupati sandstones.

The Gollapalli standstones occur in the Chintalpudi and Kovvur taluks and have characteristics somewhat similar to the Chintalapudi sandstones. By installing deep tubewells fitted with deep well pumps the development of groundwater in this formation is feasible.

The Raghavapuram Shales overlie the Gollapalli sandstones and occur over a small area in West Godavari district. These shales are poor producers and do not yield water in sufficient quantities to meet irrigation needs.

The Tirupati Sandstones consisting of beds of sandstones, sands, clays and gravels are exposed in parts of the Chintalapudi, Eluru, Kovvur, Rajahmundry and Peddapuram taluks of the Godavari districts. They are the most prolific producers of groundwater among the Gondwana formations occurring in the area. There are very good artesian aquifers in the beds of sands and gravels. There is already some development of groundwater by means of tubewells and dug-cum-bore wells in this formation, some of which tap artesian zones. Further development of groundwater is possible in this area.

Deccan Traps are exposed in a narrow belt between Nallajerla in West Godavari district and Katravulapalli in East Godavari district across the river Godavari. These are not likely to yield appreciable quantities of groundwater.

Rajahmundry Sandstones overlie the Deccan traps and consist of beds of sandstones, sands, gravels and clays. They are exposed between Pithapuram in East Godavari district and Gannavaram in Krishna district and form one of the most important geological formation from the viewpoint of groundwater potential. This formation includes a number of artesian aquifers, and heavy duty tubewells can be built to exploit them.

Alluvial deposits occupy the largest area in the Godavari districts. These consist of beds of sand, silt and clay. The beds of sand possess good water bearing characteristics as they are connected to the river beds providing a perennial source of supply. It is believed that there are many such inter-connected beds of sand inside these deposits. As the areas occupied by them are covered by a canal system, tubewells sunk in this area are likely to have the benefit of influent seepage from the network of canals in this area and sinking of tubewells will be relatively easy, as the alluvial materials are unconsolidated.

The successful development of groundwater through the construction of tubewells is feasible both in the sedimentary areas and in the alluvial deposits of the Godavari Delta. The development of groundwater achieved so far has been negligible. Statistics of the existing number of tubewells and other wells and area irrigated therein the Godavari districts during the agricultural year 1965–66 are given in Table 5.15.

Table 5.15

Details of Tubewells and Wells in the Godavari Districts

District	Tubewells		Other wells		Total	Area irrigated by tubewells and other wells (hectares)
	Govt.	Private	Govt.	Private		
1	2	3	4	5	6	7
West Godavari	15	2,107	529	6,406	9,057	24,130
East Godavari	29	362	327	1,169	1,887	6,825

It is clear that most of the existing tubewells and other wells are built and managed by the farmers themselves which indicates their interest in ground water and its use for irrigation.

5.29 There are about 303,000 surface wells in use in the Godavari basin which annually irrigate about 0.3 million hectares. No data are available, however, with regard to the yield from these wells. Broadly each well is capable of irrigating about 1.2 to 1.6 hectares annually.

5.30 In regard to Maharashtra, the Fact Finding Committee for the survey of scarcity areas in Bombay State (1960) in their report have stated that:

"Unlike the alluvial plains in the country, such as those in the Punjab and Uttar Pradesh, the Deccan conditions present altogether a different and complicated problem in so far as groundwater and its flow is concerned. In the Indo-Gangetic plains striking water wells is not at all an uncertain factor as it is related to a water table which spreads all over the area. . . . . .

In the Deccan, however, there is no such thing as a water table. The wells derive their supply from the water seams the exact location of which cannot be predicted. Any well sunk in the Deccan has to be excavated in rock to some extent except in certain regions where the rock level happens to be very low and excavation is limited to the upper layer consisting of "MAN" or "CHOPAN". The cost of sinking wells in the Deccan varies from about Rs. 3,000 to Rs. 5,000. A normal well in the Deccan plateau is about 40 to 50 feet deep and water is struck at a depth of about 25 to 40 feet. The capacity for irrigation of a normal well in the Deccan (not within the commands of irrigation canals) is noticed to be between three to five acres. The supplies of these wells are adequate for irrigation up to about the middle of March and then dwindle rapidly, giving barely sufficient water for drinking purposes at the end of the hot weather. As a matter of fact a number of wells are known to get dry by the end of April . . . . Well irrigation should therefore be resorted to where the other more economic modes of providing irrigation are not available or where an adequate and copious supply of underground water with a low lift can be guaranteed as, for example, in the areas under command of major irrigation works."

The condition in respect of wells in other parts of the Godavari basin is also not likely to be very different from that described above, except areas with good or good to fair, water bearing characteristics.

Although there is no water table in the Godavari basin of the type found in the Indo-Gangetic plains, wells have played a very important role in the irrigation development of the basin. About 20 per cent of the irrigated area in the Godavari basin gets its water supplies from surface wells.

5.31 There has been considerable activity in the Godavari basin during the last few years under the programme of minor irrigation. Large sums have been spent, or are in the process of being spent, under this programme for improvements to wells, digging new wells etc. There is still considerable room for further development of ground water in the coastal area, along the Godavari, in the sub-basins and in the areas under the command of major irrigation works both existing and proposed. Increased withdrawals from the sub-soil in these areas are also necessary for preventing waterlogging. However, before planning future development, it is necessary to conduct a detailed and systematic investigation for groundwater.

EXISTING DEVELOPMENT

5.32 Irrigation has been practised in the Godavari basin from historic times. Wells and tanks, some of them very old, are found everywhere. There are about 2,000 small tanks and diversions on the Godavari river system. Most of these wells and tanks have been built by the cultivators. Some tanks were built from time to time by progressive rulers or through cooperative efforts of the people. Tanks are the source of water supply for domestic use for the villages. They also provide irrigation from a few hectares to thousands of hectares. Many tanks irrigate an area of less than 200 hectares. Irrigation from tanks is largely in the beds of nullahs and streams or other low lying areas and in small isolated patches. On some streams, tanks have been built one below the other in a chain, each tank receiving the overflow of the tank immediately upstream of it as well as the inflow from the intermediate catchment. Most of these tanks are under the control of the Civil Authorities and the PWD carry out repairs when called upon to do so.

Each tank consists of an earthen embankment across a valley, a natural nullah or a small stream. The valley immediately below the embankment grows a paddy crop, mainly in kharif. The tanks run almost dry just before the monsoon, but the first good shower partly fills them, and withdrawals for sowing paddy follow immediately thereafter. The next shower replenishes the tank and the process continues throughout the rainy season. It is only when the tank is full that there is any escape into the nullah or stream. At the end of the south-west monsoon, the tank would, generally be full, and the water available in it is utilised for maturing the paddy crop and for domestic use until the next monsoon.

On some streams, where topographical conditions are favourable, weirs have been built and short canals are led from them to irrigate areas of paddy and occasionally, sugarcane or garden crops. These diversions, also, generally irrigate areas less than 200 hectares each.

The most important irrigation work in the Godavari basin is the Godavari Delta Canal System at the mouth of the river. The project, completed in the year 1877, provided for the irrigation of a part of the deltaic plains, with the headworks located at Dowleishwaram, where the Godavari attains a width of about 6.4 km. Below this point, the river divides into two branches, the eastern or the Gautami Godavari and the western or the Vasista Godavari. The works originally carried out are described below.

On the left flank of the river was the head regulator of the Eastern Delta System, with a navigation lock and connected undersluices. Two weirs, the Dowleiswaram weir, 1,506 m. long and the Ralli weir, 871.3 m. long, joined by an embankment with its top 6.4 m. above the crest level of the weirs, spanned the Gautami Godavari. At the western end of the Ralli weir were the undersluices, the navigation lock and the head regulator of the Central Delta System of Canals. The Vasista Godavari or the western branch of the river was similarly crossed by two weirs, the Maddur and Vizeswaram weirs, 471.8 m. and 791.8 m. long respectively and from the western end of the latter an embankment led to the head regulator and lock of the Western Delta System. The headworks thus comprised about 4 km. of weirs, 2.4 km. of embankments and three sets of canal headworks, the largest set of diversion works in the world at the time. The project cost Rs. 31.554 million. It has an irrigation potential of 0.41 million hectares, and has been of untold value to the tract irrigated by it. The delta, which was formerly one of the areas most liable to famine, is now a vast expanse of paddy fields broken by gardens of fruit trees. Failure of crops is practically unknown and the main canals are navigable.

5.33 The First Irrigation Commission had made the following observations in respect of irrigation development in the Godavari basin:

"Our principal and most important recommendation for large works have been made for the protection of the Deccan districts in the Bombay and Madras Presidencies. For the former we propose that the catchment areas of all the rivers which derive their supplies from the unfailing rainfall of the Western Ghats should be carefully examined, with a view to the construction of as many large storage reservoirs as possible, and of the works necessary for carrying the supply into those tracts in which irrigation is most urgently needed."

"It has been proved beyond all question that irrigation works in the Deccan cannot be made to pay; and the financial prospects of all projects that have been proposed have been so unpromising. . . But we doubt not that if the protection of the Deccan be given a foremost place in the future irrigation policy of Government, subject to whatever limitation of cost may appear to be reasonable. . . ."

"Of the schemes which have been laid before us, the most important is that for the utilization of the water of the Pench and Kanhan rivers and the construction of a large reservoir on the Pench river, opposite the town of Ramtek. . . ."

Regarding the scope for further extension of irrigation in the Godavari delta area, the Commission had made the following observations:

"Our evidence indicates that the supply in the Godavari is generally sufficient for the requirements of the delta; and that there is at any rate no scope for such an extension of either first or second crop cultivation within the delta as would justify the construction of expensive storage works in the Upper Godavari for the benefit of this tract, which is now completely protected against famine. No doubt many storage works might be proposed on the Upper Godavari or its affluents, for the protection of tracts in their neighbourhood. But many or most of these would be in zamindari lands, or in the territories of feudatory chiefs, regarding which we have no evidence; or in scarcely populated and unhealthy forest tracts, in which the development of cultivation would be very slow."

5.34 As a result of the above recommendations, a number of projects, the more important of which are the Godavari Canals, the Pravara Canals and the Ramtek tank were undertaken in Maharashtra for the development of irrigation in the Godavari basin. The Godavari Canal Project constructed in 1915–16, provided for a masonry dam 1,634 m. long and 25 m. high across the river Dharna, a tributary of the Godavari, a weir 1,103 m. long across the Godavari at Nandur-Madhmeshwar and a canal system on either bank for irrigating an area of 0.032 million hectares annually. The project cost Rs. 10.70 million.

The Pravara Canal Project, constructed in 1926, comprised a masonry dam, 507 m. long and 82 m. high across the river Pravara near Bhandardara and a 271 m. long pick-up weir at Ozar, 85 km. downstream of the dam for irrigating an area of 0.023 million hectares annually. The estimated cost of the project was Rs. 16.235 million.

The Ramtek Project, constructed in 1909–10, consisted of an earthen dam 3,460 m. long and 22 m. high across the Sur river, a tributary of the Wainganga, and a canal system on the right bank for irrigating an area of 0.011 million hectares annually. The project cost Rs. 2.912 million.

5.35 Among the other important irrigation works, mention may also be made of the Wainganga Canals in Madhya Pradesh built in 1923 and the Nizamsagar Project in Andhra Pradesh constructed in 1931.

The Wainganga Canal Project, costing Rs. 5.319 million, provided for a 504 m. long weir across the Wainganga river near Dhuti village and a canal system on the right bank for irrigating an area of 0.032 million hectares annually.

The Nizamsagar Project, costing Rs. 45.708 million, comprised a masonry dam 2,286 m. long and 48 m. high across the river Manjra at Atchampet and a canal system on the right bank for irrigating an area of 0.097 million hectares annually.

5.36 As part of the post-war reconstruction programme a number of irrigation works were undertaken in the Godavari basin in the States of Andhra Pradesh, Madhya Pradesh and Maharashtra. The new irrigation projects undertaken in the various States during the period are described briefly in the following paragraphs.

Andhra Pradesh

The Kaddam Project in Adilabad district was taken up by the erstwhile Hyderabad State in 1949. The project comprises a composite dam 2,102 m. long, 40.6 m. high across the river Kaddam, a tributary of the Godavari. It will provide irrigation to an area of 34,400 hectares annually, at a total cost of Rs. 83.90 million. The work on the project is nearing completion.

The Pochampad Project in Nizamabad district was taken up for construction in the year 1963–64. The project provides for a masonry dam, a 765.05 m. long spillway and a 47.24 m. long non-overflow dam and a 12,588.24 m. long earthen dam across the river Godavari near village Pochampad. The project estimated to cost Rs. 401.00 million (under revision) will provide irrigation to an area of 230,679 hectares and is expected to be completed during the Fourth Five Year Plan.

Details of seven medium schemes which were also undertaken during the Plan periods are given in Table 5.16.

Madhya Pradesh

Some details of six medium schemes undertaken in the Plan periods in Madhya Pradesh are given in Table 5.17.

Maharashtra

The Purna Project in Parbhani district was taken up in the year 1957 and was completed in 1968. The project consists of two dams across the

Table 5.16

Details of Medium Schemes Undertaken during the Plan Periods in Andhra Pradesh

Sl. No.	Name of the project	Estimated cost (Rs. million)	Area proposed to be irrigated (thousand hectares)	Stage of construction
1	2	3	4	5
1.	Bandakettu Channel	0.292	1.46	Completed
2.	Sirala	0.282	0.85	,,
3.	Ramadugu	3.726	2.02	,,
4.	Salivagu	4.057	1.15	,,
5.	Torrigedda Pumping Scheme	6.579	6.52	Under construction
6.	Swarna	11.562	2.83	,,
7.	Nallavagu	7.621	2.39	,,

Table 5.17

Details of Medium Schemes Undertaken during the Plan Periods in Madhya Pradesh

Sl. No.	Name of the project	Estimated cost (Rs. million)	Area proposed to be irrigated (thousand hectares)	Stage of construction
1	2	3	4	5
1.	Ari Tank	3.000	4.25	Completed
2.	Gangulpara Tank	5.425	3.45	,,
3.	Sagarnadi	4.587	1.59	,,
4.	Kharadi Tank	3.004	3.84	,,
5.	Nahleshara	21.420	4.51	,,
6.	Bagh Right Bank Canal	34.840	10.84	Under construction

river Purna, a tributary of the Godavari, one at Yeldari and the other at Siddeshwar 64.4 km. downstream of Yeldari. The total cost of the project is Rs. 187.40 million. It provides irrigation to an area of 61,514 hectares and has an installed capacity of 3 units of 7,500 KW each.

The Bagh Project in Bhandara district envisages an earthen dam, 2,836 m. long, 28.5 m. high across the Bagh river near Sirpur village and a pick-up weir at village Pujantara. Work on the project was started in 1958 and is likely to be completed in 1972. Costing Rs. 58.40 million, the project will irrigate an area of 33,671 hectares.

The Itiadoh Project in Bhandara district was taken up in the year 1958. The project envisages an earthen dam 527 m. long and 28 m. high across the river Garvi, a tributary of the Wainganga. The project, estimated to cost Rs. 69.20 million, will provide irrigation to an area of 46,136 hectares annually. It is expected to be completed during the Fourth Five Year Plan.

The Mula Project in Ahmednagar district was started in the year 1959. It provides for an earthen dam, 2,820 m. long, 46.63 m. high across the river Mula at village Baregaon-Nandur. Estimated to cost Rs. 161.60 million, it will provide irrigation to an area of 65,561 hectares and is expected to be completed in 1971–72.

The Pus Project in Yeotmal district consists of a storage dam across the river Pus, a tributary of the Wainganga and a pick-up weir downstream near Wenwasla. Work was started in 1964 and is expected to be completed in 1972. The project costing Rs. 51.281 million will irrigate an area of 11,720 hectares annually.

The Jayakwadi Project—Stage I, in Aurangabad district provides for a 10,000 m. long, 36.6 m. high earth dam with a masonry spillway at Paithan across the river Godavari. Work on the project was started in 1964 and is expected to be completed during the Fourth Five Year Plan. The project costing Rs. 384.60 million will irrigate an area of 141,645 hectares annually.

The Upper Godavari Project in Nasik district consists of four dams viz. the Karanjwan dam across the Kadwa, the Waghad dam across the Kalwan, the Ozarkhed dam across the Renada and the Palkhed dam across the Kadwa and canal systems. The work on the project was started in 1968. The project costing Rs. 142.90 million, will extend irrigation to an area of 44,272 hectares. It is proposed to be taken up in phases and the first phase envisages the construction of two storages viz., Karanjwan and Palkhed, without gates, the rest of the works being in the second phase. The first phase, which costs Rs. 50.00 million is expected to be completed during the Fourth Five Year Plan and the second phase in subsequent Five Year Plans.

5.37 Some details of thirty-six medium projects undertaken during the Plan period are given in Table 5.18.

Some particulars of the important major and medium projects under operation and under construction in the Godavari basin are given in Appendices 5.1 and 5.2.

Besides the major and medium projects in the Godavari basin, a number of minor schemes consisting of tanks, wells and tubewells have a considerable area under irrigation. In many villages there is more than one tank, irrigating adjoining agricultural lands.

Table 5.18

Details of Medium Projects Undertaken during the Plan Period in Maharashtra

Sl. No.	Name of the project	Estimated cost (Rs. million)	Area proposed to be irrigated (thousand hectares)	Stage of construction
1	2	3	4	5
1.	Gangapur Dam Stage-I	39.600	16.79	Completed
2.	Jui	3.605	2.21	,,
3.	Dheku	3.993	2.71	,,
4.	Bendsura	5.881	3.37	,,
5.	Shivna	0.100	0.28	,,
6.	Purna anicut	0.235	0.10	,,
7.	Khelna	7.064	2.47	,,
8.	Sindphana	5.840	1.78	,,
9.	Jivarekha	4.161	1.06	,,
10.	Kolhi	2.313	0.47	,,
11.	Ekburjee	4.249	2.43	,,
12.	Pindrabodi	4.246	0.86	,,
13.	Sukhna	10.769	2.51	,,
14.	Wunna	9.900	1.21	,,
15.	Ghirni	10.282	2.83	,,
16.	Mohesangvi	3.845	1.94	,,
17.	Gangapur Dam Stage-II	13.360	7.69	,,
18.	Galhati	8.224	4.65	,,
19.	Wan	16.449	5.26	,,
20.	Upper Dudhna	7.649	3.40	,,
21.	Manar Stage-I	24.344	10.12	,,
22.	Bor	35.800	13.36	,,
23.	Sangrampur	2.109	0.97	,,
24.	Thirna	8.130	2.43	,,
25.	Dinanadi	34.227	16.54	Under construction
26.	Manar Stage-II	29.300	16.59	,,
27.	Saikheda (Khuni)	17.800	3.64	,,
28.	Managarh	4.667	1.70	,,
29.	Sorna	3.705	1.23	,,
30.	Malkhed	5.324	1.78	,,
31.	Umri	4.166	1.57	,,
32.	Adula	19.722	5.75	,,
33.	Kundral	6.491	1.72	,,
34.	Bhageda	4.670	2.05	,,
35.	Kudala	2.925	0.57	,,
36.	Kanholi	14.565	5.79	,,

5.38 Most of the important data and information relating to water resources development in the basin are either non-existent or have not as yet been compiled and analysed. Working statistics of canals and reservoirs in the basin have also neither been compiled nor published. According to the data available in the Report of the Krishna-Godavari Commission and the information collected from the CW&PC, on completion and full development, major and medium projects in operation and under construction in the basin in 1968–69 would use about 16,998 m. cu. m.

As regards the statistics of a large number of minor schemes comprising tanks, wells and diversions, no information is available. In respect of these schemes no observations have ever been made and no records are maintained of the quantity of water diverted by these works. Some information is available with regard to the areas irrigated. The area irrigated by minor schemes in 1968–69 was about 1.25 million hectares. Based on rough duties an approximate estimate of the quantity of water utilised by these works has been made. The approximate annual utilisation by the minor schemes would be of the order of 13,324 m. cu. m.

Reservoir Losses

5.39 On the basis of assumptions detailed in para 1.28 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and medium schemes	1,612 m. cu. m.
(ii) Minor schemes (tanks)	6,187 m. cu. m.
Total	7,799 m. cu. m.

Thus, the major and medium projects in operation and under construction in 1968–69 in the basin would use about 18,610 m. cu. m. on completion and full development. Taking minor schemes into consideration also, the annual utilisation in the basin is of the order of 38,121 m. cu. m. (32,732 m. cu. m. of surface + 5,389 m. cu. m. of ground).

The major and medium projects in operation and under construction will irrigate about 1.55 million hectares on full development. As stated in para 5.38, the area irrigated by the minor schemes, small tanks and diversions is of the order of 1.25 million hectares. Thus, a total area of 2.80 million hectares will be irrigated by the projects under operation and under construction, on full development.

There are a number of industries located in the basin which are utilising the Godavari waters. Of these, the textile mills spread over the

Vidarbha and Nagpur regions, the cement factory at Adilabad and paper mills at Ballarshah in Maharashtra and Sirpur Kagaznagar and Rajahmundry in Andhra Pradesh deserve mention. Data on the industrial water needs is not readily available. In the future, such needs are expected to grow with greater industrialisation.

The problem of water pollution in the Godavari due to the discharge of industrial wastes has not assumed serious proportions so far. However, with the rapid expansion of industries, this problem may develop and should not be lost sight of.

FUTURE DEVELOPMENT

5.40 Twenty-two major and medium projects are proposed to be taken up for construction in the basin in the Fourth Five Year Plan period, of which 2 are in Andhra Pradesh, 2 in Madhya Pradesh, 17 in Maharashtra and 1 in Orissa. Some details of these projects are given in Appendix 5.3. These projects, on full development, would irrigate a total area of 1.08 million hectares. Project reports for many of these schemes are not yet ready. An approximate estimate of the quantity of water that will be diverted from these projects, is expected to be of the order of 12,977 m. cu. m. including the reservoir losses. The utilisation by minor schemes in the basin is expected to increase by about 1,969 m. cu. m. during the Fourth Plan period. Thus, the additional utilisation by the end of he Fourth Plan through major, medium and minor projects would be of the order of 20,946 m.cu.m. benefiting an area of about 1.58 million hectares. On the completion and full development of Fourth Plan projects, about 59,067 m. cu. m. of waters (51,477 m. cu. m. of surface + 7,590 m. cu. m. of ground) would have been used for irrigating a total area of 4.38 million hectares.

5.41 Of the Fourth Plan projects, special mention may be made of the Godavari barrage project in Andhra Pradesh, Upper Wardha, Upper Penganga, Mhaladevi, Pench, Sahasrakund (Lower Penganga) and Lendi projects in Maharashtra and Upper Indravati project in Orissa. Brief particulars of these projects are given below.

5.42 The Godavari barrage project provides for a barrage, 46 m. upstream of the present anicut at Dowleishwaram to replace this existing 117 years old structure. The barrage consists of 4 sections, shaped more or less like the existing anicut. The 141 spillway gates and 33 river sluices are so arranged to maintain the same proportionate flow into the Gautami and Vasista rivers below the anicut as are now obtaining, in order not to disturb the rivers' regimes. The cost of the project is estimated at Rs. 210.00 million.

5.43 The Upper Wardha project, costing Rs. 169.72 million, consists of a 2,111 m. long, 36.32 m. high dam across the river Wardha near village Thana, a spillway 268 m. long and a right bank canal 141 km. long to irrigate an area of 75,960 hectares.

5.44 The Upper Penganga project envisages two dams, the first across the river Penganga near village Isapur, 3.78 m. long and 46 m. high, and the second across the river Kayadhu near village Sapli, 2,652 m. long and 19 m. high. Two canals, one on either bank, take off from the Isapur dam. The project costing Rs. 330.722 million will provide irrigation to an area of 111,500 hectares.

5.45 The Mhaladevi project provides for a 1,885 m. long, 37.125 m. high dam across the Pravara near village Mhaladevi, about 35.2 km. from Sangamner and a 72 km. long canal on the left bank. The project costing Rs. 52.679 million will irrigate an area of 16,835 hectares.

5.46 The Pench irrigation project consists of a storage-cum-pick up weir, 1,639 m. long and 22.81 m. high, on the Pench river to harness and distribute the supplies available from the tail-race of the Pench hydel project located upstream at Totladoh and to store the yield available from the free catchment between the Pench hydel and the Pench irrigation projects. A canal 56.5 km. long will take off on the right bank to irrigate an area of 89,970 hectares. The project will cost Rs. 205.212 million.

5.47 The Sahasrakund (Lower Penganga) project provides for two dams on the Penganga river, one at Takli 5,486 m. long, 15.7 m. high and the other at Chikalwardha 1,920.5 m. long and 14 m. high; a powerhouse at the foot of the Takli storage, with an installed capacity of 2 units of 25 MW each and a left bank canal taking off from the Chikalwardha storage, which branches off into the left and right bank canals at 52 km. The project will cost Rs. 225.80 million and will irrigate an area of 112,911 hectares.

5.48 The Lendi project, costing Rs. 56.50 million, provides for a 1,710 m. long, 32 m. high dam on the Lendi river near village Golegaon and a canal system on the left bank to provide irrigation to an area of 22,760 hectares.

5.49 The Upper Indravati project, envisages the diversion of Indravati waters to the Hatli river in the Mahanadi basin for irrigating 148,110 hectares and generating 210 MW at 100 per cent load-factor. The project, costing Rs. 241.918 million, consists of a dam across the main river Indravati and three other dams across its tributaries the Podabad, the Kapur and the Muran. A cut between the reservoirs of Indravati and Podagad dams and another cut between the reservoirs of Kapur and Muran dams will enable the project to have a single reservoir for all four dams. The water from the reservoir is proposed to be released from the head-regulator located in one of the right dykes of the Indravati reservoir to the Hatli river from where it will be picked up by a weir for irrigation on either side of the river.

5.50 As stated in para 5.22 the average annual yield of the Godavari system at Dowleishwaram, as estimated by the Krishna-Godavari Commission, is of the order of 1,17,997 m. cu. m. After completion and full development of Fourth Plan projects, a balance of 75,886 m. cu. m. would still be available for utilisation by future projects in the basin.

5.51 The Krishna-Godavari Commission, in their report, have listed the major and medium projects, which are proposed to be taken up by the different States in the Godavari basin. A few of these projects have since been completed or are in various stages of construction in the various States.

5.52 The Madhya Pradesh Government*, and the Orissa Government** have also indicated the major and medium schemes to be taken up in the future in the basin in the two States.

5.53 Some details of the new projects proposed by the various States are given in Appendix 5.4. On completion, these projects are expected to provide irrigation facilities to 4.41 million hectares. All these projects have not been investigated and project reports for most of them are not available. It is quite possible that some of them may not prove feasible after detailed investigations. Considering the large water resources still available in the basin extension of irrigation on a large scale is possible.

5.54 As the concerned States have not been able to arrive at any

*Irrigation and Power Potential of Madhya Pradesh Rivers, Government of Madhya Pradesh (PWD)—1963.

**Orissa's Decade of Destiny (1963-73)—A Plan for the integrated development of the river basins of Orissa 1963, by Dr. A. N. Khosla.

settlement regarding the sharing of the Godavari waters, the matter has been referred to a Tribunal by the Government of India and its award is awaited. After the pronouncement of the award, it would be possible for the different States to plan their future projects within the limits of the share of water allocated to them.

5.55 The Krishna-Godavari Commission had examined, in detail, the feasibility of diverting surplus supplies in the Godavari to the Krishna. There are possibilities of diverting the Godavari waters into the Krishna from two places; one near Albaka along the alignment of the Godavari-Pulichintala Link and the other from the proposed Polavaram barrage to Vijayawada. The former link canal will outfall into the proposed Pulichintala reservoir and the latter above the Krishna barrage at Vijayawada. The Polavaram-Vijayawada Link and the Godavari-Pulichintala Link would be able to transfer from the Godavari to the Krishna about 5,975 m. cu. m. and 2,690 m. cu. m. respectively. In all about 8,665 m. cu. m. would be available for the use of the area developed, or proposed to be developed, from the Krishna below Nagarjunasagar. The entire flow of the Krishna river system available up to Nagarjunasagar can be utilised at, and above, Nagarjunasagar. For the areas already developed from the Krishna below Nagarjunasagar, and those proposed to be developed from the waters in this reach, a much more assured supply would be available from the diverted water of Godavari than can be provided from the Krishna, and considerable improvement in the intensity and type of irrigation would be possible. However, in case the above diversions are effected, the hydroelectric development proposed at Pulichintala and Nagarjunasagar will have to be abandoned and that at Srisailam will have to be reduced in accordance with the requirements of the canals at Nagarjunasagar. That Commission has, however, cautioned that these proposals are based only on a study of the toposheets of the area and the particulars of various projects furnished by the State Governments and it may be found necessary to modify these proposals after detailed field investigations. The field investigations have since been done by the CW & PC and project proposals have been framed. The question of the diversion of any surplus supplies of the Godavari to the Krishna has also been referred to the Tribunal.

5.56 The construction of giant projects like the Inchampalli and the Ippur in future, will cause a serious change in the ecosystem of the basin. The adverse effects of such mighty dams on the lower reaches of the river and especially the delta may be disastrous and shall have to be carefully studied in all aspects. It would also be necessary to maintain the ecological balance of the basin.

FLOODS, WATERLOGGING AND DRAINAGE

5.57 The Godavari is purely rain-fed and carries enormous quantities of water during the monsoon period. The river flow in its lower reaches during the non-monsoon period is chiefly derived from regeneration. The disparity in the maximum and the minimum flows in the river is very marked. During the monsoon, the river spills its banks in the lower reaches, flooding in particular the delta areas.

5.58 The formation of sand bars at the mouth of the Godavari, due to littoral drift along the east coast, chokes the river mouth, thereby aggravating its flood problems. Also, the sand which blows landwards from the sea coast piles up in the shape of long sandy ridges obstructing land drainage in the coastal areas.

5.59 In the Marthawada region of Maharashtra, the flood problem mostly exists in the growing industrial city of Nanded, situated on the banks of the Godavari, where the low lying parts of the city are submerged by the river in high floods. The inundation of agricultural lands on the banks of rivers also occurs in Nanded and Parbhani districts. The Vidarbha region is even more susceptible to floods. In this region the main rivers viz., the Wardha and the Wainganga flow through flat plains, where they overtop their banks, and inundate large areas. In this region, the main flood problem is the threat to towns and villages situated on the river banks.

5.60 The parts of the basin lying in Madhya Pradesh and Mysore have generally no serious flood problem; but there are occasions where due to storms of high intensity, some local flooding takes place.

5.61 In Orissa, the Indravati and Sabari sometimes cause flooding.

5.62 In Andhra Pradesh, the submergence of large areas by the flooding of the Kolleru lake is an acute problem. This lake is a depression lying between the two deltas of the Godavari and the Krishna. The area draining into it is 5,491 sq. km. Four major coastal streams, namely the Budameru, the Thammileru, the Ramaleru and the Gunderu, along with a part of the flow of the Yerrakalva and a number of deltaic drains flow into the lake. During the monsoon season when the various inflowing streams are simultaneously in flood, the combined inflow is far in excess of the discharging capacity of the Upputeru river, which is the only outlet from the lake. The lake level, therefore, rises, submerging the marginal lands. It is known to have risen as high as 8.3 m. above mean sea level.

In addition, the inundation along the Budameru, the Thammileru, the Yerrakalva and other drains also increases, due to the backing up of the water. Roughly, an area of 155 sq. km. of cultivated land gets submerged almost every year, 288 sq. km. every alternate year and 311 sq. km. every third year.

5.63 The flood of 1953 in the Godavari was the highest on record with a discharge of 80,137 cumecs.* Owing to heavy rainfall all over the basin, the flood was sudden. Godavari broke its banks near Kapileshwaram and the flood waters entered Rajahmundry about the midnight of 15th and 16th August, 1953 rendering several thousand families homeless. Polavaram island in the East Godavari district was also completely inundated. The sluices of the Torrigedda river falling into the Godavari about 21 km. upstream from Rajahmundry were washed away resulting in the submersion of several villages on the left bank of the Akhanda Godavari. There were three other breaches on the left bank of the river within a distance of 13 km. The havoc caused by the floods in the Central Delta was colossal. There were several breaches in the flood bank of the Gowthami and in the banks of the canals.

5.64 In 1958 also, heavy floods occurred in the river. Although the water level at the anicut was 0.46 m. lower than the flood level of 1953, yet it was higher by about 0.15 m. in the lower reaches of the river, 8 to 16 km. from the sea.

5.65 In the past, flood control measures in Andhra Pradesh were primarily confined to the construction of embankments. These embankments were built in the deltaic areas. The existing embankments along the Akhanda Godavari and its branches for a length of 480 km. have been strengthened and raised by 0.9 to 1.5 m. over recorded high flood levels. An important scheme in the Kolleru system which has been completed, is the diversion of a maximum of 2,124 cumecs of the flood discharge of the Budameru into the Krishna. In Maharashtra, the work done so far relates to the investigation of the problem. In other States, there has really been no serious flood problem and in consequence, no large-scale flood control measures exist.

5.66 The work done so far has been essentially of the nature of strengthening and raising the existing embankment system and that too mostly in the Godavari delta. However, the problem of the delta cannot be considered as having been adequately solved. The protection of some

*Report of the High Level Committee on Floods (1958).

towns on the river banks has still to be ensured. The partial diversion of the Budameru into the Krishna only touches the fringe of the problem. A systematic and comprehensive examination of old embankment systems, and existing tanks, is called for, together with a comprehensive study of the pattern and incidence of coastal cyclonic rainfall of heavy intensity and short duration which is accompanied by high wind velocities. As regards the construction of reservoirs on the Godavari and its tributaries, it is considered that storage reservoirs constructed solely for the purpose of flood moderation would not normally be economically justified. If, however, these dams are built on a multipurpose basis, and are economically justified otherwise, they would be most useful in moderating floods in this river.

5.67 In Maharashtra, a number of drains have been constructed in the areas irrigated by the Pravara and Godavari canals to check water-logging and more are under construction.

The main drainage problem in Andhra Pradesh is the disposal of surface water from flat deltaic tracts where rice is the staple crop. In all there are 2,087 km. of drains in the Godavari Delta area. They are divided into three classes, namely, (i) major drains, with the catchment area of each drain exceeding 52 sq. km., (ii) medium drains, with the catchment area of each drain from 13 to 52 sq. km. and (iii) minor drains, with the catchment area of each drain less than 13 sq. km. Apart from the delta, the country is generally undulating and easily drained and no drainage problems have so far arisen there.

There have been no drainage problems so far in Madhya Pradesh, Mysore and Orissa and no drains have been constructed.

SOIL CONSERVATION

5.68 The Godavari basin largely comprises ridges and valleys. In the upper reaches of the river and its tributaries land slopes are relatively steep and there is considerable soil erosion during rainfall of high intensity. For conserving the storage capacities of reservoirs, it is important for soil conservation measures to be undertaken in the cultivated areas and also in the culturable but not cultivated areas, and in the areas under forests. Soil conservation measures comprise afforestation, terracing and contour bunding, pasture development and protection of marginal and sub-marginal lands, stream control measures and desiltation works like check dams etc.

5.69 During recent years, efforts have been made to take up soil and water conservation measures, and the progress on afforestation in the different States up to the year 1962 has been shown in Table 5.19:

Table 5.19

Progress on Afforestation in the Different States—Godavari Basin

States	Areas	Districts
1	2	3
Andhra Pradesh	1,012 hectares	Khammam, Warangal, East Godavari
Orissa	8,094 ,,	
Madhya Pradesh	283 ,,	Seoni, Bastar, Chhindwara

5.70 After taking into consideration the silt load, rainfall and its characteristics, soil-vegetal cover and topography etc. in Maharashtra, the catchments of major and medium projects have been graded for consideration under the afforestation programme in the Fourth Five Year Plan. The catchment areas of Purna (Yeldari—7,770 sq. km.), Mula (2,274 sq. km.) and Manar (1,585 sq. km.) have been included in this programme.

5.71 In Andhra Pradesh contour bunding in the basin was taken up during the First Plan in Adilabad district. In the Second Plan, areas in Medak, Nizamabad, Karim Nagar and Warangal districts were protected by contour bunding. In the Third Plan, soil conservation measures were taken up in other areas of these districts. The problem of soil and moisture conservation is most acute in the part of Godavari basin lying in the Bidar district of Mysore State. The Government of Mysore formulated a land improvement scheme in 1942. As a result, contour bunding is being done now in medium and shallow soil. In deep black soils at present contour bunding is being done only as an experiment.

5.72 Soil and water conservation measures were started in the erstwhile Bombay State in 1942, with the main object of preventing soil erosion and of conserving moisture to help agricultural production in dry areas. These measures include contour and graded bunding, bench terracing etc. Bunds of various types are being constructed to suit each agro-climatic zone. Work done in the Godavari basin till the end of August, 1969 in Maharashtra State is shown in Table 5.20.

Contour-bunding has been carried out generally in unirrigated areas and the results have been promising.

Table 5.20

Soil and Water Conservation Works done in Maharastra—Godavari Basin

(*hectares*)

Sl. No.	Basin	Bundable area	Area bunded so far	Area terraced so far
1	2	3	4	5
1.	Wainganga	784534	116184	14723
2.	Wardha	254939	68048	—
3.	Penganga	442145	203963	—
4.	Godavari	4157329	1383749	7478
5.	Purna	1202469	455605	—

5.73 In order to carry out a detailed study of soil and conservation work in river valley projects, the Maharashtra Government had appointed a study group in 1962 consisting of officers of the Agriculture, Forest, Irrigation and Power Departments. The group was to assess the vulnerability of particular catchment areas and river valley projects to the hazards of soil erosion and draw up a list of vulnerable catchments and also a scheme for co-ordinating different soil conservation works in the most vulnerable catchments. After a detailed study of the catchments of river valley projects taken up during the Second Five Year Plan, the group graded them in order of vulnerability to soil erosion hazards and placed the Purna and Mula projects as second and fourth respectively. Soil and water conservation operations like contour and graded bunding already in progress will minimise the problem of silting in major and medium reservoirs.

Under the Centrally sponsored programme of soil conservation in catchments of major river valley projects, the Machkund project has been included, and work in the catchment was started during the Third Five Year Plan. Priorities in soil conservation measures have been fixed on the basis of silt load data, extent of erosion, slope percentage etc. An expenditure of Rs. 19.8 million was incurred on the project up to the end of 1969 on treating an area of 33,000 hectares.

A capacity survey of the Machkund Reservoir to determine the rate of its silting has not yet been undertaken. However, the CW & PC has conducted some studies regarding the siltation in the reservoir, by the inflow-outflow method. The gross storage capacity of the reservoir is 999.7 m. cu. m., of which 921.7 m. cu. m. is the live storage and the balance 78.0 m. cu. m. the dead storage. The silt inflow and outflow data since 1958–59 is shown in Table 5.21.

Table 5.21

Silt Inflow and Outflow Data—Machkund Reservoir

Year	Inflow of silt in m.cu.m.	Outflow of silt in m.cu.m.	Suspended silt trapped in the reservoir in m.cu.m.	Total silt including bed load (2.5% of suspended load trapped in m.cu.m.)
1	2	3	4	5
1958-59	1.04	0.49	0.55	0.56
1959-60	1.29	0.55	0.74	0.76
1960-61	0.61	0.13	0.48	0.49
1961-62	0.75	0.39	0.36	0.37
1962-63	0.73	0.39	0.34	0.35
1963-64	0.72	0.29	0.43	0.44
1964-65	0.76	0.21	0.55	0.56
1965-66	0.59	0.20	0.39	0.40
1966-67	0.47	0.10	0.37	0.38
1967-68	0.57	0.10	0.47	0.48
Total	7.53	2.85	4.68	4.79
Annual average	0.753	0.285	0.468	0.479

*Sedimentation data on selected reservoirs in India (Revised Edition), Soil Conservation Directorate, CW & PC (Unpublished).

An analysis of the above data shows that the total suspended silt retained in the reservoir from 1958–59 to 1967–68 is of the order of 4.68 m. cu. m. i.e. on an average annually 0.468 m. cu. m. Adding bedload at 2.5% of the suspended load trapped, this works out to 0.479 m. cu. m. against the annual rate of siltation of 0.765 m. cu. m. assumed in the project estimate.

The siltage in the reservoir is lower, about 0.6 of the siltage assumed in the project estimates. A lower rate of bedload i.e. at 2.5 per cent as compared to about 15.20 per cent assumed elsewhere may be one reason for the lower calculated silt rate. With the implementation of soil conservation measures in the catchment since 1956–57, the rate of inflow is showing a downward trend.

5.74 Sedimentation studies have been carried out of the Nizamsagar

Reservoir across the river Manjra, a tributary of the Godavari. The results of the capacity survey are shown in Table 5.22.

Table 5.22

Results of the Capacity Survey—Nizamsagar Reservoir

Period covered	Rate of annual siltation (m.cu.m.)	Rate of annual deposit per 100 sq.km. of the catchment area	Total live storage loss per cent	Rate of annual loss per cent live storage	Calculated life of live storage
1	2	3	4	5	6
30 years (1931 to 1961)	8.70	0.04	37	1.2	83.3 years
5 years (1962 to 1966)	23.62	0.11	16	3.2	31.3 years
36 years (1930 to 1966)	10.76	0.05	53	1.5	66.6 years

5.75 It will be seen from the above that annual rate of siltation in the live capacity over 36 years per 100 sq. km. of catchment area has been of the order of 0.05 m. cu. m. as compared to 0.003 m. cu. m. deposition in the overall storage estimated in the project report. These studies clearly bring out that the rate of siltation in live storage has been nearly 17.5 times higher than anticipated and if allowed to continue at this rate, the live capacity will be badly impaired within a few years time. There is urgent need for taking up soil conservation measures in the catchment area of this dam. In this connection our recommendations in paras 14.4 in Volume I and 1.34 in Volume II of the Report may also be referred to.

5.76 Studies of the behaviour of water table in bunded areas in Mysore, Madhya Pradesh and Maharashtra have shown a rise in water table. Similar studies have not been made in Orissa. The Agriculture and Forest Departments are entrusted with soil conservation work in all these States.

GENERAL

5.77 The Godavari and its tributaries are an inter-State river system, flowing through the States of Maharashtra, Madhya Pradesh, Mysore, Orissa and Andhra Pradesh. A number of projects have already been constructed in the basin. Others are under construction in the various States. The approach all along has been to look at projects in the light of the benefit they would confer on the individual States concerned, except in a few cases where the projects have been constructed jointly by two States. Once the award of the Godavari Tribunal is announced, it would be possible for the different States to plan their future projects within the limits of the share of the water allocated to them. However, till such time as the award is announced, the concerned States could do detailed investigations of the promising new projects and prepare their project reports with estimates of costs and benefits.

5.78 The number and distribution of rain-gauge stations should be reviewed and new stations to fill in any gaps should be established. It is also important that the daily rainfall data for all these stations should be published on a monthly basis, preferably by sub-basins.

5.79 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs should be established.

5.80 As stated in para 5.26 out of the 38 sites recommended by the Krishna-Godavari Commission, 34 sites have been established by the Central Gauging Circle of the CW&PC and on the remaining 4 sites, independent stations are being set up by the Commission. Gauge and discharge observations at the sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects but also for the regulation of available river water.

5.81 Systematic and scientific exploratory work in the basin is needed for a quantitative and qualitative assessment of the groundwater resources, so that these resources are developed in a rational way for use, either independently or in conjunction with surface waters.

5.82 There is need for inter-State co-operation, and agreement in respect of soil conservation measures and conserving the storage capacities of existing and proposed reservoirs.

5.83 As a number of dams are being constructed in the Godavari basin, it is necessary that systematic data is collected with regard to the sediment carried by the rivers, which would be of considerable use in working out dead storage and the life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE KRISHNA BASIN

(i) Source: Just north of Mahabaleshwar about 64 km. from the Arabian Sea. (Latitude 18°2′N, Longitude 75°42′E).

(ii) Length: Andhra Pradesh	612 km.	380 miles
Maharashtra	306 km.	190 miles
Mysore	483 km.	300 miles
	1,401 km.	870 miles

(iii) Drainage area: Andhra Pradesh	76,252 sq.km.	29,441 sq. miles
Maharashtra	69,425 ,,	26,805 ,,
Mysore	113,271 ,,	43,734 ,,
	258,948 sq.km.	99,980 sq. miles

(iv) Population (1971 census)	38.50 millions.	
(v) Density of population	149 per sq. km.	366 per sq. mile.
(vi) Maximum discharge at Vijayawada on the 7th Oct., 1903	33,810 cumecs	11,94,000 cusecs.
(vii) Minimum discharge at Vijayawada:	Less than 2.88 cumecs.	Less than 100 cusecs.

	m.cu.m.	MAF
(viii) Average annual runoff as assessed by the Krishna-Godavari Commission	62,784	50.90
(ix) Maximum annual flow recorded to-date In the year 1916-17	98,358	79.74
(x) Minimum annual flow recorded to-date In the year 1918-19	22,005	17.84

	Thousand hectares	Thousand acres
(xi) Culturable area (1967-68)	20,299	50,161
(xii) Net area sown (1967-68)	15,538	38,396
(xiii) Gross area sown (1967-68)	16,357	40,420
(xiv) Net area irrigated (1967-68)	1,819	4,495
(xv) Gross area irrigated (1967-68)	2,110	5,214
(xvi) Area irrigated after completion and full development of Fourth Plan projects	5,247	12,965
(xvii) Probable additional irrigation by future projects	N.A.	

xviii) Water utilisation, including reservoir losses

		m.cu.m.	MAF
(a) On completion and full development by the major, medium and minor projects under operation and construction in 1968-69	Surface water	52,437	42.51
	Ground water	6,513	5.23
Total		58,950	47.79
(b) On completion and full development of Fourth Plan projects	Surface water	57,181	46.36
	Ground water	8,583	6.96
Total		65,764	53.32

CHAPTER VI

THE KRISHNA BASIN

The Krishna basin extends over an area of 258,948 sq. km. which is nearly 8% of the total geographical area of the country. The basin lies between east longitudes 73°21′ to 81°9′ and north latitudes 13°7′ to 19°25′. Lying in the Deccan plateau, it covers large areas in the States of Maharashtra, Mysore and Andhra Pradesh. The State-wise distribution of the area is given below:

Table 6.1

Drainage Area—State-wise

Sl. No.	Name of State	Drainage area in sq.km.
1.	Andhra Pradesh	76,252
2.	Maharashtra	69,425
3.	Mysore	113,271
	Total	258,948

6.2 The Krishna basin is bounded on the north by the ridge separating it from the Godavari basin, on the south and east by the Eastern Ghats and on the west by the Western Ghats. The basin is roughly triangular in shape with its base along the Western Ghats, the apex at Vijayawada and the Krishna itself forming the median. All the major tributaries draining the base of the triangle fall into the river in the upper two-thirds of its length.

Except for the hills forming the watershed around the basin, the entire drainage basin of the river comprises rolling and undulating country, a series of ridges and valleys interspersed with low hill ranges. Large flat areas of the type seen in the Indo-Gangetic plains are scarce, except in the delta.

The western edge of the basin is an almost unbroken line formed by the Western Ghats whose height ranges from 600 m. to 2,100 m. It has the heaviest rainfall and the most humid climate in the basin. Hardly 50 to 60 km. east of the Ghats lie the sparsely cultivated and undulating plains of the Deccan with a dry climate and poor rainfall.

The interior of the basin is a plateau, the greater part of which is at an elevation 300 to 600 m. Its general slope is eastwards. Great undulating plains, divided from each other by flat-topped ranges of hills are the main characteristics of this plateau. The hill-sides are marked by conspicuous, wide, terraces except in the southern part where the hills are frequently crowned with great 'tors' or rounded hummocks of bare rock, the result of constant weathering.

The Eastern Ghats which form the eastern boundary of the peninsula are by no means so well-defined or continuous as the Western Ghats. To the south of the Krishna, the Eastern Ghats comprise parallel ranges, which are the successive outcrops of an ancient series of stratified rocks.

The delta of the Krishna formed by deposits at the mouth of the river over past ages, consists of a wide belt of river-borne alluvium. The process of silt deposition at the mouth of the river is still continuing and the delta is gradually extending into the sea.

THE KRISHNA RIVER SYSTEM

6.3 The Krishna rises in the Western Ghats at an altitude of 1,337 m. just north of Mahabaleshwar, about 64 km. from the Arabian Sea and flows from west to east through the States of Maharashtra, Mysore and Andhra Pradesh to join the Bay of Bengal.

About 137 km. from the source, it receives a main tributary, the Koyna, from the western side of the Mahabaleshwar hills. Lower down, the river Yerla falls into the Krishna from the left and then the Varna, the Panchganga and the Dudhganga from the right.

Just near its confluence with Dudhganga and about 306 km. from its source, the Krishna enters Mysore State. At this point, the bed level of the river is at an altitude of about 533 m. and the river has emerged from the heavy rainfall zone along, and near, the Western Ghats. After flowing for 201 km. in Mysore territory, the Krishna receives, from its right, the waters of the Ghataprabha, and 35 km. lower down, those of the Malaprabha. Both these tributaries have their source in the Western Ghats.

A short distance downstream of its confluence with the Malaprabha, the Krishna drops about 122 m. from the table-land of the Deccan plateau to the alluvial lands of Raichur. The Krishna receives its two major tributaries, the Bhima and the Tungabhadra, the former on its left at 789 km. from its source and the latter 129 km. further downstream, near Kurnool from its right. Both the Bhima and the Tungabhadra drain large areas of the Western Ghats and each is a major river in its own right.

From a short distance below its confluence with the Tungabhadra, the Krishna runs in a deep gorge through a series of hills, for nearly 290 km. before emerging into the coastal belt at Pulichintala, at an elevation of about 37 m. above sea level. Beyond this point, the river flows for about 80 km. before it spreads into the delta. Vijayawada is at the head of the delta.

The Dindi and the Musi join the Krishna from its left between Kurnool and Pulichintala and two more tributaries, the Palleru and the Muneru, also from the left, fall into the river between Pulichintala and Vijayawada.

The total length of the river from the source to its outfall into the sea is about 1,400 km., of which 612 km. are in Andhra Pradesh, 306 km. in Maharashtra and 483 km. in Mysore. Together with its tributaries, the river drains about 708 km. of the Western Ghats, which is its chief source of supply.

6.4 The Ghataprabha, the Malaprabha, the Bhima, the Tungabhadra and the Musi are the principal tributaries.

The Ghataprabha

6.5 The Ghataprabha rises in the Western Ghats at an altitude of 884 m. and flows eastwards for a length of 283 km. before joining the Krishna at Kudlisangam, about 35 km. north-east of Kaladgi, at an elevation of 500 m. The river flows for about 60 km. in the Ratnagiri and Kolhapur districts of Maharashtra before entering the Belgaum district of Mysore. Two of its tributaries, the Hiranyakeshi and the Markandeya, also rise in the Western Ghats and flow through Maharashtra and Mysore. The total catchment area of the Ghataprabha and its tributaries is 8,829 sq. km. The principal source of supply is an area of about 64 km. of the Western Ghats, to a depth of about 64 km. in width to the east of these hills; within this area the annual rainfall decreases from about 3,048 mm. to about 1,016 mm.

The Malaprabha

6.6 The Malaprabha rises in the Western Ghats, at an altitude of about 793 m., about 16 km. west of Jamboti in the Belgaum district of Mysore. The river flows first in an easterly and then in a north-easterly direction and joins the Krishna at an elevation of about 488 m., about

306 km. from its source. The total catchment area of the Malaprabha and its tributaries is 11,549 sq. km. Its principal source of supply is, however, only about 32 km. of the Western Ghats and a small area east of it.

The Bhima

6.7 The Bhima also rises in the Western Ghats at an altitude of about 945 m. and flows south-eastwards through Maharashtra and Mysore. It has a total length of 861 km. and falls into the Krishna about 26 km. north of Raichur at an altitude of 343 m.

About 137 km. from its source, the Bhima receives, from its right, the combined waters of the Mula and the Mutha rivers from Poona, and about 29 km. lower, the Ghod joins the Bhima from the left. Lower down, it is joined on its right bank by the Nira, which also rises in the Western Ghats, and then by the Man. For a length of 74 km. the Bhima runs along the boundary between Maharashtra and Mysore. In this reach it receives the waters of the Sina, which rises near Ahmednagar. For the last 299 km. of its course, the Bhima flows in Mysore. No major tributary falls into the Bhima in this reach.

The total catchment area of the Bhima is 76,614 sq. km. but its principal source of supply is a length of about 161 km. of the Western Ghats.

The Tungabhadra

6.8 The Tungabhadra, an important tributary of the Krishna, is formed by the union of the twin rivers Tunga and Bhadra, which rise together in the Western Ghats at Gangâmula at an elevation of about 1,196 m. The united river Tungabhadra flows for about 531 km. in a generally north-easterly direction, through Mysore and Andhra Pradesh and joins the Krishna beyond Kurnool at an elevation of about 264 m. The Varada and the Hagari are the two important tributaries of the Tungabhadra. The Varada drains a large area of the Western Ghats and falls into the Tungabhadra at an elevation of about 509 m., about 161 km. below the confluence of the Tunga and the Bhadra. The Hagari joins the Tungabhadra about 169 km. upstream of its confluence with the Krishna. The total drainage area of the Tungabhadra is 71,417 sq. km. Like the Bhima, it drains about 206 km. length of the Western Ghats.

The Musi

6.9 The Musi rises at an altitude of about 661 m. in the Medak district of Andhra Pradesh. It flows through Hyderabad city and runs mostly west to east until it is joined by the Aleru. It then flows southwards and drops into the Krishna near Wazirabad, at an elevation of about 61 m. The river drains about 11,212 sq. km. and traverses a low rainfall area with an annual rainfall of 635 mm. to 813 mm.

6.10 Some particulars of the Krishna and its more important tributaries are given below:

Table 6.2

Details of the Krishna and its Important tributaries

Sl. No.	Name of the sub-basin	Area (Sq. km.)	Percentage of Krishna basin
1.	Upper Krishna (from source to its confluence with the Dudhganga)	17,972	6.94
2.	Middle Krishna (from its confluence with the Dudhganga to its confluence with the Bhima)	17,558	6.78
3.	Ghataprabha	8,829	3.41
4.	Malaprabha	11,549	4.46
5.	Upper Bhima (from source to its confluence with the Sina)	46,066	17.79
6.	Lower Bhima (from its confluence to the point where it falls into the Krishna)	24,548	9.48
7.	Lower Krishna (from its confluence with the Bhima to the sea)	36,125	13.95
8.	Tungabhadra	71,417	27.58
9.	Musi	11,212	4.33
10.	Palleru	3,263	1.26
11.	Muneru	10,409	4.02
	Total	258,948	100.00

CLIMATE

6.11 Four distinct seasons occur in the Krishna basin in the year. They are (i) the cold weather, (ii) the hot weather, (iii) the south-west monsoon and (iv) the post-monsoon.

The cold weather season from mid-October to mid-February is generally pleasant in the entire basin. The western and the north-eastern regions are colder than the rest.

In the hot weather season, the heat is unbearable in the central, northern and eastern regions. It is comparatively pleasant in the westernmost parts.

The south-west monsoon sets in by mid-June and ends by mid-October. During this period, the basin receives about 80% of its total annual rainfall.

After the withdrawal of the south-west monsoon in the middle of October, the weather clears up gradually and it is cool thereafter.

Rainfall

6.12 Like most other parts of India, the Krishna basin receives its maximum rainfall during the south-west monsoon. The monsoon winds strike the west coast of the Indian peninsula from the west and south-west and strike the Western Ghats or the Sahyadri Range, which present an almost uninterrupted barrier ranging from 610 m. to 2,134 m. in height. After surmounting this barrier and depositing most of the moisture on the wind-ward side, the monsoon currents sweep across the interior of the peninsula, on a course which is mainly westwards. The amount of rainfall on the ghats, at any particular place, is governed largely by the local orographic features. This factor introduces considerable spatial variation in the amounts of rainfall. In crossing the ghats, the monsoon winds lose a large part of their moisture. As the crest of the ghats forms the general watershed of the peninsula and the average slope of the country from it is towards the east coast, which slope is followed by the monsoon winds, the conditions in the interior are somewhat unfavourable for heavy precipitation, except in association with depressions from the Bay of Bengal.

6.13 The high rainfall zone along the Western Ghats forms the western boundary of the Krishna basin for a distance of about 708 km. and many channels, big and small, carry the drainage of this area into the Krishna. The annual rainfall varies from 3,048 mm. to 1,016 mm. in this reach.

East of the Western Ghats, the annual rainfall decreases rapidly until it is less than 600 mm. along the line running approximately from Chitradurga to Sangli, to Poona and then to a point north and east of a line connecting Kurnool, Raichur, Bijapur and Ahmednagar. East of this, the rainfall again gradually increases to about 900 mm. in and around Guntur.

There is a large belt, a short distance east of the Western Ghats and varying in width from about 258 km. from the south to about 80 km. in the north where the normal annual rainfall is less than 600 mm. This belt, about 1,06,200 sq. km. in area, includes portions of the Anantapur and Kurnool districts of Andhra Pradesh, the Raichur, Bellary, Chitradurga, Dharwar, Belgaum, Bijapur and Gulbarga districts of Mysore, and the Satara, Sholapur, Poona and Ahmednagar districts of Maharashtra.

From the maps showing the seasonal distribution of rainfall in the country in the 'Irrigation Atlas of India' it will be seen that January and February are almost entirely dry months in the Krishna basin. The rainfall during these two months is less than 15 mm. During the three months, March to May, the rainfall in most parts of the basin varies from 20 mm. to about 50 mm.

June to September are the four months of the south-west monsoon during which all parts of the basin receive their maximum rainfall. The seasonal and annual average weighted rainfalls in the various sub-basins of the Krishna basin are given below:

Table 6.3

Seasonal and Annual Average Weighted Rainfalls

Sl. No.	Name of Sub-basin	Rainfall (millimetres)				Annual
		Jan.-Feb.	Mar.-May	June-Sept.	Oct.-Dec.	Total of cols. 3 to 6
1.	Upper Krishna (from source to confluence with Dudhganga)	5	65	1,286	152	1,508
2.	Middle Krishna (from confluence with Dudhganga to confluence with Bhima)	7	62	366	130	565
3.	Ghataprabha	5	92	671	153	921
4.	Malaprabha	4	93	431	147	675
5.	Upper Bhima (from source to confluence with Sina)	8	36	527	105	676
6.	Lower Bhima (below confluence with Sina)	12	51	499	99	661
7.	Lower Krishna (below confluence with Bhima)	12	60	508	141	721
8.	Tungabhadra	8	95	622	159	884
9.	Musi	14	65	546	124	749
10.	Palleru	14	55	605	136	810
11.	Muneru	19	78	723	134	954
	Krishna basin	9	69	570	136	784

6.14 The actual rainfall varies widely from year to year. There are also variations in the incidence and distribution of rainfall in time and space. These variations have an important bearing on agricultural operations and river flows. The date of the onset of the south-west monsoon is important from the point of view of sowing operations, as well as the availability of river supplies. Studies carried out by the India Meteorological Department indicate that there is considerable variation in the dates of the onset and withdrawal of the monsoon, and also in the speed with which the monsoon currents move from Kerala towards Bombay and across the peninsula. The standard deviation for the west coast is about five to six days. In individual years, however, the monsoon has been known to break on the west coast as many as 19 days earlier or 13 days later than the mean date.

6.15 Apart from the dates of the onset of the south-west monsoon, it is also important to know the rainfall variations in different months and different years.

The co-efficient of variability of monthly rainfall for different meteorological sub-divisions as worked out by the India Meteorological Department are shown in the following table:

Table 6.4

Coefficient of Variability

Sl. No.	Name of the Sub-basin	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
1.	Hyderabad (North)	251	167	163	61	97	35	25	41	40	71	120	204
2.	Hyderabad (South)	294	102	218	97	70	37	33	41	43	82	106	168
3.	Rayalaseema	207	241	221	81	61	41	52	63	45	56	83	172
4.	Andhradesa	134	161	184	103	77	40	27	29	32	50	70	142

A co-efficient of variability of 294 during the month of January for Hyderabad (South) indicates that the magnitude of standard deviation would be about three times as large as the mean rainfall of the month. Such a situation arises from the fact that it rains in this area during January only on one day in three years. Likewise, a co-efficient of variability of 25 in a month of July for Hyderabad (North) indicates that the standard deviation would be one-fourth of the mean rainfall of the month.

A closer examination of the figures in the table would show that the co-efficient of variability for the north-east monsoon (October to December) is considerably larger than that for the south-west monsoon (June to September). This confirms the view expressed by some experts that the north-east monsoon is much less dependable than the south-west monsoon, and that any agriculture as also, river flows dependent on the former would be more precarious than those dependent on the latter. It will be noticed, also, that the rainfall during December to May is, in general, not dependable for agricultural operations.

Temperature

6.16 The Krishna basin has a tropical climate. The mean annual surface temperature in the Western Ghats is about 24°C; it increases gradually towards the east and attains a maximum of 29.4°C on the east coast.

During January, which may be taken as representative of the winter months, the mean daily minimum temperature increases from west to east, from 15°C in the Western Ghats to about 18°C at the east coast; the mean daily maximum temperature generally exceeds 30°C in the western part of the Krishna basin and is only slightly less than 30°C in the eastern part. The daily maximum and the daily minimum temperatures are considerably higher than in northern India.

During April, which may be taken as representative of the summer months, preceding the monsoon, the mean daily minimum temperature is about 22°C in the western end and it increases eastward to a maximum of about 26°C near the east coast. The mean daily maximum temperature, which is about 35°C in the western end increases to about 40°C in the middle of the plateau and then falls to about 35°C near the east coast. During this month, the temperature in the Krishna basin is about the highest in the country.

During July, which may be taken as representative of the monsoon months, the mean daily minimum temperature in the Western Ghats area is about 20°C and it increases eastward to about 26°C near the east coast. The mean daily maximum temperature is about 27°C in the Western Ghats area and it increases eastward to about 33°C near the east coast.

During October, which may be taken as representative of the post-monsoon months, the mean daily minimum temperature is about 20°C in most parts of the basin and it increases to about 23°C on the east coast. The mean daily maximum temperature is a little more than 39°C over the entire basin.

Evaporation

6.17 Evaporation is an important climatic factor bearing on agricultural and water resource development. Unfortunately very little data on evaporation is available for the Krishna basin. The India Meteorological Department have compiled the evaporation data in respect of 30 departmental and 42 agro-meteorological observatories possessing data for more than five years. These observatories are scattered all over the country. Observations at all these observatories are taken with the standard U.S. Evaporation pan (Class A) covered with wire-mesh. For the departmental observatories, the data pertains to the period 1959–68 and is available monthwise, whereas the data for the agro-meteorological observatories pertains to the period 1961–1968 and has been presented for 12 periods into which the calendar year is divided for agro-meteorological purposes. Of the above 72 observatories, one departmental observatory at Hyderabad and two agro-meteorological observatories at Raichur and Bellary are located in the Krishna basin.*

SOILS

6.18 No systematic soil survey of the Krishna basin has been carried out so far. The general data regarding soils of India, however, indicate that the basin consists mainly of (i) black soils (regur), (ii) red soils, (iii) laterite and lateritic soils, (iv) alluvium, (v) mixed soils (red and black, red and yellow, etc.) and (vi) saline and alkaline soils.

6.19 The principal soil types found in the various districts in the basin are given below.†

Table 6.5

Soils in the Krishna Basin

Sl. No.	Name of State/ District	Type of soil
(1)	(2)	(3)
	Andhra Pradesh	
1.	Anantapur	Red and black
2.	Guntur	Black
3.	Hyderabad	Red and Shallow black
4.	Karimnagar	Red

*Evaporation Data (India), India Meteorological Department (April, 1970).

†Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, C. D. & Cooperation (1967).

Table 6.5—Contd.

(1)	(2)	(3)
5.	Khammam	Sandy loam, clayey loam and loam
6.	Krishna	Deep black, red sandy, red and black
7.	Kurnool	Black
8.	Mahbubnagar	Deep, shallow black and red sandy loam
9.	Medak	Shallow black and red
10.	Nalgonda	Sandy loam, clayey loam and loam
11.	Warangal	Red sandy, red loamy and deep black
Maharashtra		
12.	Ahmednagar	Black, red and grey or white
13.	Bhir	Shallow medium and black
14.	Kolhapur	Laterite, medium black and deep black
15.	Osmanabad	Medium black and shallow reddish brown soils
16.	Poona	Black or medium black, red and coarse grey
17.	Ratnagiri	Laterite
18.	Sangli (South Satara)	Deep black, medium deep brown to dark-brown, shallow sandy and reddish laterite
19.	Satara	Reddish to light brown laterite, deep-black to dark-brown and medium deep-brown to dark-brown soils
20.	Sholapur	Black, coarse grey and red
Mysore		
21.	Belgaum	Red, black and laterite
22.	Bellary	Red and black
23.	Bidar	Black
24.	Bijapur	Black
25.	Chikmagalur	Red and laterite
26.	Chitradurga	Red
27.	Dharwar	Red, black and brown
28.	Gulbarga	Black
29.	Hassan	Loams
30.	Kanara	Laterite
31.	Raichur	Red and black
32.	Shimoga	Red, black and alluvium
33.	Tumkur	Red

LAND USE AND AGRICULTURAL PRACTICES

6.20 State-wise land use details in the basin as in 1967–68, the latest year for which the statistics are available, are given below:

Table 6.6

Land Use Details

(Thousand hectares)

Sl. No.	Item	Name of State: Andhra Pradesh	Maharashtra	Mysore	Total
1	2	3	4	5	6
1.	Gross area	7,625	6,943	11,327	25,895
2.	Reporting area	7,611	6,936	11,092	25,639
3.	Area under forests	1,405	635	954	2,994
4.	Area not available for cultivation	949	535	862	2,346
5.	Culturable area	5,257	5,766	9,276	20,299
6.	Uncultivated culturable area	1,630	948	2,183	4,761
7.	Net area sown	3,627	4,880	7,093	15,538
8.	Area sown more than once	400	244	175	819
9.	Total cropped area	4,027	5,062	7,268	16,357
10.	Net area irrigated	647	557	615	1,819
11.	Gross area irrigated	869	562	680	2,110
12.	Percentage of net area sown to culturable area	69.0	83.6	76.5	76.6
13.	Percentage of net area irrigated to culturable area	12·3	9.7	6.6	9.0
14.	Percentage of net area irrigated to net sown area	17.9	11.6	8.7	11.7

All the area shown under forests in the basin is not necessarily wooded, as some areas classified as forests were denuded and not replanted. The original classification, however, continues.

The culturable area in the basin is about 10.4% of the total culturable area of the country. The total cropped area in the basin forms about 10.0% of the total cropped area in the country and 80.6% of the total culturable area in the basin.

6.21 The general cropping pattern, State-wise, is described below:

Andhra Pradesh

6.22 Of the gross irrigated area of 868,800 hectares, about 82.6% is under paddy, 0.9% under sugarcane and the balance under other crops. The other irrigated crops are jowar, bajra, maize, wheat, ragi, millets, condiments, spices, groundnut, sesamum, cotton, tobaccco and fodder crops. Food and non-food crops cover about 92.1% and 7.9% of the irrigated cropped area respectively.

Maharashtra

6.23 Of the gross irrigated area of 562,100 hectares, nearly 32.7% is under jowar, 16.5% under sugarcane, 10.3% under wheat, 5.1% under bajra, 4.7% under paddy, and the balance under other crops. The other irrigated crops are maize, ragi, cotton, barley, gram, pulses, condiments, spices, groundnut, sesamum, tobacco and fodder crops. Food and non-food crops cover about 89.9% and 10.1% of the irrigated cropped area respectively.

Mysore

6.24 Of the gross irrigated area of 679,500 hectares, 47.8% is under paddy, 12.9% under jowar, 7.6% under sugarcane, 3.3% under maize, 1.9% under wheat and the balance under other crops. The other irrigated crops are ragi, barley, millets, gram, pulses and cotton. The food and non-food crops represent about 83.9% and 16.1% of the irrigated cropped area respectively.

6.25 Summing up, of the total irrigated area in the basin, 50.6% is under paddy, 13.2% under jowar, 7.2% under sugarcane, 3.4% under wheat, 1.6% under bajra, 2.0% under maize and the balance under other miscellaneous crops.

6.26 Because of the relatively equable climate of the basin, crop seasons are not so well-defined as in northern India. The sowing of crops and other agricultural operations is determined by the timing of rainfall and the availability of river water, which in turn, also depend on the incidence of rainfall.

In Andhra Pradesh and most of Mysore, the crop season begins with the advent of the rains in June; the un-irrigated crops are harvested in October and the irrigated paddy is not harvested until about December. If irrigation water is available, another paddy crop follows, which is sown in January-February and harvested in April-May. Paddy can, however, be grown at practically any time during the year, and paddy in all stages of growth can be seen at the same time in one and the same locality. Such fields as cannot be sown in July and August are sown during the September rains.

In Maharashtra, there are three official crop seasons, namely, the kharif from the 15th June to the 14th October, the rabi from the 15th October to the 14th February and the hot weather from the 15th February to the 14th June. Many crops, however, extend from one season to the other. Jowar is grown both in kharif and rabi. Cotton and groundnut can be grown in all three seasons if irrigation supplies are available.

In general, paddy, cotton and groundnut can be grown throughout the year in the basin, provided that irrigation supplies can be made available. Cotton is almost entirely an unirrigated crop in the basin. The short staple variety is grown. It requires sufficient moisture during the early stages of its growth and comparatively drier conditions during the flowering and maturing stages. Rainfall during the boll-opening and harvesting period is definitely harmful. Long-staple varieties of cotton have a relatively longer crop-period and need, therefore, some irrigation supplies in addition to rainfall. These varieties have a relatively larger yield and in suitable soils and sufficient drainage, long-staple cotton can be a good cash-crop. Like cotton, groundnut is also grown mainly as a rain-fed crop in the basin. The average yield of the spreading varieties grown in these conditions is 1,344 to 1,550 kg. per hectare and of the bunch varieties is 896 to 1,120 kg., per hectare. With a relatively small quantity of irrigation water, groundnut is a valuable cash-crop yielding 3,360 kg. or more per hectare.

6.27 The sowing and harvesting periods in the different States for the different crops are given below:*

Table 6.7

Sowing and Harvesting Periods

Name of Crop	Period of Sowing	Period of Harvesting
(1)	(2)	(3)
Andhra Pradesh		
Winter Rice.	June-October	November-March
Summer Rice	November-February	March-June
Kharif Jowar	June-October	November-February
Rabi Jowar	October	March-April

*Indian Crop Calendar, Directorate of Economics and Statistics, Ministry of Food, Agriculture, C. D. and Cooperation (1967).

Table 6.7—Contd.

(1)	(2)	(3)
Bajra	June-August	September-December
Kharif Maize	June-August	October-November
Rabi Maize	September-December	January-March
Sugarcane	January-April	December-March
Maharashtra		
Winter Rice	June-July	October-November
Wheat	October-November	February-March
Gram	September-November	January-March
Kharif Jowar	June-July	November-January
Rabi Jowar	September-October	January-March
Bajra	June-July	October-November
Maize	June-July	September-October
Sugarcane	January-July	October-February
Mysore		
Autumn Rice	May-August	November-February
Winter Rice	December-January	April-May
Summer Rice	December-June	May-December
Wheat	October-November	January-February
Gram	October-December	January-February
Kharif Jowar	May-July	September-January
Rabi Jowar	September-November	January-April
Bajra	June-August	September-January
Kharif Maize	June	September
Rabi Maize	November	February
Sugarcane	December-March	November-April

REGIONAL ECONOMY

Population

6.28 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 38.50 millions. The State-wise distribution is shown in Table 6.8.

There are eleven main cities in the basin which have a population of more than one lakh each. They are Hyderabad, Vijayadada, Guntur, Masulipatnam and Kurnool in Andhra Pradesh; Ahmednagar, Poona,

*Census Paper I of 1971 (Supplementary), Registrar-General (India).

Table 6.8

Population in the Krishna Basin—State-wise

Sl. No.	State	Population
1.	Andhra Pradesh	11.92 millions
2.	Maharashtra	12.10 millions
3.	Mysore	14.48 millions
	Total	38.5 millions

Sholapur and Kolhapur in Maharashtra and Hubli and Belgaum in Mysore. The average density of population in the basin is 149 persons per sq. km. The density varies from region to region within the basin. The coastal plain is generally densely populated while the hilly areas have a relatively low density. In 1971, the most densely populated district of Hyderabad had 362 persons per sq. km., while the district of North Kanara with 83 persons per sq. km. stood at the other extreme.

80.9% of the population in the basin live in rural areas and the balance of 19.1% in cities and towns. The working force constitutes about 38.3% of the population. Nearly 35.0% of the working force is engaged as cultivators, 31.5% as agricultural labourers and the balance 33.5% are employed in mining, manufacturing and tertiary activities.

Forests & Agriculture

6.29 Forests and agriculture are the mainstay of the people. Out of a total area of 26 million hectares, nearly 3 million hectares are under forests. The area annually cropped in the Krishna basin is about 16.4 million hectares. Agriculture is generally rain-fed with relatively low yields except in about 2.1 million hectares of irrigated area, of which about 1.07 million hectares grow paddy.

Power

6.30 The development of power in the basin had not taken place on a large-scale earlier. The hydroelectric survey conducted by the Central Water & Power Commission indicates the total potential in the Krishna basin to be 1,636 MW at 60% load factor. Against this, the total installed capacity of the hydroelectric stations in operation and under construction in the basin is 1,787.72 MW. The installed capacity of the thermal generating plants in operation is 34.5 MW. Project-wise details are given below:*

Table 6.9

Details of Hydro and Thermal Power Stations

Sl. No.	Name of the Station	Installed capacity in MW	
		Hydro	Thermal
1.	Bhivpuri	72.00	—
2.	Khopali	70.00	—
3.	Bhira	132.00	—
4.	Bhatgarh	1.02	—
5.	Radhanagari	7.50	—
6.	Munirabad	18.00	—
7.	Tungabhadra }	54.00	—
8.	Hampi }		
9.	Koyna (Stages I, II & III)	860.00	—
10.	Nagarjunasagar	100.00	—
11.	Srisailam	440.00	—
12.	Bhadra	33.20	—
13.	Hyderabad	—	22.50
14.	Vijayawada	—	12.00
	Total:	1,787.72	34.50

Mineral Wealth

6.31 The basin has a rich variety of mineral wealth spread over vast areas. The principal minerals found are listed below:

Bauxite: In the Kolhapur district of Maharashtra.

Manganese: In the Bellary, Chitradurga, Shimoga and Tumkur districts of Mysore.

Iron Ore: In the Khammam, Krishna and Kurnool districts of Andhra Pradesh and in the Bellary and Chikmagalur districts of Mysore.

*Techno-Economic Surveys of Andhra Pradesh, Maharashtra and Mysore, NCAER.

Copper: In the Anantapur district of Andhra Pradesh.

Gold: At Hati in the Raichur district of Mysore and in river beds.

Coal: In the Khammam district of Andhra Pradesh.

Limestone Deposits: In the Gulbarga and Shimoga districts of Mysore.

Other minerals like lead, zinc, corundum, ilmenite, refractory minerals and Kaolin are also found in small quantities in different parts of the basin.

Industries

6.32 Rich in forests, agricultural and mineral resources, the industrial potential of the Krishna basin is high. There is also a large hydropower potential awaiting development. The present developments are only modest indications of the large potential, which remains to be developed in the area.

A small part of the enormous forest wealth of the basin is at present utilised as timber and in the manufacture of paper and other timber products in the district of Shimoga of Mysore.

Of the industries based on agricultural produce, mention may be made of the processing of agricultural commodities in rice milling, cotton ganning, pressing, spinning and weaving, the manufacture of sugar, the manufacture of textiles, the extraction of oil from groundnut and other oilseeds and bidi manufacture. The mining of ores like manganese, coal etc. are important activities in the districts rich in minerals.

Iron and steel are manufactured in the basin at Bhadravati in the Shimoga district of Mysore. Small engineering industries are spread all over the basin.

Cement is manufactured in the districts of Guntur and Krishna in Andhra Pradesh and at Bijapur, Gulbarga and Shimoga in Mysore.

Communications

6.33 The basin is served by the Central, Southern and South-Central Railways. The main line connecting Bombay and Madras passes through it in its upper reaches. The main Madras-Calcutta line passes through the basin just above the delta. There are some branch lines, partly or wholly in the basin, namely, the Secunderabad-Poona line, the Kazipet-Hyderabad line, Hyderabad-Wadi line, the Guntur-Vijayawada-Masulipatnam line, etc. These lines serve some of the prominent towns like Hyderabad, Secunderabad, Guntur, Vijayawada, Masulipatnam, etc.

National Highways connecting Bombay with Vijayawada, Hyderabad with Nagpur and Madras with Calcutta traverse the basin. Besides these, there is a network of State Highways, district and village roads connecting important towns and villages.

The navigable waterway of the Krishna System comprises the Krishna river, its delta arms and the network of the delta irrigation-cum-navigation canals. The Krishna is navigable throughout the year by country boats and small steamers up to 30 tonnes capacity, in its tidal reach for about 66 km. from sea to a point 40 km. below Vijayawada.* From this point to Vijayawada, navigation is routed through the Krishna delta canals, which are connected with the river above the Krishna Barrage by suitable locks. The river is also navigable throughout the year for about 35.4 km. upstream of the Krishna Barrage by country boats and small steamers up to 30 tonnes capacity. During the monsoon (July to November) boats can ascend for a further distance of 64 km.

The Krishna delta canals forming the connecting links between the Godavari canals in the north and the Buckingham Canal in the south, provide through communication.

From what has been said above, it would be seen that major portion of the basin is fairly served with communications.

Dependence on Rainfall and Water Resources

6.34 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence, except for small parts of the basin where facilities for irrigation have been provided. The latter areas are also the seat of industries based on agriculture produce. For these reasons, a keen demand exists in the basin for the accelerated development of water resources.

WATER RESOURCES

Surface Water

6.35 The water potential of the Krishna river system has been assessed at different times by different authorities. The first assessment was made by the First Irrigation Commission. This Commission used the records of the surplus flow of the Krishna from the greater part of its catchment extending back for a sufficient number of years to estimate the average flow as accurately as possible. The Commission assessed the total annual surface flow in the Krishna river system as 84,863 m. cu. m.

6.36 In the year 1949 when the assessment of the water resources of the country (basin-wise) was made on the basis of Khosla's formula, the

*Navigable Waterways of India, Central Water and Power Commission (1961).

annual runoff of the Krishna river system was estimated to be 44,923 m. cu. m.*

6.37 The Technical Committee for the Optimum Utilisation of Krishna and Godavari Waters, in its report dated 1953, estimated the average annual runoff of the Krishna river system at Vijayawada based on Khosla's formula to be 46,872 m. cu. m.**

6.38 The Central Water & Power Commission, when conducting the irrigation potential studies of the country, assessed the total annual runoff of the Krishna river system to be 57,764 m. cu. m.†

6.39 The Krishna Godavari Commission set up by the Government of India, in their report dated July/August, 1962, estimated the average annual yields, sub-basinwise and reported that the aggregate yield of all the sub-basins of the Krishna system is 62,784 m. cu. m.‡

6.40 Until 1964, there was no planned or systematic observations of discharges on the Krishna and its tributaries. Some *ad hoc* and irregular observations were being made on the main river and on a number of tributaries. The only systematic records available pertained to existing anicuts or reservoirs where the river flows were generally calculated on the basis of gauge readings, observed at different points in the system. The Krishna-Godavari Commission went into this question in great detail, and after a study of the data available at 62 sites on the Krishna river system, concluded that regular observations were being continued at 21 sites only. Observations at the remaining sites had been discontinuous or irregular. Of the 21 sites, where regular observations were being made, the data for the period of 10 years or more was available for 16 sites and for a period of 20 years or more, for only 5 sites, namely, Vijayawada on the Krishna, Dhupdal on the Ghataprabha, Bhatgar on the Yelwandi, Sunkesula on the Tungabhadra and Lakkavalli on the Bhadra.

Based on the data of 62 sites made available to them, the Krishna Godavari Commission made the following observations regarding the general features of the flows in the Krishna river basin.

In the upper reaches, the Krishna and its tributaries are generally dry before the advent of the south-west monsoon and they begin to flow

*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

**Report of the Technical Committee for the Optimum Utilisation of the Krishna and Godavari Waters (1953), Planning Commission.

†Report of technological possibilities of irrigation projects in India, Central Water & Power Commission (Unpublished).

‡Report of the Krishna-Godavari Commission (July, 1962).

after the onset of the rains. While the Tungabhadra rises towards the end of May, the Krishna and the Bhima do not have much water before June. July and August are the months of maximum discharge, the volume of flow in these two months varying from 55 to 85 per cent of the annual flow. There is a sharp fall in the river supplies in September and October and in November they carry only a relatively small discharge.

In general, the volume of flow during the six months June to November, is about 95 to 97 per cent of the annual river flow. After January, the river is practically dry.

In the lower reaches, the Krishna and its tributaries begin to rise after the onset of the monsoon, generally by the middle of June. The highest discharges generally occur in August; July being next and in these two months together the rivers carry about 50 to 60 per cent of the annual flow. The river falls in September and October; but these two months together account for about 30% of the annual flow. There is then a sharp fall and after December, the rivers are practically dry.

6.41 The Krishna Godavari Commission also observed:

(i) that in most cases, rough and ready methods as followed many years earlier were still in vogue and no advantage appeared to have been taken of later developments which include modern standards for such discharge observations and for the estimation of river flows;

(ii) that the records of observations had not, in many cases, been properly maintained, which added to the difficulty of assessing their reliability;

(iii) that at some sites, with erodable beds, river discharges were computed on the basis of daily, or even more frequent, velocity observations by floats, but the cross-section was taken only once a year or even once in 3–5 years. At other places, the slope-area method was used, but a uniform slope was assumed once a year, or less frequently, and so the results of such observations could not be considered to be reliable;

(iv) that on most weirs or anicuts, the State Governments were applying formulae or co-efficients which required to be looked into in the light of the latest research findings;

(v) that the discharge sites were distributed over the catchment area in a very uneven fashion.

6.42 The Commission, therefore, recommended that a comprehensive system of daily discharge observations should be set up on the Krishna river and its trubutaries. The observations should be made in a systematic and scientific manner and the results of these observations scrutinised, tabulated and carefully recorded. After consulting the States' representatives and carefully studying the river system, the Commission prepared a list of discharge sites at which such regular discharge observations should be started. These sites are listed in the following table.*

Table 6.10

Discharge Sites Proposed by the Krishna-Godavari Commission

Sl. No.	Name of site	Name of river or tributary	Location
(1)	(2)	(3)	(4)
1.	Khodshi Weir	Krishna	Upstream of the confluence with Koyna.
2.	Shirol	-do-	Upstream of confluence with Panchganga.
3.	Kolhar	-do-	Upstream of confluence with Ghataprabha
4.	Upper Krishna Dam	-do-	—
5.	Gonal	-do-	Upstream of confluence with Bhima.
6.	Deosugur (Devarsugur)	-do-	Below the confluence with Bhima.
7.	Pragatur	-do-	Upstream of confluence with Tungabhadra.
8.	Srisailam	-do-	—
9.	Nagarjunasagar Dam	-do-	—
10.	Pulichintala	-do-	—
11.	Amaravati	-do-	Upstream of confluence with Muneru.
12.	Vijayawada	-do-	—
13.	Koyna Dam (Talkewadi)	Koyna	—
14.	Karad	-do-	Upstream of confluence with Krishna.
15.	Samdoli	Warna	-do-
16.	Kurandvad	Panchganga	-do-
17.	Dattwad	Dudhganga	-do-
18.	Dhupdal	Ghataprabha	—

*Report of the Krishna-Godavari Commission (July, 1962).

Table 6.10—Contd.

(1)	(2)	(3)	(4)
19.	Murmuttisangam	-do-	Upstream of confluence with Krishna.
20.	Hiresangam	Malaprabha	-do-
21.	Dhond	Bhima	Below the confluence with Ghod.
22.	Maligaon	-do-	Below the confluence with Nira.
23.	Takali	-do-	Upstream of confluence with Sina.
24.	Sugur	-do-	Upstream of confluence with Krishna.
25.	Narsingpur	Nira	Upstream of confluence with Bhima.
26.	Wadakbal	Sina	-do-
27.	Havanur	Tungabhadra	—
28.	Tungabhadra Dam	-do-	—
29.	Rajolibanda	-do-	—
30.	Sunkesula	-do-	—
31.	Roza	-do-	Upstream of confluence with Krishna.
32.	Tunga Anicut	Tunga	—
33.	Lakkavalli	Bhadra	—
34.	Belvigi	Varada	Upstream of confluence with Tungabhadra.
35.	Bhairavanithippa	Vedavati	—
36.	Sidaragadde	-do-	Upstream of confluence with Tungabhadra.
37.	Wazirabad	Musi	—
38.	Vemulapalle	Muneru	—

The sites proposed by the Commission were considered to be key sites necessary for the determination of important elements relating to the hydrology of the Krishna river system. The data to be obtained at these sites was considered essential for the preparation of individual projects, for the preparation of an integrated basin-wise plan and for the subsequent operation of such a plan and the regulation, to the best advantage, of the available river water in any year.

6.43 This recommendation of the Krishna-Godavari Commission was accepted by the Government of India, and a special Circle was established within the Central Water and Power Commission for carrying out this work. The Central Gauging Circle established in 1964 is at present observing gauges and discharges on the Krishna river and its tributaries. The method of observation at each site is based on local topographic considerations and the entire work is reviewed by a committee of Chief Engineers of the States concerned, with the Chairman, Central Water & Power Commission as the Chairman of the reviewing body.

Out of the 38 sites recommended by the Krishna-Godavari Commission, 28 sites have been established by the Central Gauging Circle. Two sites, namely site No. 5 at Gonal on the river Krishna and site No. 30 at Sunkesula on the river Tungabhadra, have been omitted and 8 sites, namely site No. 8 (Srisailam), No. 13 (Koyna Dam), No. 18 (Dhupdal weir), No. 28 (Tungabhadra Dam), No. 29 (Rajolibanda), No. 32 (Tunga Anicut), No. 33 (Lakkavalli Dam) and No. 35 (Bhairwanithippa) are still with the respective State Governments. It has since been decided to set up independent stations operated by the Central Water & Power Commission at these 8 sites.

On all the 28 sites set up by the Central Gauging Circle on the Krishna river, current meter gaugings are being carried out.

Owing to the difficult foreign exchange position, the procurement of navigational and other hydrological equipment such as motor launches, outboard engines and echo sounders etc. was delayed and the current meter discharge observations could not be continued throughout the year on all the sites. The observations had to be restricted to discharge observations during low water periods only. The number of sites where discharges have been measured by current meter or computed by floats during the year 1965-66 to 1968-69 are given below:

	1965-66	1966-67	1967-68	1968-69
No. of sites for which discharges have been measured or computed for the full year:	11	12	22	26

6.44 At all gauge and discharge sites, gauge readings are recorded thrice daily during the non-monsoon period and hourly gauges are recorded during the monsoon period. Discharge measurements are taken only on working days and none are taken on Sundays and holidays. However, for those days on which actual discharge measurements have not been taken, discharges are computed from the stage discharge curves established on the basis of the actual gauge discharge observations made during the period, and also after taking into account other relevant information. Attempts are being made to take discharge observations on Sundays and holidays.

On the basis of the water year from 1st June to 31st May, the observe discharged data is scrutinised and after computing the discharges for the days when actual discharge observations could not be made, on the basis of the stage discharge relation curves, the daily discharge data is supplied to the States concerned viz. Andhra Pradesh, Maharashtra and Mysore.

6.45 Flows at Vijayawada below the Krishna barrage as observed by current meter and estimated for the years 1965-66 to 1968-69 are given below: *

	1965-66	1966-67	1967-68	1968-69
	m. cu. m.			
Flows at Vijayawada (site No. 12) below Krishna barrage:				
(i) by current meter observation ..	328 (0.9%)	2,985 (10.7%)	26,726 (85.2%)	23,509 (98.5%)
(ii) by estimation from the 1967 stage discharge curve of Vijayawada site ..	35,195 (99.1%)	24,885 (89.3%)	4,644 (14.8%)	357 (1.5%)
Total observed and estimated flow at Vijayawada ..	35,523	27,870	31,370	23,866

Note: Figures in brackets show the percentages with respect to the total observed and estimated flow.

It will be seen that the discharges have been mostly based on current meter observations only from 1967-68 so that data from that date can be taken to be reliable. However, this data is rather meagre and the continuance of discharge observations for a number of years is essential.

*Collection of Gauge and Discharge Data at sites set up by CW & PC in the Krishna basin, Central Water and Power Commission (October, 1969).

Ground Water

6.46 Systematic ground water surveys of the entire Krishna basin have not been made so far. Complete data and statistics in this respect are, therefore, not available. However, a broad study of the map showing the distribution of hard and soft rocks in the Krishna basin indicate that a large part of the basin lies over ancient crystallines and metamorphics, which have very poor water-bearing capacity. The Deccan trap, which underlies the rest of the basin, has been stated to have 'poor' water-bearing characteristics.

The major area of the basin has not been surveyed and explored for assessing in detail the ground water resources. Recently, systematic geohydrological studies of some parts of the Krishna basin have been made. The extent of areas covered by such studies in the various sub-basins/districts are given below*:

Table 6.11

Areas Covered by Geohydrological Studies

Sl. No.	Sub-basin/District	Area in sq. km.
1	2	3
1.	Bhima sub-basin (Poona, Ahmednagar and Sholapur districts)	6,300
2.	Tumkur	1,040
3.	Chitradurga	2,200
4.	South Kanara	1,200
5.	Bijapur	4,710
6.	Gulbarga	5,500
7.	Mahbubnagar	3,990
8.	Kurnool	2,165
9.	Nalgonda	2,905
10.	Krishna	1,500
11.	Guntur	2,560

*Ground Water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

6.47 The results of these studies are summarised in the following paragraphs.

In the Bhima sub-basin, in the Poona and Ahmednagar districts, geological mapping of the area has shown the presence of alternating layers of massive vesicular and fine grained traps, the latter being more prevalent. Ground water occurs in the trappean flow units both under water-table and confined conditions. Ground water development is possible in the area underlain by vesicular traps by large diameter open wells, tapping their full thickness. In the Sholapur district, the area studies has brought to light a succession of flows characterised by prominent layers of vesicular zones. Ground water occurs both under water-table and confined conditions. Ground water development by means of open wells is possible.

In the Tumkur district, the area investigated is underlain by weathered gneisses and granites traversed by dolerites, pegmatites and quartz-veins. Ground water can be developed by means of open wells.

In the Chitradurga district, the area studied indicated that ground water occurs in the weathered mantle of peninsular gneisses and in the fissures and joints of the fresh rock below. There is only limited scope for ground water development, since the areas receive only meagre rainfall.

In the South Kanara district, the area is underlain by laterite and sands. Open wells pierce the Archaean crystalline rocks within 15 m. of the surface.

In the Indi Taluk of the Bijapur district, the area studied revealed that open wells pierce Deccan traps consisting of lava flows. Ground water development is possible by means of open wells. In Sindgi taluk, the lava flows occupy most of the area and limestone of the Bhima series occurs as small patches in the eastern extremity. Yields from wells in vesicular flows are promising compared to those from wells in massive flows. But owing to the limited thickness and distribution of the vesicular flows, the ground water potentialities are limited. Ground water development to a limited extent can be effected in selected areas.

The area studied in the Bulbarga district indicated that ground water occurs in the Dharwar, Vindhyan, Deccan traps and alluvial formations. The quality of water is related to the formations in which it occurs in the area. Wells in soils and moorum yield brackish water, while wells in hard rock generally yield good water.

The area investigated in the Mahbubnagar district showed that some areas are underlain by peninsular gneissic complex intruded by dolerite dykes and quartz veins. Ground water can be developed from open wells in the weathered rocks and by filter point wells in the alluvial fills of low lands. Other areas investigated in the district are underlain by limestones, sandstones, conglomerates and granites.

In the Kurnool district in the Kurnool, Dhone and Kondumuri Samithis the areas are underlain by limestones and granite gneisses. The seasonal fluctuations in water levels are considerable and the yields from the wells are poor. Studies in Alur taluk revealed that the area is underlain by Archaean crystalline rocks. There is wide variation in the thickness of saturation and as a result, wide variation in the yield capacities of the open wells constructed in the area. Investigations carried out in Giddalur taluk indicated that the area is underlain by shales and slates, with intercalation of quartzites and limestones of the Cuddapah system. Ground water development to a limited extent can be effected through large diameter open wells in selected areas.

In the Nalgonda district, the area studied is underlain by granites and gneisses intruded by dolerite dykes. Ground water development is possible by means of open wells and filter point wells.

In the Krishna district, the area investigated in Nandigama taluk indicated scope for the development of good quality ground water by means of filter point wells in the flood plain of the Muneru, Wyra and Krishna rivers. In areas underlain by crystalline rocks, i.e. gneisses, charnockites and schists, there is very little scope for the development of ground water. The quality of water in these rocks is unsuitable for domestic purposes due to the presence of fluoride in excess of the permissible limits. Studies carried out in Tiruvuru taluk indicated that the area is not suitable for ground water development by bore-wells. Ground water development to a limited extent can take place by means of open wells piercing gneisses. Investigations made in the delta area indicated that the area is underlain by alluvial sediments consisting of sands, clays and gravels. The quality of water from the shallow zones is unsuitable for drinking purposes because of the high chloride content. The waters of aquifers occurring between 80 and 114 m. fall within doubtful permissible limits from the irrigation point of view. Although the area holds good promise for the development of ground water from confined acquifers, the existence of quality hazards imposes a limitation.

In the Guntur district, the area studied was found to be mostly covered by alluvial sediments with inliers of Gondwana sediments as small disconnected patches. This area, lying immediately to the west of the Krishna river, offers good scope for the development of ground water by means of tubewells. The quality of waters of shallow water-table aquifers occurring within 20 m. vary considerably, possibly due to pollution by water from surface percolating downwards.

6.48 The successful development of ground water through the construction of tubewells is quite feasible, both in the sedimentary areas and in the alluvial deposits of the Krishna delta. The development of ground water achieved so far, however, has been negligible. Statistics of the existing number of tubewells and other wells and area irrigated thereunder in the Guntur and Krishna districts during the agricultural year 1965–66 are given below:

Table 6.12

Ground Water Development in Guntur and Krishna Districts

Sl. No.	District	Tubewells		Other wells		Total	Area irrigated by tubewells and other wells (in hectares)
		Govt.	Private	Govt.	Private		
1.	Guntur	11	202	1,194	5,994	7,401	13,220
2.	Krishna	25	438	601	9,452	10,516	10,090

It is clear that most of the existing tubewells and other wells are built and managed by the farmers themselves, which shows their keen interest and enterprising nature in irrigating their lands with ground water.

6.49 There are about 336,000 surface wells in use in the Krishna basin. These wells irrigate, annually, about 0.46 million hectares in the basin. No statistics are, however, available with regard to the yield from these wells. Broadly, each well is capable of irrigating about 1.2 to 1.6 hectares annually.

6.50 In regard to Maharashtra, the Fact-finding Committee for the survey of scarcity areas in Bombay State (1960). in their report has stated that:

> "Unlike the alluvial plains in the country, such as those in the Punjab and Uttar Pradesh, the Deccan conditions present altogether a different and complicated problem in so far as ground water and its flow is concerned. In the Indo-Gangetic plains, striking water in wells is not at all an uncertain factor as it is related to a water-table which spreads all over the area . . . In the Deccan, however, there is no such thing as a water table. The wells derive their supply from the water seams the exact location of which cannot be predicted. Any well sunk in the Deccan has to be excavated in rock to some extent except in certain regions where the rock level happens to be very low and excavation is limited to the upper layer consisting of *MAN* or *CHOPAN*. The cost of sinking wells in the Deccan varies

from about Rs. 3,000 to Rs. 5,000. A normal well in the Deccan plateau is about 12 to 15 m. deep and water is struck at a depth of about 8 to 12 m. The capacity for irrigation of a normal well in the Deccan (not within the commands of irrigation canals) is noticed to be between three to five acres. The supplies of these wells are adequate for irrigation up to about the middle of March and then dwindle rapidly, giving barely sufficient water for drinking purposes at the end of the hot weather. As a matter of fact, a number of wells are known to get dry by the end of April. Well irrigation should therefore be resorted to where the other more economic modes of providing irrigation are not available or where an adequate and copious supply of underground water with a low lift exists, for example, in the areas under command of major irrigation works."

6.51 The conditions in respect of wells in other parts of the Krishna basin are also not very different from those described above.

It would be seen that though there is no water-table in the Krishna basin of the type found in the Indo-Gangetic plains, wells have played a very important role in the irrigation development of the basin. About 30 per cent of the irrigated area in the Krishna basin gets its water supplies from surface wells.

6.52 As in other parts of India, there has been considerable activity in the Krishna basin during the last few years under the programme of minor irrigation. Large sums have been spent, and are in the process of being spent, under this programme on improvements to wells, digging new wells etc. There is still considerable room for further development from groundwater in the coastal area, and in the areas under the command of major irrigation works, both existing and proposed. Increased withdrawals from the sub-soil in these areas are also necessary for preventing waterlogging.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, quantitative and qualitative assessment of the ground water resources. A correct assessment of the ground water resources in the basin, which will help in framing a rational plan of development for various needs can only be made when full investigations have been carried out.

EXISTING DEVELOPMENT

6.53 Irrigation has been practised in the Krishna basin from the earliest times. Wells and tanks are dotted all over the area and some of them are very old. There are about 27,000 small tanks and diversions on the Krishna river system. Most of the wells are the product of the cultivators' own efforts and so also are some of the tanks. Some tanks were built from time to time by progressive rulers or through the co-operative efforts of the people. The tank is the source of water supply for domestic use for villages in the vicinity. It also provides irrigation to areas varying from a few hectares to a few hundred hectares, and though infrequently, to a few thousand hectares. Most tanks, however, irrigate an area of less than 200 hectares. Irrigation from these tanks is largely confined to the beds of nullahs and streams or other low lying areas and to small isolated patches. On some streams, tanks have been built one below the other in series and each tank receives the overflow of the tank immediately upstream of it as well as the inflow from the intermediate catchment. Most of these works are under the control of the civil authorities, and the P.W.D. only carry out repairs when called upon to do so.

The general pattern of these tanks is that earthen embankments of varying heights have been put across valleys, natural nullahs or small streams and the valleys, immediately below the embankments bear a paddy crop, mainly in kharif. The tanks are practically dry just before the monsoon; the first good shower fills them up, in part, and withdrawals for sowing paddy follow immediately thereafter. The next shower again fills the storage, in part, and the process continues throughout the rainy season. It is only when the tank is full that there is any escape into the nullah or stream. On the conclusion of the south-west monsoon, the tank would, generally, be full and the water available is utilised for maturing the paddy crop and for domestic use until the next monsoon.

Across some streams, where topographical conditions are favourable, weirs have been built and small canals are taken to a short distance from the stream to irrigate areas of paddy, and in some cases, of sugarcane or garden crops. These diversions, also, generally irrigate areas less than 200 hectares, each.

6.54 The most important irrigation work in the Krishna basin is the Krishna Delta Canal system at the mouth of the river. The project, constructed in the year 1855, provided for the irrigation of a part of the deltaic plains, with headworks located at Vijayawada, where the Krishna attains a width of about 1.19 km. The project comprised a weir 1,021 m. long across the river Krishna with undersluices consisting of 15 vents, each 1.8 m. in width and two canals taking off from either end of the weir, for each of which a head regulator of 15 vents, 1.8 m. wide and a head lock were provided. The weir was raised by 0.3 m. in 1890 and by a further 0.61 m. in 1894, but the crest was again lowered in 1898 by 0.61 m., and 0.91 m. high falling shutters were fixed on it. The canal system consists of a main canal on either side of the river, with a network of distributing channels spreading over the whole delta. On the east, the Eastern Main Canal, after a course of nearly 1.6 km., trifurcates into the Ellore, Ryve's and Masulipatam canals. The Ellore Canal is a high level channel used both for irrigation and navigation and runs eastwards to the town of Ellore, where a junction is effected, by means of a lock, with the western high level canal of the Godavari Delta System, thus completing the navigable line between the Godavari and the Krishna. On the west, the Commamur, Nizampatam and Bank canals command the western delta. The project, with an irrigation potential of 556,440 hectares, cost Rs. 74.09 million. In 1952, the weir talus gave way endangering the anicut, and as a result a new barrage with head regulators was constructed upstream of the anicut and commissioned in 1957.

6.55 Among the other important irrigation works, mention may also be made of the Kurnool-Cuddapah and Nira canal systems which are described below.

6.56 The Kurnool-Cuddapah Canal scheme comprised a masonry anicut at Sunkesula, in two lengths across two arms of the river Tungabhadra with an island in between. The lengths of the northern and southern portions of the anicut were 324 m. and 1,004 m. respectively. A canal taking off on the right bank irrigated 39,510 hectares in the Kurnool and Cuddapah districts. The project was completed in 1866 at a cost of Rs. 76.47 million.

6.57 The Nira Canal Project, constructed in 1885–86, consisted of a 1,625 m. long, 49.7 m. high dam across the river Yelvandi at Bhatghar, a 693 m. long masonry pick-up weir on the Nira river at Vir and canal system on either bank to irrigate an area of 82,730 hectares. The project costed Rs. 71.97 million.

6.58 The First Irrigation Commission had made the following observations in respect of the irrigation development in the Krishna basin: *

> "Our principal and most important recommendation for large works have been made for the protection of the Deccan districts in the Bombay and Madras Presidencies. For the former we propose that the catchment areas of all the rivers which derive their supplies from the unfailing rainfall of the Western Ghats should be carefully examined, with a view to the construction of as many large storage reservoirs as possible, and the works necessary for carrying

*Report of the Indian Irrigation Commission (1901-03).

the supply into those tracts in which irrigation is most urgently needed."

"It has been proved beyond all question that irrigation works in the Deccan cannot be made to pay; and the financial prospects of all projects that have been proposed have been so unpromising as to discourage both the Bombay officers and the Bombay Government from persevering the costly investigations of schemes the ultimate rejection of which appeared more than probable, at any rate as long as money was required for projects of a more promising character in other parts of the country. But, we doubt not that if the protection of the Deccan be given a foremost place in the future irrigation policy of Government, subject to whatever limitation of cost may appear to be reasonable, and if money be found for the cost of surveys, future investigations will be undertaken with better heart of all concerned; and will be carried on systematically and continuously, until either a satisfactory programme of new works has been prepared, or it has been conclusively proved that such works are not practically feasible within the limits of cost proposed."

"Various proposals and suggestions for canals with ghat-fed storage works have been brought to our notice, a list of which is given below. The works have been placed provisionally in the order in which it seems to us desirable that they should be taken up, having regard to the progress already made in their preparation, to the comparative urgency of the need for protection in different districts, and to the importance of distributing protection as fairly as possible between different parts of the country. The actual order of prosecution will, however, depend on the course and results of the general hydrographical survey of the Ghats which we have proposed, and on many other considerations; and we do not desire to make any definite recommendations on the point.

Much cannot be done without the storage of the Tungabhadra. This must be an expensive work; and it can only prove reproductive if the agricultural classes decide to avail themselves regularly of the water that will flow past their lands . . . It seems certain that, if a canal could be taken through the Bellary district, and across the watershed into the districts of Anantapur, Cuddapah and Nellore, supplementing the discharge of the Penner, there are many tracts in which the water would be eagerly utilised . . . The construction of the Tungabhadra project, and the extension and improvement of the Kurnool Cuddapah Canal on the lines that we

No.	District to be irrigated	Name of the drainage line	Name of Project
3.	Belgaum and Bijapur	Ghatprabha	Gokak extension
4.	Satara and Sholapur	Gujawani	Right bank Nira Canal
6.	Poona	Bhima and Ghod	—
7.	Satara, Belgaum, Bijapur and Kolhapur	Krishna river	Krishna extension
8.	Poona	Panna river	Panna river

now propose, would render it possible to extend protection to large areas in the Bellary, Anantapur, Kurnool, Cuddapah and Nellore, districts, all of which are more liable to severe visitations of drought than any other part of the Madras Presidency."

6.59 Regarding the construction of storage work on the Krishna, the Commission had made the following observations:

"The question of providing a storage reservoir on the Kistna has also been frequently mooted, but until recently has not been seriously considered . . . One advantage of the proposal is that, if carried out, it would be possible to take off a high level canal from the right bank of the Kistna above the dam, which could be maintained in flow as a monsoon canal until the level in the reservoir fell below a certain point. This canal would be carried through the uplands of the Kistna district and then on into the northern part of the Nellore district, and could be utilised for irrigation in these tracts, and for filling storage works. When the canal ceased to flow, the water still retained in the reservoir would be utilised in maintaining the supply in the Kistna at the level of requirements in the delta, where both first and second crop irrigation would be developed to the utmost . . . The project is of such magnitude that it may not be possible to carry it out concurrently with the Tungabhadra and Cauvery projects; but it has such an important bearing on the proposals for the former, that we have recommended that further investigation should also be put in hand as soon as possible."

6.60 As a part of the post-war reconstruction programme, a number of irrigation works were undertaken in the Krishna basin in the States of Andhra Pradesh, Maharashtra and Mysore as also in other parts of India. The important irrigation projects undertaken during this period are described in the following paragraphs.

ANDHRA PRADESH

Rajolibunda Diversion Scheme

6.61 This is a joint scheme of Mysore and Andhra Pradesh. It consists of a masonry anicut 820 m. long and 9.4 m. high, across the Tungabhadra river at Rajolibunda, and a left bank canal, 143 km. long in Mysore and Andhra Pradesh, to irrigate a total area of 37,990 hectares. The cost of the project is Rs. 38.3 million. The work on the project was started during the First Five Year Plan and is expected to be completed in the Fourth Plan period.

Tungabhadra Project

6.62 This is also a scheme jointly taken up by the erstwhile Hyderabad and Madras States. The States concerned at present are Andhra Pradesh and Mysore. The project consists of a dam across the river Tungabhadra at Mallapur village in Bellary district, about 4.8 km. from Hospet in Mysore State. The dam is of the straight gravity masonry type, 2,441 m. long and has a maximum height of 49.39 m. The reservoir has a gross storage of 3,767 m. cu. m. Two canals take off, one on each bank. The total length of the right bank canal is 349 km. and it serves both Mysore and Andhra Pradesh. The left bank canal, which is 227 km. long, only serves areas in Mysore. The areas irrigated by the right bank canal are 37,374 hectares in Mysore and 60,247 hectares in Andhra Pradesh. The left bank canal irrigates an area of 234,726 hectares, which is entirely in Mysore. The work on the dam was started in 1945 and completed in 1956. The right bank canal was completed in 1955 whereas the left bank canal was completed in 1963. The project also generates power in the two power houses, one on the right bank and the other on the left bank. The ultimate installed capacities of these two power houses are 72 MW. and 54 MW. respectively. The total cost of the project was Rs. 1,053.9 million.

Musi Project

6.63 The project consists of a composite dam 21.3 m. high and 4,295.6 m. long, across the river Musi. Two canals take off, one on each bank. The left bank canal is 33.8 km. long and the right bank canal is 30.6 km. long. The total area irrigated by both the canals is 16,920 hectares in Nalgonda district. The project, which was taken up for construction in 1954, has cost Rs. 40.9 million and is nearing completion.

Nagarjunasagar Project

6.64 The project consists of a masonry and earth dam across the Krishna river near Nandikonda village in Nalgonda district, about 144 km. from Hyderabad in Andhra Pradesh State. The masonry dam is 1,450 m. long and 124.7 m. high. The earth dam has a total length of 3,414.6 m. The reservoir created by the dam has a gross storage of 11,559 m. cu. m., out of which the live storage is 6,797 m. cu. m. Two canals take off, one on each bank. The right bank main canal is 202.78 km. long and the left bank main canal is 178.63 km. long. The work on the project was started in 1956 and is expected to be completed by the end of the Fourth Plan at a total cost of Rs. 1,649 million. The project will irrigate a total area of 0.83 million hectares.

Tungabhadra High Level Canal—Stage 1

6.65 This is also a joint project of Andhra Pradesh and Mysore. The High Level Canal takes off from the high level sluices on the right side of the Tungabhadra dam across the river Tungabhadra and runs through the States of Mysore and Andhra Pradesh. The total length of the canal is 196 km. including the Uravakonda Cut. In Stage I of the project, the following works have been taken up:

(i) Main canal 186.7 km. up to Uravakonda Cut.
(ii) Urvakonda Cut.
(iii) Mid-Penner Regulator across the river Penner, in Anantapur district.
(iv) Mid-Penner South Canal including Tadpatri branch.
(v) Mid-Penner North Canal.

The work on the project was started in 1958 and was expected to be completed in 1970–71. The total cost of the project is Rs. 252.34 million and it irrigates an area of 48,206 hectares in Andhra Pradesh and 40,470 hectares in Mysore.

MAHARASHTRA

Radhanagari Project

6.66 This project was taken up in 1949 by the erstwhile Kolhapur State, which has merged in Maharashtra. The project consists of a masonry dam, 1,143 m. long and 38.4 m. high, across the Bhogawati in Panchganga valley of the Krishna basin. The water stored in the reservoir is used to generate power at the toe of the dam and the tail-race waters discharge into the river and are diverted for irrigation by lift from Kolhapur type weirs. The lifts involved range from 30 m. to 37 m. The total area irrigated is 9,308 hectares and the project costed Rs. 21.8 million. The project was completed in 1967.

Ghod Project

6.67 The project comprises the construction of an earthen dam 2,852 m. long and 29.6 m. high across the river Ghod near the village of Chinchi in Sirur taluk of Poona district in Maharashtra State. Two canals take off one on each bank. The right bank canal is 33.5 km. long and the left bank canal is 86.5 km. long. The total area irrigated by the project is 24,615 hectares. The work on the project costing Rs. 55.6 million was started in 1954 and completed in 1965–66.

Khadakwasla Project—Stage I

6.68 The project consists of an earth dam 823 m. long and 58 m. high across the river Ambi at Panshet, 27 km. upstream of the existing Khadakwasla dam in the Poona district of Maharashtra State and the strengthening of the existing Khadakwasla dam across the river Mutha, 17.7 km. from Poona. The main canal is 127 km. long. The area proposed to be irrigated by the project is 22,298 hectares. The work on the project costing Rs. 167 million was started in 1957 and is expected to be completed by the end of the Fourth Plan.

Vir Dam Project

6.69 A composite dam 3,607 m. in length and with a maximum height 34.68 m. has been constructed across the Nira river near Vir village about 16 km. east of Shirwal in the Poona district of Maharashtra State. The reservoir feeds the existing Nira right and Nira left main canals to irrigate 26.710 hectares. The work on the project costing Rs. 54.1 million was started in 1957 and is expected to be completed by 1972.

Koyna Project

6.70 The Koyna Hydroelectric project for the generation of hydropower is another important project in the Krishna valley taken up during this period. This project diverts the Koyna waters outside the Krishna basin into the Arabian sea. The project consists of a dam across the river Koyna at Deshmukhwadi near Helwak in the Satara district of Maharashtra State. The underground power station is located at Popholi, below the Western Ghats. The project was taken up for construction in three stages, the installed capacities in the stages I, II and III being 240 MW, 300 MW, and 320 MW respectively. The various stages of the project are estimated to cost Rs. 382.8 million, Rs. 181.6 million and Rs. 380.0 million respectively. Stages I and II of the project have been completed in 1963 and 1968 respectively and Stage III is likely to be completed during the Fifth Plan period.

MYSORE

Bhadra Project

6.71 The project comprises a masonry dam with earth flanks of a total length of 440.5 m. and a maximum height of 71.6 m. across the river Bhadra near Lakkavalli village, about 22.5 km. from the Bhadravati railway station in Mysore State. The reservoir has a gross storage of 2,023 m. cu. m., out of which the live storage is 1,789 m. cu. m. The main canal is 176.6 km. long and will irrigate a total area of 99,015 hectares. The work on the project costing Rs. 350 million was started in 1947 and is expected to be completed during the Fourth Plan period.

Ghataprabha Project—Stage I and II

6.72 Stage I of the project comprises the construction of a weir across the river Ghataprabha near Dhupdal in the district of Belgaum in Mysore State. The weir is 2,084 m. long and 8.95 m. high. The main canal taking off from the weir is 70.8 km. long and irrigates a total area of 74,060 hectares. The work on Stage I of the project costing Rs. 69.25 million was started in 1949 and has been completed.

Stage II of the project consists of a composite dam across the river Ghataprabha near Hidkal village, about 19 km. upstream of the Dhupdal weir. The dam will be 8,841 m. long and 50 m. high. The Stage I main canal is extended by 43.45 km. to irrigate an extra area of 46,540 hectares. The work on the project costing Rs. 485.3 million was started in 1956 and is expected to be completed during the Fifth Plan.

6.73 Besides, a number of medium schemes were undertaken during this period. Some particulars of the important major and medium projects under operation and construction in the Krishna basin are given in Appendices 6.1 and 6.2.

6.74 In addition to major and medium projects, a number of minor schemes, comprising tanks and wells, irrigate a large area in the basin. In many villages, there are more tanks than one, from which the adjoining agricultural lands receive water. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, in the basin are given below:

Table 6.13

Source-wise Irrigation, 1967–68

Sl. No.	Source of irrigation	Area irrigated ('000 hectares) Andhra	Maharashtra	Mysore	Total area irrigated ('000 hectares)
1.	Canals	273.0	176.6	277.6	727.2
2.	Tanks	240.6	8.3	168.4	417.3
3.	Tubewells	2.7	—	—	2.7
4.	Wells	111.9	333.4	116.5	561.8
5.	Other sources	19.1	38.7	52.2	110.0
	Total	647.3	557.0	614.7	1819.0

6.75 Most of the important data and information relating to water resources development in the basin are either non-existent or have not been compiled and analysed before. Working statistics of canals and reservoirs in the basin have also neither been published nor compiled. According to the data available in the Report of the Krishna-Godavari Commission, Master Plans of the Krishna-Godavari basins prepared by the Government of Maharashtra, and the information supplied by the Maharashtra and Mysore States, the annual diversion by major and medium projects under operation and construction in the basin is of the order of 38,743 m. cu. m.

Details of the large number of minor schemes comprising tanks, wells and other diversions are not available. The area irrigated from these sources in 1968–69 was about 1.18 million hectares. Based on rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been made. The approximate annual diversion by the minor schemes may be of the order of 12,596 m. cu. m. excluding reservoir losses.

Reservoir Losses

6.76 The data on reservoir losses for most of the major and medium schemes in the basin is available in the Report of the Krishna-Godavari Commission and the Master Plans of the Krishna-Godavari basins prepared by the Government of Maharashtra. For the schemes for which the data on reservoir losses is not available, these have been worked out at 20% of the annual diversion by these schemes. On the above basis, the reservoir losses from all the major and medium projects under operation and construction are of the order of 3,399 m. cu. m.

For minor schemes and small tanks, in the absence of observed statistics, it is extremely difficult to estimate the losses. Assuming that the water spread of a tank would be about 87.5 per cent of the irrigated area, and that the total loss of 1.07 m. over the surface area for the period that the tank is full, the total reservoir losses from the tanks in the basin work out approximately to 4,212 m. cu. m.

6.77 Thus, on completion and full development the major, medium and minor projects under operation and construction in 1968–69 in the basin would use about 58,950 m. cu. m. (52,437 m. cu. m. of surface waters and 6,513 m. cu. m. of ground waters).

6.78 There are a number of industries located in the basin which are utilising the Krishna waters. Of these, iron and steel industries at Bhadravati in Shimoga district and cement factories in Guntur, Krishna, Bijapur, Gulbarga and Shimoga districts deserve mention. Data on the industrial water needs is not readily available. In the future, such needs are expected to grow with greater industrialisation.

The problem of water pollution in the Krishna due to the discharge of industrial wastes has not assumed serious proportions so far. However, with the rapid expansion of industries in the future, this problem may be aggravated and should not be lost sight of.

FUTURE DEVELOPMENT

6.79 Six major and medium projects are proposed to be taken up for construction in the basin. in the Fourth Five Year Plan period, of which five are in Maharashtra and one in Andhra Pradesh. The details of these projects are given in Appendix 6.3. They will irrigate a total area of 0.14 million hectares on full development. Project reports for many of the future projects are not yet ready. An approximate estimate of the quantity of water that will be diverted from these projects based on the data supplied by the various State Governments has been made. The quantity is expected to be of the order of 1,470 m. cu. m. including the reservoir losses. The utilisation by minor schemes in the basin is expected to increase by about 5,344 m. cu. m. during the Fourth Plan (inclusive of tank losses). On completion and full development of Fourth Plan projects, about 65,764 m. cu. m. of waters (57,181 m. cu. m. of surface waters +8,583 m. cu. m. of ground waters) would have been used for irrigating a total area of 5.25 million hectares.

6.80 Brief particulars of some of the Fourth Plan projects are given below:

The Dudhganga Project

6.81 The project envisages the construction of an earth dam, 1,067 m. long and 73.2 m. high with a masonry spillway to create a live storage of 589 m. cu. m. at Kalamawadi, across the Dudhganga river in the Krishna basin. A pick-up weir 4.8 km. downstream of the dam will also be built, which will be 244 m. long and 20.1 m. high. Two canals take off from the weir, one on each bank to irrigate a total area of 67,170 hectares in Kolhapur district. The estimated cost of the project is Rs. 193.74 million.

The Khadakwasla Project—Stage II

6.82 This project aims at enlarging the scope of the Panshet Storage created in Stage I and also the construction of the Warasgaon Dam in the Bhima sub-basin. The live storage of the Panshet Dam will be enhanced to 311 m. cu. m.* The existing Mutha canal system will be lined up to 163rd km. and extended further to 266th km. The total irrigation under the project is expected to be 40,210 hectares. The cost of the project is estimated at Rs. 170 million.

6.83 The Krishna-Godavari Commission, in its report, has listed the major and medium projects, which are proposed to be taken up by the different States in the Krishna basin. A few of these projects have since been completed or are in various stages of construction in the different states. Some details of the new projects proposed by the various States are given in Appendix 6.4. These projects, on completion, are expected to provide irrigation facilities to 4.00 million hectares. None of these proposed projects has yet been investigated and project reports for most of them are not available. It is quite possible that some of them may not prove feasible on detailed investigation.

*The Warasgaon dam will be an earth dam 1,036 m. long and 62.2 m. high with a live storage of 368 m.cu.m.

6.84 As the States concerned have not been able to arrive at any settlement regarding the sharing of the Krishna waters, the issue has been referred to a Tribunal by the Government of India and the award of the Tribunal is still awaited. Once the award is announced, it would be possible for the different States to plan future projects so as to be within the limits of the share of waters allocated to them by the award.

6.85 The Krishna-Godavari Commission had suggested the diversion of surplus supplies of the Godavari to the Krishna. The diversion of Godavari waters to the Krishna has already been dealt with, in the chapter on the Godavari basin. The question of the diversion of any surplus supplies of the Godavari to the Krishna has also been referred to the Tribunal.

6.86 Giant projects now under construction or which are proposed to be taken up in the basin in future will result in changes in the ecological system in the basin. The adverse effects of very large dams on the lower reaches of the river and especially the delta, should be carefully watched since it is necessary to maintain the ecological balance when planning such large projects, and where this balance is upset, remedial measures will have to be taken.

FLOODS, WATERLOGGING & DRAINAGE

6.87 The Krishna is purely rain-fed and carries enormous quantities of water during the monsoon period. Much of the river flow, in its lower reaches during the non-monsoon period, is chiefly derived from regeneration. The disparity in the maximum and minimum flows in the river is very marked. The river spills its banks in the lower reaches causing flooding, particularly in the delta area.

In the part of the basin lying in Maharashtra State, the flood problem is acute in the Sangli and Kolhapur districts, due to the fact that the abnormally high flood plain is used for purposes of habitation and cultivation.

The Malaprabha river causes damage during floods in Belgaum and Dharwar districts of Mysore.

6.88 In Andhra Pradesh, the flood damage is considerable in the delta area. In 1949, a very heavy flood was experienced in the Krishna, which almost reached the previous maximum of 1903, when a flood discharge of 33,810 cumecs was recorded at Vijayawada.* A comparative study of

*Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

the surveys carried out from 1786 to 1800 and during 1927 to 1930 shows that the delta of this river has extended into the sea by 3.2 km. over a sea face of 22.5 km. This has resulted in the raising of the river bed in the lower reaches. The effect of this rise was demonstrated by higher gauges and more extensive damage during the 1949 flood compared with what had occurred in 1903. There are embankments along this river on both banks. On the right bank, they extend from the sea to about 1.6 km. upstream of the Krishna barrage, whereas on the left bank, the embankment extends from the sea to Vaikuntapuram. Tides from the sea travel up the river for about 48 km. bringing a considerable quantity of silt with them. During low flows, the river gets silted up in its lower reaches and is cleared when heavy floods wash down the deposited silt. The Tungabhadra dam, which is already built, the Nagarjunasagar dam, which is nearing completion and several other projects like the Upper Krishna, Srisailam etc. on the main river and its tributaries would considerably moderate the floods in this river. However, with the elimination of heavy floods in the river, the problem of the choking of the mouth of the river with silt is likely to be accentuated. The causes of floods in the Krishna in Andhra Pradesh can be summarised as follows:

(i) Raising of the river bed in the lower reaches due to extension of the delta into the sea.

(ii) Choking up of the mouth of the river with silt brought in by the tides.

The complex problem of the submergence of marginal lands of the Kolleru lake, a natural depression in-between the Krishna and the Godavari deltas, has already been discussed at some length in the chapter on the Godavari basin.

If the choking up of the mouth of the Krishna due to the moderation of floods by the upstream dams becomes a serious problem, the remedy lies in clearing the deposited silts either by dredging or through special releases from the lowest of the reservoirs on the main arm of the river.

The embankments which were built a long time back have generally prevented serious flooding in the area. They require not only proper maintenance but raising and strengthening, and extensions in some cases, to prevent breaches. A systematic and comprehensive examination of the old embankment systems, and the existing tanks, together with a comprehensive study of the pattern and incidence of coastal cyclonic rainfall of heavy intensity and short duration accompanied by high wind velocities, is also necessary.

6.89 Waterlogging has occurred in the Nira and other canal areas of Maharashtra State. The details of the damaged area in the basin are given in Table 6.14.

Table 6.14

Waterlogged and Salt Affected Areas (Maharashtra)

Name of canal	Damaged area in 1968–69 (Hectares)		
	Waterlogged	Salt affected	Total
Nira Left Bank Canal	334	5,109	5,443
Nira Right Bank Canal	313	6,695	7,008
Visapur Tank Canal	2	40	42
Ghod Right Bank Canal	13	600	613
Ghod Left Bank Canal	345	1,441	1,786
Krishna Canal	238	1,617	1,855
Total	1,245	15,502	16,747

For improving the damaged area, surface drains, deep drains and pipe drains are being constructed. Pumps and tubewells have not been used as anti-waterlogging measures. There are very few tubewells in the State. The canalwise break-up of the drainage schemes completed, in progress and proposed is given below:

Table 6.15

Particulars of Drainage Schemes

Sl. No.	Name of Canal	Drainage schemes		
		Completed	In progress	Proposed
1.	Nira Left Bank Canal	27	9	8
2.	Nira Right Bank Canal	6	10	2
3.	Visapur Tank Canal	1	Nil	Nil
4.	Mutha Right Bank Canal	1	Nil	Nil
5.	Krishna Canal	Nil	2	6
6.	Ghod Left Bank Canal	Nil	Nil	8
7.	Ghod Right Bank Canal	Nil	Nil	2
8.	Panchganga River	Nil	Nil	1
	Total	35	21	27

6.90 Waterlogging has occurred in Mysore State in the basin, and in the various canal areas. The details are given below:

Table 6.16
Waterlogged Areas in Mysore

Sl. No.	Canal	Total irrigated area (hectares)	Total water-logged area (hectares)
1.	Ghataprabha Left Bank Canal	52,608	1,638
2.	Gokak Canal	6,813	292
3.	Tungabhadra Left Bank Canal	234,714	2,023
4.	Tungabhadra Right Bank Canal	40,468	607
5.	Bhadra Project	97,123	2,023

No anti-waterlogging measures have been adopted to reclaim the damaged lands so far. The problem is being studied and the remedies proposed are surface drains, channelising of nullahs which are silted up, and closed-type drains where permeable layers are available within short depths. Some pilot schemes under the ayacuts of the projects have been taken up. Due to irrigation, the extent and magnitude of saline lands forms a very small portion of the total area. Remedial measures for such lands are also proposed to be taken up in the future.

The main drainage problem in Andhra Pradesh is the disposal of surface water from the flat deltaic tracts. Several drains exist in the delta area. Apart from the delta, the drainage problem has not arisen elsewhere in the part of the basin lying in this State.

SOIL CONSERVATION

6.91 The Krishna basin largely comprises ridges and valleys. In the upper reaches of the Krishna and its tributaries, land slopes are relatively steep and there is considerable soil erosion during rainfall of high intensity. For the conservation of the storage capacities of reservoirs in the basin, special soil conservation measures have to be undertaken in the cultivated areas, and also in the culturable but not cultivated areas, and in areas under forests. The soil conservation measures may be classified under the following heads:

(i) Afforestation.

(ii) Terracing and contour bunding.

(iii) Pasture development and protection of marginal and sub-marginal lands.

(iv) Stream control measures including fringe afforestation and stream bank control.

(v) Desiltation works like check dams etc.

During recent years, efforts have been made to take up soil and water conservation measures in the basin. The progress on afforestation in the relatively steep areas of Kurnool, Nalgonda and Guntur districts in Andhra Pradesh State in the basin, up to 1962, has been 1,620 hectares.

In Maharashtra, taking into consideration the silt load, rainfall and its characteristics, soil, vegetal cover and topography etc., the catchments of major and medium projects have been graded for consideration under the afforestation programme in the Fourth Five Year Plan. The catchment areas of the Ghod (3,629 sq. km.) and the Nira (1,756 sq. km.) have been included in this programme.

In Andhra Pradesh, the problem of soil and moisture conservation is most acutely felt in the part of Krishna basin lying in Anantapur district. Sheet erosion is a common feature in this low rainfall area and the adoption of improved methods of dry farming is the most effective way of preventing soil loss in agricultural lands. Contour bunding was taken up in the First Five Year Plan in the Anantapur, Adilabad and Kurnool districts in the basin. In the Second Plan, in addition to covering more areas in the above districts, fresh areas were covered in Cuddapah, Hyderabad, Medak, Nizamabad, Mahbubnagar, Nalgonda and Khammam districts. In the Third Plan, soil conservation measures were extended to more areas in these districts.

In Mysore except in Kanara district, the problem of soil and moisture conservation is common to the entire basin. It is most acutely felt in the dry tract covering the districts of Bijapur, Gulbarga, Raichur, Bidar, Bellary, Chitradurga, Tumkur and parts of Hassan, Chikmagalur, Dharwar, Belgaum and Shimoga. The Government of Mysore formulated a land improvement scheme in 1942, which was introduced initially in the districts of Bijapur, Belgaum and Dharwar. Contour bunding is being done in medium and shallow soils only, under this scheme. In deep black soils, at present, contour bunding is being done as an experimental measure. Up to August, 1969, a total area of 0.75 million hectares in the State has been covered under this scheme. In 1962–63, soil and water conservation measures were first undertaken in the major river valley project area of Tungabhadra. On the basis of the interpretation of aerial photographs, an area of about 11,655 sq. km. of the catchment has been classified into ten erosional units of different intensities, and priority among the ten units has been fixed. After further detailed studies, priority areas for soil survey and conservation works within each of the ten sub-catchments have also been delineated. Soil conservation and afforestation measures have been taken up in these areas to minimise the problem of reservoir silting.

In the Fourth Five Year Plan, the State Government has provided an outlay of Rs. 65.8 million on soil and water conservation works for treating an area of 0.44 million hectares.

Soil and water conservation measures were started in the then Bombay State in 1942 with the main object of preventing soil erosion and of conserving moisture to help agricultural production in dry areas. These measures include contour and graded bunding, bench terracing etc. Different types of bunding as are suitable to the particular agro-climatic zone are being adopted. The work done in the Krishna basin till the end of August, 1969 in Maharashtra State is given below:

Table 6.17

Progress of Soil Conservation Works (Maharashtra)

Sl. No.	Basin	Bundable area in hectares	Area bunded so far in hectares	Area terraced so far in hectares
1.	Bhima	3,398,016	1,386,656	7,192
2.	Krishna	1,612,424	372,911	14,042
	Total	5,010,440	1,759,566	21,234

Contour bunding has been carried out generally in unirrigated areas and the overall results have been promising.

In order to carry out a detailed study of soil and conservation work in river valley projects, the Maharashtra Government had appointed a Study Group in 1962 consisting of officers of the Agriculture, Forest and Irrigation & Power Departments. The study group was to consider the vulnerability of particular catchment areas and river valley projects, to the hazards of soil erosion, and to draw up a list of vulnerable catchments and to formulate a scheme for co-ordinating different soil conservation works in those catchments considered to be most vulnerable. After a detailed study of the catchments of river valley projects taken up during the Second Five Year Plan, the Study Group graded them in order of their vulnerability to soil erosion and gave the Ghod and the Nira projects the first and fifth priority respectively.

The sedimentation survey of the Ghod reservoir has not been undertaken so far.

6.92 The sedimentation survey of the Tungabhadra reservoir to determine the rate of silting was completed in 1963. Although the dam was completed in 1958, the first partial impounding of water in the reservoir took place in 1953. The gross capacity of the reservoir is 3,766 m. cu. m. out of which the live storage is 3,700 m. cu. m. and the balance 66 m. cu. m. is dead storage. The survey indicated that the loss of capacity due to silting is 13.49% of the original total capacity, over a period of ten years, and the annual rate of sediment accumulation is 0.181 m. cu. m. per 100 sq. km. of the net catchment. The annual rate of siltation assumed in the project report is 0.043 m. cu. m. per 100 sq. km. of the catchment area.* It will be seen from the above that the actual rate of siltation has been more than four times the assumed rate. The live capacity will thus be greatly impaired with the higher rate of siltation and the necessity therefore for taking up soil conservation measures in the catchment is urgent.

6.93 Under the centrally sponsored programme of soil conservation measures in the catchments of major river valley projects, the Tungabhadra and the Ghod projects have been included. Soil conservation works have been taken up in these catchments. The expenditure incurred and the achievements up to 1969 are given below:

Table 6.18

Progress of Centrally Sponsored Soil Conservation Works

Project	Expenditure incurred	Achievements ('000 hectares)
Tungabhadra	Rs. 4.03 million	19
Ghod	Rs. 5.42 ,,	8

Inter-State co-operation and agreement in respect of carrying out soil conservation measures to conserve the storage capacities of existing and proposed reservoirs in the basin is incumbent.

*Sedimentation data on selected reservoirs in India (Revised Edition), Soil Conservation Directorate, Central Water and power Commission (Unpublished).

The studies made of the behaviour of the water table in the bunded areas in Mysore and Maharashtra have shown that there has been a rise in water table.

The Agriculture & Forest Departments are entrusted with the soil conservation works in all the States.

GENERAL

6.93 The Krishna and its tributaries form an inter-state river system flowing through the States of Maharashtra, Mysore and Andhra Pradesh. A number of small and large projects have been constructed in the basin and some are under construction. The approach all along has been to construct projects for the benefit of the particular state concerned except in a few cases where the projects are being constructed jointly by two States. As stated in para 6.84, the question of sharing of the Krishna waters has been referred to a Tribunal by the Government of India and the award of the Tribunal is still awaited. Once the award of the Tribunal is announced, it would be possible for the different States to plan future projects within the limits of the share of waters allocated to them. However, till such time as the award is announced, the States concerned should complete detailed investigations in regard to the promising new projects and prepare project reports with estimates of costs and benefits.

6.94 The number and distribution of raingauge stations should be reviewed and new stations to fill whatever gaps exist should be established. It is also important that the daily rainfall data for all these stations should be published on a monthly basis, preferably by sub-basins.

A network of evaporation measuring stations in the basin, particularly at the sites of the existing and proposed reservoirs should be established.

6.95 As stated in para 6.43 out of the 38 sites recommended by the Krishna-Godavari Commission, 28 sites have been established by the Central Gauging Circle of the Central Water & Power Commission. Two sites have been omitted. On the remaining 8 sites also, independent stations are being set up by that organisation. Gauge and discharge observations at the sites should be continued on a permanent basis to obtain data, essential not only for the preparation of individual projects but also for the regulation of available river waters in any year.

6.96 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin so that these resources can be exploited in a rational way either independently or in conjunction with surface waters.

6.97 There is need for inter-State co-operation and agreement in respect of soil conservation measures to conserve the storage capacities of existing and proposed reservoirs in the basin.

6.98 As a number of dams are being constructed in the basin, it is necessary for systematic data to be collected of the sediment carried by the river waters, which would be of considerable use in working out dead storages and lives of reservoirs. It will also reveal the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE BASIN OF EAST FLOWING RIVERS BETWEEN THE KRISHNA AND THE PENNER

(i) Source

Three small streams up to the Vogarivagu	(1) Near Repalle in Guntur district (Latitude 16°1′N, Longitude 80°51′E). (2) Near Tenali in Guntur district (Latitude 16°15′N, Longitude 80°40′E). (3) Near Phirangipuram in Guntur district (Latitude 16°17′N, Longitude 80°18′E).
The Vogarivagu	South-west of Nekarikallu village in Guntur district. (Latitude 16°20′N, Longitude 79°52′E).
Small stream between the Vogarivagu and the Gundlakamma	Near Valaparla in Guntur district (Latitude 15°56′N, Longitude 80°1′E).
The Gundlakamma	Near Iskagundam village in Kurnool district. (Latitude 15°38′N, Longitude 78°47′E).
Small stream between the Gundlakamma and the Musi	Near Velarapalle village in Guntur district. (Latitude 15°38′N, Longitude 79°57′E).
The Musi	Near Gotlagattu village in Nellore district. (Latitude 15°32′N, Longitude 79°25′E).
The Paleru	Near Gogulapalle village in Nellore district. (Latitude 15°17′N, Longitude 79°13′E).
The Manneru	North of Sitaramapuram village in Nellore district (Latitude 15°6′N, Longitude 79°8′E).
Small stream between the Manneru and the Penner	Near Kaligiri village in Nellore district district (Latitude 14°50′N, Longitude 79°42′E).

(ii) Length

Three small streams up to the Vogarivagu	(1) 34 km.	21 miles
	(2) 38 km.	24 miles
	(3) 95 km.	59 miles
The Vogarivagu	102 km.	63 miles
Small stream between the Vogarivagu and the Gundlakamma	93 km.	58 miles
The Gundlakamma	220 km.	136 miles
Small stream between the Gundlakamma and the Musi	35 km.	22 miles
The Musi	112 km.	69 miles
The Paleru	104 km.	64 miles
The Manneru	122 km.	76 miles

Small stream between the Manneru and the Penner	40 km.	25 miles

(iii) Drainage area

	Sq. km.	Sq. miles
Three small streams up to the Vogarivagu	2,580	996
The Vogarivagu	1,348	520
Small stream between the Vogarivagu and the Gundlakamma	1,793	692
The Gundlakamma	8,494	3,270
Small stream between the Gundlakamma and the Musi	509	197
The Musi	2,219	857
The Paleru	2,483	959
The Manneru	3,734	1,442
Small stream between the Manneru and the Penner	1,509	583
Total	24,669	9,525

(iv) Population (1971 census) 3.79 millions

(v) Density of population 153 per sq. km, 396 per sq. mile

(vi) Average annual runoff 1,554 m.cu.m. 1.26 MAF for the whole basin: (Based on Khosla's formula).

	Thousand hectares	Thousand acres
(vii) Culturable area (1967-68)	1,623	4,011
(viii) Net area sown (1967-68)	1,091	2,696
(xi) Gross area sown (1967-68)	1,264	3,123
(x) Net area irrigated (1967-68)	302	746
(xi) Gross area irrigated (1967-68)	398	983
(xii) Area irrigated after completion and full development of Fourth Plan projects (Excluding area irrigated by Krishna waters):	217	536
(xiii) Area irrigated in the basin by Krishna waters after completion and full development of Nagarjunasagar Project—Stage 1:	520	1,284
(xiv) Probable additional irrigation by future projects:	N.A.	

(xv) Water utilisation including reservoir losses

		M.cu.m.	M.A.F.
(a) On completion & full development of major, medium & minor projects under operation and construction at the end of 1968-69:	Surface water	2,641	2.14
	Ground water	289	0.23
Total		2,930	2.37
(b) On completion and full development of Fourth Plan projects:	Surface water	3,177	2.58
	Ground water	358	0.29
Total		3,535	2.87

CHAPTER VII

BASIN OF THE EAST FLOWING RIVERS BETWEEN THE KRISHNA AND THE PENNER.

The basin of the east-flowing rivers between the Krishna and the Penner extends over an area of 24,669 sq. km., and lies between east longitudes 78°46′ to 80°52′ and north latitudes 14°38′ to 16°22′. Lying in the Peninsular India, the basin covers a large area in the State of Andhra Pradesh.

7.2 The basin is bounded by the Nallamala hills and the Velikonda range of the Eastern Ghats on the west, on the north by the ridge separating it from the Krishna basin, on the south by the ridge separating it from the Penner basin and on the east by the Bay of Bengal. The basin of an irregular shape, has a maximum length of 213 km. in a west-east direction and a maximum width of 186 km. in the north-south direction. There are two major topographical divisions in the basin, (i) the hilly area of the Eastern Ghats and (ii) the plains. The plains extending from the eastern slopes of the Ghats slope gently towards the Bay of Bengal. There are nine sub-basins in the basin, of which the Gundlakamma and the Manneru are the more important.

THE RIVER SYSTEMS

7.3 The various river systems in the basin from the north to the south are:

(1) Three small streams up to the Vogarivagu.
(2) The Vogarivagu.
(3) A small stream between the Vogarivagu and the Gundlakamma.
(4) The Gundlakamma.
(5) A small stream between the Gundlakamma and the Musi.
(6) The Musi.
(7) The Paleru.
(8) The Manneru.
(9) A small stream between the Manneru and the Penner.

These river systems are described briefly in the following paragraphs:

Three Small Streams up to the Vogarivagu

The northern-most stream rises near Repalle in Guntur district at north latitude 16°1′ and east longitude 80°51′ at an elevation of about 10 m. and flows south for a total distance of 34 km. to join the Bay of Bengal. The second stream also rises in Guntur district near Tenali at north latitude 16°15′ and east longitude 80°40′ at an elevation of about 40 m. and flows south for a total distance of 38 km. to join the Bay of Bengal. The third stream rises near Phirangipuram in Guntur district at an elevation of about 300 m. at north latitude 16°17′ and east longitude 80°18′ and flows in a generally south-east direction for a total distance of 95 km. to join the Bay of Bengal. These three streams, jointly drain a total area of 2,580 sq. km.

The Vogarivagu

The Vogarivagu rises south-west of Nekarikallu village in Guntur district at an elevation of about 150 m. at north latitude 16°20′ and east longitude 79°52′ and flows in a generally southern direction for a total distance of 102 km. to join the Bay of Bengal. The total area drained by this stream is 1,348 sq. km.

Small Stream Between the Vogarivagu and the Gundlakamma

This stream rises near Valaparla in Guntur district at an elevation of 120 m. at north latitude 15°56′ and east longitude 80°1′ and flows in a generally southern direction for a total length of 93 km. to empty into the Bay of Bengal. The area drained by this stream is 1,793 sq. km.

The Gundlakamma

The Gundlakamma rises near Iskagundam village in Kurnool district at an elevation of 600 m. from the eastern slopes of the Nallamala hills at northern latitude 15°38′ and east longitude 78°47′ and flows in a north-east, east and southern direction for a total distance of 220 km. to join the Bay of Bengal. The total area drained by this river is 8,494 sq. km. The Kandleru is its important left bank tributary.

Small Stream Between the Gundlakamma and the Musi

The stream rises near Velarapalle village in Guntur district at an elevation of about 120 m. at north latitude 15°38′ and east longitude 79°57′ and flows in an easterly direction for a total length of 35 km. to join the Bay of Bengal. It drains an area of 509 sq. km.

The Musi

The Musi rises near Gotlagattu village in Nellore district at an elevation of about 200 m. at north latitude 15°32′ and east longitude 79°25′ and flows in a south-easterly direction for a total length of 112 km. to join the Bay of Bengal. It drains an area of 2,219 sq. km.

The Paleru

The Paleru rises near Gogulapalle village in Nellore district at an elevation of 325 m. at north latitude 15°17′ and east longitude 79°13′ and flows in an easterly direction for a total length of 104 km. to empty into the Bay of Bengal. The Paleru drains an area of 2,483 sq. km.

The Manneru

The Manneru rises north of Sitaramapuram village in Nellore district at an elevation of 300 m. on the eastern slopes of the Velikonda range at north latitude 15°6′ and east longitude 79°8′. It flows in a generally easterly direction for a total length of 122 km. and drains a total area of 3,734 sq. km. before joining the Bay of Bengal.

Small Stream Between the Manneru and the Penner

The stream rises near Kaligiri village in Nellore district at an elevation of 80 m. at north latitude 14°50′ and east longitude 79°42′. It flows for a total length of about 40 km. in an easterly direction and drains a total area of 1,509 sq. km. before joining the Bay of Bengal.

CLIMATE

7.4 Three distinct seasons occur in the basin. They are (i) cool weather, (ii) hot weather and (iii) rainy season.

The cool weather extends from about the middle of October to the middle of February. On the eastern slopes of the Eastern Ghats, heavy showers occur due to the north-east monsoon, up to end of December. Usually, the months of January and February are dry, with very little precipitation.

In the hot weather extending from the middle of February to the middle of June, the entire basin is practically dry and experiences extreme heat.

The south-west monsoon season which follows the hot weather, extends from the middle of June to the middle of October.

Rainfall

7.5 There are at present 47 reporting raingauge stations inside the basin. The distribution of the stations is fairly even and their number is also sufficient.

The rainfall in the basin varies from region to region. The rainfall decreases from 1,016 mm. at the north east corner of the basin to about 762 mm. in the middle of the basin and to 600 mm. at the western extremity of the basin. The monthly and the annual normals of rainfall in the districts lying in the basin are shown in Appendix 7.1.

Temperature

7.6 The basin is subject to a tropical climate. In the hilly western part of the basin, the variation of temperature during the year is less marked than in the plains.

In the month of January, the mean temperature over the basin is between 22.5°C and 25°C. In April, the mean temperature varies from 30°C to 32.5°C whereas in the month of July, the mean temperature over the basin is above 30°C. In the month of October, the basin experiences temperatures above 27.5°C.

Evaporation

7.7 Data on evaporation is not available for the basin. There are no departmental or agro-meteorological observatories of the India Meteorological Department within the basin.* With the data of the observatories located in the adjoining areas, the general trends and not to exact magnitude of the evaporation can be determined.

SOILS

7.8 A detailed soil survey of the area covered by the basin has not been made. However, the general data regarding the soils of India indicate that mainly red sandy soils, mixed red and black soils, deep black soils, Coastal alluvium and deltaic alluvium occur in the basin. The basin

*Evaporation Data (India), India Meteorological Department (April, 1970).

covers partly the districts* of Guntur, Kurnool and Nellore. Whereas in Guntur and Kurnool black soils predominate, in Nellore black soils, red loams and sandy coastal soils are found, the largest area being under red loams and the least under the sandy soils.**

LAND USE & AGRICULTURAL PRACTICES

7.9 Land use details in the basin in 1967–68, the latest year for which the statistics are available, are given below:

Table 7.1
Land Use Details

Sl. No.	Item	Area in thousand hectares
1.	Geographical area	2,467
2.	Reporting area	2,458
3.	Area under forests	374
4.	Area not available for cultivation	461
5.	Culturable area	1,623
6.	Uncultivated culturable area	532
7.	Net area sown	1,091
8.	Area sown more than once	173
9.	Total cropped area	1,264
10.	Net area irrigated	302
11.	Gross area irrigated	398
12.	Percentage of net area sown to culturable area	67.2
13.	Percentage of net area irrigated to culturable area	18.6
14.	Percentage of net area irrigated to net sown area	27.7

The cultivated area in the basin as a whole constitutes 77.9% of the culturable area, which shows that agriculture has been practised quite extensively in the basin. The culturable area in the basin is about 0.83% of the total culturable area of the country. The total cropped area in the basin is about 0.78% of the total cropped area in the country.

7.10 The general cropping pattern in the irrigated area is described in the next para.

*As existing prior to the formation of Ongole district.

**Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Of the total irrigated area of 398,100 hectares, about 73.2% is under paddy, 5.1% under ragi, 4.6% under bajra, 2.8% under condiments & spices, 4.8% under groundnut and the balance under other crops. The other crops grown in the irrigated area are jowar, maize, millets, gram, other pulses, sugarcane, sesamum, cotton, tobacco and fodder crops. The food crops represent about 93.2% of the irrigated area and the balance 6.8% is under non-food crops.

7.11 There are mainly two crop seasons in the basin, (i) the kharif and (ii) rabi. The kharif crops are paddy, jowar, maize, ragi, millets, pulses, groundnut, etc. The rabi crops, which are generally grown on heavy soils, are jowar, maize, ragi, millets, pulses, potatoes, chillies, cotton, oil seeds and tobacco. Besides these seasonal crops, garden crops like sugarcane, plantains, betel leaves, turmeric etc. are also grown throughout the year. The sowing and harvesting seasons of the principal crops are tabulated below:*

Table 7.2

Sowing and Harvesting Periods

Sl. No.	Name of crop	Period of	
		Sowing	Harvesting
1.	Winter paddy	June-October	November-February
2.	Summer paddy	January-February	April-May
3.	Kharif jowar	July-October	December-February
4.	Rabi jowar	November-December	March-April
5.	Bajra	June-August	September-December
6.	Kharif maize	July-August	October-November
7.	Rabi maize	September-December	January-March
8.	Kharif ragi	June-October	October-January
9	Rabi ragi	November-January	January-April
10.	Millets	July-September	October-December
11.	Potatoes (Plains)	October-November	January-February
12.	Chillies	September	March
13.	Tobacco	October	February

*Indian crop calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

REGIONAL ECONOMY

Population

7.12 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 3.79 millions. Guntur is the only city in the basin, which has a population of more than one lakh. The average density of population in the basin is 153 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. Whereas the district of Guntur has a high density of 217 persons per sq. km., Kurnool and Nellore districts have low densities of 108 and 121 per sq. km. respectively.

Of the total population in the basin, nearly 81.2% live in rural areas while the balance of 18.8% live in urban areas. The working force constitutes nearly 41.7% of the total population. 42.2% of the working force is engaged as cultivators and 37.4% as agricultural labourers. The balance of 30.4% of the working force is employed in manufacturing and other tertiary activities.

Forests & Agriculture

7.13 Forests occupy 15.2% of the total area in the basin and the culturable area constitutes 66%. Out of the total culturable area of 1.62 million hectares, nearly 1.26 million hectares are annually cultivated. An area of 0.40 million hectares constituting 31.5% of the cultivated area is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 73.2% of the total irrigated area.

Power

7.14 There are no hydro and thermal power stations existing in the basin. The Central Water and Power Commission, when assessing the hydroelectric power potential of the country, has indicated that the hydro-potential of this basin is practically nil. At present, the demand for the electrification of towns is mainly met by means of diesel plants. The basin also gets power from the State grid.

Mineral Wealth

7.15 The principal minerals found in the basin are: †

*Census Paper I of 1971 (Supplementary) Registrar General (India).

†Techno-Economic survey of Andhra Pradesh, NCAER.

Iron ore: In the Kurnool district.
Asbestos: In the Kurnool district.
Barytes: In the Kurnool and Nellore districts.
Felspar: Which is rich in Pegmatite, in the Nellore district.
Limestone and Dolomite: In the Kurnool and Nellore districts.
Mica: In the Nellore district.
Slate and Lead: In the Kurnool district.

Industries

7.16 The important industries in the basin are located in Guntur and Ongole. They are silk and other fabrics, jute textiles, drugs and pharmaceuticals, chemicals, paints and soaps in Guntur. Tobacco products and cashewnut factories are in both Guntur and Ongole.

Communications

7.17 The basin is served by the network of the Southern Railway. The entire system is on the broad-gauge. There are a few important lines connecting different places in the basin. Some of these are the Vijayawada-Madras line, Tenali-Guntur-Nandyal line and Guntur-Machcherla line. The National Highway connecting Madras and Calcutta passes through the basin. In addition, there is a close network of State Highways, and district roads. There is no navigation on any of the rivers in the basin. The only navigable canal in the basin is the Buckingham Canal.* This canal, running close to the sea-coast, connects the Commamur Irrigation-cum-Navigation Canal of the Krishna Delta System with the backwaters in the South Arcot district of Tamil Nadu. The Godavari and the Krishna Delta Canals, being interlinked with the Buckingham Canal, provide a chain of waters from as far north as Kakinada in the East Godavari district of Andhra Pradesh to Madras City and further south. The total length of the Buckingham Canal falling within the basin is 217 km. The canal is ordinarily fit for navigation all the year round. The traffic is by country boats of capacity from 5 to 30 tonnes.

The basin is well-served with communications.

Dependence on Rainfall and Water Resources

7.18 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides

*Navigable Waterways of India, Central Water and Power Commission (1961).

a low level of subsistence except in parts of the basin where irrigation has been provided and industries have developed. There is a keen demand for the development of water resources in the basin.

WATER RESOURCES

Surface Waters

7.19 The annual runoff of the basin of the east-flowing rivers between the Krishna and the Penner had been estimated at 1,554 m. cu. m.,* in 1949, on the basis of Khosla's formula.

Gauge and discharge observations are being conducted by the Andhra Pradesh State Government at many sites on the Gundlakamma, the Paleru and the Manneru rivers. The details of the gauge and discharge sites are shown below: **

No sites have been proposed on any of the rivers in the basin under the programme of establishing and maintaining Centrally sponsored key

Table 7.3

Existing Gauge and Discharge Sites

Sl. No.	Name of river/ tributary	Location of site	Latitude	Longitude	Whether Guage or Gauge & Discharge site
1.	2	3	4	5	6
1.	The Gundlakamma	Cumbum regulator	15°32′	79°5′	GD
2.	-do-	Tangirala	15°37′	79°12′	G
3.	-do-	Jammalamadaka	15°55′	79°53′	GD
4.	-do-	Markapur anicut	16°3′	79°35′	GD
5.	The Paleru	Palair-Bitragunta	15°25′	79°55′	GD
6.	The Manneru	Pillaperu	15°00′	79°35′	GD
7.	-do-	Rallapadu regulator	15°2′	79°45′	GD
8.	-do-	Veeraraghavuni Kota anicut	15°18′	79°55′	GD
9.	-do-	Karedu anicut	15°20′	80°00′	GD
10.	-do-	Nakkalagandi	15°2′	79°34′	GD
11.	-do-	Mopad reservoir	15°3′	79°35′	GD
12.	-do-	Kondapuram anicut	15°00′	79°45′	GD
13.	-do-	Lower Uppateru	15°00′	79°50′	GD

*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

**Inventory of gauge and discharge sites in Andhra Pradesh, Central Water and Power Commission, Hydrology and statistics Directorate (1967)—unpublished.

hydrological stations in the country. The actual observed data on run-offs of the various rivers and the details regarding the method of observations and period for which the data is available have not been furnished by the Andhra Pradesh State Government.

Ground Water

7.20 Systematic investigations and studies of the ground water potential of the basin have not been made so far. Only in some parts of Kurnool, Guntur and Nellore districts, have some investigations and studies been done recently.*

The area investigated in Kurnool district, in Giddalur taluk, has been found to be underlain by shales and slates with intercalation of quartzites and limestones of the Cuddapah system. Ground water development to a limited extent is possible through large diameter open wells in selected areas.

The area investigated in Guntur district, immediately to the west of the Krishna river, is mostly covered by alluvial sediments and ground water is developed by means of open wells and filter point wells. There is scope for the development of ground water by means of tubewells. The precise nature of the aquifers has to be determined by exploratory drilling before taking up any large-scale development of ground water in the area.

In the area investigated in Nellore district, ground water is mainly developed by open wells from the sands in the alluvial sediments. The quality of water is generally good but is variable in wells located within 3 km. of the coast. There is good scope for the development of ground water in the alluvial sediments which are expected to enclose confined acquifers. Exploratory drilling and testing are in progress. Both the quality and quantity of water in these confined aquifers has to be established before undertaking any large-scale development of ground water.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, quantitative and qualitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development for various needs can only be made when full investigations are carried out.

EXISTING DEVELOPMENT

7.21 The First Irrigation Commission had not recommended

*Ground Water Resources of India, Status and surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

any specific projects by name, to be taken up for construction in the basin.*

7.22 Irrigation has been practised in the basin from early times. Many projects were constructed in the basin in the pre-Independence period. These are described in the following paragraphs:

Mopad Reservoir Scheme

This scheme, consisting of a reservoir in the Manneru basin for irrigating 5,060 hectares in the Nellore district, was completed in 1921 at a cost of Rs. 2.44 million.

Markapur Tank

Costing Rs. 0.13 million, this tank irrigates 1,620 hectares in the Gundlakamma basin in Kurnool district.

Cumbum Tank

This tank is also located in the Gundlakamma basin and provides irrigation to an area of 4,860 hectares in Kurnool district.

Kareda Anicut

Located in the Manneru basin, the Kareda Anicut System irrigates areas in the Nellore district.

Veeraraghavuni Kota Anicut

Constructed across the river Manneru, the scheme irrigates an area of 2,270 hectares in the Nellore district.

Uppateru Upper Anicut

Located in the Manneru basin, the anicut irrigates areas in the Nellore district.

Rallapadu Project—Stage I

The Rallapadu Reservoir Project has been constructed across the Manneru river for irrigating areas in the Nellore district.

*Report of the Indian Irrigation Commission (1901-03).

During the Plan periods, several projects have been taken up for construction in the basin. These are described briefly in the following paragraphs:

Romperu Drainage Scheme

The project, costing Rs. 12.80 million, provides irrigation to 4,170 hectares in the Guntur district. The project was started in 1946 and completed in 1956.

Uppateru Lower Anicut

Constructed at a cost of Rs. 1.39 million, the scheme provides irrigation to an area of 770 hectares in the Manneru basin in the Nellore district. The project was started in 1954 and completed in 1956.

Nakkalagandi Reservoir

The project has been constructed across the river Manneru for extending irrigation to 400 hectares in the Nellore district. The project costing Rs. 0.73 million was taken up for construction in 1954 and was completed in 1956.

Paleru Reservoir

The Paleru Reservoir project has been constructed across the river Paleru at a cost of Rs. 0.70 million. The project provides irrigation to 610 hectares in the Nellore district. The project was started in 1954 and was completed in 1956.

Rallapadu Reservoir Project—Stage II

Constructed across the river Manneru, the project is intended to provide irrigation to 4,450 hectares in the Nellore district. The total expenditure incurred on the project is Rs. 10.58 million. The project was taken up for execution in 1951 and was completed in 1959.

Paleru Bitragunta Supply Channel Scheme

The project is located across the Paleru river and irrigates 2,220 hectares in the Nellore district. The project costing Rs. 2.62 million was started in 1959 and was completed in 1962.

Gandipalam Project

The project, costing Rs. 13.3 million, envisages the construction of a reservoir across the river Pillaperu, 0.8 km. south-west of Gandipalam village in Udaygiri taluk of Nellore district. It will irrigate an ayacut of 4,047 hectares and is likely to be completed during the Fourth Plan period.

Some particulars of the major and medium projects under operation and construction in the basin are given in Appendix 7.2 and 7.3.

7.23 Besides the major and medium projects, a number of minor schemes comprising tanks and wells irrigate a very large area in the basin. In many villages, there are more tanks than one which irrigate the adjoining agricultural fields. The details of the area irrigated by various sources like canals, tanks, wells, etc. during the year 1967–68, in the basin, are given in table below:

Table 7.4

Source-Wise Irrigation

Sl. No.	Source of irrigation	Area irrigated in thousand hectares
1.	Canals	157.9
2.	Tanks	102.7
3.	Tubewells	1.8
4.	Wells	34.6
5.	Other sources	5.3
	Total	302.3

By the end of 1968–69, the area under minor schemes increased by about 6,237 hectares.

A considerable area in the basin is irrigated from the Krishna waters under the Krishna Delta Canal and Nagarjunasagar Right Bank Canal Systems. Under the proposed Stage II and Stage III of the Nagarjunasagar project, it is proposed to extend the Nagarjunasagar Right Bank Canal up to the Penner river covering more areas in the basin from the Krishna.

7.24 In the absence of data regarding the annual diversions and utilisations by the major and medium projects under operation and construction in the basin as in 1968–69, the utilisation on their completion and full development has been approximately estimated to be of the order of 324 m. cu. m. by the Commission.

7.25 No information is available as regards the statistics of the large number of minor schemes comprising tanks, wells and other diversions. Based on the area irrigated from these sources and on rough duties, the approximate estimate of the quantity of water diverted for irrigation by these works has been made. On their completion and full development, the approximate annual diversion by the minor schemes under operation and construction as in 1968–69 may be of the order of 1,147 m. cu. m.

Reservoir Losses

7.26 In the absence of data on the reservoir losses for the major and medium schemes in the basin, an approximate estimate of the losses has been made by the Commission, assuming that this would be of the order of 20 per cent of the annual diversions by these projects. On this basis, the reservoir losses work out to approximately 65 m. cu. m.

For minor schemes, in the absence of observed statistics, it is extremely difficult to estimate the losses. Assuming the water spread of a tank to be about 87.5 per cent of the area irrigated from it, as estimated for the Krishna-Godavari basins,* and that the total loss is of the order of 1.49 m. over the water surface area, the total reservoir losses from the tanks in the basin would work out approximately 1,394 m. cu. m.

7.27 Thus, on their completion and full development the major, medium and minor projects under operation and construction as in 1968–69 in the basin would use about 2,930 m. cu. m. of which 2,641 m. cu. m. would be from the surface water; and 289 m. cu. m. from the ground water.

7.28 There are a number of major industries located in the basin, especially round about Guntur. The data on the present industrial water needs are not readily available. In the future, such needs are expected to grow. The problem of water pollution in the basin due to discharge of industrial wastes has not been reported so far. However, the problem may arise in the future, and will have to be guarded against.

*Report of the Krishna-Godavari Commission (July, 1962).

FUTURE DEVELOPMENT

7.29 No new major or medium scheme is proposed to be taken up in the basin in the Fourth Five Year Plan period.

7.30 By the end of Fourth Plan, the area under minor schemes is expected to increase by about 35,840 hectares, requiring nearly 605 m. cu. m. of water, including reservoir losses.

7.31 On completion and full development of Fourth Plan projects, about 3,535 m. cu. m. of waters (3,177 m. cu. m. of surface water and 358 m. cu. m. of ground water) in the basin would have been used for irrigating a total area of 216,957 hectares.

The Andhra Pradesh State Government has not indicated the projects to be undertaken in the basin in the future.

FLOODS, WATERLOGGING & DRAINAGE

7.32 The occurrence of heavy floods is not a regular feature in the basin. There are, however, occasions when floods do occur and cause some damage to life and property. The coastal rivers spill over their banks during floods mostly on account of inadequate carrying capacity.* Collectively, the rivers present some flood problem by flooding areas in the lower reaches, damaging the existing sources of irrigation, inundating villages and cultivated tracts and causing damage to roads and bridges. Large-scale flood control measures neither exist nor seem to be necessary in the basin. The floods in the rivers of the basin are rare, sudden and short-lived.

7.33 Waterlogging has not been reported in the irrigated areas in the basin. The coastal region is, however, likely to be affected by salinty and drainage problems for which necessary measures may have to be undertaken.

SOIL CONSERVATION

7.34 The basin has hardly 15.2% of the area under forests. This percentage is low when compared with the all-India average and the standards laid down in the 1952 Forest Policy Resolution of the Government. Afforestation in the catchment is called for to reduce erosion hazards.

*Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

No data is available regarding the silting of the existing Tanks and reservoirs in the basin. For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures are undertaken in the basin not only in the un-cultivated areas but also in the cultivated areas.

No scheme in the basin has been included under the Centrally sponsored programme of soil conservation in catchments of major river valley projects.

GENERAL

7.35 A number of medium projects have already been constructed on the various river systems in the basin. One medium project is under construction. In addition, there are many minor schemes and more are under construction. A rough assessment of the utilisation by the above schemes indicates that on completion and full development of Fourth Plan projects, most of the waters available in the rivers would have already been utilised. To plan the future development of the basin, therefore it is essential to make a fresh assessment of the water resources of the basin and determine the extent of surplus waters that are still available for utilisation by the future projects. After the above assessment has been made, new projects for the utilisation of the surplus waters, if any, may be taken up in the basin.

7.36 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs, needs to be established.

7.37 Gauge and discharge observations at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects, but also for the regulation, of available river water in any year. Ungauged rivers should also be gauged continuously and systematically.

7.38 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with the surface water.

7.39 There is need for carrying out soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

7.40 It is necessary that systematic data is collected with regard to the sediment carried by the river waters, which would be of considerable use in working out dead storage and life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE PENNER BASIN

(i) Source: In the Chennakesava hill of Nandidurg range, Kolar District of Mysore State. (Latitude 13°33′N, Longitude 77°36′E).

	Km.	Miles
(ii) Length of the Penner river:		
In Mysore	61	38
In Andhra Pradesh	536	334
Total	597	372

	Sq. Km.	Sq. miles
(iii) Drainage area		
Mysore	6,937	2,678
Andhra Pradesh	48,276	18,639
Total	55,213	21,317

(iv) Population (1971 Census):	6.78 millions	
(v) Density of population:	123 per sq. km.	319 per sq. mile
(vi) Maximum discharge at Nellore anicut, 553 km. (352 miles) from source		14,716 cumecs 520,000 cusecs
(vii) Minimum discharge at Nellore anicut,		Nil

	M.cu.m.	MAF
(viii) Annual runoff as per irrigation potential studies of CW & PC	6,858	5.56
(ix) Maximum annual runoff recorded at Sangam anicut	5,933	4.81
(x) Minimum annual runoff recorded at Sangam anicut	543	0.44

	Thousand hectares	Thousand acres
(xi) Culturable area (1967-68)	3,551	8,775
(xii) Net area sown (1967-68)	2,081	5,142
(xiii) Gross area sown (1967-68)	2,217	5,478
(xiv) Net area irrigated (1967-68)	358	885
(xv) Gross area irrigated (1967-68)	475	1,174
(xvi) Area irrigated after completion and full development of Fourth Plan projects (excluding the area irrigated by the Krishna waters)	668	1,700
(xvii) Probable additional irrigation by future projects	N.A.	

(xviii) Water utilisation including reservoir losses:

		M.cu.m.	MAF
(a) On completion & full development of major, medium and minor projects under operation and construction at the end of Annual Plan (1968-69)	Surface water	5,031	4.08
	Ground water	1,390	1.13
	Total	6,421	5.21
(b) On completion and full development of Fourth Plan projects:	Surface water	7,356	5.96
	Ground water	1,754	1.42
	Total	9,110	7.38

THE PENNER BASIN

The Penner basin extends over an area of 55,213 sq. km., and lies between east longitudes 77°4′ and 80°10′ and north latitudes 13°16′ and 15°52′. Located in peninsular India, it covers areas in the States of Mysore and Andhra Pradesh. The State-wise distribution of the drainage basin is given below:

State	*Drainage area* (Sq. km.)
Mysore	6,937
Andhra Pradesh	48,276
Total	55,213

8.2 The fan-shaped basin is bounded on the north by the Erramala range, on the east by the Nallamala and Velikonda ranges of the Eastern Ghats, on the south by the Nandidurg hills and on the west by the narrow ridge separating it from the Vedavati valley of the Krishna basin. The other hill ranges in the basin to the south of the river are the Seshachalam and Paliconda ranges. Its maximum length east to west is 433 km. The maximum width of 266 km. from north to south is attained in the middle of the basin.

THE PENNER RIVER SYSTEM

8.3 The Penner or the Uttara Pinakini is one of the major inland rivers of the peninsula, flowing east and draining into the Bay of Bengal. In point of size, it is the fourth largest and next to the Cauvery.

The Penner rises at north latitude 13°33′ and east longitude 77°36′ in the Chenna Kesava hill of the Nandidurg range in Mysore State. Flowing in a north-westerly direction through the Kolar and Tumkur districts of Mysore State for a distance of 48 km., it enters Andhra Pradesh in the extreme south of the Hindupur taluk of Anantapur district. Two of its tributaries, the Kumudavati and the Jayamangali, join it from the left at the 69th and 82nd km. respectively from its source. After flowing for 67 km. through the Hindupur and Penukonda taluks of Anantapur district in Andhra Pradesh, the river re-enters Mysore State and cuts across the Pavagada taluk of Tumkur district for a distance of about 13 km. to emerge into the Kalyanadurg taluk of Anantapur district in Andhra Pradesh. Beyond the confluence of the Jayamangali, the river runs almost north-west for a distance of 146 km. passing through plains studded with tanks. Changing direction eastwards near Ponnahobalam, the river flows through the Marutla and Katrimala reserve forest ranges and receives two minor tributaries, the Pulivanka and the Maravanka. The Chitravati, a major tributary falls into the Penner on its right at the 336th km. of its run. Beyond this confluence, the Penner forces its way through the narrow Gandikota gorge in a north-easterly direction for a distance of about 10 km. and emerges near the town of Jammalamadugu. Taking a sharp turn towards the south-east, it enters the black cotton plains and passes Proddatur, to receive a small stream on its right at the 378th km. of its run. Near Kamalapuram, two major tributaries, the Kunderu on the left and the Papagni on the right fall into the Penner within a reach of 3 km. The Adinimayapalli Anicut stretches across the river at the 402nd km. from the source. Just upstream of this anicut, the Kurnool-Cuddapah canal flows into the Penner from the left and is picked up on the right side through a head-sluice. Flowing further in a south-easterly direction, the river cuts across the Nallamala hill range and passes the town of Siddavatam. It receives the Sagileru, on its left, at the 448th km. of its run. Turning eastward near Boyanapalli, it confluences with the Cheyyeru flowing from the right. 19 km. below this confluence, the river emerges from the Velikonda hill range of the Eastern Ghats, through the narrow gorge at Somasila, to enter plains. It widens considerably thereafter, when it is met, on the left, by the Kaveru. At the 528th km. from its source, the river flows over the Sangam anicut and traversing further a distance of 35 km., crosses the Nellore anicut near Nellore. Flowing past Nellore, for another 34 km, the Penner enters the Bay of Bengal at north latitude 14°35′ and east longitude 80°10′.

The total length of the river from the head to its outfall into the sea is 597 km., of which about 61 km. are in Mysore and the balance of 536 km. are in Andhra Pradesh.

8.4 The principal tributaries of the river are, the Jayamangali, the Kunderu and the Sagileru from the left and the Chitravati, the Papagni and the Cheyyeru from the right. These are briefly described in the following paragraphs.

The Jayamangali: Rising in the Tumkur district of Mysore State, the Jayamangali flows for a total distance of 77 km. in a north-easterly direction to join the Penner from the left bank. It drains an area of 1,282 sq. km. The Suvarnamukhi river is an important tributary of the Jayamangali.

The Kunderu: Rising in the Kurnool district of Andhra Pradesh and flowing generally southward for a total distance of 205 km., it meets the Penner near Kamalapuram from the left bank. It drains an area of 8,057 sq. km., which is about 15.55% of the total Penner catchment.

The Sagileru: Rising in the Nallamala range, the Sagileru flows generally southward for a total distance of 141 km. It joins the Penner from the left near the village of Venkatesampalli and drains an area of 3,077 sq. km.

The Chitravati: Rising near Chikballapur town in the Kolar district of Mysore State and flowing in a generally north-east direction for a total distance of 218 km., it falls into the Penner from the right near Gandaluru. It drains 5,908 sq. km., which is about 12.4% of the total basin area.

The Papagni: Rising near Sidlaghatta town in the Kolar district of Mysore State and flowing in a generally north-east direction for a total distance of 205 km., the Papagni joins the Penner from the right bank. The total area drained by this major tributary is 7,423 sq. km., which is about 14.33% of the total basin area.

The Cheyyeru: The Bahuda and the Puncha, rising in the Chittoor district of Andhra Pradesh, flow generally north-east to meet and form the Cheyyeru near Rayavaram. After traversing a distance of 87 km. from this confluence, the Cheyyeru falls into the Penner from the right bank. The Cheyyeru drains 7,325 sq. km., which is about 14.14% of the total basin area.

CLIMATE

Seasons

8.5 There are three distinct seasons in the basin: viz. (i) cool weather, (ii) hot weather and (iii) rainy season.

In the cool weather, which extends from about the middle of October to the middle of February, strong dry winds blow over the basin. On the eastern slopes of the Eastern Ghats, heavy north-east monsoon showers occur.

In the hot weather extending from the middle of February to the middle of June, the entire basin is practically dry and the interior of the basin, especially Cuddapah district, experiences severe heat.

The south-west monsoon season, which follows the hot weather, extends from the middle of June to the middle of October. The major part of the basin receives its rainfall from the south-west monsoon while areas adjacent to the sea-coast receive some rainfall from the retreating monsoon. The south-west monsoon withdraws by the middle of October.

Rainfall

8.6 There are at present 94 rain-gauge stations inside the basin. The distribution of the stations is fairly uniform and their number is adequate.

The entire basin, lies largely in a semi-arid region with low rainfall. The normal annual rainfall decreases from 988 mm. at Nellore in the eastern end of the basin to about 508 mm. at the western end. A large part of the basin lying in Mysore, Anantapur, Kurnool and Cuddapah districts of Andhra Pradesh receives less than 762 mm. Parts of Nellore and Cuddapah districts, adjacent to the sea-coast receive some rain from the retreating monsoon also. The average annual and monsoon rainfall, sub-basinwise, is shown in Table 8.1.

Temperature

8.7 In the cool weather, the temperature falls as one advances from Nellore towards Kurnool. The mean maximum and the mean minimum temperatures are 34.6°C and 15.2°C respectively at Cuddapah and Arogyavaram during this period.

During the hot weather, the temperatures are particularly high in the interior of the basin. The mean maximum and mean minimum temperatures at representative places like Cuddapah and Arogyavaram during this season are 40.9°C and 16.9°C respectively. In the region towards the east of the Eastern Ghats, particularly in Nellore district, the temperature is comparatively moderate. Towns situated in the Eastern Ghat region enjoy lower temperatures by virtue of their elevation. The hottest part of the basin is around Cuddapah.

In the rainy season, the temperature is moderate and ranges between 40.2°C and 22.2°C over the entire basin. Temperatures tend to increase from the west to east, the maximum being 38.6°C at Nellore and the minimum being 17.3°C at Arogyavaram.

Evaporation

8.8 Very little data on evaporation is available for the Penner basin. The India Meteorological Department has compiled the evaporation data in respect of 30 departmental observatories and 42 agro-meteorological

Table 8.1
Rainfall in Penner Basin

Sl. No.	Sub-basin	Average rainfall in mm.	
		Annual	Monsoon
1.	Penner main (from the source to the Jayamangali confluence)	726	559
2.	Jayamangali	685	552
3.	Penner main (from the Jayamangali confluence to the Chitravati confluence)	592	478
4.	Chitravati	635	531
5.	Penner main (from the Chitravati confluence to the Papagni confluence)	617	546
6.	Kunderu	643	552
7.	Papagni	569	478
8.	Penner main (from the Papagni confluence to the Cheyyeru confluence)	768	640
9.	Sabileru	747	579
10.	Cheyyeru	759	607
11.	Penner main (from the Cheyyeru confluence to the Sangam anicut)	838	663
12.	Penner main (from the Sangam anicut to the sea)	1,021	841

observatories scattered all over the country possessing data for more than five years. Observations at all these observatories are taken with the standard U.S. Evaporation Pan (Class A) covered with wire mesh. For the departmental observatories, the data pertains to the period 1959–68 and is available month-wise, whereas the data for the agro-meteorological observatories pertains to the period 1961–68 and has been presented for the 12 periods into which the calendar year is divided for agro-meteorological purposes. Unfortunately, none of these departmental and agro-meteorological observatories, is located in the Penner basin. The monthly evaporation losses from the reservoir, as assumed in the Somasila project in the Penner basin, are given in Table 8.2.

SOILS

8.9 No systematic soil survey of the Penner basin has been carried out so far. The general data regarding soils of India, however, indicate

Table 8.2
Monthly Evaporation Losses

Month	Evaporation mm.	Month	Evaporation mm.
January	10	July	15
February	10	August	15
March	18	September	15
April	23	October	13
May	26	November	10
June	18	December	10
		Annual	183

that the basin consists mainly of red, black, sandy and mixed soils.

The basin covers in part the districts of Anantapur, Chittoor, Cuddapah, Kurnool and Nellore in Andhra Pradesh and partly, the districts of Bangalore, Kolar and Tumkur in Mysore. The principal soil types found in the various districts in the basin are described below*:

Anantapur: Mostly red soils, which are either calcarious or non-calcarious and fairly deep. Also black and alluvial soils. The black soils are clayey, while the alluvial soils are sandy at the top with saline sub-soil layers.

Chittoor: Mainly red soils and occasionally black soils.

Cuddapah: Mainly red soils in the eastern half of the district. Black soils also. The soils are generally well-drained.

Kurnool: Mostly black soil.

Nellore: Black soils, red loams and sandy coastal soils. The largest area is occupied by the red loams and the least by the sandy soils.

Kolar: Red and lateritic soils. In the red soils, both loam and sandy types are observed.

Bangalore: Light brown or red soils, mostly sand to sandy loam.

Tumkur: Red soils which are either loamy or sandy.

LAND USE AND AGRICULTURAL PRACTICES

8.10 State-wise land use details in the basin, as in 1967–68, the latest year for which the statistics are available, are given in Table 8.3.

The land use details indicate that the resources in the basin have not

*Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Table 8.3

Land Use Details

(*Thousand hectares*)

Sl. No.	Item	Name of the State: Andhra Pradesh	Name of the State: Mysore	Total
1.	Gross area	4,827	694	5,521
2.	Reporting area	4,827	643	5,470
3.	Area under forests	1,078	48	1,118
4.	Area not available for cultivation	729	86	815
5.	Culturable area	3,028	509	3,537
6.	Uncultivated culturable area	1,183	273	1,456
7.	Net area sown	1,845	236	2,081
8.	Area sown more than once	128	8	136
9.	Total cropped area	1,973	244	2,217
10.	Net area irrigated	323	35	358
11.	Gross area irrigated	431	44	475
12.	Percentage of net area sown to culturable area	60.93	46.36	58.84
13.	Percentage of net area irrigated to culturable area	10.67	6.88	10.12
14.	Percentage of net area irrigated to net area sown	17.51	14.83	17.20

been put to intensive use and the area sown more than once is very limited. The food crops usually grown in the basin are paddy, jowar and ragi. Paddy is mainly grown in Nellore and Cuddapah districts, where irrigation facilities exist. Jowar is grown extensively in Kurnool and Kolar districts. Of the non-food crops, oilseeds are the most important. Anantapur, Cuddapah and Kurnool have large areas under oilseeds.

8.11 The general cropping pattern, Statewise is as under:

Mysore: Of the total irrigated area of 44,000 hectares, about 44.5% is under paddy and 13.6% under ragi. Other crops grown in the irrigated area are sugarcane, condiments and spices.

Food crops represent about 86.4% of the irrigated cropped area, the balance of 13.6% of the area being under non-food crops.

Andhra Pradesh: Of the gross irrigated area of 431,000 hectares, about 52.9% is under paddy and 13% under ragi. Sugarcane forms 2.1% and condiments and spices account for 2.8% of the irrigated area. Other crops grown in the irrigated area occupy the balance 29.2%.

Food crops represent about 87% of the irrigated cropped area, the balance of 13% being under non-food crops.

Summing up, of the total irrigated area in the basin, 52.2% is under paddy, 13.1% under ragi, 2.3% under sugarcane and 2.5% under condiments and spices and the rest under miscellaneous crops. Food and non-food crops cover 87% and 13% of the total irrigated area respectively.

8.12 There are two main crop seasons, the kharif and the rabi. The kharif crops are paddy, millets, pulses and groundnut. Areas with lighter types of soils are used for growing kharif crops. Cotton is grown in heavy soils. The rabi crops, which are grown as a rule on heavy soils, are cholam, chillies, garlic, onion, cotton, groundnut, ragi, korra, gingelly and other oilseed and horse gram. Besides these seasonal crops, garden crops like sugarcane, plantains, betel leaves and turmeric are also grown throughout the year.

The crops are broadly classified as first wet crop, second wet crop, garden crop, single dry crop, double dry crop etc. Paddy is the principal wet crop in the basin. The period of the first wet crop starts by the first week of July and ends by the middle of January and may be taken as 165 days. The period of the second wet crop is generally from mid-January to mid-April i.e. for 90 days.

REGIONAL ECONOMY

Population

8.13 On the basis of 1971 Census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 6.78 millions. The state-wise distribution is shown below:

Table 8.4
State-wise Population

State	Population
Mysore	1.33 millions
Andhra Pradesh	5.45 millions
Total	6.78 millions

*Census Paper 1 of 1971 (Supplementary), Registrar-General (India).

8.14 There is only one city, namely, Nellore, in the basin, which has a population of more than one lakh. The average density of population in the basin is 123 persons per sq. km. The density varies from region to region within the basin. The most densely populated district of Bangalore has 418 people per sq. km., with the district of Cuddapah with only 103 persons per sq. km. at the other extreme. 78% of the population in the basin live in rural areas and the balance of 22% live in cities and towns. The working force constitutes about 39.1% of the population. Nearly 35% of the working force is engaged as cultivators, 33% as agricultural labourers and the balance of 32% is employed on other activities.

Forests and Agriculture

8.15 Forests and agriculture are the mainstay of the people. Nearly one-fifth of the total area of the basin is forested. The luxuriant forest cover is largely confined to Cuddapah, Chittoor, Anantpur and Kurnool districts, consisting of dry deciduous or mixed deciduous types. Teak, red sanders, sandalwood and bamboo are the important economic species. The area annually cropped in the basin is about 2.22 million hectares. Agriculture is generally rainfed with relatively low yields, except for about 0.48 million hectares of irrigated area, which grows mainly paddy and ragi.

Power

8.16 The Central Water & Power Commission has assessed the hydro-potential of the Penner basin as practically nil. At present, the demand for electrification of towns etc., is mainly met by diesel and thermal power plants. Most of the district and taluk headquarters are provided with diesel generating stations. The biggest thermal station in the basin is at Nellore, and came into operation in 1965 with an installed capacity of 30 MW. The basin also receives power from the Machkund and Tunga-bhadra projects.

Mineral Wealth

8.17 The principal minerals found in the basin are:*

Asbestos: In the Tumkur, Cuddapah, Kurnool and Anantapur districts;

Barytes: In the Cuddapah, Kurnool, Anantapur and Nellore districts;

Corundum and Felspar: Corundum in the Anantapur district and Felspar, which is rich in Pegmatite, in the Nellore district;

Limestone and Dolomite: In Nellore, Cuddapah, Kurnool and Anantapur districts;

* Techno-Economic Surveys of Andhra Pradesh and Mysore, NCAER.

Kankar: In the Chikballapur in Kolar district;
Mica: In the Nellore district;
Slate and Lead: In the Cuddapah and Kurnool districts;
Vermiculite: Near Pavagada in the Tumkur district.

Industries

8.18 With limited mineral resources, water and power potential, the industrial development in the basin has not attained a high standard. The important industries in the basin, district-wise, are mentioned below:

Kolar: Manufacture of perfumes in Chintamani; Minor cotton weaving and oil mills at Chikballapur and Chintamani.

Tumkur: Rice and oil mills at Pavagada and Madhugiri respectively.

Chittoor: Groundnut decorticating, manufacture of metal containers and steel trunks; beedi manufacture and confectionery.

Anantapur: Cotton ginning and bailing, silk, groundnut decorticating and oil.

Kurnool: Cotton-carpet weaving, oil and slate industries.

Cuddapah: Oil, paints, colours and varnish; canning and preservation of fruits, cotton ginning and slate industry, manufacture of asbestos sheets.

Nellore: Beedi and sugar manufacture, saw and rice mills and allied industries, cashewnut factories, glass & ceramics, mica, matches, soaps, inks, paints & varnishes, etc.

Communications

8.19 The basin is served by the network of Southern Railway. Both broad gauge and metre gauge lines run across the basin. The following are the important routes:

	Length in the basin
(I) *Broad gauge*:	
Madras-Bombay	281 km.
Madras-Calcutta	40 km.
Total	321 km.
(II) *Metre gauge*:	
Bangalore-Secunderabad	235 km.
Renigunta-Dharmavaram	196 km.
Hubli-Masulipatam	154 km.
Total	585 km.

The Madras-Bombay line enters the basin at Sattigunta, runs parallel to the river from Cuddapah up to the crossing of the bridge between Tadipatri and Jutur and leaves near Guntakal. The Bangalore-Secunderabad metre gauge line enters the basin at Oddarhalli, 42 km. from Bangalore and runs practically parallel to the river before leaving the basin at Pendekallu. The Renigunta-Dharmavaram line runs across the basin touching the Madras-Bombay line on the one side and the Bangalore-Secunderabad line on the other, covering a distance of 196 km. between Pulicherla and Dharmavaram.

Two important national highways pass through the basin viz. National Highway connecting Kanniyakumari to Varanasi and National Highway connecting Madras to Calcutta. 209 km. of the former and 40 km. of the latter lie in the basin. In addition, there are four important State highways, viz. (i) between Nellore and Guntakal, (ii) between Kurnool and Chittoor, (iii) between Kurnool and Ongole and (iv) between Uravakonda and Guntakal. The total length of these State highways in the basin is about 727 km.

The Kurnool-Cuddapah canal constructed by the Madras Irrigation Company Limited in 1870 was navigable throughout its length up to 1934, when the reach below Lockinsula was closed to navigation, as there was little boat traffic and maintenance costs were high.* There is practically no navigation on the main Penner, its tributaries and the canal systems at present.

The basin is fairly well served with communications.

Famines

8.20 The Penner basin is frequently visited by famines as it lies in a zone of poor rainfall. Most of the Andhra Pradesh area of the basin, which forms part of Rayalaseema, is a notorious famine area. Irrigated areas under the Kurnool-Cuddapah canal and the delta in Nellore district are, however, generally free from famine. Relief measures have been undertaken from time to time in the various scarcity and famine areas.

Dependence on Rainfall and Water Resources

8.21 The economy of the basin, at present, largely depends on agriculture, which, in view of the low rainfall and its uneven incidence, provides a low level of subsistence, except for small parts of the basin where irrigation has been provided. There is a keen demand in the basin for the full development of whatever water resources are available.

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*Navigable Waterways of India, Central Water and Power Commission (1961).

WATER RESOURCES

Surface Waters

8.22 The water potential of the Penner river basin has been assessed at different times by different authorities. The very first assessment was made by the First Irrigation Commission. As the records of the surplus flow from the greater part of the Penner catchment extending back for a sufficient number of years were available, the Commission could make a fairly accurate estimate of the average flow. It assessed the annual surface flow in the Penner, Palar and Cauvery rivers together, as 56,640 m. cu. m.*

In 1949 when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's empirical formula, the annual runoff of the Penner river system was estimated as practically nil.**

In 1960, the Central Water & Power Commission, while conducting the irrigation potential studies, assessed the total annual runoff of the Penner river system as 6,858.15 m. cu. m.***

The first site where gauge and discharge observations were conducted in the basin was at the Nellore anicut. The data is available from 1877. Later on, river gauging was done at the Sangam anicut when it came into operation. In the early twenties of the present century, the Adinimayapalli anicut was constructed and gaugings were started here. As regards the gauging of the tributaries of the Penner, only the Kunderu and the Sagileru tributaries which had anicuts across them, were suitable for observations. At the Gandikota dam site, river gauging was conducted exclusively in connection with the preliminary investigation of the Gandikota dam to ascertain the available yield. The gauging was conducted for a year or two and then discontinued.

Appendix 8.1 gives the number of sites sub-basinwise, where river gauging operations are being carried out.†

At the anicut sites across the main river and its tributaries, the discharges are being computed from observed gauge readings. Gauges are fixed upstream and downstream of the anicuts. The Sangam and Nellore anicuts are provided with shutters whereas the other anicuts are of the free-flow type. The shutters on the Sangam and Nellore anicuts are lowered during the monsoons. Gauge readings are usually taken thrice daily except during the flood season, when they are taken at more

*Report of the Indian Irrigation Commission (1901-03).

**An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

***Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission (Unpublished).

†Penner Basin Report—Flood Control Wing (Field Investigations)—Central Water and Power Commission (October, 1959).

Table 8.5

Yearly Flows in Penner

Sl. No.	Year	Total flow in m. cu. m.	Sl. No.	Year	Total flow in m. cu. m.
1.	1919–20	4,959	12.	1930–31	5,440
2.	1920–21	2,492	13.	1931–32	2,183
3.	1921–22	4,539	14.	1932–33	950
4.	1922–23	3,762	15.	1933–34	3,330
5.	1923–24	543	16.	1934–35	1,418
6.	1924–25	1,579	17.	1935–36	4,502
7.	1925–26	3,959	18.	1936–37	1,838
8.	1926–27	1,098	19.	1937–38	2,479
9.	1927–28	3,836	20.	1938–39	5,933
10.	1928–29	1,357	21.	1939–40	4,330
11.	1929–30	2,245	22.	1940–41	5,316

Kurnool systems in the Andhra Pradesh area. The Archeans consist of peninsular gneisses and Closepet granites. The Dharwar system is composed mainly of a complex series of crystalline schists, igneous rocks and their altered forms and some sedimentary rocks like quartzites, conglomerates, limestones etc. The Suddapah system consists of quartzites, shales and limestones. The Kurnool system comprises quartzites, shales, limestones and sandstones and is correlated with the lower part of the Vindhyan system of Central India.

Systematic investigations and studies of the ground water potential of the basin have not been made so far. Only in some parts of Kolar, Anantapur, Cuddapah and Nellore districts, have some investigations and studies been done recently.*

Investigations in the Goribidanur and Srinivaspur taluks of Kolar district over a total area of 617 sq. km. have indicated that ground water is being developed by means of open wells in weathered and jointed granite gneisses. Ground water development can take place in this area in valleys and in low ground to a limited extent.

Geohydrological investigations over an area of 11,000 sq. km. in Anantapur district have indicated that ground water is being developed

*Ground water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August. 1970).

from granites, gneisses and scists. In general, there is vide variation in the yields of wells as well as the depth of the water table. The data indicates that the ground water potential in the area is generally poor and highly variable. Development on a limited scale can take place only in selected localities by means of open wells under favourable geological and topographical conditions. The quality of ground water is generally good and fit for irrigation. Deterioration in quality does, however, occur in areas underlain by black cotton soil.

In the Rayachoti taluk of Cuddapah district, investigations over an area of 950 sq. km. have indicated that wells which penetrate gneisses give better yields and have a better rate of recovery than wells sunk through weathered granites. Ground water development can take place in selected localities of this area by large diameter open wells and dug-cum-bore wells.

In Pulivendla taluk, studies covering an area of 400 sq. km. have indicated that there is a decline in water levels in the wells, which may be due to deficient rainfall, excessive withdrawals of ground water through dug wells during the last few years and heavy continuous pumping of ground water from the open cast barytes mines in the area. Steps to augment and conserve ground water storage in this region are warranted.

An area of 1,300 sq. km. in the alluvial plains of Nellore district has been investigated. Ground water is mainly developed by open wells from the sands in the alluvial sediments. The quality of ground water is generally good, but is variable in wells located within 3 km. of the coast. There is good scope for developing ground water from the alluvial sediments, which are expected to enclose confined aquifers. Exploratory drilling and testing are in progress. Both the quantity and the quality of water in these confined aquifers have to be established, before a large-scale development of ground water is undertaken.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, quantitative and qualitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development can only be made when full investigations have been carried out.

EXISTING DEVELOPMENT

8.25 The Nellore and Sangam anicuts, with their canals and tanks, form the oldest irrigation system in the basin. The Kurnool-Cuddapah canal, which irrigates a large area of 104,085 hectares in the Penner basin, has been dealt with under the chapter on the Krishna basin, as the supplies for this canal are drawn from the Tungabhadra river. The First Irrigation Commission had not recommended any specific project to be taken up for construction in the Penner basin. Four more anicuts, namely Adinimayapalli, Razolu, Thambalapalli and Santajittur were built in the basin during the pre-Independence period for providing irrigation. A number of medium projects have been taken up for construction in the basin during the Plan periods.

8.26 The salient features of all the major and medium projects completed in the Penner basin in the pre-Plan and Plan periods are shown in Appendix 8.2. Details of the schemes, which are under construction in the basin, are shown in Appendix 8.3. The important projects in the basin are briefly described in the following paragraphs.

Nellore Anicut: This anicut across the Penner, near Nellore town, in the Nellore district of Andhra Pradesh was taken up for construction about 1825 and was extended by stages. By 1875 the anicut completely spanned the river. Improvements were carried out to the anicut in 1949 and 0.6 m. high falling shutters were fixed on the crest. The main channel taking off from the head sluice on the right side of the anicut, divides into two after about a kilometre. The branch on the left, known as the Jaffer Sahib canal, feeds a chain of small tanks and also serves a direct ayacut. The right side channel called the Sarvepalli canal feeds the Sarvepalli reservoir.

Sangam Anicut: The anicut across the Penner river at Sangam in the Nellore district of Andhra Pradesh was taken up for construction in 1882 and completed by 1886. The anicut crest has been subsequently raised by 0.3 m. and falling shutters 0.61 m. high were fixed in 1940 on the crest of the anicut to cope with the irrigation demand. Two canals, one on each bank, take off from the anicut. The left canal feeds the Duvvur tank and the Kanigiri reservoir. The right canal feeds the Nellore tank. The total ayacut under the Nellore and Sangam anicuts, which together are known as the Penner river canals system is 114,130 hectares.

Adinimayapalli Anicut: This anicut, located across the main Penner about 19 km. from the town of Cuddapah in the Cuddapah district of Andhra Pradesh, was constructed in the early twenties. The Kurnool-Cuddapah canal drops into the Penner upstream of this anicut. An irrigation canal, 48 km. long, which is a continuation of the Kurnool-Cuddapah Canal takes off from the right bank of the anicut.

Razolu Anicut: This anicut has been constructed across the Kunderu tributary, in the Cuddapah district of Andhra Pradesh. It acts as a pick-up weir for the Kurnool-Cuddapah canal.

Thambalapalli Anicut (Upper Sagileru Project): This anicut has been constructed across the Sagileru tributary at Thambalapalli village in the

Cuddapah district of Andhra Pradesh. The area irrigated by it is 1,820 hectares.

Santajittur Anicut: This anicut is situated across the Galeru, a tributary of the Kunderu, which, in turn, is a tributary of the Penner, in the Kurnool district of Andhra Pradesh. It acts as a pick-up weir for the Kurnool-Cuddapah canal.

In the First Five Year Plan, no major project was taken up in the basin. Seven medium projects were taken up, of which the Upper Penner Project was the largest. This project is located across the Penner near Perur village in the Anantapur district of Andhra Pradesh. A 15.24 m. high and 3,490 m. long dam across the river has been constructed to create a reservoir with a gross storage of 56.63 m. cu. m. Two canals take off from the reservoir, one on each bank, to irrigate a total area of 3,930 hectares. The project cost Rs. 15.86 million and came into operation during the Second Plan period.

The other six medium projects of the First Plan have been completed in the various Plan periods and their details are as under:

Table 8.6

Particulars of Medium Projects

Sl. No.	Name of Project	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)
1.	Chennarayaswamigudi	3.26	0.46
2.	Lower Sagileru	5.73	3.24
3.	Pinchanadi	6.23	1.58
4.	Zurreru Reservoir	3.03	0.93
5.	Siddalagandi	0.62	0.16
6.	Vidyaranyaswamigudi	0.26	0.08

8.27 During the Second Five Year Plan period, the Tungabhadra High Level Canal, Stage I, was taken up for construction in the Krishna basin. This project benefits areas in the Penner basin also. The Tungabhadra High Level Canal taking off from the high level sluices on the right side of the Tungabhadra Dam, passes through the Uravakonda cut to drop into the Penner. A discharge of 26.3 cumecs is dropped into the Penner to be picked up by the Mid-Penner regulator across the Penner river in Anantapur district and diverted into the Mid-Penner South Canal (including the Tadipatri branch) and the Mid-Penner North Canal, on both the banks. This project, which was taken up for construction in 1958, was expected to be completed in 1970–71.

Under Stage II of the Tungabhadra High Level Canal Project, which was taken up for construction in 1968, the following works pertaining to the structures in the Penner basin are contemplated:

(1) Fixing of crest gates on Mid-Penner dam;
(2) Widening of the Mid-Penner South Canal and extension by 25 km.;
(3) Construction of the Mylavaram dam across the Penner; and
(4) Cuddapah South and North Canals.

These works are expected to be completed during the Fifth Plan. The areas irrigated in the Penner basin by the Tungabhadra High Level Canal, Stages I and II, will be 33,837 hectares and 36,998 hectares respectively.

8.28 In the Third Plan and Annual Plan periods, the Kanupur canal and the Bahuda reservoir projects respectively have been taken up for construction. These medium projects are under construction and are expected to be completed during the Fourth Five Year Plan. The details are given below:

Table 8.7

Medium Projects (Fourth Plan)

Sl. No.	Name of Project	Estimated Cost (Rs. million)	Ultimate irrigation ('000 hectares)
1.	Kanupur Canal	32.59	6.88
2.	Bahuda Reservoir	4.10	1.17

The Kanupur canal scheme envisages the diversion of the flood waters of the Penner to feed the existing tanks. It is proposed to take off two canals above the Sangam anicut, west of the head sluice of the Nellore tank supply channel. These canals will feed 93 tanks situated in Nellore district, which will irrigate a total area of 6,880 hectares.

The Bahuda reservoir project consists of a dam across the Bahuda river near Nimanapalli village in Chittoor district and two pick-up anicuts downstream of the dam at Mugalamari and Chintaparthi villages. A total ayacut of 1,165 hectares will be provided with irrigation facilities by the system.

8.29 Besides the major and medium projects in the Penner basin, a number of minor schemes comprising tanks and wells, irrigate a very large area. In many villages there are more tanks than one and adjoining agricultural lands receive water from them. Details of the area irrigated by various sources like canals, tanks, wells, etc. during the year 1967–68, Statewise in the basin, are as under:

Table 8.8

Source-wise Irrigation

(Thousand hectares)

Sl. No.	Source of irrigation	Name of the State: Mysore	Name of the State: Andhra Pradesh	Total
1.	Canals	@	76	76
2.	Tanks	22	119	141
3.	Wells	12	112	124
4.	Other sources	1	16	17
	Total	35	323	358

@Less than 500 hectares.

8.30 Most of the important data and information relating to water resources development in the basin are either non-existent or have not been compiled and analysed as yet. Working statistics of canals and reservoirs in the basin have not been compiled and published. Some information about major and medium irrigation works is available. Some major and medium projects under operation and construction in the basin use the Tungabhadra waters for irrigation in the basin. The quantum of Tungabhadra waters utilised is accounted for under the irrigation figures for the Krishna basin and has not been taken into consideration when working out the utilisation of the Penner waters. The average annual diversion of Penner waters on completion and full development of the major and medium projects under operation and construction in the basin at the end of Annual Plan 1968–69 is of the order of 1,837 m. cu. m.

8.31 As regards the statistics on the large number of minor schemes comprising tanks, wells and other diversions, no information is available. In respect of these schemes, no observations seem to have ever been made and no records have been maintained on the quantity of water diverted. Some information is available only with regard to the areas irrigated from these sources. On the basis of rough duties, an approximate estimate of the quantity of water diverted for irrigation by these works has been attempted. The minor schemes, under operation and construction in the basin as in 1968–69, will use 3,162 m. cu. m. on their completion and full development.

Reservoir Losses

8.32 The data on reservoir losses for the major and medium schemes in the basin is not available. To make an approximate estimate of the reservoir losses, the Commission has assumed that they would be of the order of 20% of the annual diversion by these storage projects. On this basis, the reservoir losses work out to approximately 34 m. cu. m.

For minor schemes in the absence of observed statistics it is extremely difficult to estimate the losses. Assuming that the water spread of a tank would be about 87.5% of the area irrigated from it, as estimated for the Krishna and Godavari basins, and that a total loss of 1.07 metres over the water surface area for the period the tank is full (from June to December approximately), the total reservoir losses from the tanks in the basin would work out approximately to 1,388 m. cu. m.

8.33 Thus, the total annual utilisation (including reservoir losses) by the major, medium and minor projects under operation and construction in the basin would be of the order of 6,421 m. cu. m. of which 5,031 m. cu. m. is from surface water and 1,390 m. cu. m. from ground water. As stated earlier, this figure does not include the quantity of Tungabhadra water utilised by certain projects in the basin.

The major and medium projects, which are utilising Penner water and are in operation and under construction as in 1968–69, in the basin will irrigate 0.127 million hectares on full development. The projects in operation and under construction in the basin up to the end of 1968–69, which are utilising the Tungabhadra water, will irrigate 0.175 million hectares on full development. The latest data in respect of irrigation by minor schemes in the basin is not available. However, the area irrigated by minor schemes in 1968–69 was of the order of 0.297 million hectares. On full development of all major, medium and minor projects, which are under construction (1968–69) the total areas irrigated in the basin by

Penner water and Tungabhadra water would be of the order of 0.424 million hectares and 0.175 million hectares respectively.

8.34 The industrialisation in the basin, as already stated, has not attained a high standard due to paucity of raw materials, water and power. The thermal station at Nellore utilises the Penner water for cooling purposes. Data on the present industrial water needs are not readily available and in the future, such needs are not expected to be large since there seem to be limited possibilities for locating major industries in the basin.

The problem of water pollution in the basin due to the discharge of industrial wastes has not occurred thus far. In the event of any major industry being located in the basin in future, the problem of water pollution may arise, and will have to be guarded against.

FUTURE DEVELOPMENT

8.35 Only one major project, namely the Somasila Project, is proposed to be undertaken for construction in the basin in the Fourth Five Year Plan period. The project, costing Rs. 335.2 million, provides for the construction of (i) a composite dam 767 m. long, 40 m. high across the Penner river at village Somasila on the border of the Nellore and Cuddapah districts, (ii) Somasila South Canal 53 km. long taking off from the right bank, (iii) Kavali Canal 64 km. long and (iv) Kanupur canal 37 km. long. The latter two canals take off from the Sangam Anicut, 32 km. downstream, on the left and right bank respectively. The project will extend irrigation to 64,334 hectares of new ayacut and stabilise 1,02,384 hectares of existing irrigation. It will utilise 1,500 m.cu.m. of water, including reservoir losses. There are no medium schemes included in the Fourth Plan. The utilisation by minor schemes included in the Fourth Plan would be of the order of 1,189 m. cu. m. benefiting an area of 77,560 hectares.

On completion and full development of Fourth Plan projects, about 9,110 m. cu. m. of the water (7,356 m. cu. m. of surface water + 1,754 m.cu.m. of ground water) in the basin would have been used for irrigating a total area of 668,008 hectares.

The utilisation of water on full development by the projects under operation and construction in the basin up to the beginning of the Fourth Plan period is of the order of 6,421 m. cu. m. which shows that the exploitation of the water resources is complete. The Somasila Project, when constructed, will utilise whatever little water is available in the river, although the main source of supplies for that project would be the diversions from the Tungabhadra and/or Krishna rivers.

Any future project to be taken up in this basin, will have to depend for supplies on sources outside the basin, as the potential within the basin has been exhausted. The concerned State Governments of Mysore and Andhra Pradesh have not indicated any new major or medium projects in the basin.

FLOODS, DRAINAGE & WATERLOGGING

8.36 The Penner basin is influenced by both the north-east and the south-west monsoons. The basin to the west of Gandikota gorge mainly gets the benefits of the south-west monsoon while the coastal area is influenced by the north-east monsoon. In normal years, the first freshets occur in the middle of June due to the south-west monsoon and supply in the river continues to be steady till the end of July or the middle of August. But in September, the river is generally low. Again, in October and November, after the outbreak of the north-east monsoon, which is generally heavier in the coastal areas than in the interior, the river is again in flood and the flood subsides by the first week of December. Floods in the river are of a 'flashy' nature characterised by short duration and high peaks.

The maximum flood discharge in the river is of the order of 14,716 cumecs at Nellore.* Erosion of the banks at Devarayapalle along the Penner and at Vasilli along the Boggeru tributary in Atmakur taluq has been taking place. Damage caused by the backing up of water in the tributaries when the main river is in spate, are also on record as in the case of the Beraperu and the Boggeru tributaries. Flood embankments have been constructed on both banks of the river in the lower reaches. The left flood bank starts from the Sangam anicut and ends 24 km. below the Nellore anicut, its total length being 58 km. The right flood bank is from Mulmudi to 26 km. below the Nellore anicut. Its total length is 42 km. These embankments sometimes breach and the ensuing inundations cause damage.

Flood damage statistics are not available. In order to achieve flood control and to free the delta area below Nellore from floods, the Andhra Pradesh Government proposes to construct the Somasila project across the Penner. This project is included in the Fourth Five Year Plan.

At present, flood-warning messages are received at the Nellore anicut from the Adinimayapalli and Sangam anicuts. Since the distance between these anicuts is short and the floods are of a flashy nature, this flood warning system has been found to be inadequate.

When the river is in flood, the water level rises and the drainage in the delta area is affected so that there is waterlogging.

*Report of the High Level Committee on Floods, Ministry of Irrigation and Power (1958).

8.37 Waterlogging due to flow irrigation by the projects in the basin such as the various anicuts, the Kurnool-Cuddapah canal and Upper Penner Project, has been negligible and is also not expected to cause concern in the future.

SOIL CONSERVATION

8.38 The problem of soil erosion in the Penner basin is particularly serious in the low rainfall area of the district of Anantapur. Sheet erosion on a large scale is a common feature in the black soils. Soil erosion also occurs due to bad agricultural practices like ploughing through the contours of unbunded fields. In the forests, unplanned felling and thinning of trees and uncontrolled grazing are resulting in soil erosion.

8.39 Practically no data is available regarding the silting of existing reservoirs in the basin. For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures should be taken up in the basin. The soil conservation measures to be undertaken may be classified under the following heads:

(i) Afforestation in new areas as well as in existing forests which have been either denuded or where replacement is needed;
(ii) Terracing and contour bunding and the construction of field bunds on agricultural lands which require treatment;
(iii) Pasture development and protection of marginal and sub-marginal lands; and
(iv) Stream control measures including fringe afforestation and stream bank control.

GENERAL

8.40 A network of evaporation measurement stations in the basin, particularly at the sites of existing and proposed reservoirs, should be established.

8.41 Daily discharge and sediment observations at the existing sites and at the new sites suggested under paras 8.22 to 8.23 on a permanent basis and on scientific lines should be conducted.

8.42 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin so that these resources can be exploited in a rational way either independently or in conjunction with surface water.

8.43 There is need for inter-State co-operation and agreement in respect of carrying out soil conservation measures and conserving the storage capacities of the existing and proposed reservoirs in the basin.

SALIENT FEATURES OF THE BASIN OF EAST FLOWING RIVERS BETWEEN THE PENNER AND THE CAUVERY

(i) *Source*

The Kunleru	In the Velikonda Range of the Eastern Ghats in Nellore district. (Latitude 14°13′N, Longitude 79°27′E).
The Swarnamukhi	Near Pakala village in Chittoor district. (Latitude 13°28′N, Longitude 79°9′E).
Small streams draining into the Pulicat Lake	One stream rises from the eastern slopes of the Nagari and the Nagalapuram Hills in Chittoor district. (Latitude 79°41′N, Longitude 13°29′E). The other stream rises near Satvedu in Chingleput district. (Latitude 79°56′N, Longitude 13°28′E).
The Araniar	Eastern slopes of the Eastern Ghats in Chittoor district. (Latitude 13°30′N, Longitude 79°25′E).
The Kortalaiyar	Near Kaveripak in Chingleput district, (Latitude 12°55′N, Longitude 79°28′E).
The Cooum	Near village Takkolam in South Arcot district. (Latitude 79°47′N, Longitude 13°2′E).
The Adyar	Near village Guduvancheri in South Arcot district. (Latitude 80°0′N, Longitude 12°51′E).
The Palar	Beyond Talagvara village in Kolar district. (Latitude 13°21′N, Longitude 78°0′E).
Minor streams between the Palar and the Gingee	One rises near village Perumberkandigal in North Arcot district. (Latitude 12°22′N, Longitude 79°36′E). The other rises near Tindivanam in South Arcot district. (Latitude 12°14′N, Longitude 79°36′E).
The Gingee	Near village Vettavalam in North Arcot district. (Latitude 12°9′N, Longitude 79°17′E).
The Ponnaiyar	Near Hongashenhalli village in Kolar district. (Latitude 13°25′N, Longitude 77°58′E).
The Vellar	Beyond village Tumbal in Salem district. (Latitude 11°47′N, Longitude 78°20′E).

(ii) *Length*

The Kunleru	93 km	58 miles
The Swarnamukhi	130 km	81 miles
Small streams draining into the Pulicat Lake:		
(a) Northern stream	82 km	51 miles
(b) Southern stream	36 km	22 miles
The Araniar	108 km	67 miles
The Kortalaiyar	131 km	81 miles
The Cooum	68 km	42 miles
The Adyar	39 km	24 miles
The Palar	348 km	216 miles
Minor streams between The Palar and the Gingee:		
(a) Northern stream	48 km	30 miles
(b) Southern stream	45 km	34 miles
The Gingee	94 km	58 miles
The Ponnaiyar	396 km	246 miles
The Vellar	193 km	120 miles

(iii) *Drainage area*

	Sq. km.	Sq. miles
The Kunleru	3,534	1,364
The Swarnamukhi	3,225	1,245
Small streams draining into the Pulicat Lake	3,063	1,183
The Araniar	1,290	498
The Kortalaiyar	3,521	1,359
The Cooum	942	364
The Adyar	1,529	590
The Palar	17,871	6,900
Minor streams between the Palar and the Gingee	1,999	772
The Gingee	3,369	1,301
The Ponnaiyar	16,019	6,184
The Vellar	8,558	3,305
Total	65,049	25,115

(iv) Population (1971 Census): 19.71 millions

(v) Density of population: 303 per sq. km. 785 per sq. mile

	Cumecs	Cusecs
(vi) *Maximum discharge*		
Of the Ponnaiyar at the Tirukkoyilur anicut in 1903	7,641	269,843
Of the Vallar at the Tholudur regulator in 1920	2,534	89,500
(vii) Minimum discharge	N.A.	
(viii) Average annual runoff of the basin on the basis of Irrigation Potential studies carried out by the CW & PC	16,899 m.cu.m.	13.70 MAF

		Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)		4,240	10,477
(x) Net area sown (1967-68)		2,423	5,987
(xi) Gross area sown (1967-68)		2,989	7,386
(xii) Net area irrigated (1967-68)		1,104	2,728
(xiii) Gross area irrigated (1967-68)		1,552	3,835
(xiv) Area irrigated after completion and full development of Fourth Plan projects		1,334	3,296
(xv) Probable additional irrigation by future projects		N.A.	
(xvi) Water utilisation including reservoir losses		m.cu.m.	MAF
(a) On completion & full development of major, medium and minor projects under operation and construction at the end of Annual Plan (1968-69)	Surface Water	14,182	11.50
	Ground Water	2,974	2.41
	Total	17,156	13.91
(b) On completion and full development of Fourth Plan projects	Surface Water	16,496	13.37
	Ground Water	3,548	2.88
	Total	20,044	16.25

CHAPTER IX

BASIN OF EAST FLOWING RIVERS BETWEEN THE PENNER AND THE CAUVERY

The basin of the east-flowing rivers between the Penner and the Cauvery extends over an area of 65,049 sq. km. It lies between east longitudes 77° 35′ to 80°21′ and north latitudes 11°12′ to 14°30′. Lying in peninsular India, the basin covers large areas in the State of Andhra Pradesh, Mysore and Tamil Nadu. The State-wise distribution of the area is shown below:

Table 9.1

Drainage Area—State-wise

Name of State		Drainage area Sq. km.
Andhra Pradesh		16,478
Mysore		6,256
Tamil Nadu		41,836
Pondicherry		479
	Total	65,049

9.2 The basin is bounded on the north, west and south by the various ranges of the Eastern Ghats like the Velikonda Range, the Nagari Hills, the Javadi Hills, the Shevaroy Hills, the Chitteri Hills, the Kalrayan Hills, the Kollaimalai Hills, the Pachai Malai Hills etc., and on the east by the Bay of Bengal. The basin, with an irregular shape, has a maximum length of about 290 km. and a maximum width of about 360 km. There are three major topographical divisions in the basin: (i) the hill ranges of the

Eastern Ghats, (ii) the table-land or the plateau region and (iii) the coastal plains. There are 12 sub-basins in the basin, of which the Palar, the Ponnaiyar and the Vellar are the more important. The Palar basin has the shape of a rhombus. The Ponnaiyar basin is elongated in shape, whereas the Vellar basin is fan shaped.

THE RIVER SYSTEMS

9.3 The various river systems in the basin from the north to the south are:

(1) The Kunleru
(2) The Swarnamukhi
(3) Small streams draining into the Pulicat Lake
(4) The Araniar
(5) The Kortalaiyar
(6) The Cooum
(7) The Adyar
(8) The Palar
(9) Minor streams between the Palar and the Gingee.
(10) The Gingee
(11) The Ponnaiyar
(12) The Vellar

These river systems are described briefly in the following paragraphs:

The Kunleru

The Kunleru rises in the Velikonda Range of the Eastern Ghats in Andhra Pradesh at an elevation of about 150 m. at north latitude 14°13′ and east longitude 79°27′ and flows in a generally easterly direction through the Nellore district for a total length of 93 km. to fall into the Bay of Bengal near Mathukuru. The river drains a total area of 3,534 sq. km.

The Swarnamukhi

The Swarnamukhi river rises in the Eastern Ghat ranges near Pakala in Andhra Pradesh at an elevation of 300 at north latitude 13°28′ and east longitude 79°9′ and flows up to Chandragiri in a north-easterly direction; thereafter, it flows eastward for a distance of 50 km. and, just before Kalahasti, changes its direction northwards to flow for a length of 13 km. Beyond this, it flows in a generally easterly direction and falls into the Bay of Bengal near Durgarajupatnam. The river has a total length of 130 km. from its source to its outfall through the districts of Chittoor and Nellore in Andhra Pradesh and drains a total area of 3,225 sq. km.

Small Streams Draining into the Pulicat Lake

There are two streams, which drain into the Pulicat Lake. One of them rises from the eastern slopes of the Nagari and the Nagalapuram Hills at an elevation of about 300 m., near Olluru in the Chittoor district of Andhra Pradesh and flows in a northerly direction for a considerable distance to turn east and south-east to outfall into the Pulicat Lake near Tada. The other stream rises near Satvedu at an elevation of 150 m. and joins the Pulicat Lake near Elavur. The total area drained by these minor streams is 3,063 sq. km.

The Araniar

The Araniar rises from the eastern slopes of the Eastern Ghats at north latitude 13°30′ and east longitude 79°25′ at an elevation of 300 m. and flows in a generally easterly direction for a total length of about 108 km. to join the Bay of Bengal near Pulicat. The river has been dammed at a place about 18 km. upstream of Suratpalli to create a reservoir, and lower down a pick-up anicut with a canal system at Suratpalli is built to benefit a number of tanks in the Chingleput district. The total area drained by this river is 1,290 sq. km.

The Kortalaiyar

The river Kortalaiyar rises near Kaveripak in the Chingleput district of Tamil Nadu at an elevation of about 150 m. at north latitude 12°55′ and east longitude 79°28′ and flows in a generally easterly direction for a total length of 131 km. through the Chittoor district of Andhra Pradesh and the Chingleput district of Tamil Nadu to join the Bay of Bengal near Ennur. The total area drained by this river is about 3,521 sq. km. The river is tapped to feed the Chembarambakkam tank and numerous other tanks, the most important being the Poondi reservoir formed across it, and the Red Hills, and the Cholavaram tanks which are the main source of water supply to Madras City. The Nagari is the important tributary of the Kortalaiyar and joins it on the left.

The Cooum

The Cooum is a small stream, which flows through Chingleput district of Tamil Nadu for a total length of 68 km. in a generally easterly direction and joins the Bay of Bengal flowing through the Madras City. The Cooum drains a total area of nearly 942 sq. km.

The Adyar

The Adyar, a small stream rising at north latitude 12°1′ and east longitude 80°0′, flows for a total length of 39 km. through the Chingleput district of Tamil Nadu, first in a north-easterly direction and then in an easterly direction to join the Bay of Bengal, just north of Tiruvanmiyur. The Adyar drains a total area of 1,529 sq. km.

The Palar

The river Palar rises beyond Talagvara village in the Kolar district of Mysore State at an elevation of about 900 m. at north latitude 13°21′ and east longitude 78°0′ and flows in a generally south-easterly direction for a length of 93 km. in Kolar district of Mysore State to enter the Chittoor district of Andhra Pradesh. Flowing through Andhra Pradesh for a distance of 33 km., the river enters the North Arcot district of Tamil Nadu. It continues to flow in a generally easterly direction for a length of 222 km. in North Arcot and Chingleput districts of Tamil Nadu and joins the Bay of Bengal just north of Kuvattur. An anicut with a canal system is built across the Palar, 25 km. downstream of Vellore for irrigation purposes. The total length of the Palar river is 348 km. and it drains an area of about 17,871 sq. km. The Poini and the Cheyyar are the important tributaries of the Palar on the left and right respectively. Anicuts with canal streams have been built across the Poini and the Cheyyar for irrigation purposes.

Minor Streams Between the Palar and the Gingee

There are two minor streams which flow between the Palar and the Gingee rivers. One of them rises near village Perumberkandigal in North Arcot district of Tamil Nadu at an elevation of 150 m. at north latitude 12°22′ and east longitude 79°36′ and flows in a generally easterly direction for a length of 48 km. to join the Bay of Bengal near Marakkanam. The other stream rises near Tindivanam in South Arcot district of Tamil Nadu at an elevation of 150 m. at north latitude 12°14′ and east longitude 79°36′ and flows first in a generally easterly direction up to Kaliveli Tank and then in a northerly direction to outfall into the Bay of Bengal. The stream has a total length of 54 km. from its source to its outfall. The total area drained by these minor streams is 1,999 sq. km.

The Gingee

The Gingee rises near village Vettavalam in the North Arcot district of Tamil Nadu at an elevation of 300 m. at north latitude 12°9′ and east longitude 79°17′ and flows in a generally easterly direction for a length of 94 km. to fall into the Bay of Bengal below Pondicherry. The river drains an area of 3,044 sq. km.

The Ponnaiyar

The Ponnaiyar or the Dakshina Pinakini river rises near Hongashenhalli village at an elevation of about 900 m. at north latitude 13°25′ and east longitude 77°58′ in the Kolar district of Mysore State and flows in a generally southern direction through the Kolar and Bangalore districts for a total distance of 79 km. to enter the Salem district of Tamil Nadu. The river has been dammed at Krishnagiri, 151 km. from its source to create a reservoir for irrigation purposes in the Salem district. Other works constructed in the Salem district are the Nedungal Anicut and the Barur Tank. Continuing to flow in Salem district in a generally southeasterly direction for a further length of 88 km., the Ponnaiyar enters the North Arcot district. The river is again dammed at Sathanur to create a reservoir for irrigating areas in North and South Arcot districts. The river enters the South Arcot district at 297 km. from its source and continues to flow in a generally easterly direction after crossing the Tirukoyilur Anicut at the 326th km. of its run and finally flows through the Union Territory of Pondicherry to join the Bay of Bengal, just north of Cuddalore. The Gadilam and the Varaha join the Ponnaiyar just before its outfall into the Bay of Bengal, from the right and left respectively. The total length of the Ponnaiyar from the source to its outfall is 396 km. and it drains about 15,865 sq. km.

The Vellar

The Vellar rises at an elevation of about 900 m. beyond village Tumbal in the Chitteri Hills of the Eastern Ghats at north latitude 11°47′ and east longitude 78°20′ in Salem district of Tamil Nadu and flows in a generally easterly direction through Salem and South Arcot districts of Tamil Nadu for a total length of 193 km. to fall into the Bay of Bengal near Porto Novo. The Manimuktanadi and the Gomukhi are the important left bank tributaries. The Kallar is the important right bank tributary. The Vellar basin covers an area of 8,558 sq. km. Regulators have been built across the Vellar at Tholudur, Shatiatope and Pelandurai for irrigation purposes. Two anicuts with canal systems at Vriddhachalam and

Mehamthur across the Manimuktanadi are also built for providing irrigation facilities.

CLIMATE

9.4 Four distinct seasons occur in the basin. They are (i) the cool weather, (ii) the hot weather, (iii) the south-east monsoon and (iv) the North-east monsoon.

In cool weather season, which extends from January to March, the climate is generally pleasant in the entire basin. The plateau and the hilly regions in the basin are cooler than the coastal plains.

In the hot weather season, which extends from March to May, the eastern part of the basin experiences more heat than the western parts, which, due to the higher elevation enjoy a comparatively better climate.

The south-west monsoon generally sets in by the first week of June and ends by the end of September. During this period, the western part of the basin receives the major part of its rainfall.

The north-east monsoon period is from October to December. The eastern part of the basin covering the coastal districts receives very heavy rainfall during these months.

Rainfall

9.5 There are at present 165 reporting raingauge stations inside the basin. The distribution of the stations is fairly even and their number is also sufficient.

The rainfall in the basin varies from region to region. The coastal districts in the basin get heavier rainfall than the western parts. The rainfall decreases from 1,270 mm. at the eastern extremity of the basin to 762 mm. at the western extremity. The monthly and the annual normal of rainfall in the districts lying in the basin are shown in Appendix 9.1.

Temperature

9.6 The basin is subject to a tropical climate. In the western parts of the basin lying in Mysore, the variation of temperature during the year is small.

In the month of January, the mean temperature over the basin varies from 22.5°C to 25°C. In the month of April, the mean temperature varies from 30°C to 32.5°C. In July, in the coastal districts the mean temperature is of the order of 30°C whereas in the western parts of the basin, the mean temperature varies from 27.5°C to 30°C. In the month of October, in the western parts of the basin the mean temperature is between

25°C to 27.5°C whereas in the coastal districts it is above 27.5°C. The annual normals of temperature at some representative places in the basin are given below:

Station	*Annual normals of temperature*	
	Maximum (°C)	Minimum (°C)
Madras	33.4	23.9
Salem	33.8	22.0
Bangalore	28.9	17.8

Evaporation

9.7 Very little data on evaporation is available for the basin. The India Meteorological Department have compiled evaporation data in respect of 30 departmental and 42 agro-meteorological observatories possessing data for more than five years. These observatories are scattered all over the country. Observations at all these places are taken with the Standard U.S. Evaporation Pan (Class A) covered with wire-mesh. For the departmental observatories the data pertains to the period 1959–68 and is available month-wise whereas the data for agro-meteorological observatories pertains to the period 1961–68 and has been presented for the 12 periods into which the calendar year is divided for agro-meteorological purposes. Of the above 72 observatories, two departmental observatories and two agro-meteorological observatories are located inside the basin.*

SOILS

9.8 A detailed soil survey of the area covered by the basin has not been made. However, the general data regarding the soils of India indicate that mainly red sandy soils, red loamy soils and coastal alluvium occur in the basin. Mixed red and black soils and deep black soils occur to a very small extent. The basin covers a part of the districts of Nellore, Chittoor and Cuddapah in Andhra Pradesh; Kolar and Bangalore in Mysore; Chingleput, Salem and Tiruchchirapalli in Tamil Nadu and the Union Territory of Pondicherry. The principal soil types found in the various districts lying in the basin are described below: †

Nellore: Black soils, red loams and sandy coastal soils. The largest area is occupied by the red loams and the least by the sandy soils.

*Evaporation data (India), India Meteorological department (April, 1970).

†Soils of India by S. P. Raychaudhari, R. R. Aggarwal, W. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Chittoor: Red and black soils.

Cuddapah: Both red and black soils. The eastern half of the district has mainly red soils.

Kolar: The main soil groups are the red and the lateritic soils. In the red soils, both loam and sandy types are observed.

Bangalore: The soils are light brown or red, mostly sand to sandy loam.

Chingleput: Black soils predominate in the southern talukas and red soils in the northern talukas.

North Arcot: The soils belong primarily to the red ferrugenous loams and sands. Black soils are confined chiefly to the neighbourhood of the principal rivers.

South Arcot: Red soils which are loams and clayey loams.

Tiruchchirappalli: Prevailing soils of the district are regur and red.

LAND USE AND AGRICULTURAL PRACTICES

9.9 State-wise land use details in the basin in 1967–68, the latest year for which the statistics are available, are given in Table 9.2.

Agriculture has been practised quite extensively in this basin. The cultivated area for the basin as a whole constitutes 70.48% of the culturable area. The culturable area in the basin is about 2.17% of the total culturable area of India. The total cropped area in the basin is about 1.83% of the total cropped area in the country. The general cropping pattern, state-wise is described below:

Andhra Pradesh

Of the total irrigated area of 237,800 hectares, about 63.75% is under paddy, 9.88% under ragi, 5.38% under bajra, 4.42% under sugarcane and the rest under other crops. The other crops grown in the irrigated area are groundnut, cotton, jowar, maize, wheat, millets, gram, other pulses, condiments, spices, sesamum, tobacco and fodder crops. Food crops represent about 89.49% of the irrigated area, the balance of 10.51% of the area being under non-food crops.

Mysore

Of the gross irrigated area of 41,400 hectares, 40.34% is under paddy, 12.56% under ragi and 0.72% under sugarcane. The other crops grown in the irrigated area are bajra, jowar, maize, millets, gram and tur. Food crops represent about 83.33% of the irrigated cropped area, the balance of 16.67% being under non-food crops.

Table 9.2

Land Use Details

(Thousand hectares)

Sl. No.	Item	State				
		Andhra Pradesh	Mysore	Tamil Nadu	Pondi-cherry	Total
1	2	3	4	5	6	7
1.	Geographical area	1,648	626	4,183	48	6,505
2.	Reporting area	1,645	562	4,183	47	6,437
3.	Area under forests	404	54	506	—	964
4.	Area not available for cultivation	376	83	764	10	1,233
5.	Culturable area	865	425	2,913	37	4,240
6.	Uncultivated culturable area	379	221	1,211	6	1,817
7.	Net area sown	486	204	1,702	31	2,423
8.	Area sown more than once	62	5	481	18	566
9.	Total cropped area	548	209	2,183	49	2,989
10.	Net area irrigated	178	33	868	25	1,104
11.	Gross area irrigated	238	41	1,234	39	1,552
12.	Percentage of net area sown to culturable area	56.18	48.00	58.41	83.78	57.13
13.	Percentage of net area irrigated to culturable area	20.54	7.74	29.79	67.30	26.02
14.	Percentage of net area irrigated to net sown area	36.56	16.13	51.01	80.32	45.55

Tamil Nadu

Of the gross irrigated area of 1,233,600 hectares, 75.67% is under paddy, 5.28% under ragi, 8.84% under groundnut and 3.70% under sugarcane. The other crops grown in the irrigated area are maize, wheat, millets, gram, other pulses, condiments, spices, fruits, vegetables, sesamum, cotton, tobacco and fodder crops. Food crops represent 89.74% of the irrigated cropped area, the balance of 10.26% being under non-food crops.

Pondicherry

Of the gross irrigated area of 39,000 hectares, 81.28% is under paddy, 3.85% under ragi, 5.13% under sugarcane and the rest under other crops. Food crops represent 92.31% of the irrigated area, the balance 7.69% being under non-food crops.

Summing up, of the total irrigated area in the basin, 73.04% is under paddy, 6.14% under ragi, 8.31% under groundnut, 3.94% under sugarcane and the rest under other miscellaneous crops.

9.10 There are mainly three crop seasons in that part of the basin which lies in Andhra Pradesh (i) Autumn (kharif), (ii) Winter (Rabi) and (iii) Summer (hot weather). The kharif crops are paddy, bajra, jowar, millets, maize, ragi, cotton, etc. The main summer crop is paddy. Besides these seasonal crops, garden crops like sugarcane, plantains, betel leaves, turmeric are also grown throughout the year.

As in Andhra Pradesh, three crop seasons occur in Mysore and Tamil Nadu also.

9.11 The sowing and harvesting seasons of the principal crops in the various States are shown below: *

Table 9.3

Sowing and Harvesting Periods

Name of crop	Period of	
	Sowing	Harvesting
Andhra Pradesh		
Autumn paddy	March-May	June-September
Winter paddy	June-October	November-March
Summer paddy	December-February	March-May
Kharif jowar	June-October	January-April
Rabi jowar	November-December	March-April
Bajra	June-August	September-December
Kharif ragi	June-October	September-January
Rabi ragi	November-February	January-May

*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 9.3—Contd.

Name of crop	Period of	
	Sowing	Harvesting
Barley	October	May
Sugarcane	January-May	December-April
Groundnut	May-October	September-January
Cotton	June-October	January-May
Mysore		
Autumn paddy	May-August	September-December
Winter paddy	June-October	November-March
Summer paddy	December-February	April-June
Kharif jowar	May-July	October-December
Rabi jowar	September-November	January-March
Bajra	June-August	September-January
Ragi	May-August	September-January
Rabi ragi	January	May
Sugarcane	December-March	November-March
Groundnut	June-August	September-December
Tamil Nadu		
Autumn paddy	May-November	September-February
Winter paddy	October-January	January-April
Summer paddy	February-April	May-June
Kharif jowar	June-October	September-January
Rabi jowar	November-May	February-July
Bajra	May-December	September-March
Ragi	June-November	September-March
Sugarcane	December-September	December-August
Groundnut	January-May July-October	April-May October-January

REGIONAL ECONOMY

Population

9.12 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 19.71 millions. The State-wise distribution is tabulated below:

State	*Population*
Andhra Pradesh	2.30 millions
Mysore	1.62 millions
Tamil Nadu	15.32 millions
Pondicherry	0.47 millions
Total	19.71 millions

9.13 There are five cities in the basin, which have a population of more than one lakh each according to the 1971 census. They are Bangalore and Kolar Gold Fields in Mysore State, and Madras, Salem and Vellore in Tamil Nadu. The average density of the population in the basin is 303 persons per sq. km., against the figure of 182 for India as a whole. The density varies from region to region. Whereas the district Bangalore has the highest density of 418 persons per sq. km., the lowest density of 103 occurs in Cuddapah district of Andhra Pradesh.

Of the total population in the basin, nearly 69% live in rural areas while the balance of 31% live in urban areas. The working force constitutes nearly 38.2% of the total population. 33.5% of the working force is engaged as cultivators and 32.8% as agricultural labourers. The balance of 34.7% of the working force is employed in manufacturing and tertiary activities.

Forests & Agriculture

9.14 Forests occupy 14.97% of the total reporting area in the basin and the culturable area constitutes 65.87%. Out of the total culturable area of 4.24 million hectares, nearly 2.99 million hectares are annually cultivated. One characteristic feature of the agriculture in the basin is the large area under irrigation. An area of 1.55 million hectares constituting 51.92% of cultivated area is irrigated annually. Paddy is the most

*Census Paper I of 1971 (supplementary), Registrar-General (India).

important irrigated crop in the basin covering nearly 73.04% of the total irrigated area.

Power

9.15 According to the surveys conducted by the Central Water & Power Commission, the total hydro-power potential in the basin is nil. There are three big thermal stations in the basin at Basin Bridge (Madras), Neyveli and Ennore. The Basin Bridge station has an installed capacity of 30 MW and is located within the Madras City limits. The Neyveli station is located at Neyveli between Vriddhachalam and Cuddalore in South Arcot district, about 225 km. from Madras City. The installed capacity of this station is 600 MW. The Ennore Thermal Station is located about 12.9 km. north of Madras City. The installed capacity in Stage I of the project is 340 MW, which has come into operation in 1970–71. In Stage II, an additional installed capacity of 110 MW is envisaged and this stage is expected to be completed by 1973–74. In addition, parts of the basin get hydro-power from the State grids of Mysore and Tamil Nadu.

Mineral Wealth

The principal minerals found in the basin are:*

Gold: In the Kolar district.

Barytes: In the Cuddapah and Nellore districts.

Asbestos: In the Cuddapah and Nellore districts.

Kankar: In the Kolar district.

Limestone and Dolomite: In the Cuddapah and Nellore districts.

Slate and Lead: In the Cuddapah district.

Bauxite: In the Salem district.

Iron Ore: In the Salem district.

Magnesite: In the Salem district.

Manganese: In the salem district.

Coal and Lignite: In the South Arcot and Salem districts.

Chromite: In the South Arcot district.

Salt: Is manufactured from sea-water by evaporation all along the coast of Tamil Nadu, which is one of the most important salt-producing States in the country.

Industries

9.16 With good mineral resources, water and power supply, the

*Techno-Economic Surveys of Andhra Pradesh, Mysore and Tamil Nadu, NCAER.

industrial development in the basin has attained a high standard. The important industries in the basin are given below:

Cotton textiles: In Kolar, Madras, Salem and Pondicherry.

Woollen textiles: In Bangalore, Madras and Salem.

Silk and other fabrics: In Bangalore, Kolar, Madras, Arni, Salem and Pondicherry.

Sugar: In Bangalore and Madras.

Tobacco products: In Kolar, Bangalore, Vellore, Madras and Salem.

Vegetable oils: In Bangalore, Madras and Salem.

Leather and leather goods: In Bangalore, Vellore, Madras and Salem.

Rubber and rubber goods: In Bangalore.

Plastic and allied products: In Bangalore and Madras.

Plywood, hard and soft woods: In Bangalore.

Paper, cardboard and newsprint: In Gudur, Tirupathi and Madras.

Glass and ceramics: In Bangalore, Gudur, Madras and Salem.

Asbestos sheets: In Bangalore.

Matches: In Bangalore, Madras, Salem and Pondicherry.

Power alcohol: In Bangalore.

Automobiles and automobile parts: In Madras.

Ship-building and dockyards: In Madras.

Locomotives and coaches: In Perambur (Madras) and Bangalore.

Bicycles: In Madras.

Aircraft building and repair shops: In Bangalore.

Machine tools: In Bangalore and Madras.

Electric equipment and appliances: In Bangalore and Madras.

Radio and electronics: In Madras.

Agricultural equipment: In Bangalore and Madras.

Wires and cables: In Madras.

Copper and brass: In Madras.

Metal tubes and conduits: In Bangalore and Madras.

Chemicals (Acids & Caustics): In Bangalore, Madras and Ranipet.

Inks, paints and varnishes: In Chittoor, Bangalore and Madras.

Fertilisers: In Bangalore, Madras and Ranipet.

DDT and Insecticides: In Madras.

Soaps: In Bangalore, Vellore and Madras.

Drugs & Pharmaceuticals: In Bangalore and Madras.

Communications

9.17 The basin is served by the network of the Southern Railway. All the three gauges of railway lines (broad, meter and narrow) exist in the basin. The important routes connecting Madras with Vijayawada, Madras with Tiruchchirappalli and Madras with Bangalore pass through the basin. The National Highway connecting Kanniyakumari with Varanasi also passes through it. The other important Highways are those connecting Madras with Bangalore and Bangalore with Erode. In addition, there is a close network of State Highways and District Roads in the basin.

The Buckingham Canal is the most important navigation canal.* This canal runs very close to the sea-coast and joins a series of natural backwaters and the estuaries of the rivers. This canal, which was constructed in stages and finally completed in 1882, connects at its northern extremity, the Commamur Irrigation-cum-Navigation Canal of the Krishna Delta System, with the Mercanam backwaters in the South Arcot District of Tamil Nadu at the southern extremity. The Godavari and the Krishna Delta Canals, being interlinked with the Buckingham Canal, provide a chain of waters from as far north as Kakinada in the East Godavari district of Andhra Pradesh to Madras City, and further south. The total length of this canal is 351 km. and it is ordinarily fit for navigation all the year round. The traffic in the canal is by country boats of capacity varying from 5 to 30 tonnes. The river systems in the basin are not navigable.

The basin is well served with communications.

Dependence on Rainfall and Water Resources

9.18 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence, except for parts of the basin where facilities for irrigation have been provided and industries have developed. There is a keen demand for the development of the water resources in the basin.

WATER RESOURCES

Surface Water

9.19 In 1949 when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's formula, the annual runoff of the basin of the east-flowing rivers between the Penner and the Cauvery was estimated at 9,498 m. cu. m.†

In 1960, the Central Water & Power Commission, while conducting irrigation potential studies, assessed the total annual runoff of the basin

*Navigable Waterways of India, Central Water and Power Commission (1961).
†An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

as 16,899 m. cu. m.* based on available observed data and Strange's rainfall-runoff co-efficients.

The very first site where gauge and discharge observations were conducted in the basin is at Cheyyar Anicut across the Cheyyar river. The data is available for this site from 1869. Subsequently, a number of other discharge sites were established on the various river systems in the basin. The data in respect of sites established in Mysore and Andhra Pradesh parts of the basin are not readily available. The details of the gauge and discharge sites in the Tamil Nadu part of the basin, as furnished by the State Government, are shown in the Table below:

Table 9.4

Gauge and Discharge Sites

Sl. No.	Name of the river	Discharge site	Year from which discharge observations are made
1.	2	3	4
1.	Kortalaiyar	Kosavaram Anicut	1879
2.	,,	Tamarapauk Anicut	1879
3.	,,	Vallur Anicut	1938
4.	Cooum	Korattur Anicut	1879
5.	Poini	Poini Anicut	1876
6.	Cheyyar	Cheyyar Anicut	1869
7.	Palar	Palar Anicut	1879
8.	Varahanadi	Vidur Reservoir	1960
9.	Ponnaiyar	Krishnagiri Reservoir	1958
10.	,,	Nedungal Anicut	1879
11.	,,	Tirukoyilur Anicut	1879
12.	,,	Sathanur Reservoir	1958
13.	Vellar	Tholudur Regulator	1947
14.	,,	Pelandurai Anicut	1879
15.	,,	Shatiatope Anicut	1879

It will be observed from the above table that the discharge observations are being made mostly at anicut/dam sites. The discharges over the anicuts are calculated for different flow conditions like free overflow, submerged etc. The discharges through the head sluices and under-sluices

Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

are calculated with the help of gauge readings observed from the gauges fixed in the front and rear of the sluices. Various formulae are used for the calculation of discharges according to the conditions of flow existing. The discharges at the sites are computed by adding the discharges over the anicut and those through the head-sluices and under-sluices.

The Central Water & Power Commission, under the programme of establishing and maintenance of centrally sponsored key hydrological stations in the country, have proposed establishment of the following three gauge-discharge sites in the Palar and the Pannaiyar basins:

(1) On the Cheyyar, a tributary of the Palar, 16 km. above its confluence with the Palar.
(2) On the Cheyyar, a tributary of the Palar near Vellore.
(3) On the Ponnaiyar near Villupuram.

It is understood that the last site has been established very recently. The Central Water and Power Commission have also recommended that the following gauge and discharge sites may be maintained by the concerned State Governments:

(1) Krishnagiri site on the Ponnaiyar.
(2) Site across the Vellar, 32 km. above its outfall into the sea.

According to the data supplied by the Tamil Nadu Government, the observed average annual flows of the various rivers at different sites are given in Appendix 9.2.* The data indicates the flow realised at the respective points in the rivers and are not to be taken as the total resources of the river.

Ground Water

9.20 Systematic investigations and studies of the ground water potential for the basin have not been made so far. Only in some parts of the Nellore, Cuddapah, Kolar, Chingleput, North Arcot and Salem districts, some investigations and studies have been done recently.†

In the area investigated in Nellore district, ground water is mainly developed by open wells from the sands in the alluvial sediments. The quality of water is generally good but is variable in wells located within 3 km. of the coast. There is good scope for developing ground water from the alluvial sediments, which are expected to enclose confined aquifers. Exploratory drilling and testing are in progress. Both the quality and quantity of water in these confined aquifers, have to be

*Replies of Tamil Nadu to the Questionnaire issued by the Irrigation Commission.
†Ground water Resources of India, Status and Surveys, Prospects and Perspectives, Geological Survey of India (August, 1970).

established before undertaking the large-scale development of ground water.

In the Araniar-Kortalaiyar basin, ground water occurs both under water table and confined conditions in several sand beds within 60 m. Ground water is being exploited on a large-scale by dug wells, dug-cum-tube and tubewells in the alluvial areas of these basins by tapping the water table in the confined aquifers. There is little scope for further large-scale development of ground water for irrigation without detriment to the yields of the existing wells.

In the Cooum basin, there is little scope for large-scale withdrawal of ground water over and above the existing rate. Taking into consideration the present intensity of development as an index, it is observed that selected areas only may be taken for ground water development locally.

In the Palar basin, ground water occurs mainly in the weathered portions of the crystalline rocks. Ground water is very extensively developed by means of dug wells, fitted with mechanically operated pump-sets, for irrigation. Ground water occurs both under confined and water table conditions. The quality of water is good.

In the Ponnaiyar basin, there is scope for the development of ground water by means of light medium duty tubewells tapping the confined aquifers down to 100 m. or so in the area around Pondicherry. In the Tindivanam taluk, ground water may be developed by means of tube-wells tapping confined aquifers in the tertiary sediments. The working of the Neyveli lignite field has brought to light a vast ground water reservoir.

In the Vellar basin, the area underlain by cretaceous and tertiary formations hold potentialities for large-scale development of ground water by heavy duty tubewells in cretaceous sandstones. Large diameter open wells will be able to yield more water than tubewells.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, qualitative and quantitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development for various needs can only be made when full investigations are carried out.

EXISTING DEVELOPMENT

9.21 Irrigation has been practised in this basin from historical times and a number of projects have been constructed in the basin. Some of these projects are more than a century old and are described in the following paragraphs: *

*Descriptive booklet on the important irrigation projects in Madras State (Part I), Government of Madras (now Tamil Nadu), 1955.

Chembarambakkam Tank

The Chembarambakkam Tank lies about 26 km. south-west of Madras. The tank has been in existence from ancient times. There is no record of the actual date of construction. Besides the supply from its catchment, the tank receives supplies from the Palar and Kortalaiyar rivers. The tank was constructed at a cost of Rs. 0.76 million for irrigating an area of 6,050 hectares. There are 38 villages situated close to one another receiving irrigation under this tank.

Shatiatope Anicut

The Shatiatope anicut is the third and the last anicut across the Vellar river and is located 35 km. below the Pelandurai anicut. It was originally built in 1848 but was damaged after a few years and was reconstructed in 1956–57. Due to the failure of supplies from the river, it was subsequently decided to connect the Lower Coleroon anicut system with the Shatiatope anicut system through the Vadavar and the Veeranam Tank. The Anicut was remodelled to improve the supply through the Vellar Rajan Head Sluice. The anicut is 161 m. long and has a regulator with 17 spans of 6 m. each and 4 undersluices of 3 m. each. The project costing Rs. 1.09 million irrigates an area of 13,720 hectares annually.

Palar Anicut

The Palar anicut is situated across the Palar river, 7 km. below the town of Arcot. The project, costing Rs. 2.61 million, comprises (i) an anicut 796 m. long and 1.8 m. high of brick in chunam and rough stone in chunam founded on two rows of circular wells, (ii) a head sluice of 16 vents of 2 m. each on the left bank, (iii) two head sluices on the right bank and (iv) the canal system, comprising four channels, two on either side. There is no direct irrigation from the main or branch channels. In almost every case the water is led into tanks in which it is stored. The anicut feeds 127 tanks in the northern section and 749 tanks in the southern section, irrigating an area of 33,600 hectares annually. The Palar anicut was constructed in 1858.

Vriddhachalam Anicut

The Vriddhachalam anicut is located across the river Manimukthanadi and was built in 1869 at an estimated cost of Rs. 0.11 million. This is the second and the last anicut below the junction of the three rivers Manimuktha, Gomukhi and Mayuranadi and is situated about 8 km.

south-east of Vriddhachalam town. The anicut is 102 m. long and 2 m. high above the normal bed of the river with canal systems on either flank. The anicut irrigates an area of 4,050 hectares annually.

Mehamathur Anicut

The Mehamathur anicut was built across the Manimukhanadi in 1871 at a cost of Rs. 0.09 million. This is the first anicut below the junction of the three rivers, Manimuktha, Gomukhi and Mayuranadi and irrigates an area of 2,020 hectares annually. The anicut is situated about 13 km. west of Vriddhachalam town and is 126 m. long and 1.5 m. high above the normal bed of the river. A channel takes off of its right with a head sluice having 3 vents of 1.2 m. × 1.4 m. fitted with screw gearing shutters.

Vallur Anicut

The Vallur anicut is the third and the last anicut across the Kortalaiyar, the first being at Kesavaram and the second at Tamarapuk. The anicut is in the limits of the Minjur village and is 185 m. long with a top width of 1 m. The Vallur main canal takes off with an open head on the left flank above the anicut. The project was constructed in 1872 at a cost of Rs. 0.08 million for irrigating an area of 2,020 hectares annually.

Pelandurai Anicut

The Pelandurai anicut is located across the Vellar river, a little to the south-west of the village Pelandurai. The anicut is 152 m. long. A head sluice with 5 vents of 2 m. each is located on the left bank from where a 25 km. long supply channel takes off for irrigating an area of 6,450 hectares. The project was constructed in 1876 at a cost of Rs. 0.69 million.

Madras Water Supply and Irrigation System

Madras is supplied with water from 3 reservoirs known as the Poondi, the Red Hills and the Cholavaram. The Poondi reservoir is located across the river Kortalaiyar. The Red Hills tank is fed by a channel from the river Kortalaiyar, which passes through another reservoir known as the Cholavaram tank. There is no irrigation under the Poondi reservoir but the other two irrigate a total area of 3.230 hectares. The project was constructed at a cost of Rs. 1.87 million.

Barur Tank and Nedungal Anicut

This system consists of an anicut across the Ponnaiyar at Nedungal with a supply channel feeding the Barur tank in Salem district. The supply channel also feeds a number of small tanks on the left bank while two old channels called the Nedungal and Agaram channels feed a few other small tanks on the right bank. The system irrigates an area of 2,820 hectares and was constructed in 1888 at a cost of Rs. 0.46 million.

Tirukkoyilur Anicut

The Tirukkoyilur anicut is built across the river Ponnaiyar, about 5 km. from Tirukkoyilur Railway Station in South Arcot district. It is 456 m. long and has canal systems on its either side. The scheme costing Rs. 0.42 million irrigates an area of 11,300 hectares annually.

Poini Anicut

The Poini anicut is located across the river Poini about 19 km. above its confluence with the Palar and about 4 km. south of Poini village in North Arcot district. It is 216 m. long and 2.4 m. high and has canal systems on either side for irrigating an area of 9,690 hectares. The project was constructed in 1897 at a cost of Rs. 0.30 million.

The First Irrigation Commission had not recommended any specific projects by name to be taken up for construction in the basin.

Cheyyar Anicut

The anicut is situated across the Cheyyar river near Anmarudai village, 16 km. to the east of Arni-Wandiwash Road, in North Arcot district. This is the sixth anicut across the river situated about the 80th km. of its flow. The first five anicuts are small ones supplying water for a few tanks and they are (i) The Chengam anicut, (ii) the Kothakulam anicut, (iii) the Erayur anicut, (iv) the Alathoor anicut and (v) the Upper Cheyyar anicut. The construction of this anicut was started in the year 1852. The crest level was raised in 1893 and the falling shutters were fixed by 1905. In 1914–16 extension of the apron in front of the anicut and the under-sluices was completed. The anicut is provided with flood banks on either side. The whole system is designed to fill up all the tanks by making full use of the available water in the river. The number of tanks in this system is 144 of which 40 are fed directly by the channel and the rest from tank to tank. The system irrigates 9,690 hectares. The project cost Rs. 1.04 million.

Tholudur Regulator

This is a comparatively new work in the South Arcot district, opened in 1923. The headworks consist of a regulator fitted with lift shutters across the Vellar at Tholudur from which a canal, 56 km. long, takes off and feeds the Willingdon reservoir with a capacity of about 68 m. cu.m. From the reservoir, a channel takes off and branches into two (high and low level) canals a short distance below the head. The system irrigates about 10,120 hectares and cost Rs. 2.62 million.

Swarnamukhi Project

The project, located in Chittoor district, consists of an anicut across the Swarnamukhi river with a canal system to irrigate a total area of 4,200 hectares.

During the Plan periods, number of projects have been taken up for construction in the basin. Some details of these projects are given in Appendix 9.3. The Plan projects are described briefly in the following paragraphs:

Araniar Project

The project consists of a reservoir of 52.5 m. cu. m. capacity, built across the river Araniar and also a pick-up anicut about 17.6 km. downstream of the reservoir in Tiruvallur taluk of Chingleput district. Two canals taking off from the reservoir and the channel from the anicut irrigate an area of 2,450 hectares. The project cost Rs. 10.59 million and was completed in 1958.

Mallimadugu Project

An earth dam across the Mallimadugu in the Swarnamukhi basin in Chittoor district has been constructed to create a reservoir for irrigation purposes. The project completed in 1959 at a cost of Rs. 3.19 million irrigates 1,620 hectares.

Kalangi Project

An earth dam has been constructed across the Kalangi in the Swarnamukhi basin in Chittoor district at a cost of Rs. 3.52 million, to create a reservoir for irrigation purposes. The project completed in 1960 irrigates 1,890 hectares.

Krishnagiri Project

The project consists of a dam across the Ponnaiyar river in Salem district near Krishnagiri. The reservoir created by the dam has a capacity of 68.2 m. cu. m. Two canals, one on either side, taking off from the reservoir irrigate about 3,640 hectares. The project costing Rs. 20.24 million was completed in 1959.

Vidur Reservoir Project

A dam has been built across the Varahanadi, near Vidur in South Arcot district, below the confluence of the Varaha and the Thondiar. The reservoir has a capacity of 17.1 m. cu. m. The main canal taking off on the left irrigates a total area of 1,300 hectares. The project cost Rs. 9.89 million and was completed in 1959.

Sathanur Project—Stage I

The Ponnaiyar river has been dammed near Sathanur in South Arcot district to store 130.3 m. cu. m. Due to the difficult nature of the terrain, no canal takes off directly from the dam. A pick-up weir across the river, 7.25 km. below the dam site, has been constructed and a 35 km. long canal takes off from this anicut to irrigate an area of 8,500 hectares distributed in both North and South Arcot districts. The project costing Rs. 25.8 million was completed in 1958.

Sathanur Project—Stage II

Stage II of the project, which consisted of the installation of crest gates over the spillway and the saddle dam to increase the capacity from 130.3 m. cu. m. to 229.4 m. cu. m. has been completed in 1966 at a total cost of Rs. 6 million. The additional storage created is used to stabilise irrigation of 2,020 hectares of second crop under the Tirukoyilur anicut system.

Improvements to Palar Anicut and Channels

This scheme effecting major improvements to the Palar anicut system in the North Arcot district has been completed in 1966 at a total cost of Rs. 6.3 million. The anicut has been improved and the channels remodelled to carry the required supply to the tanks. Improvements to important tanks under the system to restore the efficiency of the irrigation system have also been effected. By the improvement, not only are the supplies to the registered ayacut stabilised, but a gap of 1,380 hectares under the ayacut has also been bridged.*

Gomukhi Project

The project consists of a dam across the Gomukhi in Kachirapalayam village in South Arcot district just above the existing Vadakkanandal anicut to store 15.9 m. cu. m. of water. The left side canal taking off from the flank of the earth dam irrigates a total area of 2,020 hectares. The project cost Rs. 12.11 million and was completed in 1969.

Manimukthanadi Project

The project envisages the construction of a storage dam across the Manimukthanadi, a major tributary of the river Vellar. The dam is situated about 0.8 km. upstream of the existing Pallagachery anicut in South Arcot district. The right bank canal, 12 km. long, takes off from the dam to irrigate about 1,720 hectares. Work on the project was started in 1966 and it is expected to be completed during the Fourth Plan. The estimated cost of the project is Rs. 11.76 million.

9.22 Besides the major and medium projects, a number of minor schemes comprising tanks and wells irrigate a very large area in the basin. In many villages, there are more tanks than one. The adjoining agricultural tanks receive water from them. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, State-wise in the basin, are shown in Table 9.5.
By the end of the Annual Plan (1968–69) the area under minor schemes increased by about 29,820 hectares.

9.23 In the absence of data, regarding the annual diversions and utilisations by the major and medium projects under operation and construction in the basin, the utilisation has been approximately estimated to be of the order of 2,097 m. cu. m.

9.24 As regards the statistics of the large number of minor schemes comprising tanks, wells and other diversions, no information is available. Based on the area irrigated from these sources and on rough duties, the approximate estimate of the quantity of water diverted for irrigation by these works has been made. The approximate annual diversion by the minor schemes may be of the order of 9,081 m. cu. m.

*Administration Report of the Public Works Department in the Madras State for the year 1963-64, Government of Madras (now Tamil Nadu), 1968.

Table 9.5

Source-wise Irrigation

(Thousand hectares)

Sl. No.	Source of irrigation	Area irrigated in				
		Andhra Pradesh	Mysore	Tamil Nadu	Pondi-cherry	
1.	Canals	9.5	1.4	118.2	11.0	140.1
2.	Tanks	102.7	19.7	480.6	4.9	607.9
3.	Tubewells	0.7	Nil	235.1	8.9	14.7
4.	Wells	54.3	10.8	235.7	—	300.8
5.	Other sources	10.5	1.0	28.6	0.1	40.2
	Total	177.7	40.2	868.2	24.9	1,103.7

Reservoir Losses

9.25 On the basis of assumptions detailed in para 1.28 the reservoir losses from the various schemes in the basin will be as under:

(i) Major and Medium Schemes		1 34 m. cu.m.
(ii) Minor Schemes (tanks)		5,844 m. cu.m.
	Total	5,978 m. cu.m.

9.26 Thus, the total annual utilisation including reservoir losses by the major, medium and minor projects under operation and construction in the basin on their completion and full development would be of the order of 17,156 m. cu. m. of which 14,182 m. cu. m. would be from the surface waters and the balance 2,974 m. cu. m. from the ground water.

There are a number of major industries located in the basin, especially round about Bangalore and Madras. The data on present industrial water needs are not readily available. In the future, such needs are expected to grow. The problem of water pollution in the basin due to discharge of industrial wastes has not been reported so far. However, the problem may arise in the future, and will have to be guarded against.

FUTURE DEVELOPMENT

9.27 Two medium projects are proposed to be taken up for construction in the basin in the Fourth Five Year Plan period. Both these projects are in Tamil Nadu and are listed in Appendix 9.4. The details of the projects as available are given in the following paragraphs:

Thandarai Anicut

The project provides for the construction of an anicut in the Palar basin in the North Arcot district of Tamil Nadu. The project costing Rs. 4.70 million will irrigate an area of 570 hectares.

Restoration of Nandan Channel

The project aims at the restoration of the Nandan Channel in South Arcot district of Tamil Nadu. The cost of the work is estimated at Rs. 3.20 million. An area of 110 hectares will be brought under irrigation under the project.

On completion and full development, the above projects will utilise about 10 m. cu. m. of waters.

During the Fourth Plan, the area under minor schemes is expected to increase by about 191,720 hectares requiring nearly 2,878 m. cu. m. of water, including reservoir losses.

Thus, the additional utilisation by the Fourth Plan major, medium and minor projects on their completion and full development would be of the order of 2,888 m. cu. m. benefiting an area of 192,400 hectares. On completion and development of Fourth Plan projects, about 20,044 m. cu. m. of the waters in the basin would have been used for irrigating a total area of 1,333,570 hectares. Of this 16,496 m. cu. m. will be surface water and the balance 3,548 m. cu. m. ground water.

The concerned State Governments have not indicated any new projects to be undertaken in the basin in the future.

FLOODS, WATERLOGGING & DRAINAGE

9.28 The occurrence of heavy floods is not a regular feature in the basin. There are, however, occasions when floods do occur and cause some damage to life and property. These floods are beneficial in certain areas as they provide the necessary moisture for raising crops and keeping down the salts. Large-scale control measures neither exist nor are necessary in the basin.

The Kunleru and the Swarnamukhi rivers spill over their banks during floods on account of inadequate carrying capacity. Collectively, these rivers along with the other coastal streams present a fairly big flood problem by flooding considerable areas in the lower reaches, damaging the existing sources of irrigation, inundating villages and large tracts of cultivated areas and causing damages to roads and bridges.

The Kortalaiyar carries flood supply during the north-east monsoon. Flood banks have been provided both upstream and downstream of the Vallur anicut on either flank.

Floods in the Palar are rare and shortlived. During the floods of 1903, water level over the Palar anicut rose to a record level of 2.3 m. over the crest of the anicut on account of breaches in the Vaniyambadi and Bethamangalam tanks, causing damages to the anicut. The maximum flood discharge of the Cheyyar, a tributary of the Palar, was recorded in the year 1903 when a discharge of 2,585 cumecs passed over the Cheyyar anicut. In the case of the Poini, the maximum flood discharge ever recorded at the Poini anicut site is 1,683 cumecs in 1930.

In the Ponnaiyar, the floods are sudden and of short duration. The maximum discharge of 7,641 cumecs was recorded at the Tirukkoyilur anicut in the year 1903.

The Vellar basin being fan-shaped, is conducive for producing a high flood discharge. The highest flood discharge at the Tholudur anicut was recorded in the year 1920 when a discharge of 2,534 cumecs passed over the anicut.

Details of the highest floods ever recorded at the various sites in the basin are shown in the table given below:

Table 9.6

Highest Floods

Sl. No.	Name of the basin	Name of the river	Site	Year	Maximum flood discharge recorded in cumecs
1.	Palar	Cheyyar	Cheyyar anicut	1903	2,585
2.	,,	Poini	Poini anicut	1930	1,683
3.	Ponnaiyar	Ponnaiyar	Tirukkyoilur anicut	1903	7,641
4.	Vellar	Vellar	Tholudur anicut	1920	2,534
5.	,,	,,	Pelandorai anicut	1880	2,407

Waterlogging and Drainage

9.29 The basin is well drained and no waterlogging problems have so far been reported. The coastal region is, however, likely to be affected by salinity and drainage congestion for which anti-salinity measures and drainage works may have to be carried out.

SOIL CONSERVATION

9.30 The basin has 17.2% of its area under forests. This percentage is low when compared with the all-India average and the standards laid down in the 1952 Forest Policy Resolution of the Government. Afforestation of the catchment is called for to reduce the erosion hazards.

9.31 In Mysore, soil conservation works are executed under the provisions of Mysore Land Improvement Act 1961 and the works are taken up on a catchment basis. Soil conservation works (contour bunding) are executed in medium and shallow soils and bunding work is taken up for the time being in deep black soils. Up to March 1969 an area of 7,651 hectares in Bangalore district and 17,061 hectares in the Kolar district had been bunded.

9.32 In Tamil Nadu, the social conservation works in river valley project areas are being carried out by the Forest Department.

9.33 No data is available regarding the silting of existing tanks and reservoirs in the basin. For the conservation of the river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures are undertaken in the basin. Soil conservation measures to be undertaken may be classified under the following heads:

- (i) Afforestation in new areas as well as in existing forests, which have been either denuded or where replacement is needed;
- (ii) Terracing and contour bunding and construction of field bunds on agricultural lands which require treatment;
- (iii) Pasture development and protection of marginal and sub-marginal lands; and
- (iv) Stream control measures including fringe afforestation and stream bank control.

9.34 No new scheme has been included under the centrally sponsored programme of soil conservation in catchments of major river valley projects.

GENERAL

9.35 Some of the river systems flowing in the basin have their catchment areas in more than one State. Of these, the more important are the

Airaniar and the Kortalaiyar river systems flowing through the States of Andhra Pradesh and Tamil Nadu and the Palar and the Ponnaiyar river systems flowing through the States of Mysore, Andhra Pradesh and Tamil Nadu. A number of projects have already been constructed on these river systems and a major part of the flows available in them are already being utilised.

9.36 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs need to be established.

9.37 Gauge and discharge observations, at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects but also for the regulation of available river water in any year.

9.38 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with the surface waters.

9.39 There is need for inter-State co-operation, and agreement in respect of carrying out soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

9.40 It is necessary that systematic data is collected with regard to the sediment carried by the river waters, which would be of considerable use in working out dead storage and life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

SALIENT FEATURES OF THE CAUVERY BASIN

(i) Source: Near Talakaveri in the Brahmagiri range of hills in Coorg district of Mysore State; Latitude 12°25′N, Longitude 75°34′E.

	Km.	Miles
(ii) Length of Cauvery river		
In Mysore	320	198
In Tamil Nadu	416	258
Common border between the States	64	40
Total	800	496

	Sq. km.	Sq. Miles
(iii) Drainage area		
Kerala	2,930	1,131
Mysore	36,240	13,992
Tamil Nadu	48,730	18,815
Total	87,900	33,938

(iv) Population (1971) Census	21.60 millions.	
(v) Density of population	246 per sq. km.	637 per sq mile
(vi) Maximum discharge At Mettur in 1924	12,913 cumecs	456,000 cusecs
(vii) Minimum discharge N.A.		
(viii) Average annual runoff of the basin as per irrigation potential studies of the CW & PC		
(ix) Maximum annual runoff recorded to-date:	N.A.	
(x) Minimum annual runoff recorded to-date	N.A.	

	Thousand hectares	Thousand acres
(xi) Culturable area (1967-68)	5,797	14,325
(xii) Net area sown (1967-68)	3,741	9,244
(xiii) Gross area sown (1967-68)	4,325	10,688
(xiv) Net area irrigated (1967-68)	1,255	3,101
(xv) Gross area irrigated (1967-68)	1,574	3,890
(xvi) Area irrigated after completion and full development of projects under operation & construction	1,460	3,608

(xvii) Probable additional irrigation by future projects	N.A.	N.A.		
(xviii) Water utilisation including reservoir losses				
			m.cu.m.	MAF
(a) On completion & full development of major, medium & minor projects under operation & construction at the end of Annual Plan 1968-69	Surface water		17,930	14.54
	Ground water		2,557	2.07
	Total		20,487	16.61
(b) On completion & full development of future major & medium projects	Surface water		20,634	16.73
	Ground water		2,557	2.07
	Total		23,191	18.80

CHAPTER X

THE CAUVERY BASIN

The Cauvery Basin extends over an area of 87,900 sq. km. in the States of Kerala, Mysore and Tamil Nadu and lies between the longitudes 75°30′ and 79°45′ and north latitudes 10°5′ and 13°30′. The State-wise distribution of the drainage basin is given below:

State		*Drainage area* (Sq. km.)
Kerala		2,930
Mysore		36,240
Tamil Nadu		48,730
	Total	87,900

10.2 The Cauvery basin is bounded on the west by the Western Ghats, on the east and south by the Eastern Ghats and on the north by the ridges separating it from the Tungabhadra and the Penner basins. The basin is somewhat rectangular in shape, the maximum length and breadth being 360 km. and 200 km. respectively. The three main physiographic divisions of the basin are (i) the Western Ghats (ii) the Plateau of Mysore and (iii) the Delta. The Western Ghat region is mountainous and covered with thick vegetation. The plateau of Mysore with an average elevation of 750 m. slopes gently towards the east/south-east. The delta is the most fertile tract in the basin and covers the major portion of the Tiruchchirapalli and Thanjavur districts of Tamil Nadu and is eminently suited for intensive cultivation.

THE CAUVERY RIVER SYSTEM

10.3 The Cauvery is one of the major inland rivers of the peninsula, flowing east and draining into the Bay of Bengal. In size, it is smaller only than the Godavari, the Mahanadi and the Krishna.

10.4 The Cauvery rises at Talakaveri on the Brahmigiri range of hills (12°25′N, 74°34′E) in the Western Ghats in the Coorg district of Mysore State, at an elevation of 1,341 m. above mean sea level. The river flows down from the hills in a series of rapids and cascades and is joined at the foot of the hills by the Kannike stream at Bhagamandala. The course of the river through Coorg district is very tumultuous, but below Bhagamandala, its current, with the exception of a few localities where it traverses beds of rock, is tranquil. Its banks which are steep and high are usually formed of rich clay or mud, and covered with luxurious tropical vegetation. In the dry season, the river is fordable. Its total length in the Coorg district is about 80 km. The first important tributary to join the Cauvery, practically on the border of Coorg and Mysore districts, is the Harangi. Other smaller tributaries are the Kakkabe, the Kadanur and the Kummahole. The river then enters the Mysore district and continues to flow eastwards. The Krishnarajasagara dam has been constructed across the Cauvery about 19 km. north-west of Mysore city. Two important tributaries viz. the Hemavathi on the left bank and the Lakshmanathirtha on the right, join the Cauvery in the expanse of the Krishnarajasagara reservoir. Below the Krishnarajasagara, the Cauvery continues to flow eastwards for 15 km. up to Srirangapatnam and then changes its course south-eastwards. It receives another important tributary viz. the Kabbani on its right bank at Tirumakudal Narasipur. Another tributary viz. the Suvarnavathi joins the Cauvery from the right at Talakad about 25 km. downstream. The river then takes a north-easterly direction and receives the Shimsha from the left, below Sivasamudram. It is here that the river starts cutting through the Eastern Ghats, and from a width of one kilometre, narrows considerably and flows in cascades through a gorge. At Sivasamudram, the river divides into two branches and falls through a height of more than 91 m. in a series of falls and rapids. The two major falls are the Gagana Chukki and the Bhara Chukki. The fall of the river at this point has been utilised for the generation of hydroelectric power. The Sivasamudram Power Station built here as early as 1902 is one of the earliest of the hydroelectric power stations to be set up in Asia. The two branches of the river join after the falls and flow through a wild gorge, almost too narrow to accommodate the fury of the river. At one point, known as Mekedatu (the goat's leap) the channel is so narrow that it is said that a goat can leap across it. After flowing through the gorge, the Cauvery continues its eastward journey and forms the boundary between Mysore and Tamil Nadu States for a distance of about 64 km. Another left bank tributary viz. the Arkavathi joins the river just before it enters Tamil Nadu State.

10.5 In Tamil Nadu, the Cauvery continues to flow eastwards and forms the boundary between the Salem and Coimbatore districts. At Hoganekal falls, the river takes a southerly course and enters the Mettur reservoir which was constructed in 1934. The river emerges from the Eastern Ghats below the Mettur reservoir and continues southwards. The Bhavani river joins it on the right bank about 45 km. below the Mettur reservoir and, thereafter, the river takes a more easterly course to enter the plains of Tamil Nadu, where it is joined on the right by two more tributaries, the Noyil and the Amaravathi, before entering the Tiruchchirapalli district. Here the river widens with a sandy bed and flows in an easterly direction, as the 'Akhanda Cauvery'. Immediately below Tiruchchirappali, the river splits into two branches, the northern branch being called the Coleroon, and the southern branch retaining the name of the parent river. The well-known Upper Anicut was constructed in 1836 at this point to facilitate diversion of the low supplies of the river into the Cauvery, which was the feeder channel for the old delta. It is here that the Cauvery delta begins. Some 16 km. below, the two rivers join again to form the Srirangam island. The Grand Anicut, said to have been constructed during the first century A.D. by a Chola King, is situated at the junction point below the island and forms the head of the great irrigation system in the Thanjavur district. Below the Grand Anicut, the southern or Cauvery branch further splits into two, one being called the Cauvery and the other, the Vennar. These channels are utilised as the main canals for the supply of irrigation water to the fields in the delta. The water is regulated at their heads by regulators. The branches, in turn, divide and sub-divide into innumerable smaller branches, which form a network all over the delta, distributing the Cauvery waters in the vast irrigation system. Some branches ultimately find their way to the sea while others peter out in the wide expanse of fields. The branch which retains the name of the Cauvery throughout its course enters the Bay of Bengal, as an insignificant stream at Kaveripatnam, about 13 km. north of Tranquebar.

10.6 The northern branch, or the Coleroon, is the main flood carrier. After its bifurcation at the upper Anicut, it continues to flow in a north-easterly direction to enter the Bay of Bengal near Porto Novo.

10.7 The total length of the river from the head to its outfall into the sea is 800 km., of which about 320 km. are in Mysore, 416 km. in Tamil Nadu and the remaining length of 64 km. forms the common boundary between the States of Mysore and Tamil Nadu.

10.8 The important tributaries which join the Cauvery within the Mysore State are the Harangi, the Hemavathi, the Simsha and the Arkavathi on the north (left bank) and the Lakshmanathirtha, the Kabbani and the Suvarnavathi on the south (right bank). In Tamil Nadu, all the main tributaries of the Cauvery are from the south (right bank). They are the Bhavani, the Noyil and the Amravathi. The more important of these tributaries are described in the following paragraphs:

The Harangi

10.9 The Harangi rises in the Pushpagiri Hills in Coorg district and after draining a catchment area of 540 sq. km., joins the Cauvery near Kudige in the Somawarpet taluk. The catchment area receives heavy rainfall from the south-west monsoon.

The Hemavathi

10.10 The Hemavathi is one of the important tributaries to join the Cauvery on its northern bank. It rises in Ballalarayanadurga in the Western Ghats in the Mudigere Taluk of Chickmagalur district. The Hemavathi joins the Cauvery after traversing Hassan and Mandya districts. Important tributaries of the Hemavathi are the Yagachi and the Algur. The river drains an area of 5,200 sq. km.

The Kabbani

10.11 The Kabbani is the most imortant south-bank tributary of the Cauvery within Mysore State. It rises in the Western Ghats in the Wynad Taluk of Kerala State at an elevation of about 2,140 m. above mean sea level and joins the Cauvery at Tirumakudal Narasipur in Mysore district, after draining an area of 6,693 sq. km. and traversing a length of 210 km. The river drains a hilly and forested catchment in the upper reaches where the annual rainfall varies from 1,780 mm. to 3,175 mm.

The Suvarnavathi

10.12 The Suvarnavathi rises in the Nasrurghat range of hills situated to the south of the Chamarajanagar Taluk of Mysore district and is formed by streams the Niredurgihalla rising at Attikene and the Araikaduhalla rising at Dimbum, which join at Badibadga. Below the confluence, the river is called the Suvarnavathi or Honhole. It then flows for a length of 64 km. and drains an area of 1,689 sq. km. before joining the Cauvery at Talakad in the Kollegal taluk.

The Bhavani

10.13 The Bhavani rises in the Silent Valley forests of Malabar (Kerala) and after traversing about 20 km. in a south-easterly direction, swings round the hills and flows in north-easterly direction girdling the Nilgiri range, before it enters Tamil Nadu. It drains an area of 7,144 sq. km. and flows a distance of 216 km. before joining the Cauvery from the right at Bhavani in Coimbatore district. The important tributaries of the Bhavani are the Siruvani, the Kundah, the Coonoor and the Moyar.

CLIMATE

10.14 Four distinct seasons occur in the Cauvery basin. They are (i) the cold weather, (ii) the hot weather, (iii) the south-west monsoon and (iv) the north-east monsoon.

10.15 In the cold weather season, the climate is generally pleasant, though the western region is colder than the rest of the basin.

In the hot weather season, the central, northern and eastern regions are hotter than the western-most parts, which enjoy a comparatively pleasant climate.

10.16 The south-west monsoon sets in by mid-June and ends by mid-September. It is during this period that the basin receives a major part of its total annual rainfall.

The north-east monsoon period is from October to December and is of particular importance to the eastern part of the basin.

Rainfall

10.17 There are at present 224 reporting raingauge stations inside the basin. The distribution of the stations is fairly even, and their number is adequate.

The rainfall in the basin varies from region to region. In the Kerala region, the normal annual rainfall is about 2,415 mm., in the high ranges of the Western Ghats it may be as high as 3,810 mm., but is nowhere less than 1,650 mm. Most of the precipitation in this region is received during the south-west monsoon, which lasts from May to September. A notable feature of the pattern of rainfall in this region is that its deviation from the normal is very low.

10.18 In the Coorg district of Mysore the rainfall resembles that in

Kerala and most of the precipitation is received during the south-west monsoon and normally is of the order of 2,540 mm. or more. As in Kerala, the deviation from the normal is quite small. The other parts of the State constituting the southern maidans, through which the river flows, and which fall in the rain-shadow zone of the Western Ghats, receive on an average 635 mm. to 760 mm. of annual rainfall between April and October, resulting in the creation of semi-arid conditions. Agriculture in this region can barely be sustained on rainfall alone and can be successful only with irrigation.

In Tamil Nadu, the average annual rainfall in a large part of the basin is low, and the annual precipitation normally ranges between 508 mm. to 1,016 mm., creating semi-arid conditions. Some districts get rain both from south-west (June-September) and north-east (October-December) monsoons and others mainly from the north-east monsoon. Thanjavur district gets a fairly well distributed rainfall from both the monsoons. The total rainfall in this district is also higher than all other districts except the Nilgiris. Coimbatore and Tiruchchirappalli get less rainfall, a major portion of which is contributed by the north-east monsoon.

10.19 Both the monsoons are of great importance to the basin, especially the south-west monsoon. The north-east monsoon is chiefly important as the source of water supply for tanks, where the topography and soil type allow their construction. Apart from that in the two monsoon periods, some precipitation takes place in all the districts of the basin, during the hot months (March to June). Though early rains in March, April and May are of no consequence for agricultural purposes, they serve to improve the drinking water situation. In the Nilgiris, however, substantial rainfall takes place during the period March to June. On the whole, the district has a much higher rainfall and a much better distribution over the year than other regions. The average annual rainfall in the Nilgiris district is about 1,930 mm.

10.20 In general, the highest rainfall in the Cauvery basin usually occurs in July or early August. Up to the point where the Mettur Dam is situated, the area comes under the influence of the south-west monsoon, and from this point downwards, the catchment is within the influence of the north-east monsoon, and the high floods due to this monsoon usually occur in November. This pattern of rainfall is conductive to a fairly high flow during the irrigation season from June to January, except for a short period of about six weeks when there is a break in the monsoon. While the south-west monsoon supply is copious and dependable, the north-east monsoon supply is irregular and subject to frequent failure.

10.21 The average annual rainfall for the districts in which the Cauvery basin lies are given in the following table:

Table 10.1

Average Annual Rainfall in Cauvery Basin

Sl. No.	Name of District	Average annual rainfall in mm
	Kerala	
1.	Cannanore	3,437.9
2.	Kozhikode	3,461.3
3.	Palghat	2,459.2
4.	Kottayam	2,994.5
	Mysore	
5.	Coorg	2,725.5
6.	Mysore	761.9
7.	Mandya	691.2
8.	Hassan	1,040.7
9.	Chickmagalur	1,989.8
10.	Bangalore	793.6
11.	Tumkur	687.9
	Tamil Nadu	
12.	Coimbatore	1,030.4
13.	Nilgiris	—
14.	Salem	843.1
15.	Madurai	854.8
16.	Tiruchchirapalli	877.1
17.	Thanjavur	1,147.8

Source: Monthly and Annual Normals of Rainfall and of Rainy days (1901 to 1950) —India Meteorological Department.

Temperature

10.22 The Cauvery basin has a tropical climate. In its upper reaches which lie in the Kerala and Mysore States, the variation in temperature during the year is small. In Kerala, the maximum and minimum temperatures are 96°F and 70°F respectively. The temperatures of Mysore vary from 86°F to 64°F. In Tamil Nadu, the maximum temperature is rarely higher than 110°F, while the minimum is not lower than 65°F. In the Cauvery delta, the mean daily maximum temperature varies from 97.7°F in June to 82°F in December. The daily minimum temperature varies from 80.7°F in May to 72°F in January.

Evaporation

10.23 Evaporation is an important climatic factor bearing on agricultural and water resources development. Unfortunately, very little data on evaporation is available for the Cauvery basin. The India Meteorological Department has compiled evaporation data in respect of 30 departmental and 42 agro-meteorological observatories possessing data covering more than five years. These observatories are scattered all over the country. Observations at all these observatories were taken with the standard U.S. Evaporation Plan (Class A) covered with wire-mesh. For the departmental observatories, the data pertains to the period 1959–1968 and is available month-wise, whereas the data for the agro-meteorological observatories pertains to the period 1961–1968 and has been presented for 12 periods into which the calendar year is divided for agro-meteorological purposes. Of the above 72 observatories, 3 departmental and 7 agro-meteorological observatories are located in the Cauvery basin and adjoining areas.* The monthly evaporation losses from the reservoirs as assumed in the different parts of the Cauvery basin are given below.

Table 10.2

Monthly Evaporation losses in the Reserviors in Cauvery Basin

Sl. No.	Name of the project	Evaporation (Cm.)												
		J	F	M	A	M	J	J	A	S	O	N	D	Annual
1.	Harangi**	10	10	18	23	26	18	15	15	15	13	10	10	183
2.	Hemavathi***	10	10	18	23	26	18	15	15	15	13	10	10	183
3.	Cauvery Reservoir†	10	10	18	23	26	18	15	15	15	13	10	10	183
4.	Yagachi‡	10	10	18	23	26	18	15	15	15	13	10	10	183

*Evaporation Data (India), India Meteorological Department (April, 1970).
**Project Report on the Harangi Project, Government of Mysore (1964).
***Project Report on the Hemavathi Project, Government of Mysore (1964).
†Project Report on the Cauvery Reservoir Project, Government of Mysore (1967).
‡Project Report on the Yagachi Project, Government of Mysore (1966).

SOILS

10.24 The principal soil types found in the basin are (a) black soils, (b) red soils, (c) laterites, (d) alluvial soils, (e) forest soils and (f) mixed soils. These are briefly described below.*

Black soils are found in all the districts of Tamil Nadu except the Nilgiris. These soils generally occur in semi-arid conditions with an annual precipitation of 500–1000 mm. and are moisture retentive and fertile.

Red soils occupy large areas in the basin. In Kerala, they are derived from the micaceous or granite rocks under the influence of weather and climatic conditions. In the southern maidan in Mysore, they are predominent. In the Madurai, Coimbatore and Salem districts of Tamil Nadu the red soils cover more than 60 per cent of the cultivated area. Generally, red soils are less fertile but those of Coimbatore district are clayey in nature which makes them comparatively more fertile. Unlike the heavy black soils, red soils do not retain moisture well and are therefore unable to sustain a good crop after the main rainy season. The normally loamy structure of the red soils or the intermixture of fine and thick particles makes them suitable for the cultivation of a larger variety of crops than the black soils.

Laterite soils are found in the Coorg area in Mysore State. These soils exhibit a loamy or clayey surface with a lot of pellet concretions of varying thickness followed by laterite horizons. In the highland areas, the top soils have been eroded leaving behind slag-like masses of laterite. They occur generally on highland plateaus and are sometimes devoid of vegetative cover.

Alluvial soils are found in the Cauvery delta, which is the most important agricultural tract in the basin. They are also found in the belt along the river in Tiruchchirappalli district. The deltaic alluvium is the most fertile soil in the Tamil Nadu State. The alluvial soils in the coastal reach are known as coastal alluvium. They are generally less fertile and on account of inundation by sea water, some of the profiles contain an appreciable amount of salts.

Forest soils occur in the Nilgiri district and are generally porous in texture.

In addition to the distinct soil types described above, combinations of these types such as mixed red and black soils, etc. also occur. The properties of such soils are those of the constituent soil types.

10.25 The basin covers the entire districts of Mysore and Mandya and

*Soils of India by S. P. Raychaudhuri, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

parts of Coorg, Hassan, Chickmagalur, Bangalore and Tumkur districts in Mysore State and parts of the districts of Cannanore, Kozhikode, Palghat and Kottayam in Kerala and parts of Coimbatore, Nilgiris, Salem, Madurai, Tiruchchirappalli, South Arcot and Thanjavur districts in Tamil Nadu. The principal soil types found in the various districts lying in the basin are described below.

Cannanore: Mainly laterite and lateritic soils; also forest soils, red soils and alluvium.

Kozhikode: Forest soils, laterite and lateritic soil, red soils and alluvium.

Palghat: Large areas are covered with forest soils, red soils, laterite and alluvium.

Kottayam: Swamp peaty soil, generally in low areas. The soils in the hills are loamy.

Coorg: The easternmost area has clay while the area lying in the middle and to the west has red loam. Laterite soil also.

Mysore: Red soils in most of the area.

Hassan: Generally loams.

Chickmagalur: The major groups of soils are the red and the laterite soils.

Bangalore: Light brown or red soils, which are mostly sand to sandy loams.

Tumkur: Only red soils.

Coimbatore: The predominant soils are of red, black and mixed types.

Nilgiris: Mainly forest and hilly soils.

Salem: Red soils.

Madurai: Red and laterite soils.

Tiruchchirappalli: The prevailing soils are regur and red. The alluvial soil is confined to the lands on either side of the river Cauvery.

Thanjavur: Black, red and alluvial soils.

LAND USE AND AGRICULTURAL PRACTICES

10.26 State-wise land use details in the Cauvery basin in 1967–68, the latest year for which the statistics are available, are given in Table 10.3.

In Mysore State, in the upper and middle reaches of the basin, the percentage of the cultivated area to the culturable area is of the order of 60, while the corresponding figure for Tamil Nadu is more than 85. The cultivated area for the basin as a whole constitutes three-fourths of the culturable area. The culturable area in the basin is about 3.0 per

Table 10 3

Land Use Statistics of Cauvery Basin (1962-68)

(Thousand hectares)

Sl. No.	Item	State			Total
		Kerala	Mysore	Tamil Nadu	
1.	Geographical area	293	3,624	4,873	8,790
2.	Reporting area	293	3,574	4,360	8,227
3.	Area under forests	81	540	657	1,278
4.	Area not available for cultivation	29	442	681	1,152
5.	Culturable area	183	2,592	3,022	5,797
6.	Uncultivated culturable area	16	1,147	893	2,056
7.	Net area sown	167	1,445	2,129	3,741
8.	Area sown more than once	29	111	444	584
9.	Total cropped area	196	1,556	2,573	4,325
10.	Net area irrigated	2	257	996	1,255
11.	Gross area irrigated	3	289	1,282	1,574
12.	Percentage of net area irrigated to culturable area	1.1	9.9	33.0	21.7
13.	Percentage of net area irrigated to net sown area	1.2	17.8	46.8	33.5
14.	Percentage of net area sown to culturable area	91·3	55.7	70.4	64.5

cent of the total culturable area of India, and the total cropped area is about 2.7 per cent of the total cropped area in the country.

The area under irrigated crops is about 36.0 per cent of the cropped area in the basin. Of the irrigated area, a large part is irrigated by canals, which are largely confined to the delta region.

The general agricultural practices in the basin follow the same pattern as in the rest of South India. There are broadly three categories of cultivation, namely, (i) wet land, irrigated from the Cauvery and tanks, (ii) garden land irrigated from wells, and (iii) dry land dependent entirely on rain-fall. In the wet land, paddy is by far the most important crop, whereas ragi, jowar and other millets constitute the important crops under rain-fed conditions. Cocoanut, arecanut, betel leaves, pepper, oranges and lime are grown as garden crops.

10.27 The general cropping pattern under irrigated conditions, state-wise, is as follows.

Kerala

Kerala State constitutes the uppermost catchment areas of three of the tributaries of the Cauvery viz. the Kabbani, the Bhavani and the Amaravathi. The area is mostly hilly and receives very heavy rain-fall. The most important crop grown is paddy. Other crops include tapioca, ginger and turmeric. Cash crops like cardamom, coffee, tea and rubber are also grown in small patches.

Mysore

Rice is the most important crop grown in the irrigated areas in the State. Of the 289 thousand hectares irrigated during 1967–68, 204 thousand hectares alone were under paddy (70.6 per cent). Sugarcane and ragi constituted 7.6 per cent and 12.8 per cent respectively of the area. More than 96 per cent of the irrigated area was under food crops, while on the remaining area, non-food crops were grown.

Tamil Nadu

In Tamil Nadu also, rice dominates other crops. 69.6 per cent (892 thousand hectares) of the total irrigated area (1,282 thousand hectares) was under paddy. Food crops constitute the main agricultural produce. More than 90 per cent of the total irrigated area was devoted to these crops. Among the non-food irrigated crops, cotton is important.

10.28 The table 10.4 gives details of irrigated crops in different States in the basin during 1967–68.

Crop Seasons

10.29 Paddy is the most important crop in the basin. In Mysore State, the crop season for paddy is from June-July to December-January. The cropping season normally starts with the commencement of the south-west monsoon in early June. Whenever facilities are available, the seedlings are usually transplanted in June and July. The local variety of paddy is harvested in December-January, and is a rain-fed crop. It is a coarse, short-term crop and is harvested after the end of the south-west monsoon (i.e. November-December). In recent years, new high yielding strains like ADT 27 have been introduced in the Krishnarajasagara command. The crop season for these varieties extends from June to October making it possible for a second crop of either paddy or semi-dry crops like ragi to be grown, depending on the availability of water.

Table 10.4

Area Irrigated in Cauvery Basin—State-wise, crops-wise

Sl. No.	Name of crop	State: Kerala Area ('000 hectares)	Kerala % to total	Mysore Area ('000 hectares)	Mysore % to total	Tamil Nadu Area ('000 hectares)	Tamil Nadu % to total
1.	Rice	2	66.7	204	70.6	892	69.6
2.	Jowar	—	—	4	1.4	70	5.5
3.	Ragi	—	—	37	12.8	42	3.3
	Total foodgrains	2	66.7	249	86.2	1,051	82.0
4.	Sugarcane	—	—	22	7.6	43	3.3
5.	Other food crops	Neg.	Neg.	7	2.4	64	5.0
	Total food crops	3	100.0	278	96.2	1,158	90.3
6.	Non-food crops	Neg.	Neg.	11	3.8	124	9.7
	Total cropped area	3	100.0	289	100.0	1,282	100.0

Other crops grown in the basin within Mysore State include ragi, jowâr, bajra, pulses and groundnut. Their crop season is governed by the south-west monsoon. Normally, it extends from June to October-November. Wherever irrigation facilities are available, these crops are grown as 'follow-on' crops to paddy, the season for them extending from October-November to February-March.

10.30 In Tamil Nadu, the Cauvery delta is the most important agricultural tract in the basin, and paddy is the most important crop grown there. Agricultural operations in the delta start with the advent of freshets in the river with the commencement of the south-west monsoon. In the areas where a single crop is cultivated during the year, the 'Samba' variety of paddy is grown, and constitutes the major crop in the delta. The transplantation of the 'Samba' crop starts in the middle of July and goes on till September. The crop is harvested after the north-east monsoon is over. The crop season extends from July to January. Wherever a double crop of paddy is taken a short-term crop of paddy followed by a long-term crop is cultivated. The short-term crop extends from June to October. There are several varieties of this crop, namely, the 120 day variety called 'Kar' and the 100 day variety called 'Kuruwai'. In recent years, the high yielding strain ADT 27 has also been introduced. The first crop season extends from June to October. The second crop locally known as 'Thaladi' is sown after the first is harvested and extends up to February.

REGIONAL ECONOMY

Population

10.31 On the basis of the 1971 census* and the percentage of the area of each district within the basin, to the district as a whole, the total population in the basin is about 22 millions. The State-wise distribution is given below.

State	*Population*
Kerala	1.06 millions
Mysore	7.15 ,,
Tamil Nadu	13.39 ,,
Total	21.60 or say *22 millions.*

There are six cities in the basin, which have a population of more than one lakh each (1971 census). They are Mysore and Bangalore (the latter is just on the basin boundary) in the Mysore State and Coimbatore, Salem, Tiruchirappalli and Thanjavur in the Tamil Nadu. The average density of population in the basin is 246 per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. While the density is highest in the Kozhikode district, the population is the sparsest in the hilly district of Coorg. All the districts in Tamil Nadu with the exception of the Nilgiris, have higher densities than the average, while it is lower in Mysore State except for Bangalore. The most densely populated district is Kozhikode in Kerala (557 persons per sq. km.) and the least populated is the Coorg district (92 persons per sq. km.) in Mysore.

Of the total population in the basin, nearly 78 per cent live in rural areas and the rest in urban areas. The working force constitutes nearly 34 per cent of the population, of which 31 per cent is engaged as cultivators and 28 per cent as agricultural labourers. The rest of the working force is employed in mining, manufacturing and tertiary activities.

Forests and Agriculture

10.32 Except in the upper reaches and in the reach where the Cauvery cuts through the Eastern Ghats, the land in the basin is flat and culturable. Forests occupy only 15 per cent of the total geographical area and the culturable area constitutes 71 per cent. Out of a total culturable

*Census Paper I of 1971 (Supplementary), Registrar General (India).

area of 5.80 million hectares, nearly three-fourths i.e. 4.33 million hectares are annually cultivated. One characteristic feature of agriculture in the basin is the large percentage of the area under irrigation. An area of 1.57 million hectares (constituting 36 per cent of cultivated area) is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 70 per cent of the total irrigated area.

Power

10.33 According to the surveys conducted by the Central Water & Power Commission, the total hydro-power potential in the Cauvery basin has been assessed as 758.5 MW at a 60 per cent load factor. Hydro-power was first generated in the country in this basin when the power station at Sivasamudram was built in 1902 to supply power to the Kolar Gold Fields and neighbouring areas. Since then, a number of schemes have been completed. There has been practically no thermal power generation. The present hydro-power development in the basin is given below.

Sl. No.	State/Project	Installed capacity (MW)
1.	Kerala	Nil
2.	Mysore: (i) Sivasamudram (ii) Simsha	61
3.	Tamil Nadu:	
	(i) Kundah—Stages I & II	145
	(ii) Kundah—Stage III.	245
	(iii) Mettur Tunnel H.E. Scheme	200
	Total	651

Mineral Wealth

10.34 The principal minerals found in the basin are:*

Iron Ore is found in large quantities in the Chickmagalur district in

*Techno-Economic Surveys of Kerala, Mysore and Tamil Nadu, NCAER.

Mysore and in the Salem district of Tamil Nadu. The deposits in Chickmagalur are estimated to be of the order of 370–420 million tonnes while those in the Salem district are of the order of 300 million tonnes. The ore found in Chickmagalur is of medium to high grade while that of Salem is of comparatively poor quality.

Bauxite is found in the Shevroy hills of Salem district. The reserves are estimated to be of the order of 6.8 million tonnes and the quality is considered satisfactory in comparison with other major deposits in the country.

Magnesite deposits in Salem district are the largest in India—the reserves being estimated as 84 million tonnes. The quality of the ore is very high and 95 per cent of the magnesite mined in the country is from these deposits. Workable deposits of the mineral are also found in Mysore district.

Manganese: Low to medium grades of manganese ore are found in the Tumkur district of Mysore State.

Gypsum is found in Tiruchchirappalli and Coimbatore districts. The reserves in Tiruchchirappalli are considered to be most important and are estimated to be 15 million tonnes.

Other minerals found in the basin include limestone in Salem, Tiruchchirappalli and Mysore districts; clays, kaolin in Hassan and Chickmagalur districts and chromite in Mysore, Hassan and Chickmagalur districts.

Salt is manufactured from sea water by evaporation all along the coast of Tamil Nadu, which is one of the most important salt producing States in the country.

Industries

10.35 The Cauvery basin, endowed as it is with a strong and well developed agricultural base, the availability of electricity and a variety of minerals, has a good potential for the development of industries.

Industries based on agricultural produce have been fully developed in the basin. The cotton textile industry in Coimbatore, Bangalore and Mysore, the sugar industry in Mysore and Tiruchchirapalli and the vegetable oil industry in Bangalore, Mysore and Salem districts play an important role in the economy of the basin. Rice milling is an important industry in the paddy growing tract of Tiruchchirappalli, Thanjavur and Mysore districts.

Industries based on minerals and metals also flourish in the basin. The Mysore-Bangalore region of Mysore State and Coimbatore, Tiruchchirappalli and Thanjavur districts of Tamil Nadu have a large number of industries based on minerals and metals. Bangalore district has a huge industrial complex comprising a machine-tools factory, an aeronautical industry, an electronic factory, telephone industry and many other light engineering and other enterprises. Coimbatore and Tiruchchirappali are other districts which have a large number of engineering industries like motor vehicles, machine building industries, etc. Cement factories are situated in Coimbatore and Tiruchchirappalli districts.

Mention may also be made of the proposed steel plant near Salem to utilise the iron ore deposits of the area.

Communications

10.36 The Cauvery basin is served by the Southern Railway. There are a number of branch lines crossing the basin (particularly in Tamil Nadu) linking most of the important towns. While most of the basin is served by a metre-gauge railway, a small part of it is also served by broad-gauge, and the broad-gauge trunk-route from Madras to Ernakulam passes through the basin.

Three National Highways viz. National Highway No. 7 connecting Kanniyakumari to Bangalore, National Highway No. 4 connecting Bangalore to Poona and National Highway No. 45 connecting Madras to Tiruchchirappalli pass through the basin. In addition, the basin is served by a number of State Highways, district and other roads.

The cauvery and its tributaries are not navigable. The only navigable canal, namely, the Vedaraniyam Canal is located in the delta area, and is also fed by salt water. It is 57 km. long and connects Nagappattinam Port with Vedaraniyam. However, it is navigable for only 53 km. by country boats of 7.11 tonnes capacity and 0.6 m. draft.* There is no passenger traffic, and only local produce such as, fodder, firewood and dried fish, etc. are carried through the canal.

From what has been said above, it would be seen that the greater part of the basin is well served with communications.

Dependence on rainfall and water resources

10.37 The economy of the basin at present largely depends on agriculture which, in view of the uneven incidence of the rainfall, provides a low level of subsistence, except for small parts of the basin where facilities for irrigation have been provided. The latter areas are also the seat of industries based on agricultural produce. For these reasons, there is a keen demand in the basin for the accelerated development of water resources.

*Navigable Waterways of India, Central Water and Power Commission (1961).

WATER RESOURCES

Surface Waters

10.38 The water potential of the Cauvery river system has been assessed at different times by different authorities. The first assessment was made by the First Irrigation Commission. This Commission used the records of the surface flow of the Cauvery from a greater part of its catchment extending back for a sufficient number of years, to estimate the average flow as accurately as possible. According to the above assessment, the total annual surface flow in the Cauvery, the Penner and the Palar rivers was 56,634 m. cu. m.*

In 1949, when the basin-wise assessment of the water resources of the country was done on the basis of Khosla's formula, the annual runoff of the Cauvery river system was estimated to be 9,991 m. cu. m.**

In 1960, the Central Water and Power Commission while conducting irrigation-potential studies, assessed the total annual runoff of the Cauvery river system to be 18,601 m. cu. m.† on the basis of Strange's Co-efficient for average catchments.

Gauge and discharge observations were started on the Cauvery as early as 1873 when the first observation site was established at the Upper Anicut by the Irrigation Department of Tamil Nadu.

Subsequently, in the year 1879, three more gauge and discharge sites were established by the State one across the Coleroon at the Lower Anicut and two on its tributaries, at the Kediveri Anicut across the river Bhavani and the Pallapalayam Anicut across the river Amaravathi. The observation stations were increased from time to time and at the time of Independence, there existed five gauge and discharge sites across the main Cauvery and four on its major tributaries in Tamil Nadu viz. Bhavani, Noyil and Amaravathi. In the First Five Year Plan, one more site was established at the Sedarpalaiyam Bed Regulator across the main river. In addition, observations were also started at the Lower Bhavani Dam across the river Bhavani and the Kunnimathur Anicut across the river Noyil. The table 10.5 shows the details of the various gauge and discharge sites in Tamil Nadu.‡

*Report of the Indian Irrigation Commission (1901-03).

**An appraisal of Water Resources by Dr. A. N. Khosla, UNESCO.

†Report of the technological possibilities of irrigation projects in India, Central Water and Power Commission (Unpublished).

‡Inventory of gauge and discharge sites in Tamil Nadu, Directorate of Statistics, Central Water & Power Commission (Unpublished).

Table 10.5

Gauge and Discharge Sites in Tamil Nadu

Sl. No.	Name of the river	Name of the tributary	Location	Whether G or GD	Started in	Agency
1.	Cauvery	—	Mettur Dam	GD	1934	SID
2.	-do-	—	Sedarpalaiyam Bed Regulator	GD	1952	SID
3.	-do-	—	Kulittalai Bed Regulator	GD	1952	SID
4.	-do-	—	Upper Anicut	GD	1873	SID
5.	-do-	—	Grand Anicut	GD	1891	SID
6.	Cauvery (Coleroon)	—	Lower Anicut	GD	1879	SID
7.	Cauvery	Bhavani	Lower Bhavani Dam	GD	1953	SID
8.	-do-	,,	Kediveri Anicut	GD	1879	SID
9.	-do-	,,	Kalingarayan Anicut	GD	1880	SID
10.	-do-	Noyil	Noyil Anicut Chitrachavadi	GD	1880	SID
11.	-do-	,,	Kunnimathur Anicut	GD	1952	SID
12.	-do-	Amaravathi	Pallapalayam Anicut	GD	1879	SID

G = Gauge observations.
GD = Gauge and discharge observations.
SID = State Irrigation Department.

10.39 In Mysore, the Gauge and Discharge observations on the Cauvery were first started in the year 1916 when a gauge and discharge observation site was established by the State Government at Sivasamudram. In 1922, observations were started at Chunchanakatte site on the Cauvery, at Akkihebbal on the Hemavathi and at Unduvadi on the Lakshmanathirtha. In 1947 one more gauge and discharge site was established at Dhangere by the State Electricity Board. Observations are also made at the Krishnarajasagara. Among other tributaries, observations are made on the Kabbani, at Hullahalli (established in the year 1916) and Nugu at Birwal (1922). The table 10.6 shows the salient features of the various gauge and discharge observation sites in the Cauvery basin in Mysore State:*

*Inventory of gauge and discharge sites in Mysore, Directorate of Statistics, Central Water & Power Commission (Unpublished).

Table 10.6

Gauge and Discharge Sites* in Mysore

Sl. No.	Name of the river	Name of the tributary	Location	Whether G or GD	Started in
1.	Cauvery	—	Chunchanakatte	GD	1922
2.	-do-	—	Krishnarajasagara	GD	1956
3.	-do-	—	Dhangere	GD	1947
4.	-do-	—	Sivasamudram	GD	1916
5.	-do-	Hemavathi	Akkihebbal	GD	1922
6.	-do-	Lakshmanathirtha	Unduvadi	GD	1922
7.	-do-	Kabbani	Hullahalli	GD	1916
8.	-do-	Nugu	Birwal	GD	1922

G = Gauge observations.
GD = Gauge and discharge observations.

10.40 Under the programme of establishing and maintaining centrally-operated key hydrological stations in the country, the Central Water and Power Commission has included five gauge and discharge sites in the Cauvery basin, namely (1) on the Cauvery at Kallighat, (2) on the Cauvery below its confluence with the Arkavathi, and (3) on the Kabbani above its confluence with the Cauvery in Mysore, and (4) on the Cauvery below its confluence with the Bhavani, and (5) on the Cauvery above its confluence with the Aiyar river in Tamil Nadu. In addition, they have suggested that three gauge and discharge sites, namely (1) on the Cauvery at Chunchanakatte, (2) on the Hemavathi at Akkihebbal, and (3) on the Lakshmanathirtha at Unduvadi in Mysore and two sites namely (1) on the Bhavani at the Kediveri Anicut, and (2) on the Amaravathi above its confluence with the Cauvery, may be maintained by the State Governments concerned.

10.41 Based on the data available, the average annual runoffs of the Cauvery basin at some of the important sites have been assessed by the Central Water & Power Commission, while conducting irrigation-potential studies, and are given in Table 10.7.

*Report of the technological possibilities of irrigation projects in India, Central Water & Power Commission. (Unpublished).

Table 10.7

Average Annual Runoff of the Cauvery Basin at Various Sites

Sl. No.	Discharge gauging station	Catchment area in sq. km.	Average annual runoff in m.cu.m.
1.	Krishnarajasagara Dam	10,360	6,846
2.	Mettur Dam	42,217	9,707
3.	Bhavani Bridge	44,512	9,744
4.	Akhanda Cauvery at the Upper Anicut	67,547	14,432

GROUND WATER

10.42 Systematic investigations and studies of the water potential of the Cauvery basin have not been made so far. Only in some parts of Mysore, Coimbatore, Thanjavur and Tiruchchirappalli districts, have some investigations and studies been done recently.*

Investigations in an area of 980 sq. km. in Mysore district indicate that ground water occurs in the weathered gneisses, granites and in joints, fractures and shear-zones of fresh rocks. The yield of wells in these rocks varies from place to place depending on various factors like the nature of the rocks, the amount and depth of weathering, joint-patterns, etc. The prospects for sinking deep borewells are not bright. In some localities, better yields may be obtained by dug-cum-borewells and borewells descending 30 to 50 m. The water from gneisses is generally good, though hard and alkaline, and is fit for irrigation.

Geo-hydrological investigations in an area of 1,500 sq. km. in Coimbatore district indicate that open wells, which tap water from Archaean rocks generally ranged in depth from 6 to 21 m. and sometimes to 27 m. Depths to water level in these rocks ranged between 4.5 and 4.0 m. below the ground level. A limited development of ground water is possible by locating sites in favourable areas.

Investigations in Thanjavur district indicate that ground water occurs

*Ground Water Resources of India, Status and Surveys, Prospects and Perspective, Geological Survey of India (August, 1970).

in alluvial sands under water table and confined conditions. The water table generally lies between 1.5 and 3 m. below ground level recording a wide range of seasonal fluctuations. The development of ground water is generally taking place by means of filter point wells, dug-cum-tube-wells and tubewells. The density of filter-point wells is generally high between Karuvendinathapuram and Mayavaram where favourable geo-hydrological conditions occur. The filter-point wells vary in depth from 8 to 12 m. piercing the shallow confined aquifers between 6 and 12 m. below ground level. These wells are generally in use between February and June every year depending on the demand for water. Ground water development by means of dug-cum-tubewells and tubewells is only on a small scale, at present. The ground water is suitable for irrigation in the western and central parts of the basin. Considering the moderate to high permeability of the shallow, confined aquifers occurring within 60 m. and the expected high degree of influent seepage from coastal areas, there is large scope for ground water development by filter-point wells and shallow tubewells.

Investigations in Tiruchchirappalli district over an area of 1,300 sq. km. indicate that the area is underlain by cretaceous, tertiary and recent formations of rocks. Sandstones, sands and clays forming a part of the Cuddalore sandstones of Upper Miocene age occurring over an area of 985 sq. km. are the most important formations met with in the area. Ferruginous friable sandstones exposed in the narrow strip of the area bordering the cretaceous rocks form the recharge area for the confined aquifers. Water occurs in the Cuddalore sandstones both under water-table and confined conditions. Wells of depths varying from 9 to 22 metres tap ground water from the water-table zone and tubewells tap water from the confined acquifers. Exploratory boreholes drilled in the area have indicated the presence of sands and gravels to a depth of up to 450 metres and tubewells drilled up to 250 metres have given good results. Geophysical investigations have revealed that the thickness of sediments in the area is of the order of a few hundred metres, indicating great potentialities for large-scale ground water development.

In addition to the work carried out by the Geological Survey of India, the Tamil Nadu Government, under the auspices of the United Nations Development Programme, has also been carrying out exploration work in an area of 11,700 sq. km. in the delta.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific quantitative and qualitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development for various needs, can only be made when full investigations have been carried out.

EXISTING DEVELOPMENT

10.43 Irrigation has been in vogue for centuries in the Cauvery basin through tanks and anicuts. There are innumerable such works using the waters of the Cauvery and its tributaries for irrigating fields within their command. Some of these works are reported to have been in existence for centuries and are still in good working condition.

10.44 The most important work across the Cauvery is the Grand Anicut, reputed to have been built by the Great Chola Kings in the first century A.D. This anicut has been responsible for the vast irrigation system in the Cauvery delta and for the agricultural prosperity of Thanjavur district. The Grand Anicut, in its original form, was a masonry structure built along the left bank of the Cauvery to prevent the flow in the Cauvery from being diverted into the Coleroon. It consisted of a core of roughly dressed granite set in mud, covered with an outer facing of roughly dressed granite blocks set in lime mortar. Like most old irrigation works in South India, the anicut was not of uniform section or shape. A portion of the crest was built in Ogee form while the rest was constructed in a series of steps, the foot of the solid dam being protected by a rough stone apron. As time passed, improvements to the arrangements for the distribution of water below the Grand Anicut were made. Ten scouring sluices were provided at the anicut in 1830. In 1886, automatic falling shutters were fitted on the crest. The falling shutters were later substituted by 30 lifting shutters. Immediately downstream of the Grand Anicut and almost at right angles to it are the regulators across the Cauvery and the Vennar. These were constructed in about 1886 for distributing the available flow between the Cauvery and the Vennar and for excluding from both, the flood water of the main river.

10.45 Another important structure built across the Cauvery is the Upper Anicut. This regulates the flood flow into the Cauvery. The Upper Anicut was constructed in 1839 by Sir Arthur Cotton across the north branch of the river at the upper end of the Srirangam island. The primary object of this anicut was to divert the low supplies in the river into the southern branch, which was the feeder channel to the old delta. Subsequently, in 1845, a grade wall (the Cauvery dam) was built across the southern branch (the Cauvery arm of the river) to restrict the proportion of flood water in the latter. In 1899, the Upper Anicut was rebuilt and then consisted of an open dam with 55 vents 12.2 m. wide fitted with lifting gates. The Upper Anicut does not have any direct irrigation under it, but serves as an ancillary structure for safeguarding the irrigation system below the Grand Anicut. An area of about 0.4 million hectares is irrigated under the Upper and Grand Anicut systems.

10.46 Another important pre-Plan project in the Cauvery basin is the Lower Anicut built across the Coleroon (north branch) at about the same period as the Upper Anicut (1836). The anicut is located on the Coleroon, about 110 km. downstream of the Upper Anicut. As originally built, it consisted of a solid masonry section. It was remodelled in 1901 to improve its working. An area of 44,500 hectares is irrigated in Thanjavur district by the scheme.

10.47 The First Irrigation Commission made the following observations in respect of the irrigation development in the Cauvery basin: *

"In the case of the Cauvery of which one-third of the total catchment of 31,000 square miles lies in the Native State of Mysore, the main obstacle to the further utilisation of the surplus flow resulting from an average rainfall of 38 inches, lies in the fact that throughout the upper part of its course, the river flows through a deep and wide valley at right angles to the general direction of the drainage from the Western Ghats on its right bank. It then cuts off all this drainage from the dry tract on its left bank, where the water would be of the greatest value. This tract, therefore, is dependent for its irrigation upon a local rainfall, which, though usually sufficient, has sometimes failed. When, as in 1875–76, the drought is prolonged, the tanks and all local sources of irrigation must, as we have shown, fail to afford full protection to cultivation."

With regard to the construction of large storage works in the Cauvery basin, the Commission observed as follows:

"The question of constructing a large storage work on the Cauvery or one of its principal tributaries has been under discussion for many years and a project for constructing a reservoir on the Bhavani, a tributary of the Cauvery, near Satyamangalam, with a capacity of 27,000 million cubic feet, has been recently prepared in detail. The work is estimated to cost over a crore of rupees, and to provide for an extension of irrigation of about 90,000 acres, although the main object is to give greater security to the existing irrigation. The project is however, in abeyance, as the question has been raised whether any storage work that may be proposed should not be constructed on the main Cauvery, where it is said that a very suitable site exists for a

*Report of the Indian Irrigation Commission (1901-03).

reservoir to hold 30,000 million cubic feet. The average supply of the Bhavani is not more than one-fifth of that of the main river, and it has been contended that a reservoir constructed on it will be liable to fail in dry years at the most critical period. It appears to be admitted that a reservoir on the main river would be more powerful and less likely to fail than one on the tributary, and would render possible a much greater extension of irrigation. But, the suitability of the site for a dam, 130 feet in height, which will be required to pass the full floods of the Cauvery, has not yet been fully demonstrated; the probable cost of the work has not been estimated in detail; and an objection has been raised that it will intercept much of the silt now brought down by the Cauvery, which is said to be of such fertilizing value that the lands, which are benefited by it, require no other manure, and would deteriorate if deprived of it, however ample the supply of water. No final decision is likely to be arrived at until both projects have been investigated in the same degree of detail, and further information has been obtained on many points that affect the question. Both projects are of great magnitude, but it is believed that, whichever may be ultimately preferred, the expenditure is likely to prove directly remunerative. The greater part of the Tanjore district is now so well protected that the construction of this work does not appear to be of urgent importance as a protection against famine. But, it will add greatly to the wealth of the district, and render the existing irrigation revenue much more secure; it will give protection to some outlying areas; and it will probably fulfil the conditions of a productive irrigation work. We may add that, although we are unable to offer an opinion on the relative merits of these alternative projects, there is one argument in favour of the reservoir on the main Cauvery which may deserve attention. Neither project provides for an extension of irrigation in the Coimbatore district. The Bhavani reservoir is not high enough up the river to give the requisite command; but if it is once built, it is very unlikely that a reservoir will ever be built higher up for the benefit of Coimbatore, as it would intercept and divert the water required for Tanjore. On the other hand, if the reservoir for Tanjore be built on the main Cauvery, there will be no objection to constructing a reservoir at any suitable point on the Bhavani for the benefit of Coimbatore. It appears possible also that some extension of irrigation might be effected in the Salem district if the reservoir is constructed on the main Cauvery. In both these districts there is great need of protection."

"Other large works which have been proposed in Madras are storage reservoirs in the Cauvery and Krishna rivers. It is hoped that it may be possible to sanction both of these works or at least the former, on their merits as works which are likely to be productive; but both schemes will have a protective value which will justify sanction being accorded to them, even if there are doubts as to their proving fully remunerative."

10.48 All the works described in paras 10.43 to 10.46 were diversion works, and in times of scarcity, failed to supply much-needed water to the crops in the delta. The question of improving conditions by building a storage reservoir across the Cauvery was first considered in 1834 by Sir Arthur Cotton. However, it was only after the conclusion of an agreement in 1924 regarding the utilisation of Cauvery water between the erstwhile Princely State of Mysore and the Madras Presidency, that work on the reservoir in Tamil Nadu could start. The reservoir, as constructed, is situated near Mettur in Salem district. The dam is built of rough stone masonry in red cement mortar and red cement concrete. The main dam is 2,150 metres long with a saddle spillway of 720 metres length and 94 metres high above the deepest foundations.* The gross storage capacity of the reservoir (including flood storage) is 2,923 m. cu. m., while the live storage capacity is 2,652 m. cu. m. The work on the dam started in 1927 and was completed in 1934. The dam is one of the biggest in India, and at the time when it was built, was the biggest in the world. The water stored in the reservoir, in addition to stabilising irrigation in the delta, has extended irrigation over an area of 122,000 hectares under a new canal called the Grand Anicut Canal taking off from the Grant Anicut.

10.49 The Krishnarajasagara dam† is the most important pre-Plan project within Mysore State to be executed in the Cauvery basin. The work on the project started in 1911 but had to be slowed down and then stopped, till agreement was reached with the Madras Govt. in 1924. The Cauvery has a catchment area of 10,360 sq. km. at the dam site and an estimated yield of 6,846 m. cu. m. However, the impounding of water in the reservoir and its utilisation is restricted by the 1924 agreement. The dam as constructed is situated about 19 km. north-west of Mysore City and is 2,620 metres long and 44.5 metres high above the deepest foundations. The reservoir has a gross capacity of 1,381 m. cu. m. and live capacity of 1,246 m. cu. m. The project provides irrigation to an area of 50,000 hectares in Mysore and Mandya districts in addition to supplying water to the Sivasamudram Hydro-Power Station for the generation of electricity.

*History of the Cauvery—Mettur Project by C. G. Barber (1940).

†Pamphlet on the Krishnarajasagar Project (Mysore).

Besides, there are innumerable tanks and anicuts in the basin supplying water to small commands under them.

Projects in Tamil Nadu

10.50 In Tamil Nadu, the expansion of irrigation facilities in the Cauvery basin continued during the Plan periods. Starting from 1951, a number of projects have been completed, the more important among them being the Lower Bhavani Project, the Amaravathi Project, the Kattalai High Level Canal, the Pullambadi Canal and the Mettur Canal. The following paragraphs give brief description of the projects executed during the Plan periods.

10.51 *Lower Bhavani Project*: Work on the project started in 1949 i.e. before the commencement of the First Five Year Plan, but had to be continued beyond 1951, and hence the Lower Bhavani is considered to be a Plan project. The project was completed in 1956 and consists of a masonry-cum-earth dam having a total length of 8,800 m. and a maximum height of 62 m., across the Bhavani river just below its confluence with the Moyar in Coimbatore district. It has a gross storage capacity of 925 m. cu. m. of which 900 m. cu. m. is effective storage, and provides irrigation facilities to 78,920 hectares in Coimbatore district.

10.52 *Amaravathi Project*: The project was taken up during the First Plan and completed during the Second Plan. It includes an earthen dam across the Amaravathi river—a tributary of the Cauvery—in Coimbatore district and a canal system to provide irrigation to 21,650 hectares.

10.53 *Kattalai High Level Canal and Pullambadi Canal*: These two schemes consist of bed regulators on the main Cauvery river and canal systems to irrigate 8,340 hectares and 8,950 hectares respectively in Tiruchchirappalli district. Both these schemes were taken up and completed during the Second Plan period (1956–61).

10.54 *Mettur Canal*: The project consists of a canal taking off from the Mettur reservoir to irrigate 18,210 hectares in Salem and Coimbatore districts. It was completed during the Second Plan period (1956–61).

It may be stated here, that the Mysore Government had objected to the construction of the last three projects viz. the Kattalai High Level Canal, the Pullambadi Canal and the Mettur Canal on the ground that they violated the 1924 agreement. The schemes were, however, approved by the Planning Commission on the Tamil Nadu Government's assurance that they will utilise only the surplus waters of the Cauvery without prejudicing the distribution of such waters between the two States, and that in the event of deficiencies, these areas would be fed by improving the duty and effecting economies in the existing canal system.

Projects in Mysore

10.55 The development of irrigation projects in the Cauvery basin within Mysore State has been, in contrast to the development in Tamil Nadu, slow and halting. Though a number of schemes—big and small—had been proposed by the State during the three Plans, work on them has been slow for a variety of reasons. The most important project under construction in the basin in Mysore State is the Kabbani project. Costing Rs. 248.0 million, it provides for the construction of a 2,701 m. long, 59.45 m. high composite dam across the Kabbani river near the village of Bidarahalli. Two canals take off on either side to irrigate an area of 50,992 hectares annually. The project was started in 1959 and is likely to be completed in the Fifth Plan period.

10.56 Some details of the six medium projects undertaken during the Plan period are given below:

Table 10.8

Medium Projects in Mysore State

Sl. No.	Name of project	Estimated cost (Rs. million)	Ultimate irrigation (Thousand hectares)	Stage of construction
1.	Nugu reservoir	31.114	8.07	Completed
2.	Hebbahalla	5.860	1.21	-do-
3.	Chickhole	8.875	1.60	-do-
4.	Lakshmanathirtha	16.044	2.83	Under construction
5.	Arkavathi	19.850	2.83	-do-
6.	Manchanabele	23.736	2.83	-do-

10.57 Some particulars of the important major and medium projects under operation and construction in the Cauvery basin are given in Appendix 10.1 and 10.2.

10.58 Besides major and medium projects, a number of minor schemes consisting of tanks and dug wells have a considerable area under irrigation. In fact, these sources irrigate a major part of the total area.

Details of the area irrigated by various sources like canals, tanks wells, etc. during the year 1967–68 in the basin are shown below:

Table 10.9

Source-wise Irrigation in Cauvery Basin (1967-68)

('000 hectares)

Sl. No.	Source of irrigation	State			Total
		Mysore	Tamil Nadu	Kerala	
1.	Canals	122	612	1	735
2.	Tanks	91	118	—	209
3.	Wells	25	255	—	280
4.	Other sources	19	11	1	31
	Total	257	996	2	1,255

By the end of the Annual Plan 1968–69, the area under minor schemes increased by about 41,200 hectares.

10.59 Most of the important data and information relating to water resources development in the basin such as the working statistics of canals and reservoirs are not readily available. On the basis of rough duties, an approximate estimate of the quantity of water diverted for irrigation from these works has been made. The average annual diversion by the major and medium projects operating and under construction in the basin is of the order of 12,680 m. cu. m.

10.60 As regards the statistics of the large number of minor schemes comprising tanks, wells and other diversions, no information is available. In respect of these schemes, no observations seem to have ever been made and no records maintained of the quantity of water diverted. Some information is available only with regard to the areas irrigated from these sources. The approximate annual diversion by the minor schemes may be of the order of 4,749 m. cu. m.

Reservoir Losses

10.61 The data on reservoir losses for the major and medium schemes in the Cauvery basin is not available. To make an approximate estimate of the reservoir losses, the Commission has assumed that they would be of the order of 20 per cent of the annual diversion by these projects. On this basis, the reservoir losses work out to approximately 652 m. cu. m.

In the absence of observed statistics, it is extremely difficult to estimate the losses for minor schemes. Assuming that the water spread of a tank would be about 87.5 per cent of the area irrigated from it, as estimated for the Krishna and Godavari basins and that a total loss of 1.22 m. occurs over the water surface area for the period when the tank is full (from June to December approximately), the total reservoir losses from the tanks in the basin would work out approximately to 2,406 m. cu. m.

10.62 Thus, the total annual utilisation by major, medium and minor projects under operation and construction in the basin (including reservoir losses) would be 20,487 m. cu. m. on their full development. Of this 17,930 m. cu. m. would be from the surface waters and the balance of 2,557 m. cu. m. from the ground waters.

10.63 The major and medium projects in operation and under construction in the basin will irrigate 0.9 million hectares on full development. The up-to-date data in respect of irrigation by minor schemes in the basin is not available, however, the area irrigated by the minor schemes in 1968–69 was of the order of 0.56 million hectares. Thus, on full development, the total area irrigated by major, medium and minor schemes in the basin would be of the order of 1.46 million hectares.

10.64 There are quite a few industries located in the basin, which are utilising the Cauvery waters. Of these, the cotton textile industries in Coimbatore and Mysore districts, the cement factories in Coimbatore and Tiruchchirappalli districts deserve mention. Data on the industrial water needs is not readily available. In future, such needs are expected to grow with greater industrialisation.

No water pollution in the basin due to the discharge of industrial wastes has been reported so far. However, this aspect should not be lost sight of in the future.

FUTURE DEVELOPMENT

10.65 The utilisation of the available flows in the Cauvery basin has been almost complete. Any further expansion of irrigation in the basin, therefore, can only be marginal. The Mysore State has on hand a number of major and medium projects (some under construction and others, under formulation). Some of them were proposed during the previous Plans. However, most of them have not so far been sanctioned. The following paragraphs describe briefly the schemes proposed by Mysore State.

(i) *Hemavathi Project*: The project envisages the construction of a dam 64 metres high across the Hemavathi—one of the important tributaries to join the Cauvery upstream of Krishnarajasagara. The reservoir, as proposed by the State, is situated near Gorur in Hassan district and will have an effective storage of 617 m. cu. m. and provide irrigation to 40,500 hectares. The utilisation of water under the scheme is expected to be 549 m. cu. m.

(ii) *Harangi Project*: The project envisages the construction of a masonry dam, 52 m. in height across the river Harangi—a tributary of the Cauvery. The dam, as proposed, will be located in Coorg district and will provide irrigation to an area of 30,400 hectares utilising 453 m. cu. m. of water.

(iii) *Kabbani Project*: The project, as originally planned (and approved by the Planning Commission), was to provide irrigation to 12,200 hectares. The State Government has, however, revised the scheme to extend irrgation to 51,000 hectares. The project, as now envisaged, has already been described in para 10.55. The project is expected to utilise 804 m. cu. m. of water.

(iv) *Cauvery Reservoir Project*: The project envisages the construction of a storage reservoir across the Cauvery near Hosapatna in Coorg district. The dam will be 1,430 metres long and 32 metres high with a central spill-way (176 metres). The reservoir will have a live storage capacity of 145 m. cu. m. and provide irrigation to 8,100 hectares. The utilisation of water is expected to be 160 m. cu. m.

(v) *Yagachi Reservoir Project*: The project envisages the construction of a storage reservoir across the River Yagachi (a tributary of the Hemavathi) upstream of the Belur Bridge near Chikkabyadagere. The dam will be 1,500 metres long and 26 metres high. The reservoir will have a storage capacity of 96 m. cu. m. and will provide irrigation to 13,000 hectares. The utilisation of water is expected to be 144 m. cu. m.

(vi) In addition to the above major projects, Mysore has proposed some medium projects shown in Table 10.10.

10.66 To sum up, Mysore has proposals to provide irrigation to 171,300 hectares and utilise 2,487 m. cu. m. of water as follows:

		Hectares	*M. cu. m.*
(1)	Hemavathi	40,500	549
(2)	Harangi	30,400	453
(3)	Kabbani	51,000	804
(4)	Cauvery reservoir	8,100	160
(5)	Yagachi	13,000	144
(6)	Medium Projects	29,200	377
	Total	172,200	2,487

Table 10.10

Proposed Medium Projects in Mysore

Sl. No.	Name of project	Name of river	Benefits ('000 hectares)	Utilisation in M.cu.m.
1.	Suvarnavathi	Suvarnavathi	6.9	95
2.	Manchanabele	Arkavathi	2.8	39
3.	Gundal Reservoir	Gundal	6.1	51
4.	Sagare Doddakere	Bandiganda	0.8	14
5.	Taraka	Taraka	7.3	124
6.	Votehole	Votehole	5.3	54
	Total		29.2	377

10.67 In addition to the above, two schemes viz. Lakshmanathirtha and Arkavathi have been sanctioned by the Planning Commission and are under construction. These two schemes will provide irrigation to a total area of 5,667 hectares. The data on water utilisation proposed under these projects is not available. However, calculating at the rate of 60 hectares per m. cu. m., the utilisation can be of the order of 94 m. cu. m. The total utilisation proposed for future projects in Mysore State will be of the order of 2,581 m. cu. m.

10.68 The Tamil Nadu Government has proposed one major project and five medium projects in the basin to be taken up during the Fourth Plan. These are described briefly in the following paragraphs.

(i) *Modernisation of the Cauvery Delta Scheme*: The scheme has been formulated to improve the existing system in the Cauvery delta in order to achieve better duties and to utilise the water thus saved for the expansion of irrigation.* The works proposed to be taken up include the lining of the river portion and those canals where seepage is heavy, the construction of field channels up to a 20 hectares limit, the construction of new bed regulators and the provision of adequate drainage facilities. It is expected that with the implementation of the scheme, an additional area of 142,000 hectares will be brought under irrigation. The scheme does not envisage any further increase in the total utilisation of water. With the proposed improvements, better water management and supplementing surface water resources with ground water, an additional area would be provided with irrigation.

*Modernising Cauvery Delta Project (Tamil Nadu), prepared by the Tamil Nadu State for World Bank assistance.

(ii) In addition to the scheme described in the preceding para, the Tamil Nadu Government has proposed the following medium projects:

Table 10.11

Proposed Medium Projects in Tamil Nadu

Sl. No.	Name of the project	Name of river	Benefits ('000 hectares)	Utilisation in M.cu.m.
1.	Parappalar	Nanganji	1.0	12
2.	Palar-Porandalkar	Palar-Porandalkar	6.1	67
3.	Chinar (Dharmapuri)	Chinar	1.8	21
4.	Ponnaniar	Ariyarvur	0.85	10
5.	Dodahalla	Dodahalla	0.77	13
	Total		10.52	123

The new medium schemes proposed by the State are expected to irrigate 10,520 hectares utilising 123 m. cu. m. of water.

10.69 The utilisation of water in the Cauvery basin is governed by the Agreements of 1892 and 1924 between the erstwhile Government of Madras Presidency and the former Princely State of Mysore. The Agreement of 1892 covered all the rivers including the Cauvery, which flowed from Mysore into Madras, while the 1924 Agreement related specifically to the construction of the Krishnarajasagara Dam by the Mysore State.

10.70 According to the 1892 Agreement, the Mysore Government cannot, without the previous consent of the Madras Government, build in the Cauvery basin, any new irrigation reservoirs across the Cauvery and its tributaries the Hemavathi, the Lakshmanathirtha, the Kabbani, the Honhole or the Suvarnavathi, and any reservoirs on the Yagachi, a tributary of the Hemavathi up to the Belur Bridge. The Mysore Government was also required not to build without the previous consent of the Madras Government, any new anicuts (diversion weirs) across the Suvarnavathi; across the Yagachi up to Belur bridge; on the Cauvery below the Ramaswami Anicut and on the Kabbani below the Rampur Anicut.

When the Mysore Government desires to construct any work requiring the previous consent of Madras, full information regarding the proposed work has to be forwarded to the Madras Government and work can be started only after such consent has been obtained. The Madras Government was bound not to refuse its consent except for the protection of the prescriptive rights already acquired and actually existing. Differences arising in any case had to be referred to the final decision of arbitrators appointed by both Governments or by the Government of India.

10.71 The Government of Mysore subsequently asked for the consent of the Madras Government to the construction of the Krishnarajasagara Project, which has a catchment area of 10,619 sq. km. As there were differences of opinion, an arbitrator was appointed in 1914 whose award was ratified by the Government of India. The award was, however, not acceptable to the Government of Madras, who, appealed to the Government of India and later to the Secretary of State. The question was re-opened. The principal objection of the Government of Madras to the award of 1914 lay in the fact that it did not provide for what were contended by Madras to be their established rights in regard to existing irrigation in the Cauvery delta. Negotiations between the Governments of Madras and Mysore were then commenced with a view to reach an equitable and friendly settlement on the points of issue. In July 1921, rules of regulation for the Krishnarajasagara, which also fixed the limit gauge readings at the Cauvery dam, were agreed to by the Chief Engineers of the Governments and in 1924 an agreement was reached in regard to the construction of a dam and reservoir at Krishnarajasagara.

10.72 This Agreement was subject to review after 50 years in regard to certain clauses. The followings are the principal features of the agreement:

(1) Mysore could build the Krishnarajasagara Dam for a capacity of 1,269 m. cu. m. and irrigate 50,585 hectares from this project.

(2) Certain flows were recognised as the natural flows in the Cauvery which should be ensured at the Upper Anicut when these flows were available in the river system. The proportionate contribution of the natural flow of the Cauvery at Krishnarajasagara to these natural flows at the Upper Anicut in various months was laid down and Mysore was at liberty to store only whatever flows in the river to be in excess of these limits. The discharges adopted at the Upper Anicut and at Krishnarajasagara are given in the Table on page 333. The Krishnarajasagara reservoir had to be operated according to the rules for regulation drawn up to ensure that the proportionate natural flows were let down the reservoir and only flows in excess were to be made use of by Mysore.

(3) Mysore could construct new reservoirs on the Cauvery and its tributaries as mentioned in the 1892 Agreement, which may be of an aggregate capacity of 1,274 m. cu. m., and to have additional

Month	Minimum flow at Upper Anicut (Cumecs)	Contribution of Krishnarajasagara to figure in col. 2 (Cumecs)
June	844	527
July & August	1,136	710
September	991	619
October	844	253
November	709	252
December	252	76
January	175	52
February to May	—	25.5*

* at Siva Samudram

irrigation for 44,515 hectares from such reservoirs. These reservoirs, however, had to be so regulated as not to make any material diminution in the natural flows at the Upper Anicut. Full particulars of such schemes and of the impounding therein have to be furnished by Mysore to Madras to enable the latter to satisfy itself that the supplies at Upper Anicut would not be affected.

(4) Madras should limit the new area of irrigation under the Cauvery-Mettur Project to 1,21,809 hectares and the effective capacity of the Mettur Reservoir to 2,648 m. cu. m.

(5) The limitations and arrangements in (3) and (4) above would be open to reconsideration after 50 years i.e. in 1974 in the light of the experience gained and of an examination of the possibilities of the further extension of irrigation in the two States and of such modifications and additions as might be mutually agreed upon.

(6) The limit on the extension of irrigation would not preclude the expansion of irrigation solely by the improvement of duty, without any increase in the quantity of water used.

(7) Madras could construct new irrigation works on the tributaries of the Cauvery in Madras. If they built any new storage reservoir on the Bhavani, Amaravathi or Noyil rivers, Mysore could construct a set-of reservoir of capacity not exceeding 60% of the new reservoir in Madras, on any one of the tributaries of the Cauvery in Mysore. It was provided that the impounding of water in such reservoirs should not diminish or affect in any way the supplies to which Madras and Mysore respectively are entitled under the

Agreement, or affect in any way the division of surplus water, which it was anticipated would be available for division in 1974.

(8) The Agreement would not qualify or limit in any manner the operation of the 1892 Agreement in other matters or affect the rights of Mysore to construct new irrigation works on these tributaries of the Cauvery which are not mentioned in the schedule of the 1892 Agreement.

(9) Disputes as to the interpretation, operation or implementation of the Agreement would be settled by arbitration, or if the parties so agree, would be submitted to the Government of India.

10.73 The Tamil Nadu Government has been objecting to the projects proposed by Mysore on the plea that they would reduce the flows in the Cauvery (at the Upper Anicut) as guaranteed to that State in the 1924 Agreement. Pending a settlement of the dispute between the two States, none of the above projects of Mysore has been sanctioned so far. The Union Ministry of Irrigation and Power has been trying to bring about a settlement between the two States, though no agreement has yet been reached.

10.74 In the case of the Kabbani Project, the Kerala Government has also been protesting on the ground that the requirements of the area transferred to that State on the reorganisation of States in 1956 have to be taken into account and that the modified Kabbani Project as proposed by Mysore would submerge about 100 hectares in Kerala.

10.75 From the above, it appears that future development of irrigation in the Cauvery basin is closely linked with a settlement of disputed issues between the contending States. Following the failure of all attempts at a settlement, the Tamil Nadu Government has requested that the dispute be referred to arbitration as provided in the 1924 Agreement. No final decision has, however, been taken in the matter so far.

10.76 Some particulars of the new projects proposed by the various States are given in Appendix 10.3.

FLOODS, WATERLOGGING AND DRAINAGE

Floods

10.77 The Cauvery river, in its upper and middle reaches, flows within well defined banks and causes very little flooding. One of the tributaries of the Cauvery viz., the Arkavathi causes some flooding near

Ramanagaram in Bangalore district. The Mysore Government has proposed a flood-control-cum-irrigation scheme called the Manchanabele Project across the Arkavathi. The project, costing Rs. 28.7 million, has been taken up for construction.

Occasional floods occur in the delta of the Cauvery. The highest flood, within living memory, occurred in 1924, when the discharge at the Mettur dam site was estimated to be 12,913 cumecs. The construction of the Mettur reservoir in 1934, acted as a flood moderator for the delta. In this reservoir, a flood storage of 271 m. cu. m. has been provided by keeping a margin of 1.83 m. between the Full Reservoir Level and the Maximum Water Level. It is estimated that with the reservoir at F.R.L. at the commencement of a flood, there will be a flood moderation of nearly 15 per cent. With a lower reservoir level before a flood, the moderation will still be greater.

When the Mettur dam was constructed, it was thought that a high flood similar to that of 1924 was inconceivable. However, in 1961, very high floods occurred in the Cauvery, causing breaches in the flood banks of the Coleroon, which is the chief flood carrier of the Cauvery system. This, in turn, caused breaches in the banks of other rivers in the delta.

After the floods, the Tamil Nadu Government appointed a special officer to examine the causes of floods and to suggest remedial measures. Some of the measures recommended were:

(i) The construction of a regulator across the Cauvery arm of the river at the Upper Anicut;
(ii) strengthening the Cauvery-Vennar Regulators:
(iii) raising of the flood banks; and
(iv) the establishment of wireless flood-warning system.

No action appears to have been taken yet, on these recommendations.

Waterlogging and Drainage

10.78 Waterlogging conditions are being experienced in the Krishnarajasagara command in Mysore State. Surveys conducted in this respect have revealed that low lying areas of the irrigated tract have become waterlogged due to poor drainage. The water table in these areas is within a metre of the surface. These conditions are affecting the yields of all crops except, perhaps, paddy. The State Government has formulated schemes for the reclamation of lands rendered waterlogged by providing suitable drains and by incorporating green manure and chemical additives based on soil analysis. It also has plans to include drainage as a part of all future irrigation projects in the basin, to obviate the occurrence of waterlogging conditions.

10.79 Problem of drainage congestion is more acute in the Vennar sub-delta, which suffers greatly during the north-east monsoon floods. The problem is further aggravated as drainage from the uplands also finds its way into the Vennar delta. It is estimated that an area of 16,200 hectares is affected in the Cauvery delta due to drainage congestion. The State Government proposes to undertake the following remedial measures:

(i) Controlling the entry of floods into the Cauvery arm by the construction of a barrage;
(ii) diverting the upland drains;
(iii) providing more outlets for draining water to the sea; and
(iv) improving the existing drains.

A beginning with these works is being made during the Fourth Plan.

SOIL CONSERVATION

10.80 The main object of soil conservation in the project catchments is soil retention and the consequent reduction of the sediment load, which would otherwise reduce the life of the reservoirs. The approach to soil conservation in this context is two-fold:

(i) To so treat the source areas of sediment as to reduce their contribution to the silt load in the streams; and
(ii) To retain the soil in the catchment areas for agriculture.

10.81 There are no projects in the Cauvery basin within the Kerala State. However, the State Government has enacted the 'Kerala Land Development Act 17 of 1964' under which soil conservation measures can be taken up in any project in the State. The Department of Soil Conservation is the agency entrusted with the work of soil conservation. The State Government proposes to constitute a study team consisting of the Director of Soil Conservation, the Director of Agriculture, the Chief Engineer (Irrigation), the Chief Conservator of Forests and the Chief Engineer (Elec.) to co-ordinate the soil conservation schemes.

10.82 The drainage area lying within Mysore State is either the forest area of the Western Ghats or the table land. Sedimentation surveys of the Krishnarajasagara Project have revealed that there has been very little silting in the reservoir. The State Government, therefore, has not formulated any special programme for soil conservation in the Cauvery catchment.

10.83 In Tamil Nadu also, the problem of soil conservation in the project areas on the main Cauvery is not serious. In fact, the surveys in the Mettur reservoir (for the period 1941–48) indicated a rate of silting of 2.4 m. cu. m. per year, which is less than 0.1 per cent of the total capacity of the reservoir. However, the Forest Department of the State Government has taken up afforestation in the catchment area of the Mettur reservoir. One Division of the Department has been working on this scheme since 1965. The catchment has been divided into 60 sub-catchments, spreading into the Salem and Dharmapuri districts. The sub-catchments, where soil erosion is considered to be acute, are being given priority in the execution of works. Agricultural works like contour bunding and the construction of checkdams and stone-walls are also being carried out as a part of the soil conservation programme. In the Fourth Plan, an outlay of Rs. 3 million has been made for these works.

10.84 The problem of soil erosion in the catchment of the Lower Bhavani Project, however, appears to be more acute. The project has a catchment area of 4,200 sq. km., a considerable part of which lies in the Nilgiri hills. There has been large-scale denudation of the forests in the Nilgiri hills within the catchment for developing plantations, and this has resulted in severe soil erosion. Large areas have been denuded of their cover due to the washing away of the top soil and the lands have almost become barren or have been rendered less fertile. A sedimentation survey of the Bhavani reservoir has indicated that its capacity has been reduced from the original 930 m. cu. m. to 909 m. cu. m. over a period of 12 years (a reduction in capacity of 2.3 per cent). A subsequent survey between 1965–69 has, however, shown some decrease in the rate of silting. The State Government has proposals for taking up soil conservation measures in the Lower Bhavani Project area.

GENERAL

10.85 The Cauvery and its tributaries are an inter-State river system, flowing through the States of Kerala, Mysore and Tamil Nadu. A number of small and large projects have already been constructed in the basin. A few more are under construction. As stated in paras 10.73 to 10.75 a dispute has arisen among the concerned States with regard to further development in the Cauvery basin.

10.86 A network of evaporation measuring stations in the basin, particularly at the sites of the proposed reservoirs, needs to be established.

10.87 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the groundwater resources in the basin, so that these resources may be exploited in a rational way, either independently or in conjunction with surface waters.

10.88 There is need for inter-State co-operation and agreement in respect of carrying out soil conservation measures, especially in the Bhavani sub-catchment so as to conserve the storage capacities of the existing and proposed reservoirs in the basin.

10.89 It is necessary for systematic data to be collected with regard to the sediment carried by the rivers, which would illustrate the effect of any soil conservation works carried out in the basin.

SALIENT FEATURES OF THE BASIN OF EAST FLOWING RIVERS BETWEEN THE CAUVERY AND KANNIYAKUMARI

(i) Source: The Vellar	Near Puttanattam village in Tiruchchirappalli district (Latitude 10°27′N, Longitude 78°20′E).
Small stream between the Vellar and the Varshalei	Near Tirumayam village in Tiruchchirappalli district (Latitude 10°15′N, Longitude 78°40′E).
The Varshalei	Near Tavarankurichchi village in Madurai district. (Latitude 10°20′N, Longitude 78°15′E).
Small stream between the Varshalei and the Vaigai	Near Pagneri village in Ramanathapuram district (Latitude 9°58′N, Longitude 78°32′E).
The Vaigai	Near Kottaimalai in Madurai district. (Latitude 9°32′N, Longitude 77°23′E).
The Gundar	Near Saduragiri in Madurai district. (Latitude 9°45′N, Longitude 77°35′E).
Small stream between the Gundar and the Vaippar	Near Pandelkudi village in Ramanathapuram district (Latitude 9°25′N, Longitude 78°10′E).
The Vaippar	Near Sivagiri in Tirunelveli district. (Latitude 9°18′N, Longitude 77°20′E).
Small streams between the Vaippar and Tambraparni	(1) Near Ettaiyapuram in Tirunelveli district. (Latitude 9°8′N, Longitude 77°50′E). (2) Near Kurukkuchalai village in Tirunelveli district. (Latitude 8°57′N, Longitude 78°3′E). (3) Near Ottappidaram in Tirunelveli district. (Latitude 8°52′N, Longitude 78°3′E). (4) Near Kadambur in Tirunelveli district (Latitude 8°57′N, Longitude 77°52′E).
The Tambraparni	Near Alwarkurichchi village in Tirunelveli district (Latitude 8°46′N, Longitude 77°15′E).

Small streams south of Tambraparni up to Kanniyakumari	(1) Near Nanganeri in Tirunelveli district. (Latitude 8°30′N, Lontigude 77°40′E).
	(2) Near Tirukkurungudi in Tirunelveli district. (Latitude 8°25′N, Longitude 77°29′E).
	(3) From the Mahendragiri in Kanniyakumari district. (Latitude 8°20′N, Longitude 77°32′E).

	Km	Miles
(ii) Length: The Vellar	128	79
Small stream between the Vellar and the Varshalei	68	42
The Varshalei	125	78
Small stream between the Varshalei and the Vaigai	72	45
The Vaigai	258	160
The Gundar	146	91
Small stream between the Gundar and the Vaippar	51	32
The Vaippar	130	81
Small streams between the Vaippar and the Tambraparni:		
(1)	52	32
(2)	18	11
(3)	18	11
(4)	50	31
The Tambraparni	130	81
Small streams south of the Tambraparni up to Kanniyakumari:		
(1)	50	31
(2)	52	32
(3)	30	19

	Sq. Km.	Sq. miles
(iii) Drainage area: The Vellar	1,484	573
Small stream between the Vellar and the Varshalei	871	336
The Varshalei	3,104	1,198
Small stream between the Varshalei and the Vaigai	2,045	789
The Vaigai	7,741	2,989
The Gundar	4,838	1,868
Small stream between the Gundar and the Vaippar	967	373
The Vaippar	5,288	2,042
Small streams between Vaippar and the Tambraparni	1,709	660
The Tambraparni	5,482	2,117
Small streams south of the Tambraparni up to Kanniyakumari	1,561	603
Total	35,090	13,548

(iv) Population (1971 Census): 9.48 millions

(v) Density of population: 270 per sq. km 699 per sq. mile

(vi) Maximum discharge	Of the Vaigai at the Peranai anicut on 8th November, 1884	958 cumecs	33,824 cusecs
(vii) Minimum discharge		N.A.	
		m.cu.m.	MAF
(viii) Average annual runoff of the basin as per irrigation potential studies of the CW&PC		9,522	7.72
		Thousand hectares	Thousand acres
(ix) Culturable area (1967-68)		2,636	6,514
(x) Net area sown (1967-68)		1,656	4,092
(xi) Gross area sown (1967-68)		1,849	4,569
(xii) Net area irrigated (1967-68)		638	1,577
(xiii) Gross area irrigated (1967-68)		780	1,927
(xiv) Area irrigated after completion and full development of Fourth Plan projects		826	2,041
(xv) Probable additional irrigaion by future projects		N.A.	
		m.cu.m.	MAF
(xvi) Water utilisation including reservoir losses			
(a) On completion and full development of major, medium and minor projects under operation and construction at the end of Annual Plan (1967-68)	Surface water	9,558	7.75
	Ground water	1,206	0.98
	Total	10,764	8.73
(b) On completion and full development of Fourth Plan projects	Surface water	11,655	9.45
	Ground water	1,506	1.22
		13,161	10.67

CHAPTER XI

BASIN OF EAST FLOWING RIVERS BETWEEN THE CAUVERY AND KANNIYAKUMARI

The basin of the East-flowing rivers between the Cauvery and Kanniyakumari extends over an area of 35,090 sq. km. It lies between east longitudes 77°9′ to 79°17′ and north latitudes 8°5′ to 10°30′, in peninsular India and covers a large area in the State of Tamil Nadu.

The basin is bounded by the Varushanad hills, the Andippatti hills the Cardamom hills and Palani hills on the west; by the Indian Ocean on the south, by the Palk Strait, Palk Bay and the Gulf of Manaar on the east and the ridge which separates it from the Cauvery basin on the north. The basin, with an irregular shape, has a maximum length of 235 km. in the north-west-south-east direction and a maximum width of 275 km. in the north-east-south-west direction. There are two major topographical divisions in the basin: (i) the hilly area and (ii) the plains. The plains extending from the eastern slopes of the hills slope gently east-south eastward. There are 11 sub-basins in the basin, of which the Vaigai and the Tambraparni are the more important. The Vaigai basin is elongated in shape, whereas the Tambraparni basin is fan-shaped.

THE RIVER SYSTEMS

11.2 The various river systems in the basin from north to south are as under:

(1) The Vellar
(2) A small stream between the Vellar and the Varshalei
(3) The Varshalei
(4) A small stream between the Varshalei and the Vaigai
(5) The Vaigai
(6) The Gundar
(7) A small stream between the Gundar and the Vaippar
(8) The Vaippar
(9) Small streams between the Vaippar and the Tambraparni
(10) The Tambraparni

(11) Small streams south of the Tambraparni up to Kanniyakumari. These river systems are described briefly in the following paragraphs:

The Vellar

The Vellar rises on the eastern slopes of the Western Ghats in Tiruchchirappalli district at an elevation of about 400 m. at north latitude 10°27′ and east longitude 78°20′ near Puttanattam village and flows in a generally easterly direction for a total length of 128 km. through the Tiruchchirappalli and Tanjavur districts to fall into the Palk Strait near Manamelkudi. The river drains a total area of 1,484 sq. km.

Small Stream Between the Vellar and the Varshalei

The stream rises in Tiruchchirappalli district at an elevation of about 150 m. at north latitude 10°15′ and east longitude 78°40′ near Tirumayam village and flows in a generally easterly direction for a total length of 68 km. to join the Palk Strait near Mimisal. The stream drains a total area of 871 sq. km.

The Varshalei

The Varshalei rises in Madurai district at an elevation of 450 m. at north latitude 10°20′ and east longitude 78°15′ near Tavarankurichchi village and flows in a generally easterly direction for a total distance of 125 km. to join the Palk Bay near Sundarapandyanpattanam. The river drains a total area of 3,104 sq. km. The Manimuttar is the important right bank tributary.

Small Stream Between the Varshalei and the Vaigai

This stream rises in Ramanathapuram district at an elevation of about 18 m., at north latitude 9°58′ and east longitude 78°32′, near Pagneri village and flows in a generally easterly direction for a total length of 72 km. to fall into the Palk Bay. This stream drains an area of 2,045 sq. km.

The Vaigai

The Vaigai rises on the western slopes of the Varushanad hills, at an elevation of 1,200 m., near Kottaimalai in Madurai district, at north latitude 9°32′ and east longitude 77°23′ and flows in a northerly and north-easterly direction up to its confluence with the Varahanadi and then takes a turn towards the east and south-east to flow through the Madurai and Ramanathapuram districts and joins the Palk Bay near Mandapam. The total length of the river from the source to its outfall is 258 km. The river has been dammed downstream of its confluence with the Suruli, to store its flows and the diverted flows from the Peranai anicut and canal system lower down.

The Gundar

The Gundar rises from the eastern slopes of the Varushanad hills at an elevation of about 900 m. at north latitude 9°45′ and east longitude 77°35′ near Saduragiri in Madurai district and flows in a generally south-easterly direction for a total length of 146 km to join the Gulf of Manaar. The river drains a total area of 4,838 sq. km.

Small Stream Between the Gundar and the Vaippar

This stream rises at an elevation of about 75 m. at north latitude 9°25′ and east longitude 78°10′ near Pandelkudi village in Ramanathapuram district and flows in a generally south-easterly direction for a total length of 51 km. to join the Gulf of Manaar. The area drained by this stream is 967 sq. km.

The Vaippar

The Vaippar rises from the eastern slopes of the Varushanad hill range at an elevation of about 1,500 m. at north latitude 9°18′ and east longitude 77°20′ near Sivagiri in Tirunelveli district and flows in a generally easterly and south-easterly direction for a total length of 130 km. to join the Gulf of Manaar near Kalattur. The river drains a total area of 5,288 sq. km. The Arjuna is its important left bank tributary.

Small Streams Between the Vaippar and the Tambraparni

There are four small streams between the Vaippar and the Tambraparni. The northern-most one rises at an elevation of about 90 m. at north latitude 9°8′ and east longitude 77°50′ near Ettaiyapuram in Tirunelveli district and flows in a south-easterly direction for a total length of 52 km. to join the Gulf of Manaar. The second stream rises at an elevation of 75 m. at north latitude 8°57′ and east longitude 78°03′ near Kurukkuchalai village in Tirunelveli district and flows in a south-easterly direction for a total length of 18 km. to join the Gulf of Manaar. The third stream rises at an elevation of 70 m. at north latitude 8°52′ and east longitude 78°3′ near Ottappidaram in Tirunelveli district and flows for a total distance of 18 km. in a south-easterly direction to join the Gulf of Manaar. The fourth and the southern-most stream rises at an elevation of 70 m. at north latitude 8°57′ and east longitude 77°52′ near Kadambur in Tirunelveli district and flows for a total distance of 50 km. in a generally south-easterly direction to join the Gulf of Manaar near Tuticorin. The total area drained by all the above four streams is 1,709 sq. km.

The Tambraparni

The Tambraparni rises on the eastern slopes of the Western Ghats at an elevation of about 1,400 m. at north latitude 8°46′ and east longitude 77°15′ near Alwarkurichchi village in Tirunelveli district to flow in a generally easterly direction for a total length of 130 km. and join the Gulf of Manaar. The Chittar and the Manimuthar are the important left and right bank tributaries of the Tambraparni. The total area drained by the Tambraparni is 5,482 sq. km. There are number of anicuts across this river, of which the more important are the Marudur and the Srivaikuntam anicut systems.

Small Streams South of Tambraparni up to Kanniyakumari

There are three streams between the Tambraparni and Kanniyakumari. The northern-most one rises at an elevation of about 90 m. at north latitude 8°30′ and east longitude 77°40′ near Nanguneri in Tirunelveli district and flows in a generally south-easterly direction for a total length of 50 km. to join the Gulf of Manaar. The second stream rises at an elevation of about 1,200 m. at north latitude 8°25′ and east longitude 77°29′ near Tirukkurungudi in Tirunelveli district and flows in a south-eastern and southern direction to join the Gulf of Manaar. The third and the last stream rises at an elevation of about 500 m. at north latitude 8°20′ and east longitude 77°32′ from the Mahendragiri in Kanniyakumari district and flows generally in a southern direction for a total length of 30 km. to join the Gulf of Manaar. The above three streams together drain a total area of 1,561 sq. km.

CLIMATE

11.3 Three distinct seasons occur in the basin. They are (i) south-west monsoon (ii) north-east monsoon and (iii) transitional dry (hot weather) season.

The south-west monsoon season extends from June to September. The south-west winds are descending winds blowing on the leaward side of

Western Ghats and hence give little rain unless they are forced to ascend by the intervening groups of hills. In the basin, part of Tirunelveli district gets more rainfall during this season than during the north-east monsoon season.

The north-east monsoon is closely associated with seasonal depressions in the Bay of Bengal. Rainfall during this season is heaviest along the east coast and declines steadily towards the interior.

During the hot weather season, the climate is generally dry and is interrupted by thunder-storms whose frequency increases with the increase in temperature.

Rainfall

11.4 There are at present 89 reporting raingauge stations inside the basin. The distribution of the stations is fairly even and their number is also sufficient.

The rainfall in the basin varies from region to region. The rainfall decreases from 1,270 mm. at the western extremity of the basin to 635 mm. at the south-eastern extremity.

Temperature

11.5 The basin is subject to a tropical climate. In the hilly western part of the basin, the variation of temperature during the year is small.

In the month of January, the mean temperature over the basin is above 25°C. In April, the mean temperature varies from 27.5°C to 30°C whereas in October the temperature over the entire basin is generally above 27.5°C. The annual maximum and minimum normals of temperature at Madurai in the basin are 33.7°C and 23.5°C recpectively.

Evaporation

11.6 Very little data on evaporation is available for the basin. The India Meteorological Department have compiled evaporation data in respect of 30 departmental and 42 agro-meteorological observatories scattered all over the country possessing data for more than five years. Observations at all these places are taken with the Standard U.S. Evaporation Pan (Class A) covered with wire-mesh. For the departmental observatories the data pertains to the period 1959–68 and is available month-wise whereas the data for the agro-meteorological observatories pertains to the period 1961–68 and has been presented for the twelve periods into which the calendar year is divided for agro-meteorological purposes. Of the above 72 observatories, no departmental observatory is situated in the basin. There is only one agro-meteorological observatory located at Kovilpatti.*

SOILS

11.7 A detailed soil survey of the area covered by the basin has not been made. However, the general data regarding the soils of India indicate that mainly red sandy soils and coastal alluvium occur in the basin. Mixed red and black soils occur to a small extent. The basin covers parts of the districts of Madurai and Thanjavur and the whole of Ramanathapuram and Tirunelveli districts. The principal soil types found in the various districts lying in the basin are described below.**

Madurai: Mainly red sandy loams.
Thanjavur: Mainly red and alluvial soils.
Tiruchchirappalli: The prevailing soils are 'regur' and red.
Ramanathapuram: Red and coastal alluvial soils.
Tirunelveli: Both red and black cotton soils. Black soils are generally heavy.

LAND USE AND AGRICULTURAL PRACTICES

11.8 Land use details in the basin in 1967–68, the latest year for which the statistics are available, are given in Table 11.1.

Agriculture has been practised extensively in the basin. The cultivated area for the basin as a whole constitutes 70.14% of the culturable area. The culturable area in the basin is about 1.35% of the total culturable area of India. The total cropped area in the basin is about 1.13% of the total cropped area in the country.

11.9 The general cropping pattern in the irrigated area is described below:

Of the total irrigated area of 780,300 hectares, about 67.27% is under paddy, 4.23% under ragi, 3.95% under cotton, 2.49% under groundnut, 1.33% under sugarcane and the balance under other crops. The other crops grown in the irrigated area are tobacco, maize, millets, gram, pulses, condiments, spices, fruits, vegetables, sesamum, other oil seeds and fibre crops. Food crops represent about 92.14% of the irrigated area, the balance 7.86% being under non-food crops.

*Evaporation data (India), India Meteorological Department (April, 1970).
**Soils of India by S. P. Raychaudhari, R. R. Aggarwal, N. R. Datta Biswas, S. P. Gupta and P. K. Thomas.

Table 11.1

Land Use Statistics of East Flowing Rivers Between the Cauvery and Kanniyakumari (1967–68)

Sl. No.	Item	Area in thousand hectares
1	2	3
1.	Geographical area	3,509
2.	Reporting area	3,493
3.	Area under forests	307
4.	Area not available for cultivation	550
5.	Culturable area (2–3–4)	2,636
6.	Uncultivated culturable area	980
7.	Net area sown (5–6)	1,656
8.	Area sown more than once	193
9.	Total cropped area (7–8)	1,849
10.	Net area irrigated	638
11.	Gross area irrigated	780
12.	Percentage of net area sown to culturable area	62.82
13.	Percentage of net area irrigated to culturable area	24.19
14.	Percentage of net area irrigated to net sown area	38.15

There are three main crop seasons in the basin: (i) Autumn (kharif), (ii) Winter (rabi) and (iii) Summer (hot weather). The kharif crops are paddy, bajra, ragi, jowar, millets, cotton etc. The main summer crop is paddy. The rabi crops are cholam (jowar), millets, gram, other pulses etc. Besides the seasonal crops, garden crops like sugarcane, plantains, betel leaves and turmeric are also grown throughout the year. The sowing and harvesting seasons of the principal crops are given in Table 11.2.*

*Indian Crop Calendar, Ministry of Food, Agriculture, Community Development and Cooperation (1967).

Table 11.2

Sowing and Harvesting Seasons of Principal Crops

Name of crop	Period of	
	Sowing	Harvesting
Autumn paddy	May-November	September-February
Winter paddy	October-January	January-April
Summer paddy	February-April	May-June
Kharif jowar	June-October	September-January
Rabi jowar	November-May	February-July
Bajra	May-December	September-March
Ragi	June-November	September-March
Sugarcane	December-September	December-August
Groundnut	January-May July-October	April-May October-January

REGIONAL ECONOMY

Population

11.10 On the basis of the 1971 census* and the percentages of the area of each district within the basin to the district as a whole, the total population in the basin is about 9.48 millions. There are two cities in the basin which have a population of more than one lakh each according to the 1971 census viz. Madurai and Tuticorin. The average density of population in the basin is 270 persons per sq. km. against the figure of 182 for India as a whole. The density varies from region to region. Whereas the districts of Thanjavur and Madurai have high densities, the Ramanathapuram district has a low density (227 persons per sq. km.).

Of the total population in the basin, nearly 73.1% live in rural areas while the balance of 26.9% live in urban areas. The working force constitutes nearly 36.7% of the total population. 31.0% of the working force is engaged as cultivators and 29.1% as agricultural labourers. The balance of 39.9% of the working force is employed in manufacturing and tertiary activities.

*Census Paper I of 1971 (supplementary), Registrar-General (India).

Forests and Agriculture

11.11 Forests occupy 8.79% of the total reporting area in the basin and the culturable area constitutes 75.47%. Out of the total culturable area of 2.64 million hectares, nearly 1.85 million hectares are annually cultivated. An area of 0.78 million hectares constituting 42.2% of cultivated area is irrigated annually. Paddy is the most important irrigated crop in the basin covering nearly 67.27% of the total irrigated area.

Power

11.12 There are two major hydro-power projects functioning in the basin. They are the Papanasam Project in the Tambraparni basin and the Periyar Hydro Project in the Vaigai basin. The Papanasam Project has an installed capacity of 28 MW and is an old project. The Periyar Project was constructed in two stages. The first stage of the project costing Rs. 104.8 million was started in 1955 and completed in 1959. It has an installed capacity of 105 MW. The Stage II of the Project costing Rs. 8.88 million was completed in 1965. The additional installed capacity in this stage is 35 MW. This project is located 64 km. south-east of Madurai. The power from both the Papanasam and the Periyar Projects is fed into the State grid. There is a thermal power station at Madurai with an installed capacity of 14 MW.

Mineral Wealth

11.13 The principal minerals found in the basin are:*

Iron ore: In the Tiruchchirappalli district.

Gypsum: In the Tiruchchirappalli and Tirunelveli districts.

Limestone: In the Tiruchchirappalli, Ramanathapuram and Tirunelveli districts.

Ilmenite: In the Tirunelveli district.

Monazite: This important radioactive mineral from which Thorium, a substitute for Uranium, can be extracted occurs in the Tirunelveli district.

Salt is manufactured along the coast, but the major concentration of the industry is in Tuticorin where 13 large salt works with a total annual production of 150,000 tonnes are located.

Clays: Fire clays occur in the Tiruchchirappalli and Ramanathapuram districts.

*Techno-Economic Survey of Tamil Nadu, NCAER.

Besides the above minerals, small deposits of several other minerals also occur in the basin. Important among these are corondum, graphite, mica, apatite, granite stones, copper, chromite, feldspar and baryte. The present production of these minerals is quite small and in some places the deposits have not been exploited at all. The prospects for these minerals are restricted to small-scale operations.

Industries

11.14 The important industries in the basin are as under:
Cotton textiles: In Madurai, Tuticorin and Tirunelveli.
Silk and other fabrics: In Madurai.
Tobacco products: In Madurai, Dindigul and Tirunelveli.
Sugar industry: In Madurai and Dindigul.
Vegetable oils: In Madurai and Dindigul.
Cashewnut factories: In Dindigul.
Rubber and rubber goods: In Madurai.
Leather and leather goods: In Madurai.
Matches: In Madurai, Sivakasi and Kovilpatti.
Essential oils: In Madurai.
Paper, cardboard and newsprint: In Madurai.
Agricultural equipment: In Madurai.
Drugs and Pharmaceuticals: In Madurai and Tuticorin.
Fertilisers: In Madurai.
Chemicals, acids, and caustics: In Madurai.
DDT and Insecticides: In Madurai.
Soaps: In Ramanathapuram.

Communications

11.15 The basin is served by the network of the Southern Railway. The entire system is on metre-gauge. There are a number of important lines connecting different places in the basin. Some of the important routes are Tiruchchirappalli-Dindigul-Madurai-Dhanushkodi line, Tiruchchirappalli-Karaikkudi-Manamadurai line, Madurai-Tuticorin line and Madurai-Tenkasi-Tirunelveli-Tirucchendur line. The National Highways connecting Kanniyakumari with Varanasi, Ramanathapuram with Madurai and Dindigul with Madras pass through the basin. In addition, there is a close network of State Highways and district roads in the basin. There is no navigation on any of the rivers or canal systems in the basin. The basin is well served with communications except in parts of Ramanathapuram district where the facilities are not adequate.

Dependence on Rainfall and Water Resources

11.16 The economy of the basin at present largely depends on agriculture, which, in view of the uneven incidence of the rainfall, provides a low level of subsistence except in parts of the basin where irrigation facilities have been provided and industries have developed. There is a keen demand for the development of the water resources in the basin.

WATER RESOURCES

Surface Waters

11.17 In 1949, when the basin-wise assessment of the water resources of the country was made on the basis of Khosla's formula, the annual runoff of the basin of the east-flowing rivers between the Cauvery and Kanniyakumari was estimated at 7,870 m. cu. m.*

In 1960, the Central Water & Power Commission, while conducting the irrigation potential studies, assessed the total annual runoff of the basin at 9,522 m. cu. m.** based on available observed data and Strange's rainfall runoff co-efficients.

The very first site where gauge and discharge observations were conducted in the basin is at the Srivaikuntam anicut across the Tambraparni. The data is available for this site from 1885. Subsequently, a number of other discharge sites were established on the various river systems in the basin. The details of the gauge and discharge sites established in the basin as furnished by the Tamil Nadu State Government are given in Table 11.3.†

It will be observed from this table that the discharge observations are being made only in the Vaigai and Tambraparni basins mostly at anicut/dam sites. The discharges over the anicuts are calculated for different flow conditions like free overflow, submerged etc. Many of the other rivers in the basin do not have any gauge and discharge sites on them. It is desirable to have at least one gauge and discharge site on each river, at a suitable place, so that the water resources available can be properly assessed on the basis of observed data.

11.18 The Central Water & Power Commission, under the programme of establishing and maintenance of centrally sponsored key hydrological stations in the country, has proposed the establishment of a gauge and dis-

*An appraisal of water resources by Dr. A. N. Khosla, UNESCO.

**Report of technological possibilities of irrigation projects in India, Central Water and Power Commission (unpublished).

†Replies of Tamil Nadu to the questionnaire issued by the Irrigation Commission.

Table 11.3

Gauge and Discharge Sites in the Basin

Sl. No.	Name of river	Discharge site	Year from which discharge observations are made
1.	2	3	4
1.	Tambraparni	Srivaikuntam anicut	1885
2.	Vaigai	Peranai regulator	1899
3.	Vaigai	Vaigai reservoir	1958
4.	Manimuthar	Manimuthar reservoir	1958

charge site across the Vaigai near Paramagudi. They have also recommended that the discharge site on the Tambraparni, 32 km. above its confluence with the sea, may be maintained by the Tamil Nadu Government.

According to the data supplied by the Tamil Nadu Government, the observed average annual flows from the various rivers at different sites are shown in Table 11.4. The data indicates the flow measured at the respective points on the rivers and are not to be taken as the total resources of the rivers.

Ground Water

11.19 Systematic investigations and studies of the ground water potential of the basin have not been made so far. Only in some parts of the basin, have some investigations and studies been done recently.*

In Madurai and Tiruchchirappalli districts, the area is underlain chiefly by granites and charnockites. Investigations have shown that by deepening existing open wells down to 18 m. or so in the weathered and jointed rocks, the yields of wells could be increased.

Investigations conducted in the Sattur, Devakottai, Sivaganga, Ilayangudi, Paramagudi and Tirupattanam taluks of Ramanathapuram district have indicated that there is great scope for the development of ground water by means of tubewells in the alluvial sediments, especially in Paramagudi and Ilayangudi taluks. Limited development of ground water in Devakottai and Karaikudi taluks by tubewells tapping the confined zones in the Gondavana sediments is possible.

*Ground water Resources of India, status and surveys, prospects and perspectives, Geological Survey of India (August, 1970).

Table 11.4

Average Annual Runoff in Various Rivers at Different Sites

Sl. No.	Name of river	Site	Catchment area in sq. km.	Normal rainfall in mm.	Average annual flow in m.cu.m.	Remarks
1	2	3	4	5	6	7
1.	Vaigai	Vaigai reservoir	2,253	99.6	911	Average struck from 1959-60 to 1967-68.
2.	-do-	Peranai regulator	3,600	99.6	1102	Average struck from 1928-29 to 1959-60 except 1939-40 and 1952-53.
3.	Tambraparni	Srivaikuntam	4,504	70.1	821	Average struck from 1931-32 to 1962-63 except 1940-41 and 1945-46.
4.	Manimuthar in Tambraparni basin	Manimuthar reservoir	162	410.3	255	Average struck from 1958-59 to 1968-69.

The investigations in Sankaranainarkoil and Nanguneri taluks of Tirunelveli district have indicated that the ground water resources are poor on account of the poor water-bearing capacity and rates of percolation of the weathered gneisses and jointed massive rocks. Only a limited development of ground water by open wells is possible. In Srivaikuntam taluk, investigations have indicated that small quantities of potable water are available for domestic purposes in the north-western part of the area. Scarcity of water exists even for drinking in north, north-west and eastern parts, ground water being brackish due to the black cotton soil. The area is underlain by crystalline rocks in the western part and covered by late tertiary, sub-recent and recent sediments in the east. Possibilities of developing large supplies of fresh water are not promising.

The investigations carried out so far point to the urgency and importance of carrying out further systematic exploratory work in the basin for a scientific, qualitative and quantitative assessment of the ground water resources. Such an assessment, which will help in framing a rational plan of development for various needs can only be made when full investigations are carried out.

EXISTING DEVELOPMENT

11.20 Irrigation has been practised in the basin from historical times and a number of projects have been constructed in the basin. These are describing in the following paragraphs:

Marudur Anicut System

In the Tambraparni basin, this is the last anicut of the pre-British period and by far the largest. In shape, it is a curious irregular horse-shoe about 1.2 km. in length. Two channels take off from above the anicut, one on the left side, called the Kilakkal channel and the other on the right side called the Melakkal channel. The anicut was constructed at a cost of Rs. 0.06 million for irrigating an area of 8,480 hectares in Tirunelveli district.

Srivaikuntam Anicut System

It is the last anicut across the river Tambraparni and was built by the British in 1873. The anicut is 421 m. long. Two channels take off from it. On the left is the North Main Channel feeding a series of tanks and finally emptying into the Koramballam tank. On the right side, the South Main Channel takes off and supplies the large Kadamba tank and a series of tanks below it. Irrigation under this channel extends as far as Tiru-chendur in the south. The system irrigates about 10,500 hectares in Tirunelveli district. The capital expenditure on the system was Rs. 1.66 million.

Periyar System

The main feature of this system is the diversion of a part of the west-flowing catchment to the east. A large dam, with a live storage capacity of 278 m. cu. m. has been constructed across an inaccessible gorge in the erstwhile Travancore State (about 878 m. above sea-level). The dam is of stone in lime surki mortar with masonry facing on the lake side. Its height is about 52 m. above the river bed at the deepest point. A tunnel 1,737 m. long has been bored through the watershed on the east to carry the waters of the lake to the plains of Madurai. The water flows into the Suruliyar, a tributary of the Vaigai. After irrigating about 5,665 hectares in the Suruliyar basin, the water is again picked up at the Peranai regu-lator, across the Vaigai, about 129 km. downstream of the tunnel. From here, it is diverted into the Periyar main canal along the left side of the river. The canal is about 56 km. long and irrigates about 52,035 hectares in Madurai district. The project was constructed in 1897 at a cost of Rs. 10.84 million.

11.21 The First Irrigation Commission had not recommended any specific projects by name, to be taken up for construction in the basin.*

11.22 During the plan periods a number of projects have been taken up for construction in the basin. These are described briefly in the following paragraphs:

Manimuthar Project

A reservoir of 156 m. cu. m. capacity has been built across the Manimuthar, a tributary of the Tambraparni.† The project is designed not only to stabilise supplies for 33,586 hectares of the existing ayacut under the several Tambraparni channels, but also to supply 8,094 hectares in Tirunelveli district under 313 precariously rain-fed tanks which do not get adequate supply due to the poor and ill-distributed rainfall. The expenditure on the project which was completed in 1958, was Rs. 50.50 million.

Vaigai Reservoir Project

Under this project, a dam has been constructed across the river Vaigai near Andipatti village in Madurai district. The reservoir is designed to store the surplus waters of the Periyar and Vaigai rivers. The capacity of the reservoir is 193 m. cu. m. The total irrigation by this project is 8,830 hectares. The project was completed in 1959 at a cost of Rs. 33.00 million.

Gatana Reservoir Project

The scheme provides for a storage reservoir on the Gatananadi, a tributary of the Tambraparni river, 3.2 km. from Sambankulam village in Ambasamudram taluk of Tirunelveli district. The project costing Rs. 20.00 million will irrigate an area of 3,290 hectares in the Tirunelveli district. The project was started in 1966–67 and is likely to be completed during the Fourth Plan.

*Report of the Indian Irrigation Commission (1901-03).

†Administration Report of the Public Works Department in the Madras State for the year 1963-64, Government of Madras (now Tamil Nadu), 1968.

Ramanadhi Project

The project, costing Rs. 11.5 million, envisages the construction of (i) an earthen dam 788 m. long across the Ramanadhi, a sub-tributary of the Tambraparni, near Malakadayam village in Tirunelveli district, (ii) an anicut across Thankal branch of the river about 0.6 km. below the dam, and (iii) a 2.2 km. long canal taking off from the anicut. The project will provide irrigation to an area of 1,420 hectares. The project was started in 1967 and is likely to be completed during the Fourth Plan.

Modernising Vaigai Channels

The project provides for two regulators across the Vaigai, one at Virahanur and the other at Parthibanur with common channels on either side of them to feed several existing tanks and channels for stabilising 38,802 hectares of existing irrigation and also to bridge the gap of 5,625 hectares. The cost of the project is estimated at Rs. 39.40 million. The project was started in 1968–69 and is expected to be completed during the Fourth Plan.

11.23 Some particulars of the major and medium projects under operation and construction in the basin are given in Appendix 11.1 and 11.2.

11.24 Besides the major and medium projects, a number of minor schemes comprising tanks and wells, irrigate a very large area in the basin. In many villages, there are more tanks than one which irrigate the adjoining agricultural land. The details of the area irrigated by various sources like canals, tanks, wells etc. during the year 1967–68, in the basin, are shown in Table 11.5.
By the end of the Annual Plan (1968–69) the area under minor schemes increased by about 19,650 hectares.

11.25 In the absence of data, regarding the annual diversions and utilisations by the major and medium projects under operation and construction in the basin at the end of Annual Plan 1968–69 the utilisation by such projects on their completion and full development has been approximately estimated to be of the order of 1,467 m. cu. m. by the Commission.

As regards the statistics of the large number of minor schemes comprising tanks, wells and other diversions, no information is available. Based on the area irrigated from these sources and on rough duties, the approximate estimate of the quantity of water diverted for irrigation by these works has been made.

Table 11.5

Source-wise Irrigation in the Basin (1967–68)

Sl. No.	Source of irrigation	Area irrigated in thousand hectares
1.	Canals	115.9
2.	Tanks	361.4
3.	Tubewells	0.3
4.	Wells	152.3
5.	Other sources	7.7
	Total	637.6

The approximate annual diversion by the minor schemes under operation and construction at the end of Annual Plan 1968–69 may be of the order of 4,124 m. cu. m. on their completion and full development.

Reservoir Losses

11.26 In the absence of data on the reservoir losses for the major and medium schemes in the basin, an approximate estimate of the losses has been made by the Commission, assuming that this would be of the order of 20% of the annual diversions by these projects. On this basis, the reservoir losses work out to approximately 293 m. cu. m.

For minor schemes, in the absence of observed statistics, it is extremely difficult to estimate the losses. Assuming that the water spread of a tank to be about 87.5% of the area irrigated from it, as estimated for the Krishna and Godavari basins, and that the total loss is of the order of 1.49 m. over the water surface area, the total reservoir losses from the tanks in the basin would work out approximately 4,880 m. cu. m.

11.27 Thus, on their completion and full development the major, medium and minor projects under operation and construction in the basin at the end of Annual Plan 1968–69 would use 10,764 m. cu. m., of which 9,558 m. cu. m. would be from the surface water and the balance 1,206 m. cu. m. from the ground water.

11.28 There are a number of major industries located in the basin, especially round about Madurai. The data on the present industrial water needs are not readily available. In the future, such needs are expected to grow. The problem of water pollution in the basin due to discharge of industrial waste has not been reported so far. However, the problem may arise in the future, and will have to be guarded against.

FUTURE DEVELOPMENT

11.29 Five medium projects are proposed to be taken up for construction in the basin in the Fourth Five Year Plan period. These projects are listed in Appendix 11.3. The details of the projects available are given in the following paragraphs:

Improvement to Periyar Channels

The project, located in the Madurai district, will provide irrigation to an area of 8,700 hectares in the Vaigai basin. The cost of the project is estimated at Rs. 42.50 million.

Marudhanadi Scheme

This project is also located in the Madurai district. An area of 940 hectares will be provided with irrigation in Vaigai basin under this project, which is expected to cost Rs. 6.20 million.

Karuppanadi Scheme

The project costing Rs. 14.00 million will provide irrigation to an area of 1,160 hectares in the Tambraparni basin in Tirunelveli district.

Anicut Across Vaippar at Athankarai

The project envisages an anicut across the Vaippar river at Athankarai. The project costing Rs. 2.30 million will provide irrigation to an area of 420 hectares in the Tirunelveli district.

Pilavaikkal Scheme

Located in the Vaippar basin, the Pilavaikkal project will provide irrigation in an area of 1,070 hectares in Ramanathapuram district. The project will cost Rs. 7.60 million.

On completion and full development, the above projects will utilise about 157 m. cu. m. of waters, including the reservoir losses.

During the Fourth Plan, the area under minor schemes is expected to increase by about 134,600 hectares, requiring nearly 2,240 m. cu. m. of water, including reservoir losses.

Thus, the additional utilisations by the Fourth Plan major, medium and minor projects on their completion and full development would be of the order of 2,397 m. cu. m. benefiting an area of 146,890 hectares. On completion and full development of Fourth Plan projects, about 13,161 m. cu. m. of the waters in the basin would have been used for irrigating a total area of 825,765 hectares. Of this 11,655 m. cu. m. will be surface water and the balance 1,506 m. cu. m. ground water.

The Tamil Nadu State Government has not indicated any new project to be undertaken in the basin in the future.

FLOODS, WATERLOGGING & DRAINAGE

11.30 The occurrence of heavy floods is not a regular feature in the basin. There are, however, occasions when floods do occur and cause some damage to life and property. These floods are beneficial in certain areas as they provide the necessary moisture for raising crops and keeping down the salts. Large-scale flood control measures neither exist nor are necessary to be undertaken in the basin.

Floods in the rivers of the basin are rare, sudden and short-lived.

The highest floods in the Vaigai generally occur in May or November. Between May and September, the river generally carries from 0.3 to 4.2 cumecs. The maximum observed flood in the Vaigai was 958 cumecs. on the 8th November, 1884 at Peranai.*

Waterlogging & Drainage

11.31 So far, waterlogging has not been reported in the irrigated areas in the basin. The coastal region is, however, likely to be affected by salinity and drainage problems for which necessary measures may have to be undertaken.

SOIL CONSERVATION

11.32 The basin has hardly 8.79% of the area under forests. This percentage is low when compared with the all-India average and the standards laid down in the 1952 Forest Policy Resolution of the Govern-

*Descriptive booklet on the important irrigation projects in Madras State, Part I, Government of Madras (now Tamil Nadu), 1955.

ment. Afforestation in the catchment is called for to reduce the erosion hazards.

The soil and moisture conservation works in river valley project areas are being carried out by the Tamil Nadu Forest Department. The following works have been undertaken by the State Forest Department in the Vaigai catchment:

(1) Planting in village grazing grounds.
(2) Planting in degraded shoals.
(3) Raising grass farms.
(4) Growing of fodder banks.
(5) Pasture development.
(6) Planting on stream banks.
(7) Road-side planting.
(8) Reclamation of swamps.
(9) Bench terracing.
(10) Contour bunding.
(11) Contour trenching, and
(12) Construction of check dams, retaining walls etc.

The Vaigai catchment has been divided into 15 sub-catchments for executing soil conservation works. Under the Fourth Plan, the State Government has proposed to cover an area of 5,000 hectares in the Vaigai catchment by soil and moisture conservation works at a cost of Rs. 3 million.*

11.33 No data is available regarding the silting of the existing tanks and reservoirs in the basin. For the conservation of river supplies and especially of the storage capacities created in the reservoirs, it is important that soil conservation measures are undertaken in the basin.

No scheme in the basin has been included under the centrally sponsored programme of soil conservation in catchments of major river valley projects.

GENERAL

11.34 A number of major and medium projects have already been constructed on the various river systems in the basin. Three medium projects are under construction. Five medium projects are proposed to be taken up during the Fourth Five Year Plan. In addition, there are many minor schemes and more are under construction. A rough assess-

*Replies of Tamil Nadu to the Questionnaire issued by the Irrigation Commission.

ment of the utilisation by the above schemes indicates that on completion and full development of the Fourth Plan major, medium and minor schemes, most of the resources available in the rivers would have been utilised. To plan the future development of the basin, it is, therefore, essential to make a fresh assessment of the water resources of the basin and determine the extent of surplus waters that are still available for utilisation by the future projects. After the above assessment is made, new projects for the utilisation of the surplus waters may be taken up in the basin.

11.35 A network of evaporation measuring stations in the basin, particularly at the sites of existing and proposed reservoirs needs to be established.

11.36 Gauge and discharge observations at the various sites should be continued on a permanent basis, to obtain data essential not only for the preparation of individual projects but also for the regulation, of available river water in any year. Ungauged rivers should also be gauged continuously and systematically.

11.37 Systematic and scientific exploratory work is needed for a quantitative and qualitative assessment of the ground water resources in the basin, so that these resources can be exploited in a rational way, either independently or in conjunction with the surface waters.

11.38 There is need for carrying out soil conservation measures and conserving the storage capacities of existing and proposed reservoirs in the basin.

11.39 It is necessary that systematic data is collected with regard to the sediment carried by the river waters, which would be of considerable use in working out dead storage and life of reservoirs. It will also reflect the effect of soil conservation works carried out in the basin.

APPENDIX 1.1

Monthly and Annual Normals of Rainfall of East-flowing River Basins Between the Ganga and the Baitarani

Sl. No.	State/ District	Monthwise Normal Rainfall in mm.												Normal Annual Rainfall in mm
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Bihar													
1.	Ranchi	27.1	41.0	24.0	19.5	45.4	205.8	395.5	386.6	220.9	92.3	18.9	5.6	1482.6
2.	Singhbhum	20.6	33.4	21.8	28.8	72.2	212.0	379.8	352.0	210.0	81.1	18.6	4.3	1434.6
3.	Hazaribagh	22.6	30.3	17.7	13.9	37.3	170.5	330.9	333.8	206.5	75.4	14.9	4.3	1258.1
	Orissa													
4.	Balasore	17.1	30.6	34.3	53.1	105.1	218.2	332.6	313.8	243.1	171.0	42.3	7.2	1568.4
5.	Mayurbhanj	21.9	35.5	29.8	47.3	96.7	235.2	426.4	375.5	232.3	113.6	27.4	6.6	1648.2
	West Bengal													
6.	Midnapur	13.3	30.5	33.1	45.0	113.2	260.0	333.2	328.3	216.2	134.3	28.8	2.6	1538.5
7.	Purulia	18.9	29.5	21.7	24.1	61.3	218.8	346.6	333.6	203.6	85.8	15.8	3.4	1363.1

Source : Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX 1.2

Salient Features of Existing Major and Medium Projects in the Basin of the East-flowing Rivers Between the Ganga and the Baitarani

Sl. No.	Name of the Project	Zone/District	Cost/Total Expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion	Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7	8	9	10	11
Orissa										
1.	Baldiha	Mayurbhanj	3.09	Palpala Nala	1912	Flow	7.00	3.69	3.69	
2.	Haldia	-do-	4.00	Chipat Nala	1912	Storage	4.07	2.43	3.64	
Bihar										
3.	Torlow	Singhbhum	1.62	Torlow	1962-63	Flow	4.05	2.67	2.20	

Source : (1) Irrigation Statistics of India (1960-61), Central Water & Power Commission.
(2) Note Volume of Irrigation Chapter for Bihar, Central Water & Power Commission (1969)—Unpublished.
(3) Replies of Orissa to the questionnaire issued by the Irrigation Commission.

APPENDIX

Salient Features of Major and Medium Projects Under Construction

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of con-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
Bihar					
1.	Roro	Singhbhum	Construction of 73 m long, 5.93 m high cement concrete weir across the Roro river, a tributary of the Kharkai and a canal system on the left bank	1957	Headwork completed. Work on the canal system is in progress
2.	Kanchi Weir	Ranchi	Construction of a 229 m long, 1.98 m high diversion weir across the Kanchi river, a tributary of the Subarnarekha and a canal system on either bank	1958	Headworks completed. Work on the canal system is in progress
3.	Sona Weir	Singhbhum	Construction of a diversion weir across the river Sona in the Subarnarekha basin near village Korkate and canal system on the right bank	1962	Headworks completed. Work on the canal system is in progress
4.	Kokro	Ranchi	Construction of a weir across the river Kokro in the Subarnarekha basin about 1.6 km north-west of villages Fulwer and Behra and canal system on the right bank	1962	Headworks completed. Work on the canal system is in progress

1.3

in the Basin of East-flowing Rivers Between the Ganga and the Baitarani

struction	Cost					
Date of likely completion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate Irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
V Plan	13.61	11.07 (Up to Mar. '69)	20.23	11.33	10.93	
V Plan	15.21	13.31 (Up to Mar. '69)	34.20	17.10	18.21	
IV Plan	6.33	5.60 (Up to Mar. '69)	N.A.	N.A.	6.52	
V Plan	3.50	2.84 (Up to Mar. '69)	N.A.	N.A.	3.84	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of con-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
5.	Bijoy	Singhbhum	Construction of a weir across the river Bijoy in the Subarnarekha basin near village Subansari and canal system on the right bank	1962	Headworks completed. Work on the canal system is in progress
6.	Subarnarekha Multipurpose Project	Ranchi	Construction of a 2270.70 m long, 35.4 m high composite dam across the river Subarnarekha at Getalsud, 30 km from Ranchi City	1965-66	Dam has been completed. Work on construction of the powerhouse is in progress

Source: (1) Irrigation Statistics of India (1960-61), Central Water & Power Com-
(2) Note Volume of Irrigation Chapter for Bihar (1969), Central Water &
(3) India, Irrigation & Power Projects (Five Year Plans), April, 1970,

1.3—*Contd.*

struction	Cost		G.C.A.	C.C.A.	Ultimate	Remarks
Date of likely comple-tion	Total cost (Rs. million)	Expenditure incurred (Rs. million)	('000 hectares)	('000 hectares)	irrigation ('000 hectares)	
7	8	9	10	11	12	13
IV Plan	3.33	3.15 (Up to Mar. '69)	N.A.	N.A.	2.02	
First Unit in IV Plan Second Unit in V Plan	129.00	N.A.	—	—	—	The project has power & water supply benefits

mission.
Power Commission—Unpublished.
Central Water & Power Commission.

APPENDIX 1.4

Salient Features of New Major and Medium Projects Proposed by the State Governments in the Basin of the East-Flowing Rivers Between the Ganga and the Baitarani

Sl. No.	Name of the Project	Zone/ District	Source of supply (Name of river)	Estimated Cost (Rs. million)	Ultimate Irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7
Orissa						
1.	Burhabalang	Mayurbhanj	Burhabalang	110.00	34.20	
2.	Burhabalang-Subarnarekha	-do-	Burhabalang and Subarnarekha	1,450.00	360.00	

Source: Replies of Orissa to the Questionnaire issued by the Irrigation Commission.

APPENDIX 2.1

Monthly and Annual Normals of Rainfall of the Brahmani-Baitarani Basin

Sl. No.	State/ District	Monthwise Normal Rainfall in mm												Annual Normal Rainfall in mm
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Bihar													
1.	Ranchi	27.1	41.0	24.0	19.5	45.4	205.8	395.5	386.6	220.9	92.3	18.9	5.6	1,482.6
2.	Singhbhum	20.6	33.4	21.8	28.8	72.2	212.0	379.8	352.0	210.0	81.1	18.6	4.3	1,434.6
	Madhya Pradesh													
3.	Raigarh	20.1	33.3	21.5	17.1	27.3	230.9	487.5	455.3	239.5	66.5	15.8	4.9	1,619.7
	Orissa													
4.	Balasore	17.1	30.6	34.3	53.1	105.1	218.2	332.6	313.8	243.1	171.0	42.3	7.2	1,568.4
5.	Cuttack	13.7	27.5	20.8	34.2	86.5	222.3	351.8	315.8	229.2	147.4	46.7	5.4	1,501.3
6.	Dhenkanal	15.5	30.8	18.7	28.8	59.5	208.9	382.0	333.0	220.6	93.6	25.2	4.5	1,421.1
7.	Keonjhar	22.2	38.0	23.0	43.3	88.9	209.5	391.8	335.3	233.0	112.7	31.7	5.1	1,534.5
8.	Mayurbhanj	21.9	35.5	29.8	47.3	96.7	235.2	426.4	375.5	232.3	113.6	27.4	6.6	1,648.2
9.	Sambalpur	14.3	24.4	16.4	17.6	30.9	218.7	469.6	430.9	224.3	61.6	14.7	3.6	1,527.0
10.	Sundargarh	19.9	36.7	19.3	20.1	41.1	250.9	480.2	458.2	223.9	75.9	16.1	5.3	1,647.6

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX

Salient Features of Existing Major and Medium

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion	Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)
1	2	3	4	5	6	7	8
Orissa							
1.	Orissa Canal System	Cuttack and Balasore	27.19	Mahanadi, Birupa, Brahmani and Baitarani	1868	Flow	239.09

Source: (1) Replies of the Orissa State to the Questionnaire issued by the Irrigation Commission.

(2) Note Volume of Irrigation Chapter, Orissa State, 1970, Central Water & Power Commission—(Unpublished).

2.2

Projects in the Brahmani-Baitarani Basin

C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal & branches	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
9	10	11	12	13	14
109.31	114.17*	441.40	One seasonal	Kharif crops	*Of this, about 53,900 hectares lie in the Brahmani-Baitarani basin

APPENDIX

Salient Features of Major and Medium Projects Under

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of con-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
Orissa					
1.	Salandi	Balasore	Construction of a composite dam 818 m long, 51.8 m high across the Salandi at Hadgarh and a 204.3 m long barrage about 5.6 km downstream of the dam at Bidyadharpur with a 80.5 km long canal taking off from the head regulator on the left flank of the barrage.	1960	The project is nearing completion
2.	Derjang	Dhenkanal	Construction of an earth dam of maximum height 27 m across the rivers Hingra and Matalia about 9.7 km from Angul town and a canal taking off on the left flank.	1960	The earth dam is completed. Spillway is completed up to R.L. 472. Canal system is also in progress.
3.	Pitamahal	Sundargarh	Construction of an earth dam of maximum height 9.7 m across the Pitamahal river and two canals taking off from the reservoir.	1968	The work of this project has been started recently.

Sources: (1) Note Volume of Irrigation Chapter, Orissa, March, 1970, Central Water & Power Commission—(Unpublished).

(2) Orissa State Replies to Questionnaire issued by the Irrigation Commission.

2.3

Construction in the Brahmani-Baitarani basin

struction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely completion	Total cost (Rs. million)	Expenditure incurred (Rs. million)				
7	8	9	10	11	12	13
IV Plan	130.77	137.16 (Dec. '69)	67.40	45.73	61.92	
IV Plan	37.24	32.88 (Mar. '69)	7.29	6.48	9.71	
IV Plan	8.30	0.19 (Mar. '69)	4.07	3.24	4.86	

APPENDIX 2.4

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission in the Brahmani-Baitarani Basin

Sl. No.	Name of Project	Zone/ District	Source of supply (Name of river)	Estimated cost (Rs. million)	Type (Flow/ Storage/ Lift)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7	8	9
Orissa								
1.	Anandpur Barrage	Keonjhar	Baitarani	214.90	Flow	110.60	158.62	

Source: (1) Fourth Five Year Plan 1969-74 and Annual Plan 1969-70 'Reports of the Working Group on Irrigation and Flood Control.'
(2) Replies of the Orissa State to the Questionnaire issued by the Irrigation Commission.

APPENDIX 2.5

Salient Features of New Major and Medium Projects Proposed by the State Governments in the Brahmani-Baitarani Basin

Sl. No.	Name of Project	Zone/ District	Source of Supply (Name of River)	Estimated Cost in Rs. million	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7
Orissa						
1.	Bhimkund Multi-purpose Project	Keonjhar	Baitarani	800.00	32.00	
2.	Kusai	-do-	Kusai River, tributary of Baitarani	20.00	12.95	
3.	Upper Baitarani Multipurpose Project	-do-	Baitarani	194.30	84.05	
4.	Aunli	Dhenkanal	Aunli River, tributary of Brahmani	4.80	3.80	
5.	Dadaraghati	-do-	Gambharia Jore, tributary of Brahmani	23.30	4.01	
6.	Mankara	-do-	Mankara, tributary of Brahmani	12.00	4.02	
7.	Tikra	-do-	Tikra River, tributary of Brahmani	150.00	69.00	
8.	Extension of Distributary 2 of Jaipur Canal	Cuttack	Baitarani	N.A.	8.45	
9.	Kansbahal	Sundargarh	Badjore, tributary of Sankh	7.5	5.18	
10.	Lodani	-do-	Brahmani	101.00	86.58	
11.	Upper Brahmani (Barkot)	Sundargarh Sambalpur	-do-	300.90	242.70	

Source: Replies of the Orissa State to the Questionnaire issued by the Irrigation Commission.

APPENDIX 3.1

35 Years Runoff Series at G.D. Sites on the Main Stream of Mahanadi

(All values unless otherwise specified are in m.cu.m.)

Sl. No.	Year	Saradih (C.A. 61, 626 Sq. km)	Sambalpur (C.A. 84, 245 Sq. km)	Sonepur (C.A. 116, 961 Sq. km)	Baramul (C.A. 125, 918 Sq. km)	Kaimundi (C.A. 131, 696 Sq.km)
1	2	3	4	5	6	7
1.	1930-31	24,231	34,772	44,860	48,512	48,972
2.	1931-32	29,208	41,427	48,396	52,164	53,554
3.	1932-33	29,739	41,405	51,811	57,314	58,505
4.	1933-34	36,268	53,538	69,072	80,917	84,731
5.	1934-35	37,222	54,608	69,250	78,614	81,051
6.	1935-36	26,422	37,746	45,721	49,638	49,975
7.	1936-37	43,405	63,616	81,668	96,461	97,609
8.	1937-38	37,316	53,752	64,675	72,953	74,461
9.	1938-39	35,610	49,943	58,109	63,262	64,761
10.	1939-40	33,937	50,713	66,220	77,655	80,014
11.	1940-41	32,605	45,150	64,868	65,871	66,600
12.	1941-42	14,604	24,629	33,838	36,748	37,532
13.	1942-43	34,624	48,488	59,298	66,813	67,972
14.	1943-44	36,049	53,987	65,893	75,192	77,204
15.	1944-45	37,176	53,731	67,616	77,623	80,479
16.	1945-46	31,869	47,054	59,506	65,373	66,935
17.	1946-47	33,012	53,003	61,704	68,860	71,975
18.	1947-48	35,595	50,457	49,682	66,611	68,440
19.	1948-49	30,601	42,946	51,098	55,011	56,130
20.	1949-50	33,231	49,280	610,21	68,444	70,347
21.	1950-51	24,058	43,925*	45,959	55,867*	58,061*
22.	1951-52	23,745	31,377*	40,968	43,638*	46,902*
23.	1952-53	26,485	53,498*	53,891	71,951*	66,968*
24.	1953-54	28,942	49,345*	53,297	62,560*	59,493*
25.	1954-55	23,166	29,365*	40,463	35,768*	35,827*
26.	1955-56	35,970	46,268*	62,209	61,662*	58,272*
27.	1956-57	36,581	48,654*	68,300	69,719*	66,307*
28.	1957-58	24,691*	28,206*	37,861*	39,827*	40,127*
29.	1958-59	35,534*	43,851*	64,936*	69,757*	76,685*
30.	1959-60	35,071*	46,217*	60,800*	70,550*	72,007*
31.	1960-61	26,481*	41,936*	56,566*	60,327*	67,599*
32.	1961-62	58,569*	87,781*	102,651*	119,451*	140,216*
33.	1962-63	16,572*	21,697*	36,095*	40,538*	42,586*
34.	1963-64	28,655*	38,674*	53,288*	61,707*	64,679*
35.	1964-65	43,012*	57,469*	68,913*	79,229*	79,452*

N.B.—All values marked with asterisks (*) are observed (Historical) Runoff.

Source: Surface water studies of Mahanadi Basin by S.W.R., Directorate of C.W. & P.C. (Unpublished).

APPENDIX

Salient Features of Existing Major and

Sl. No.	Name of Project	Zone/ District	Cost/ Total expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion
1	2	3	4	5	6
Madhya Pradesh					
1.	Pindraon Tank	Raipur	0.233	Tribuatry of Kharum	1905
2.	Maroda Tank	Durg	0.378	Bhananda Nalla	1909
3.	Khapri Tank	-do-	0.248	Dhobe Nalla	1921
4.	Tandula Tank	-do-	11.100	Tandula	1921
5.	Mahanadi canal, Murramsilli reservoir	Raipur	15.659	Silari Nalla	1923
6.	Kumhari Tank	-do-	0.653	Tributary of Sheonath	1927
7.	Maniari Tank	Bilaspur	6.235	Maniari	1930
8.	Kharung Tank	-do-	6.563	Kharung	1931
9.	Gondli	Durg	6.995	Jujhara Nalla	1948
10.	Saroda	-do-	16.673	Utani Nalla	1965
11.	Development of Maniari Tank	Bilaspur	3.705	Maniari	1967
12.	Kedar Nalla	Raigarh	8.472	Kedar Nalla	1968
13.	Keswa Nalla	Raipur	5.992	Keswa Nalla	1969
14.	Remodelling of Mahanadi canal system	Raipur	28.269	Mahanadi	1966
Orissa					
15.	Mahanadi delta Irrigation Scheme—				
	(*i*) Jobra Weir	Cuttack	1.01	Mahanadi	1877
	(*ii*) Birupa Weir	-do-	0.226	-do-	1869
16.	Hirakud	Sambalpur—			
		Stage I	678.1	Mahanadi	1957
		Stage II	149.5		

Source: (*i*) Irrigation Statistics of India (1960-61), Central Water & Power Commission.
(*ii*) Note Volumes of Irrigation Chapters for Madhya Pradesh and Orissa (March, 1970)—Central Water & Power Commission (Unpublished).

3.2

Medium Projects in the Mahanadi Basin

Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal & branches	Whether perennial, two seasonal or one seasonal	Cropping pattern
7	8	9	10	11	12	13
Storage	4.10	3.79	2.59	N.A.	N.A.	N.A.
-do-	N.A.	0.63	0.42	N.A.	N.A.	N.A.
-do-	7.10	5.70	4.25	N.A.	N.A.	N.A.
-do-	272.63	246.45	67.00	110.69	One seasonal	Rice
Flow-cum-storage	225.41	170.37	85.00	193.10	Two seasonal	Rice and other rabi crops
Storage	8.43	5.41	2.63	N.A.	N.A.	N.A.
-do-	65.50	51.15	30.35	7.88	Two seasonal	Rice and other rabi crops
-do-	67.55	50.15	37.95	109.25	-do-	,,
-do-	2.91	2.45	3.08	28.50	N.A.	N.A.
-do-	12.55	11.36	7.35	39.30	One seasonal	Rice
-do-	78.80	64.74	9.71	N.A.	N.A.	N.A.
-do-	5.53	5.12	4.65	2.00	Two seasonal	Kharif & rabi crops
-do-	4.55	3.30	3.84	28.00	One seasonal	Rice
Flow-cum-storage	225.41	170.37	56.66	309.46	-do-	,,
Flow	238.8	N.A.	82.254	441.40	N.A.	N.A.
Storage	260.21	153.78	253.75	147.25	Perennial	Sugarcane, rice, wheat, barley, gram, pulses & other rabi crops

(*iii*) India—Irrigation & Power Projects (Five Year Plans)—Central Water & Power Commission, April, 1970.

(*iv*) Replies of Madhya Pradesh and Orissa States to the Questionnaire issued by the Irrigation Commission.

APPENDIX

Salient Features of Major and Medium Projects

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of con-	
				Date of commencement	Important items of work completed
1	2	3	4	5	6
Madhya Pradesh					
1.	Dudhwa	Raipur	Construction of a dam across the river Mahanadi and remodelling of Mahanadi canal system (which is included as a separate project in Second Five Year Plan). The project aims at enlarging the scope of existing Mahanadi canal system	1955	Headworks completed. Work on waste weir and the raising of Kankar Dudhwa road including Nala crossing is in progress
2.	Hasdeo	Bilaspur	Construction of a 283.77 m long masonry barrage across the river Hasdeo, a tributary of the Mahanadi	1961	Work is completed except for some small items like extension and raising of divide wall etc.
3.	Hasdeo Right Bank Canal	,,	Construction of a canal system ex-Hasdeo barrage for irrigating areas on the right bank	1967	So far no targets have been fixed for taking up the works—work is likely to be taken up soon
Orissa					
4.	Mahanadi Delta Irrigation Project (Mundali Weir)	Cuttack	Construction of a concrete weir 1353 m long across the river Mahanadi at Mundali & remodelling of the existing Mahanadi Delta System	1955	Headworks nearly completed. Work on canal system is in progress

3.3

Under Construction in the Mahanadi Basin

struction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely comple-tion	Total cost (Rs. million)	Expenditure incurred (Rs. million)				
7	8	9	10	11	12	13
1973	33.36	31.33 (Up to Mar. '69)	225.37	170.37	56.66	
IV Plan	98.60	98.60 (Up to Mar. '70)	—	—	—	The project will supply cooling water to Korba Thermal Power Station
1974	49.72	11.35 (Up to Mar. '70)	N.A.	N.A.	47.46	
IV Plan	683.81	303.54 (Up to Sept. '69)	N.A.	389.81	680.71	

Appendix

1	2	3	4	5	6
5. Salki		Phulbani	Construction of a masonry anicut across the river Salki, a tributary of the Mahanadi near Paljhar & two canals, one on either bank	1958	Headworks completed. Work on canal system is in progress
6. Budhabudiani		Puri	Construction of an earthen dam 1308 m long and 22 m high across river Dilant, a tributary of river Kusumi and canal system	1961	The project is nearing completion
7. Uttei		Kalahandi	Construction of a 53.3 m long diversion weir across the river Uttei, a tributary of Tel river, near village Ambagaon and a canal on the right bank	1968	The work is in initial stages of construction
8. Dahuka		Puri	Construction of a concrete diversion weir, 152.4 m long across the river Dahuka, a tributary to the river Kusumi, near village Padamapur and two canals one on either bank	—	The work on the project has not been taken up physically

Source: (*i*) Irrigation Statistics of India (1960-61), Central Water & Power Commission.
(*ii*) Note Volumes of Irrigation Chapters for Madhya Pradesh and Orissa States, Central Water & Power Commission (March 1970)—(Unpublished).
(*iii*) India—Irrigation and Power Projects (Five Year Plans), Central Water & Power Commission (April, 1970).
(*iv*) P&P Directorate of Central Water & Power Commission (Water Wing).

3.3—*Contd.*

7	8	9	10	11	12	13
IV Plan	16.60	13.83 (Up to Mar. '69)	23.81	16.19	21.89	
IV Plan	14.87	14.97 (Up to Mar. '69)	N.A.	2.43	3.72	
IV Plan	9.02	0.50 (Up to Mar. '69)	N.A.	N.A.	11.83	
IV Plan	5.61	Nil (Up to Mar. '69)	N.A.	N.A.	4.65	

APPENDIX 3.4

New Schemes included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission

Sl. No.	Project	District	Estimated Cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6
Madhya Pradesh					
1.	Satiara	Raipur	140.00	56.66	
2.	Mayana	Bastar	5.14	1.48	
3.	Pairi	Raipur	39.20	2.02	
4.	Piparinala	Durg	20.00	8.09	
Orissa					
5.	Ong (Gochhapalli)	Bolangir Patna	40.00	28.33	
6.	Mahanadi Chitrotpala	Cuttack	47.89	52.84	

Source: (i) Irrigation and Power Potential of Madhya Pradesh Rivers, P.W.D., Government of Madhya Pradesh (1963).

(ii) Reports of the Working Group on Irrigation and Flood Control, Fourth Five Year Plan 1969-74 and Annual Plan 1969-70, for Madhya Pradesh and Orissa States.

(iii) Draft Fourth Five Year Plans for Madhya Pradesh and Orissa States.

APPENDIX 3.5

Salient Features of New Major and Medium Projects Proposed by the State Governments in the Mahanadi Basin

Sl. No.	Name of State/ Project	District	Location of Dam		Area proposed to be irrigated ('000 hectares)	Remarks
			Latitude	Longitude		
1	2	3	4	5	6	7
	Madhya Pradesh					
	I. Multipurpose Schemes					
1.	Jonk	Raipur	21°34′	82°34′	40.47	
2.	Mahanadi Canal Hydel	Raipur	21°9′	81°50.2′	40.47	
3.	Sitanadi	Raipur	20°8.8′	81°53.5′	2.23	
4.	Hasdeo	Bilaspur	22°36′	82°33′	238.76	
5.	Atem	Bilaspur	22°58.7′	82°42.6′	18.21	
6.	Ghornai	Bilaspur	22°23.8′	82°49.5′	17.40	
7.	Ahiran	Bilaspur	22°33.5′	82°21.8′	6.88	
8.	Mand	Raigarh	22°56′	83°28′	46.54	
9.	Maini	Raigarh	22°54′	83°37′	2.83	
10.	Ib	Raigarh	23°1′	83°54′	10.93	
11.	Lawa	Raigarh	22°58.4′	84°3′	20.23	
				Total	444.95	
	II. Major and Medium Irrigation Schemes					
12.	Kumharpara	Bastar	20°13.7′	81°14.8′	1.90	
13.	Turi	Bastar	20°15′	81°36′	3.24	
14.	Hatkul	Bastar	20°12.5′	81°31.3′	31.57*	*All under Mahanadi canal
15.	Bairadih	Bastar	20°16.8′	81°18′	16.59†	†Includes 10.52 thousand hectares under Mahanadi canal
16.	Dudhawa Right Canal	Bastar	N.A.	N.A.	6.07	
17.	Kudar Nala	Raipur	21°11.6′	82°10.5′	6.07	
18.	Ghulghul	Raipur	21°31.7′	81°50.1′	9.31	

Appendix 3.5—*Contd.*

Sl. No.	Name of State/ Project	District	Location of Dam Latitude	Location of Dam Longitude	Area proposed to be irrigated ('000 hectares)	Remarks
1	2	3	4	5	6	7
19.	Lath Nadi	Raipur	21°12.5′	83°12′	1.62	
20.	Ghordagi	Raipur	20°38′	81°40.7′	1.62	
21.	Kotripani	Raipur	20°57.9′	82°22.9′	1.62	
22.	Kodapal	Raipur	21°13.2′	83°10.5′	1.62	
23.	Kharkhara	Durg	20°50.3′	80°59.3′	27.92	
24.	Konka	Durg	21°28′	81°13′	1.74	
25.	Mongra	Durg	20°45.3′	80°50′	48.56	
26.	Bhuta	Durg	21°46.5′	81°1.8′	2.02	
27.	Bhainswar	Durg	21°49.1′	81°2.1′	2.43	
28.	Mohar	Durg	20°4.5′	80°49.4′	1.62	
29.	Deorani Jethani	Durg	20°37.5′	80°23.5′	1.78	
30.	Durg Dongri	Durg	20°31.6′	81°2.0′	2.83	
31.	Pusowar	Durg	20°24.5′	81°5.8′	1.62	
32.	Chorhanala	Durg	20°40′	81°21.2′	2.43	
33.	Kasawahi	Durg	20°37.7′	81°29.6′	1.62	
34.	Amner	Durg	21°25′	81°3′	25.09	
35.	Bhamhih	Durg	21°0′	80°47′	24.28	
36.	Awardha	Durg	21°19′	81°8′	8.90	
37.	Balod Gahan	Durg	20°41′	81°28′	1.70	
38.	Jhipania	Durg	20°46′	81°13′	1.62	
39.	Lohara	Durg	20°46.8′	81°3.50′	2.02	
40.	Arpa	Bilaspur	22°19′	80°5′	84.98	
41.	Hap	Bilaspur	22°16′	81°19′	40.47	
42.	Phonk	Bilaspur	22°12′	81°13′	7.28	
43.	Sagri Bagdeva	Bilaspur	22°17.4′	82°21.8′	2.43	
44.	Kuaripali	Bilaspur	21°50.9′	83°7.6′	1.62	
45.	Ghogra Nala	Raigarh	21°33.7′	83°45.0′	2.02	
46.	Dongadarha	Raigarh	21°28′	83°13.7′	2.02	
47.	Kelo	Raigarh	21°54.7′	83°24.5′	28.33	
48.	Kikari Nala	Raigarh	21°28′	83°17.8′	4.05	
49.	Saria Nala	Raigarh	23°23′	83°16.3′	2.27	
				Total	414.88	
				Grand Total	859.83	

Appendix 3.5—*Contd.*

Sl. No.	Name of State/ Project	District	Location of Dam: Latitude	Location of Dam: Longitude	Area proposed to be irrigated ('000 hectares)	Remarks
1	2	3	4	5	6	7
	Orissa					
50.	Tikerpara	Puri and Dhenkanal	20°30′	84°52′	2549.48 (50–51)	
51.	Gania	N.A.	N.A.	N.A.		
52.	Bheden	N.A.	N.A.	N.A.	N.A.	
53.	Tel	N.A.	N.A.	N.A.	N.A.	
54.	Bagh	Bolangir Patna & Phulbani	20°38′	84°2′	27.52	
				Total	2577.00	

Source: (i) Irrigation and Power Potential of Madhya Pradesh Rivers, P.W.D., Government of Madhya Pradesh (1963).

(ii) Orissa's Decade of Destiny (1963-73)—A Plan for the integrated development of the river basins of Orissa by Dr. A. N. Khosla.

(iii) Mahanadi Basin Report, Central Water & Power Commission—(Unpublished).

APPENDIX 4.1

Monthly and Annual Normals of Rainfall of East-flowing River Basins Between the Mahanadi and the Godavari

Sl. No.	State/ District	Monthwise Normal Rainfall in mm.												Annual Normal Rainfall in mm
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Andhra Pradesh													
1.	Srikakulam	8.0	18.4	15.9	37.3	66.0	132.8	168.4	196.6	208.4	181.4	71.7	11.8	1,116.7
2.	Visakhapatnam	7.8	21.0	15.2	41.4	67.7	116.9	139.8	148.3	191.4	195.0	83.9	13.7	1,042.1
3.	East Godavari	5.8	13.0	12.8	25.3	52.1	133.6	203.0	174.8	186.5	214.0	108.1	8.6	1,137.6
	Orissa													
4.	Puri	14.2	26.2	19.7	26.8	67.2	207.0	310.8	300.3	244.7	167.0	57.9	7.3	1,449.1
5.	Ganjam	10.8	22.2	21.3	42.3	76.8	169.2	221.6	242.4	229.6	179.8	68.6	11.0	1,295.6
6.	Koraput	6.7	11.3	16.2	53.4	75.0	205.8	351.1	380.3	262.1	116.5	35.8	7.6	1,521.8
7.	Baudh Khondmals	13.0	27.6	25.1	35.5	66.0	239.1	390.8	373.8	260.3	127.2	31.8	6.9	1,597.1
8.	Kalahandi	11.5	15.4	13.6	23.7	33.7	228.3	343.5	384.6	220.9	81.9	17.9	3.2	1,378.2

Source: Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX

Salient Features of Existing Major and Medium Projects in the Basin of the

Sl. No.	Name of Project	Zone/ District	Cost/ Total expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion
1	2	3	4	5	6
Andhra Pradesh					
1.	Thotapalli Regulator	Srikakulam	1.36	Nagavali	1910
2.	Nagavali	-do-	1.95	-do-	1913
3.	Yeleru Canal System	East Godavari	N.A.	N.A.	N.A.
4.	Varaha System	Visakhapatnam	N.A.	Varaha	N.A.
5.	Sarada System	-do-	N.A.	Sarada	N.A.
6.	Srikakulam Minor River System	Srikakulam	0.29	N.A.	N.A.
7.	Gambheeramgedda Reservoir	Visakhapatnam	1.41	Gambheeram-gedda	1957
8.	Vegavathi Anicut Scheme	Srikakulam	2.33	Vegavati	1959
9.	Narayanapuram Anicut	-do-	9.69	Nagavali	1963-64
10.	Seethanagaram Anicut Scheme	-do-	1.25	-do-	N.A.
11.	Nagavali Right Side Channel	-do-	2.69	-do-	N.A.
12.	Paidigam Project	-do-	2.42	Mahendra-tanaya	1965
Orissa					
13.	Rushikulya Canal System	Ganjam	5.62	Rushikulya	1898

Sources: (1) Irrigation Statistics of India (1960-61), Central Water & Power Commission.

(2) Note Volume of Irrigation Chapter, Andhra Pradesh, October, 1970—(Unpublished).

(3) Note Volume of Irrigation Chapter, Orissa, March, 1970—(Unpublished).

(4) Replies of the Orissa State to the Questionnaire issued by the Irrigation Commission.

4.2

East-flowing Rivers Between the Mahanadi and the Godavari

Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal & branches (Km)	Whether perennial two seasonal or one seasonal	Cropping pattern	Remarks
7	8	9	10	11	12	13	14
Flow	N.A.	1.17	1.17	38	N.A.	N.A.	
-do-	20.20	12.63	14.65	104	One seasonal	Rice	
-do-	N.A.	N.A.	15.38	N.A.	N.A.	N.A.	
-do-	N.A.	N.A.	0.73	N.A.	N.A.	N.A.	
-do-	N.A.	N.A.	3.64	N.A.	N.A.	N.A.	
-do-	N.A.	N.A.	27.85	N.A.	N.A.	N.A.	
Storage	N.A.	0.63	0.24	..	Two seasonal	Rice & other kharif crops	
Flow	N.A.	1.84	2.35	19	One seasonal	Rice	
-do-	N.A.	19.87	14.91	53	-do-	-do-	
N.A.	N.A.	N.A.	1.62	N.A.	N.A.	N.A.	
N.A.	N.A.	N.A.	3.64	N.A.	N.A.	N.A.	
Flow	4.78	3.24	2.00	17	One seasonal	Rice	
Storage	57.50	47.51	114.17	..	-do-	Kharif crops	

APPENDIX

Salient Features of Major and Medium Projects Under Construction in the

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of cons-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
Andhra Pradesh					
1.	Thandava Reservoir	Visakhapatnam	Construction of a 201.17 m long, 32 m high earth dam across the Tandava River near Gantayarikothagudem village in the Visakhapatnam district and canal system on either bank	1965	Construction of the dam and investigation work on the canal systems are in progress
2.	Pampa Reservoir	East Godavari	Construction of reservoir across the river Pampa at Annavaram in the East Godavari district and canal system on the right flank.	1965	Headworks and the main canal have almost been completed. Work on the distribution system is in progress.
3.	Varaha Reservoir	Visakhapatnam	Construction of a 215.4 m long, 25 m high earth dam across the Varaha river near Kalyanapulva in the Visakhapatnam district and a canal system on the left flank.	1965	Work on the earth dam and spillway is in progress. The canal system is in initial stage of its construction.
4.	Vottigedda Project	Srikakulam	Construction of a 2,849.9 long earth dam across the Vottigedda river, a tributary of the Nagavali near Ravada	1966	Works on the earth dam and right side canal system are in progress

Basin of the East-flowing Rivers Between the Mahanadi and the Godavari

truction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely completion	Total cost (Rs. Million)	Expenditure incurred (Rs. Million)				
7	8	9	10	11	12	13
IV Plan	40.37	11.43 (Mar. '69)	N.A.	N.A.	18.58	
IV Plan	9.92	5.64 (Mar. '70)	N.A.	N.A.	4.86	
IV Plan	11.19	5.14 (Mar. '69)	N.A.	N.A.	3.26	
IV Plan	20.22	6.55 (Mar. '69)	N.A.	N.A.	6.75	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of cons-	
				Date of com-mence-ment	Important items of works completed
1	2	3	4	5	6
			village in the Srikakulam district and canal system on either bank.		
Orissa					
5.	Dhanei	Ganjam	Construction of a 17.7 m high earth dam across the Dhanei river about 1.6 km downstream of village Barasingi in the Ganjam district and canal system on either bank.	1959	The dam has been completed and the work on canal system is in progress.
6.	Salia	Puri and Ganjam	Construction of an earthen dam, 445 m long, 28.3 m high across the Salia river at Panesnidhi in the Puri district with canals on either side.	1960	Work on the earthen dam and canal system is in progress.
7.	Godahado	Ganjam	Construction of a 1,667 m long, 24 m high earthen dam with masonry spillway across the Godahado river at Bijayanagargarh and a pick up weir across the Kantaikolinalla at Snukrakholi and canal system on either bank.	1960	Work on the earth dam is in progress. The right and left main canals are almost complete and work on the distribution system is in progress.

4.3—*Contd.*

truction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely completion	Total cost (Rs. Million)	Expenditure incurred (Rs. Million)				
7	8	9	10	11	12	13
IV Plan	13.21	12.57 (Mar. '69)	6.07	3.85	5.26	
IV Plan	29.40	24.74 (Mar. '69)	12.56	8.10	10.83	
IV Plan	19.73	11.77 (Mar. '69)	6.50	4.33	6.48	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of cons-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
8.	Bahuda—Stage-I	Ganjam	Construction of 5 diversion weirs namely (*i*) at Tarubidi across the Bahuda (*ii*) at Kalingadala across the Bahuda (*iii*) at Budagoda across the Poichodia (*iv*) at Badulia across the Barteda and (*v*) at Kalna across the Baginalla and interconnecting canal system.	1962	The Kalingadala weir has been completed and its distribution system is in progress. The work on the weirs across Bagi and Poichodia has been taken up and is in progress.
9.	Hiradharbati	Ganjam	Construction of an anicut across the river Rushikulya near Athagada in the Ganjam district and a canal system on the left bank.	1963	Headworks completed. Distribution system is in progress.
10.	Baghua	Ganjam	Construction of a 99 m long weir across the river Baghua, a tributary of Ṛushikulya & canal system on the left flank.	N.A.	N.A.

Sources: (1) Note Volumes of Irrigation Chapter for Andhra Pradesh and Orissa
(2) Replies of Andhra Pradesh and Orissa States to the Questionnaire

4.3—*Contd.*

truction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely completion	Total cost (Rs. Million)	Expenditure incurred (Rs. Million)				
7	8	9	10	11	12	13
IV Plan	15.89	7.01 (Mar. '69)	11.90	8.50	9.11	
IV Plan	3.45	3.48 (Mar. '69)	6.27	5.09	5.31	
IV Plan	6.8	N.A.	N.A.	3.24	4.05	

States, Central Water & Power Commission, 1970—(Unpublished).
issued by the Irrigation Commission.

APPENDIX 4.4

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the Project	Estimated cost (Rs. million)	Ultimate Irrigation ('000 hectares)	Remarks
1	2	3	4	5
Andhra Pradesh				
1.	Yeluru Reservoir	30.00	40.47	
2.	Neradi Barrage	19.40	10.12	

Source: Fourth Five Year Plan 1969-74 and Annual Plan 1969-70—'Report of the Working Group on Irrigation and Flood Control', Ministry of Irrigation & Power.

APPENDIX 4.5

Salient Features of New Major and Medium Projects Proposed by the State Governments in the Basin of the East-flowing Rivers between the Mahanadi and the Godavari

Sl. No.	Name of the Project	Zone/ District	Source of supply (Name of river)	Estimated cost in Rs. million	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7
Orissa						
1.	Joro-Harbhangi	Ganjam	Harbhangi and Joro River	52.7	29.10	
2.	Ramanadi	Ganjam	Ramanadi	13.0	5.15	
3.	Machaghat	Ganjam	Dahanala tributary of Laharakhandi	18.0	7.00	
4.	Pipalpankha	Ganjam	N.A.	22.7	18.40	

Source: Enclosure to Section 2 of the Replies of Orissa State to the Questionnaire of Irrigation Commission.

APPENDIX

Salient Features of Existing Major and

Sl. No.	Name of the Project	Zone/Distt.	Cost/total expenditure incurred in (Rs. million)	Source of supply (Name of river)	Year of completion	Type (flow/ storage/lift)
1	2	3	4	5	6	7
						ANDHRA
1.	Godavari Delta System	East & West Godavari	31.554	Godavari	1877	Flow
2.	Khanapur Channels	Adilabad	N.A.	Godavari supplemented by supply from 11 tanks	1900	Flow
3.	Mahboob Nehar	Medak	1,585	Manjra	1904	Flow
4.	Laknawaram Lake	Warangal	0.458	Laknawaram	1909	Storage
5.	Pocharam Project	Nizamabad	3.212	Alair Stream	1922	Flow-cum-storage
6.	Fateh Nehar	Medak	0.46	Manjra	1926	Flow
7.	Nizam Sagar Project	Nizamabad	45.708	Manjra	1931	Flow-cum-storage
8.	Maner Project	Karimnagar	10.476	Maner	1949	Flow-cum-storage
9.	Bandakettu Channel	West Godavari	0.292	N.A.	1959	N.A.
10.	Sirala	Adilabad	0.282	N.A.	1965	N.A.
11.	Ramadugu	Nizamabad	3.726	N.A.	1968-69	N.A.
12.	Salivagu	Warangal	4.057	Salivagu	1968-69	Storage
						MADHYA
13.	Roomal Tank	Seoni	0.319	Lodhia Nala	1912	Storage
14.	Jamunia Tank	Balaghat	0.546	Dhoda Nalla	1915-16	-do-
15.	Sarathi Tank	Balaghat		Sarathi Nalla	1918-19	-do-
16.	Wainganga Canal	Balaghat	5.319	Wainganga	1923	Flow
17.	Bori Tank	Seoni	1.012	Gadam Nalla	1927-28	Storage
18.	Moorum Nalla Tank	Balaghat	1.099	Moorum Nala	1946-47	-do-
19.	Chichbund Tank	Seoni	0.876	Bharkunda Nalla	1949-50	-do-
20.	Ari Tank	Seoni	3.00	Hirri Nadi	1951	-do-
21.	Gangulpara Tank	Balaghat	5.425	Ghisri Nala	1957	-do-
22.	Sagarnadi	Seoni	4.587	Sagarnadi	1966	-do-
23.	Kharadi Tank	Balaghat	3.004	Pandharipat Nalla	1968	Flow-cum-storage
24.	Nehlesara	Balaghat	21.420	Chandan	1968	-do-
						MAHA
25.	Kadwa River Works	Nasik	1.036	Kolwan, Kadwa & Banganga	1968-69	Flow-cum-storage

5.1

Medium Projects in the Godavari Basin

G.C.A. thousand hectares	C.C.A. thousand hectares	Ultimate irrigation thousand hectares	Length of main canal and branches (km.)	Whether perennial two-seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
PRADESH						
572.66	473.44	408.73	801.28	Perennial	Perennial crops and paddy	
7.28	4.37	4.37	34.59	Two-seasonal	Paddy	
7.08	5.63	3.04	42.64	Two-seasonal	Paddy	
N.A.	4.85	2.87	39.26	Two-seasonal	Paddy	
11.94	9.71	4.05	57.92	Two-seasonal	Paddy	
4.90	3.20	2.75	12.87	One-seasonal	Paddy	
217.11	126.50	96.72	154.46	Perennial	Paddy, sugarcane and garden	
15.50	9.91	5.79	49.80	Two-seasonal	Paddy	
N.A.	N.A.	1.46	N.A.	N.A.	N.A.	
N.A.	1.21	0.85	N.A.	N.A.	N.A.	
N.A.	1.58	2.02	N.A.	N.A.	N.A.	
3.60	1.09	1.15	3.57	One-seasonal	Paddy	
PRADESH						
5.91	3.24	1.89	31.22	One seasonal	Paddy, whea	
11.13	4.82	2.19	55.67	Two-seasonal	Paddy, wheat	
8.30	7.37	31.65	107.48	Perennial	Sugarcane, paddy and wheat	
50.63	43.14		127.11	Two-seasonal	Paddy & wheat	
6.60	5.63	3.04	40.87	Two-seasonal	Paddy and other rabi	
4.82	2.83	2.10	32.18	Two-seasonal	Paddy	
3.60	3.44	2.02	27.03	-do-	Paddy, wheat	
11.01	8.86	4.25	81.74	-do-	Paddy, wheat	
4.57	4.09	3.45	42.96	-do-	Paddy, wheat	
2.47	2.19	1.59	36.69	-do-	Paddy, wheat	
6.68	5.02	3.84	46.18	-do-	Paddy, wheat	
9.59	5.34	4.51	45.86	-do-	Paddy, wheat	
RASHTRA						
16.35	14.73	13.87	38.78	Perennial	Sugarcane, other perennial, cotton, other two-seasonal paddy, bajri, other kharif, jowar, wheat, other rabi and hot weather crops.	

Appendix

1	2	3	4	5	6	7
26.	Khairbanda Tank	Bhandara	2.079	Local Nalla	1906-07	Storage
27.	Chandpur Tank	Bhandara	0.685	Lamandohi Nalla	1907-08	Flow-cum-storage
28.	Ram tek Tank	Bhandara Nagpur	2.912	Sur	1909-10	-do-
29.	Ghorazari Tank	Chanda	1.188	Bokardoh Nalla	1909-10	Storage
30.	Asola-mendha Tank	Chanda	1.808	Pathri Nadi	1911-12	Flow-cum-storage
31.	Godavari Canals	Ahmednagar, Nasik	10.700	Dharna	1915-16	-do-
32.	Bodalkasa Tank	Bhandara	0.674	Baghdeo Nalla	1916-17	-do-
33.	Chorkhamara	Bhandara	0.869	Kondegoni	1918	-do-
34.	Pravara Canals	Ahmednagar	16.235	Pravara	1926	-do-
35.	Gangapur Dam Stage I	Nasik	39.600	Godavari, Alandi Nalla & Nasarda Nalla	1960	-do-
36.	Jui Project	Aurangabad	3.605	Jui	1960	-do-
37.	Dheku Project	-do-	3.993	Dheku	1961	-do-
38.	Bendsura Project	Bhir	5.881	Bendsura	1961	-do-
39.	Shivna Project	Aurangabad	0.100	N.A.	1962	N.A.
40.	Purna Anicut	-do-	0.235	N.A.	1963	N.A.
41.	Khelna Project	-do-	7.064	Khelna	1966	Flow-cum-storage
42.	Sind-phana Project	Bhir	5.840	Sindhphana	1966	Flow-cum-storage
43.	Jivarekha Project	Aurangabad	4.161	N.A.	1966-67	N.A.

5.1—*Contd.*

8	9	10	11	12	13	14
12.46	11.25	3.84	33.63	One-seasonal	Paddy	
14.93	11.61	4.86	30·89	One-seasonal	Kharif crops	
39.78	36.91	10.52	45.05	Perennial	Sugarcane, paddy, wheat	
19.59	12.87	3.844	19.31	Perennial	Sugarcane, paddy	
49.57	37.92	9.91	43.64	Perennial	Perennial crops, paddy and other rabi.	
90.05	88.63	32.15	188.25	Perennial	Sugarcane, other perennial, cotton, other two-seasonal paddy, bajri, other kharif, wheat, other rabi & hot weather crops	
14.65	9.83	4.05	47.14	One-seasonal	Paddy	
17.52	13.23	4.05	28.00	-do-	Paddy	
80.45	63.70	23.07	130.33	Perennial	Sugarcane, other perennial, cotton, other two-seasonal paddy bajri, other kharif, wheat, jowar other rabi & hot weather crops	
32.24	27.24	16.79	75·62	Perennial	Sugarcane, other perennial, vegetable, fodder, fruits, paddy bajri, other kharif wheat, other rabi & hot weather crops	
3.40	2.71	2.21	17.70	Two-seasonal	Two-seasonal crops, paddy, other kharif & other rabi crops.	
3.84	3.20	2.71	24.14	-do-	Two-seasonal crops-paddy, other kharif & other rabi.	
4.65	3.76	3.37	35.40	Perennial	Sugarcane, other perennial, kharif crops, jowar & wheat.	
N.A.	N.A.	0.28	N.A.	N.A.	N.A.	
N.A.	N.A.	0.10	N.A.	N.A.	N.A.	
4.86	3.80	2.47	20.92	Two-seasonal	Two-seasonal crops, paddy, other kharif and other rabi crops.	
4.86	3.32	1.78	16.09	-do-	Two seasonal crops, paddy. other kharif jowar.	
N.A.	N.A.	1.06	N.A.	N.A.	N.A.	

Appendix

1	2	3	4	5	6	7
44.	Kolhi Project	-do-	2.313	N.A.	1967	N.A.
45.	Ekburjee	Akola	4.249	Chandrabhaga	1967	Flow-cum-storage
46.	Pindrabodi	Nagpur	4.246	Tributary of Amb river	1967	-do-
47.	Purna Project (Siddeshwar Dam)	Parbhani Nanded	187.40	Purna	1968	-do-
48.	Sukhna Project	Aurangabad	10.769	Sukhna	1968	-do-
49.	Wunna	Nagpur	9.90	Wunna	1968	-do-
50.	Ghirni	Osmanabad	10.232	Ghirni	1968	-do-
51.	Mohesangvi	Bhir	3.845	N.A.	1968	N.A.
52.	Gangapur Dam Stage II	Nasik	13.360	N.A.	1969	Flow-cum-storage
53.	Galhati Project	Aurangabad	8.224	Galhati	1969	-do-
54.	Wan Project	Bhir	16.449	Wan	1969	-do-
55.	Upper Dudhna Project	Aurangabad	7.649	Dudhna	1969	-do-
56.	Manar Project Stage I	Nanded	24.344	Manar	1969	-do-
57.	Bor	Wardha	35.80	Bor	1969	-do-
58.	Sangrampur	Bhandara	2.109	N.A.	1969	N.A.
59.	Thirna	Osmanabad	8.13	Thirna	1969	Flow-cum-storage

Source: (*i*) Irrigation Statistics of India (1960-61), CW & PC.
(*ii*) Report of the Krishna Godavari Commission, Annexure XII to XV.
(*iii*) Note volumes of irrigation chapters for Andhra Pradesh, Madhya Pradesh, Maharashtra, Mysore and Orissa States, CW & PC (1970)—Unpublished.
(*iv*) India, Irrigation and Power Projects (Five Year Plan), CW & PC (April, 1970).

5.1—*Contd.*

8	9	10	11	12	13	14
N.A.	N.A.	0.47	N.A.	N.A.	N.A.	
4.05	3.04	2.43	37.01	Two-seasonal	Cotton, paddy, other kharif, jowar & wheat.	
3.04	2.27	0.86	35.40	-do-	Chillies, paddy, wheat and jowar.	
96.72	95.18	61.51	54.71	Perennial	Sugarcane, other perennial, cotton, paddy, other kharif, other rabi and hot weather crops.	
14.25	8.34	2.51	54.71	Two-seasonal	Two-seasonal crops paddy, other kharif and jowar.	
6.07	9.64	1.21	20.92	Two-seasonal	Paddy, wheat, and other rabi.	
7.24	6.52	2.83	48.27	-do-	Cotton, kharif and rabi jowar.	
N.A.	N.A.	1.94	N.A.	N.A.	N.A.	
N.A.	N.A.	7.69	N.A.	N.A.	N.A.	
9.23	7.20	4.65	17.70	Two-seasonal	Cotton, paddy, other kharif, jowar.	
9.31	7.49	5.26	2.10	-do-	Two-seasonal crops, paddy, other kharif and other rabi crops	
5.91	4.57	3.40	9.65	-do-	Two seasonal crops, paddy, other kharif and jowar.	
15.05	13.52	10.12	91.71	Perennial	Sugarcane, other perennial, cotton, other two-seasonal, paddy, jowar, fodder.	
32.58	23.43	13.36	22.53	Perennial	Perennial crops, cotton paddy, wheat, gram and hot weather crops.	
N.A.	N.A.	0.97	N.A.	N.A.	N.A.	
3.84	3.16	2.43	30.57	Two-seasonal	Paddy, other kharif and jowar.	

APPENDIX

Salient Features of Major and Medium Projects

Sl. No.	Name of the project	Zone/Distt.	Description of the Scheme	Time schedule of construction	
				Date of commen-cement	Important items of works completed
1	2	3	4	5	6
					ANDHRA PRADESH
1.	Kaddam	Adilabad	Construction of a composite dam 2,102 m. long, 40.6 m. high across river Kaddam, a tributary of the Godavari and main canal 77 km. long	1949	The work is more or less completed
2.	Torrigedda Pumping Scheme	East Godavari	Installation of 3 vertical spindle deep well pumps of 740 H.P. with a pumping capacity of 1,71,838 litres per minute each to lift water from Akhanda Godavari at Puroshottapatnam upstream of Dowlaiswaram Anicut, for irrigation.	1958	The work is nearing completion. A little work on minor distributaries and excavation of a separate minor distributary direct from right side channel is left with.
3.	Swarna	Adilabad	Construction of an earthen bund 2148.8 m. long and 22.4 m. high across river Swarna, a tributary of the Godavari.	1959	About 89 per cent of excavation of foundation work has been completed.
4.	Nallavagu	Medak	Construction of an earthen dam, 1935.5 m. long and 14.8 m. high across Nallavagu stream, a tributary of river Manjira.	1963	The headworks have been completed. Work on the canal system is in progress.
5.	Pochampad	Nizamabad	Construction of a masonry dam, 765.05 m. long spillway and 47.24 m. long non-overflow dam and 12,588.24 m. long earthen dam across the river Godavari near village Pochampad. A main canal 112.63 km. long takes off on the right bank.	1963-64	On masonry dam, 77 per cent masonry and 14 per cent concreting completed. On earth dam 52 per cent earth work completed. Construction of canal system is also in progress.
					MADHYA PRADESH
6.	Bagh Right Bank Canal	Balaghat	The project envisages the construction of a right bank canal to utilise Madhya Pradesh share of water under Bagh Project which has been taken up by Maharashtra State.	1967-68	About 50 per cent work on construction of staff quarters completed. Earth work of main canal is in progress.
					MAHARASHTRA
7.	Bagh	Bhandara	Construction of an earthen dam, 2,836 m. long, 28.5m. high across Bagh river near Sirpur village, a pick-up weir 2974 m. long, 19·5 m. high at village Pujantara and a canal 64 km. long taking off from the weir.	1958	48 per cent headworks and 51 per cent canal system completed.
8.	Itiadoh	Bhandara	Construction of an earthen dam 527 m long and 28 m high across river Garvi, a tributary of the Wainganga and a right bank canal 80 km. long.	1958	Headworks completed. Work on canal system is in progress.

5.2

Under Construction in the Godavari Basin

Date of likely completion	Cost		G.C.A. (thousand hectares)	C.C.A. (thousand hectares)	Ultimate Irrigation (thousand hectares)	Remarks
	Total cost (Rs. million)	Expenditure incurred (Rs. million)				
7	8	9	10	11	12	13
IV Plan	83.90	80.241 (up to Mar. '70)	66.37	53.09	34.40	
IV Plan	6.579	6.261 (up to Mar. '70)	10.52	8.09	5.52	
1972-73	11.562	6.099 (up to Mar. '70)	10.32	8.50	2.83	
IV Plan	7.621	4.956 (up to Mar. '70)	4.45	3.80	2.39	
IV Plan	401.00 (under revision)	250.00 (up to Ma. '70)	335.48	232.57	230.68	
1973-74	34.840	10.840 (up to Mar. '70)	21.45	14.97	10.84	
1972	58.40	31.166 (up to Mar. '70)	42.49	24.89	33.67	
IV Plan	69.200	48.754 (up to Mar. '70)	73.65	36.42	46.14	

Appendix

1	2	3	4	5	6
9.	Mula	Ahmednagar	Construction of an earthen dam 2,820 m. long, 46.63 m high across river Mula at village Baregaon-Nandur and two canals one on either bank.	1959	Earth work of dam 72 per cent completed. Work on spillway is also in progress.
10.	Dinanadi	Chanda	Construction of an earthen dam 21 m. high across river Dina at village Regree and a canal 59.5 km. long.	1959	Headworks 18 per cent and canal system 4 per cent completed.
11.	Manar-Stage II	Nanded	Raising of the existing earthen dam by 2.4 m. waste weir by 3.4 m. and construction of 129 km branch canals together with the distribution system.	1963	Work on headworks and branches completed. Work on distribution system is in progress.
12.	Saikheda (Khuni)	Yeotmal	Construction of an earthen dam with an ungated spillway on left flank across river Khuni near village Lingt.	1964	Headworks completed. Work on the canal system is in progress.
13.	Pus	Yeotmal	Construction of a storage dam across river Pus, a tributary of the Wainganga, a pick-up weir downstream near Wenwasla and a canal system.	1964	Earth dam 25 per cent completed, spillway excavation and construction of pick-up weir completed. Main canal about 80 per cent completed. Survey and investigations of distributaries are in progress.
14.	Managarh	Bhandara	Construction of a storage tank across a local stream which is a tributary of Bagh river. A right bank canal takes off from the dam.	1964	Headworks completed. Canals and distributaries are in an advanced stage of construction.
15.	Jayakwadi-Stage-I	Aurangabad	Construction of a 10,000 m. long, 36.6 m. high earth dam with masonry spillway at Pathan across river Godavari and a 185 km. long canal on the left bank.	1964	Earth dam 74 per cent completed. On masonry dam excavation 51 per cent, concreting 1 per cent and masonry 16 per cent completed. Work on canal system is also in progress.
16.	Sorna	Bhandara	Construction of an earthen dam 1,448 m. long 14 m. high near village Dhop.	1965	Headworks 60 per cent completed and canal system 35 per cent completed.
17.	Malked	Amravati	Construction of an earthen dam across Kholad Nalla and a canal taking off on the left bank.	1966	Headworks and canal system 30 per cent completed.
18.	Umri	Nagpur	Construction of a dam at Umri across Ambadaha Nalla, a tributary of Kolar river and a left bank canal 8 km. long.	1966	Headworks 65 per cent completed and canal system 60 per cent completed.

5.2—*Contd.*

7	8	9	10	11	12	13
1971-72	161.600	137.886 (up to Mar. '70)	158.23	120.68	65.56	
1972	34.827	7.580 (up to Mar. '70)	31.40	20.27	16.54	
IV Plan	29.300	29.240 (up to Mar. '70)	42.57	23.27	16.59	
IV Plan	17.800	14.334 (up to Mar. '70)	6.07	4.86	3.64	
1972	51.281	36.712 (up to Mar. '70)	25.25	17.64	11.72	
IV Plan	4.667	3.658 (up to Mar. '70)	5.01	3.39	1.70	
IV Plan	384.600	101.417 (up to Mar. '70)	203.96	183.57	141.65	
IV Plan	3.705	1.676 (up to Mar. '70)	1.70	1.55	1.23	
IV Plan	5.324	3.091 (up to Mar. '70)	N.A.	N.A.	1.78	
IV Plan	4.166	2.432 (up to Mar. '70)	N.A.	N.A.	1.57	

Appendix

1	2	3	4	5	6
19.	Adula	Ahmednagar	Construction of an earthen dam 1015 m. long, 40 m. high near Deothau across river Adula, a tributary of Parwara river.	1966	Headworks 3.20 per cent completed.
20.	Kundral	Nanded	Construction of an earthen dam across Kundral stream, a tributary of Lendi river and two canals one on either bank.	1967	Headworks 76 per cent completed and canal system 24 per cent completed.
21.	Bhageda	Bhandara	Construction of an earthen dam across Ambagarh Nalla, a tributary of Wainganga river & a canal system.	1967	Earth dam 50 per cent completed. Excavation of waste weir nearing completion. Canals nearly completed & work on distributaries is in progress.
22.	Upper Godavari	Nasik	Construction of four storages with canal system as stated below: i) Karanjwan dam across the Kadwa river, near village Karanjwan. ii) Waghad dam across the Kalwan river, near village Waghad. iii) Ozarkhed dam across the Renada river, near village Ozarkhed and a left bank canal 12 km long therefrom. iv) Palkhed dam across the Kadwa river, near village Palkhed with remodelling of the existing right bank canal 19 km. long and construction of a new left bank canal 102 km. long.	1968	Preliminary works on the project just started. Headworks 1.78 per cent completed.
23.	Kudala	Nanded	Construction of an earthen dam across Kudala Nalla and a canal system.	1969	Headworks 20 per cent completed.
24.	Kanholi	Nagpur	Construction of an earthen dam. 1,219.2 m. long 21m. high across Kanholi Nalla, a tributary of Wunna river and a right bank canal 8 km. long.	1969	The work is held up due to non-availability of land by private negotiation and is therefore held in abeyance.

Source: i) Irrigation Statistics of India (1960-61), CW&PC.
ii) Irrigation Statistics of India (1965-66), CW&PC—Unpublished.
iii) Report of the Krishna Godavari Commission, Annexure XIII to XV.
iv) India, Irrigation and Power Projects (Five Year Plans), CW&PC (April, 1970).
v) Note volumes of Irrigation Chapters for Andhra Pradesh, Madhya Pradesh, Maharashtra, Mysore and Orissa States, CW&PC (1970)—Unpublished.
vi) P & P Directorate of CW&PC (Water Wing).

5.2—*Contd.*

7	8	9	10	11	12	13
1973	19.722	0.646 (up to Mar. '69)	N.A.	N.A.	5.75	
IV Plan	6.491	4.257 (up to Mar. '70)	N.A.	N.A.	1.72	
IV Plan	4.670	2.455 (up to Mar. '70)	N.A.	N.A.	2.05	
Stage-I IV Plan	142.90 (50.00 Stage-I)	3.105 (up to Mar. '70)	177.13	63.53	44.27	
IV Plan	2.925	1.50 (up to Mar. '70)	N.A.	N.A.	0.57	
1973	14.565	0.22 (up to Mar. '70)	3.44	2.10	5.79	

APPENDIX 5.3

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by The Planning Commission

Sl. No.	Name of the State/Project	Estimated cost (Rs. million)	Area proposed to be irrigated (thousand hectares)	Remarks, if any
1	2	3	4	5
Andhra Pradesh				
1.	Godavari Barrage	210.000	408.73	
2.	Yeleru Reservoir	30.000	40.47	
Madhya Pradesh				
3.	Bargoor	7.174	2.44	
4.	Barunadi	30.000	12.55	
Maharashtra				
5.	Upper Wardha	169.720	75.96	
6.	Upper Penganga	330.722	111.50	
7.	Mhaladevi	52.679	16.84	
8.	Pench Irrigation	205.212	89.97	
9.	Sahasrakund	225.800	112.91	
10.	Lendi	56.500	22.76	
11.	Ghatshil	7.800	2.38	
12.	Chulband	8.748	5.62	
13.	Pardi Takamore	3.116	1.40	
14.	Chargaon	12.551	5.45	
15.	Takli	3.686	1.32	
16.	Panchdhara (Danganga)	9.190	2.18	
17.	Amalnalla	22.000	5.79	
18.	Karahdkhed (Seeta)	6.966	1.70	
19.	Masoli	10.151	3.99	
20.	Tiru	8.620	2.26	
21.	Tawarja	13.225	3.38	
Orissa				
22.	Upper Indravati	241.918	148.11	

Source: Reports of the working group on Irrigation and Flood Control, Fourth Five Year Plan 1969-74 and Annual Plan 1969-70 for Andhra Pradesh, Madhya Pradesh, Maharashtra, Mysore, and Orissa States.

APPENDIX 5.4

Details of New Major and Medium Projects Proposed in Godavari Basin by Different States

Sl. No.	Name of State/Project	District	Ultimate Irrigation (thousand hectares)
1	2	3	4
	Andhra Pradesh		
1.	Suddavagu	Adilabad	7.3
2.	Mandamari	-do-	3.2
3.	Peddavagu	-do-	13.4
4.	Satnala	-do-	5.1
5.	Kinnersani	Khammam	4.0
6.	Penganga	Adilabad	12.1
7.	Godavari Canal Project (Pochampad) Stage II	Nizamabad	644.7
8.	Godavari Canal Project (Pochampad) Stage III	-do-	121.4
9.	Inchampalli	Warangal	182.1
10.	Ippur Reservoir Scheme	East Godavari	678.2
11.	Gutala Pumping Scheme	West Godavari	5.5
12.	Providing 6 Drum Gates to Godavari Anicut	East & West Godavari	101.0
13.	Manjra	Medak	9.1
14.	Kappalvagu	Nizamabad	3.9
15.	Lower Maner Project	Karimnagar	28.7
16.	Pranhita	Adilabad	101.2
	Total		1,920.9
	Madhya Pradesh		
17.	Narainpur	Bastar	3.2
18.	Deodha	-do-	13.2
19.	Wardha	Chhindwara	2.5
20.	Upper Wainganga	Seoni	72.3
21.	Dheria Nala Scheme	Seoni	1.8
22.	Bijna	-do-	24.9
23.	Saliwara	Mandla	2.2
24.	Halon	Seoni	4.9
25.	Thanwar	Mandla	4.9
26.	Chakornala	-do-	2.4
27.	Dhanai	Seoni	4.9
28.	Uskal	Balaghat	2.4
29.	Murmari	Durg	4.5

Appendix 5.4—*Contd.*

1	2	3	4
30.	Nahara Hydel Scheme	Balaghat	10.1
31.	Deo-Ama-Son Scheme	-do-	4.0
32.	Bawanthari (Jointly with Maharashtra)	-do-	54.2
33.	Jam	Chhindwara	2.8
34.	Sitakund	-do-	1.5
35.	Dokdoh	-do-	2.4
36.	Mohgaon	-do-	10.0
37.	Pench Diversion Scheme	Seoni	124.5
38.	Kulbhera	Chhindwara	3.6
39.	Umra Nala	-do-	3.3
40.	Bhoopalapatnam (Jointly with Maharashtra)	Bastar	51.8
41.	Goriabahar	-do-	4.0
42.	Motkot	-do-	6.9
43.	Jarandi Nala Project	-do-	5.1
44.	Markandi	-do-	15.0
45.	Tirka Nala Project	-do-	7.3
46.	Boroda-Waler and Upper Nibra Scheme	-do-	8.9
47.	Dantewara	-do-	5.3
48.	Godri Nadi Project	-do-	3.6
49.	Bhanpur	-do-	4.9
50.	Mari Nadi Project	-do-	2.9
51.	Berudi	-do-	4.0
52.	Tonda Nadi Scheme	-do-	2.0
53.	Boria Tibhu Project	Durg	5.1
54.	Parwi Tank	Bastar	4.0
55.	Bhanupratappur	-do-	4.0
56.	Hatkonda	-do-	2.0
57.	Kokral	-do-	2.0
58.	Jallavagu	-do-	5.1
59.	Talperu	-do-	2.0
60.	Mukpara	-do-	6.1
61.	Kormanar	-do-	1.9
62.	Vemkamadugu	-do-	1.9
63.	Joranvagu	-do-	6.7
64.	Sabari Multipurpose Project (Jointly with Orissa)	-do-	429.0
65.	Konta (Jointly with Orissa)	-do-	12.1
66.	Kaklur—Mupari Scheme	-do-	8.1
67.	Barsipara Tank	-do-	2.8
68.	Gorali Naddi Project	-do-	5.3
69.	Sailervagu	-do-	7.6
70.	Ordeltong	-do-	2.0
71.	Janavagu	-do-	12.7
	Total		1,002.6

Appendix 5.4—*Contd.*

1	2	3	4
Maharashtra			
72.	Kayadhu	Parbhani	32.3
73.	Jayakwadi Project Stage II	Aurangabad	251.0
74.	Bharvir	Nasik	11.0
75.	Pravara River Project	Ahmednagar	58.0
76.	Purna Canal Extension Project	Nanded	10.5
77.	Kapra	Parbhani	6.3
78.	Kalyan	Aurangabad	2.8
79.	Lower Dudha Project	Parbhani	49.8
80.	Dhanegaon	Bhir	20.6
81.	Devnoor	Nanded	21.4
82.	Lower Tirna Project	Osmanabad	29.9
83.	Upper Wardha Project Stage II	Amravati	13.9
84.	Bembala	Yeotmal	30.8
85.	Lower Wunna Project	Nagpur	48.6
86.	Dham	Wardha	10.5
87.	Chandai	Chanda	4.5
88.	Dongargaon	Nanded	39.7
89.	Pimpri Barwat Project	Akola	17.0
90.	Ar Project	Yeotmal	10.8
91.	Waghari	-do-	9.2
92.	Lower Wainganga Project	Bhandara	97.1
93.	Eastern Bagh River Project	-do-	11.3
94.	Kanhan River Project	Nagpur	134.1
95.	Kolar	-do-	3.4
96.	Sasakuran Nalla Project	Bhandara	12.9
97.	Satti River Project	Chanda	18.2
98.	Khobragadi	-do-	10.3
99.	Tultuli	-do-	30.8
100.	Kathani	-do-	38.0
101.	Pohar	-do-	9.7
102.	Human	-do-	17.2
103.	Andhari	-do-	29.1
	Total		1,090.7
Mysore			
104.	Manjra	Bidar	4.0
105.	Karanja	-do-	19.4
106.	Nagora Tank	-do-	2.1
	Total		25.5

Appendix 5.4—*Contd.*

1	2	3	4
Orissa			
107.	Indravati-Kolab Project	Koraput	165.5
108.	Tumaria	-do-	8.8
109.	Bhaskel	-do-	25.0
110.	Belgam-Nilundi Project	-do-	15.8
111.	Nangi-Singari Project	-do-	8.9
112.	Pattia	-do-	4.1
113.	Dasupar Mohan Project	-do-	3.2
114.	Jadapara	-do-	2.8
115.	Personpalli	-do-	9.3
116.	Balimela Irrigation Project	-do-	129.2
	Total		372.6
	Grand Total		4,412.3

Source: (*i*) Report of the Krishna-Godavari Commission (1962).
(*ii*) Irrigation and Power Potential of Madhya Pradesh rivers, PWD, Government of Madhya Pradesh, 1963.
(*iii*) Orissa's Decade of Destiny (1963-1973)—A Plan for the Integrated Development of the river basins of Orissa by Dr. A. N. Khosla.

APPENDIX

Salient Features of Existing Major and

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expen-diture incurred (Rs. million)	Source of supply (Name of river)	Year of comple-tion	Type (Flow/ Storage/ Lift)
1	2	3	4	5	6	7
Andhra Pradesh						
1.	Krishna Delta System	Krishna	74.09	Krishna	1855	Flow
2.	Kurnool-Cuddapah Canal System	Kurnool Cuddapah	76.47	Tungabhadra	1866	-do-
3.	Muniyeru	Krishna	1.15	Muniyeru	1898-99	-do-
4.	Pakhal lake	Warangal	0.39	Munair	1922	Flow-cum-storage
5.	Wyra Project	Khammam	3.08	Wyra	1930	-do-
6.	Palair Project	-do-	2.18	Palair	1940-41	-do-
7.	Dindi Project	Nalgonda	3.89	Dindi	1943	-do-
8.	Koil Sagar	Mahbubnagar	9.12	Peddavagu	1955	-do-
9.	Tungabhadra low-level canal (jointly with Mysore)	Bellary, Anantapur, Kurnool	134.50	Tungabhadra	1957	-do-
10.	Sarlasagar	Mahbubnagar	3.56	Chinnavagu	1959	Storage
11.	Krishna barrage (Prakasam barrage)	Krishna	29.16	Krishna	1959-60	Flow
12.	Bhairavanitippa	Anantapur	14.58	Hagari	1961	Flow-cum-storage
13.	Improvements to K. C. Canal	Kurnool, Cuddapah	75.77	Tungabhadra	1962	Flow
14.	Lakhnapur	Hyderabad	3.56	Ullamarivagu	1969	Storage
15.	Jutpali	-do-	2.37	Jutpalivagu	1969	-do-

6.1

Medium Projects in the Krishna Basin

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ulti-mate irriga-tion ('000 hectares)	Length of main canal and branches Km.	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
644.20	548.37	556.44	605.00	Perennial	Sugarcane, paddy	
187.38	178.07	39.51	672.11	Perennial for first 27 km and then two-seasonal	Sugarcane, paddy & others	
7.04	6.47	6.11	80.06	Two seasonal	Paddy, ground-nut	
7.77	5.14	5.06	38.62	Perennial	Paddy	
7.52	7.04	7.04	30.57	One seasonal	,,	
8.58	7.36	7.59	28.16	Non-perennial	Paddy, groundnut	
18.21	15.78	7.89	41.84	Two seasonal	Paddy	
5.83	5.06	5.87	40.23	,,	,,	
223.86	198.71	60.25	349.15	Perennial	Sugarcane, garden, paddy, jowar, groundnut, wheat, cotton and others	
N.A.	4.80	1.70	19.31	Two seasonal	Others (Kharif and rabi)	
728.46	566.58	43.14	N.A.	Perennial	Sugarcane, paddy	
7.37	4.86	6.86	392.60	Two seasonal	Paddy	
N.A.	N.A.	122.22	307.00	Perennial	Sugarcane, paddy & others	
N.A.	1.62	1.05	19.30	,,	Garden and orchards, others.	
1.61	1.13	0.99	10.07	Two seasonal	Paddy, other rabi.	

Appendix

Sl. No.	Name of the project	Zone/ District	Cost/ Total expen-diture incurred (Rs. million)	Source of supply (Name of river)	Year of comple-tion	Type (Flow/ Storage/ Lift)
1	2	3	4	5	6	7
Maharashtra						
16.	Krishna Canal	Satara	0.95	Krishna	1868	Flow
17.	Ekruk tank	Sholapur	1.34	Adhila	1871	Flow-cum-storage
18.	Ashti tank	-do-	0.84	Ashti nala	1881	-do-
19.	Nehr tank	Satara	0.78	Yerla	1881-82	-do-
20.	Mhaswad tank	-do-	2.10	Man	1884-85	Storage
21.	Mutha canal	Poona	7.04	Mutha	1884-85	Flow-cum-storage
22.	Nira canals	-do-	71.97	Yelvandi and Nira	1885-86	-do-
23.	Visapur tank	Ahmednagar	N.A.	Hanga	1927	Storage
24.	Ranand	Satara	3.02	N.A.	1958	-do-

6.1—*Contd.*

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches Km.	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
14.93	13.52	4.99	66.00	Perennial	Sugarcane, cotton, paddy, jowar, wheat and others	
6.96	4.05	3.24	77.25	,,	Sugarcane, cotton, vegetable, paddy, groundnut, wheat, jowar, fodder & others	
7.24	6.80	4.73	34.59	,,	Sugarcane, cotton, paddy, bajra, wheat, jowar, fodder and others	
4.53	4.33	2.18	52.45	Two seasonal	Paddy, wheat, jowar, others	
12.95	12.14	4.45	40.01	Perennial	Sugarcane, cotton, bajra, groundnut, paddy, wheat, jowar, fodder and others	
38.04	20.23	6.80	141.62	,,	Sugarcane, other perennial, cotton, other two seasonal, paddy, vegetable, bajra, other kharif, wheat, jowar, fodder, other rabi	
308.29	241.80	82.73	432.42	,,	Sugarcane, cotton, bajra, wheat, jowar, paddy, others	
7.28	6.07	1.38	28.96	,,	Sugarcane, cotton, bajra, wheat, jowar, gram, others	
N.A.	N.A.	1.09	N.A.	N.A.	N.A.	

Appendix

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expen-diture incurred (Rs. million)	Source of supply (Name of river)	Year of comple-tion	Type (Flow/ Storage/ Lift)
1	2	3	4	5	6	7
25.	Pushpavati	Poona	1.60	N.A.	1962	Flow
26.	Harni Project	Osmanabad	5.65	Harni	1963	Flow-cum-storage
27.	Kamli	Bhir	2.00	Kamli	1964	Storage
28.	Talwar	Bhir	1.42	Talwar	1964	Storage
29.	Bandhara at Urmodi	Satara	1.77	Khan	1965	Flow
30.	Bandhara on Tarali	-do-	1.75	Tarali	1965	-do-
31.	Budhial tank	Sholapur	9.05	Belvan nalla	1965	Flow-cum-storage
32.	Ghod dam	Ahmednagar	55.62	Ghod	1965-66	-do-
33.	Extensions of Krishna canal	Satara	7.03	Krishna	1966	Flow
34.	Khasapur Project	Osmanabad	5.13	Dunda nalla	1966	Flow-cum-storage
35.	Chandni	-do-	7.16	Chandni	1966	-do-
36.	Kada Project	Bhir	5.85	Kari	1966-67	-do-
37.	Radhanagri H.E. Project	Kolhapur	21.80	Bhogawati	1967	-do-
38.	Mehekari	Bhir	9.56	Mehekari	1969	-do-

6.1—*Contd.*

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches Km.	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
N.A.	2.19	1.63	N.A.	N.A.	N.A.	
4.65	3.56	1.66	28.96	Two seasonal	Jowar, Paddy, wheat and other two-seasonals	
1.19	0.97	0.97	9.66	,,	Millets, grams and pulses	
0.79	0.67	0.67	9.66	Perennial	Garden and orchards, millets, grams and pulses	
N.A.	1.83	1.66	N.A.	N.A.	N.A.	
N.A.	2.40	2.20	N.A.	N.A.	N.A.	
5.63	5.50	3.24	26.56	Two seasonal	Wheat, jowar, others	
52.97	41.92	24.62	120.80	Perennial	Sugarcane, cotton, cereal, wheat, jowar	
N.A.	8.64	9.17	N.A.	,,	N.A.	
6.07	5.46	3.56	32.20	Two seasonal	Cotton, jowar, wheat, grams, others	
6.64	5.06	2.02	32.20	Two seasonal	Jowar (kharif), wheat, jowar (rabi), others	
4.37	2.99	1.21	20.90	,,	Kharif jowar, wheat, rabi jowar	
N.A.	N.A.	9.31	N.A.	Perennial	Sugarcane, paddy, wheat and others.	
8.50	6.64	4.05	27.30	Two seasonal	Cotton, kharif jowar, paddy, wheat, rabi jowar, other rabi.	

Appendix

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expenditure incurred (Rs. million)	Source of supply (Name of river)	Year of completion	Type (Flow/ Storage/ Lift)
1	2	3	4	5	6	7
39.	Kurnoor	Osmanabad	10.08	Bori	1969	-do-
Mysore						
40.	Gokak canal	Belgaum	1.58	Ghataprabha	1889	Flow
41.	Vanivilas sagar	Chitradurga	4.38	Vedavathi	1906	Flow-cum-storage
42.	Bhadra anicut	Shimoga	1.16	Bhadra	1931	Flow
43.	Anjanapur Reservoir	-do-	2.21	Kumudavathi	1938	Flow-cum-storage
44.	Ghataprabha Stage-I	Belgaum	69.25	Ghataprabha	1966	-do-
45.	Tunga Anicut	Shimoga	30.23	Tunga	1966	Flow
46.	Ramanahalli	Bijapur	4.08	Local nalla	1967	Storage
47.	Kolchi Weir	-do-	4.20	Malaprabha	1967	Flow
48.	Areshankar	-do-	2.14	Nalla of Krishna	1967	Storage
49.	Kalascope tank	-do-	2.14	N.A.	1967	-do-
50.	Nagathana	-do-	1.65	Kyadgi nalla	1968	-do-
51.	Dharma canal system	Dharwar	0.57	Dharma	N.A.	Flow-cum-storage
52.	Dharma Reservoir Project	North Kanara	13.76	-do-	1968	-do-
53.	Ambigola	Shimoga	11.17	Salura nalla	1969	Storage

Source: 1) Report of the Krishna-Godavari Commission (July, 1962).
2) Irrigation Statistics of India (1960-61), Central Water & Power Commission, April, 1970.

6.1—*Contd.*

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches Km.	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
9.63	8.10	3.64	64.40	Perennial	Sugarcane, other perennial, other two seasonal, other rabi, other kharif, other hot weather	
7.56	7.16	7.11	25.90	,,	Sugarcane, paddy, maize, jowar, cotton, pulses, wheat & others	
12.14	10.52	4.45	128.70	,,	Sugarcane, paddy, gardens, coconut	
5.58	5.01	3.57	107.80	,,	Sugarcane, paddy	
8.09	6.88	6.35	220.50	One seasonal	Paddy	
180.41	107.51	74.06	114.00	Two seasonal	Kharif, rabi crops	
19.06	14.40	8.70	153.00	Perennial	Sugarcane, paddy	
N.A.	N.A.	1.94	N.A.	N.A.	N.A.	
N.A.	1.64	1.27	14.00	One seasonal	Paddy	
N.A.	N.A.	1.24	N.A.	N.A.	N.A.	
N.A.	N.A.	1.14	N.A.	N.A.	N.A.	
N.A.	N.A.	0.57	N.A.	N.A.	N.A.	
5.50	5.22	4.05	27.00	One seasonal	Rabi crops	
5.87	5.66	5.67	Nil	Perennial	Sugarcane, paddy, pulses	
4.61	3.76	2.95	42.00	One seasonal	Paddy	

3) India—Irrigation & Power Projects (Five Year Plans), April, 1970.

4) Note volumes of Irrigation Chapter for Andhra Pradesh, Maharashtra and Mysore, Central Water and Power Commission (unpublished).

APPENDIX

Salient Features of Major and Medium Projects Under

Sl. No.	Name of the Project	Zone/ District	Description of scheme	Time schedule of cons-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
Andhra Pradesh					
1.	Rajolibanda diversion scheme	Mahboobnagar	Construction of an anicut 820 metres long and 9.4 metres high across river Tungabhadra and a left bank canal 143 km long, of which 43 km in Mysore	1944	The headworks have been completed. Certain balance works under distributaries are remaining to be done
2.	Musi	Nalgonda	Construction of a composite dam 21.33 m high and 4,296.6 m long across river Musi and two irrigation canals one on either side	1954	The scheme has physically been completed
3.	Guntur channel	Guntur	Construction of a high level channel taking off from the right bank of Krishna just upstream of Prakasam barrage	N.A.	Head regulator is almost completed except hoisting arrangements for the gates; other works are in progress
4.	Okachettivagu (Rama Krishna Puram anicut)	Mahboobnagar	Raising of FRL of Koilsagar by 1.83 m by erecting automatic falling shutters and dropping the water in surplus course for utilisation on the extra ayacut proposed	N.A.	The work on the project is not yet started; preliminaries are in progress

6.2

Construction in the Krishna Basin

truction	Cost		G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
Date of likely comple- tion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)				
7	8	9	10	11	12	13
IV Plan	38.30	38.51 (Up to Mar. '70)	53.70	47.63	35.61	Joint venture of Andhra Pradesh and Mysore
			(For Andhra Pradesh only)			
IV Plan	40.90	32.42 (Up to Mar. '70)	26.59	23.35	26.92	
IV Plan	17.00	6.38 (Up to Mar. '70)	N.A.	N.A.	10.93	
IV Plan	6.00	—	10.36	6.23	2.77	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons-	
				Date of com-mence-ment	Important items of works completed
1	2	3	4	5	6
5.	Gajuladinne	Kurnool	Construction of an earth dam across river Handri 3,347.92 m long and 12.8 m high and two canals one on either bank	N.A.	The detailed investigations have been completed & revised estimates sent to the Govt. Approval is awaited
6.	Nagarjuna-sagar	Nalgonda	Construction of a masonry and earth dam 4,864.6 m long and 124.7 m high across river Krishna near Nandikonda village in Nalgonda district with two canals one on either side	1956	Construction of the dam completed. Work on canal system is in progress
7.	Tungabhadra High Level Canal—Stage I Jointly (with Mysore)	Anantapur	Construction of main high level canal from the high level sluice of the Tungabhadra dam, Mid-Penner Regulator across the river Penner and Mid-Penner North and South Canals	1958	The high level canal is nearly completed together with the distributary system. Construction of Mid-Penner dam is in Progress
8.	Kotepalli vagu	Hyderabad	Construction of an earth dam across river Kotepallivagu 389.80 m long with surplus weir 390.14 m long and two irrigation Canals	1966	Construction of headworks completed. Canal system is in Progress

6.2—*Contd.*

truction	Cost					
Date of likely comple-tion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
N.A.	9.64	—	6.07	5.18	5.06	
IV Plan	1,648.90	1,620.46 (Up to Aug. '70)	1,623.55	1,386.62	829.64	
1970-71	190.00	126.00 (Up to June '70)	163.46	136.14	48.21	
		For Andhra Pradesh only				
1970-71	7.70	6.46 (Up to Mar. '70)	5.22	4.04	4.04	

Appendix

Sl. No.	Name of the project	Zone/ District	Description of scheme	Time schedule of cons-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
9.	Lankasagar	Khammam	Construction of an earth dam 2,196.39 m long and 13.41 m high across Kottaleru stream and two canals on either flank	N.A.	Construction of the dam and spillway completed. Canal system is in progress.
10.	Tungabhadra High Level Canal—Stage II (Jointly with Mysore)	Cuddapah, Anantapur, Kurnool	Construction of Mylavaram dam across river Penner, widening and lining of Tungabhadra High Level main canal and costruction of Guntakal branch, Cuddapah North and South canals, fixing crest gates to Mid-Penner dam and widening and extension of Mid-Penner South Canal.	1968	Widening and lining of High Level Canal and Guntakal Branch Canal in progress. Construction of Mylavaram dam is in initial progress.
	Maharashtra				
11.	Koyna (Stages I, II & III)	Satara	Construction of a dam across the river Koyna at Deshmukhwadi near Helwak and underground power station at Popholi below the Western Ghats.	1954	Stages I and II completed. Stage III is in progress.

6.2—*Contd.*

truction	Cost					
Date of likely completion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
N.A.	7.66	5.29 (Up to Mar. '70)	3.64	2.83	2.06	
V Plan	112.60	12.69 (Up to May '70)	181.38	129.88	55.62	
			For Andhra Pradesh only			
V Plan	944.4	N.A.	—	—	—	Hydroelectric project

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons- Date of commencement	Important items of works completed
1	2	3	4	5	6
12.	Vir Dam	Poona	Construction of a composite dam 3,601 m long, 34.68 m high across river Nira, remodelling of the existing Nira Right Bank Canal & constructing tail tank at Tisangi Sanoke.	1957	The works have almost been completed and the percentage of ancillary works in progress is very meagre.
13.	Khadakwasla Stage I	Poona	Construction of an earthen dam 823 m long, 58 m high across the river Ambi at Panshet and strengthening of the existing Khadakwasla dam together with the construction of a main canal 127 km long.	1957	The project is in advanced stage of construction.
14.	Warna	Sangli	Construction of an earthen and masonry dam 1458 m long and 58.52 m high across river Warna with two canals one on either bank.	1964	No physical progress has been done on main dam. Survey and investigations are in progress.
15.	Bhima Irrigation	Poona and Sholapur	Two composite dams one across river Pawana and other across river Bhima with canal systems on both sides.	1964	Construction of Pawana dam is in progress.

6.2—*Contd.*

truction	Cost					
Date of likely completion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
1972	54.10	47.97 (Up to Mar. '70)	86.38	77.31	26.71	
IV Plan	167.00	163.14 (Up to Mar. '69)	73.29	26.39	22.30	
V Plan	310.87	3.00 (Up to Mar. '68)	120.90	N.A.	99.06	
V Plan	425.80	52.63 (Up to Mar. '70)	189.11	N.A.	172.89	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
16.	Tulshi	Kolhapur	Construction of an earthen dam 975.36 m long and 44.19 m high across river Tulshi with two canals one on each bank.	1965	Headworks not yet started. Work on preliminaries is in progress.
17.	Kadi	Bhir	Construction of a 547 m long earth dam across the Kadi rivulet together with a right bank canal 9.65 km long.	N.A.	Construction of headwork is almost completed and the canal system is in progress.
18.	Padwal Karwadi	Sholapur	Construction of an earthen dam 935.73 m long and maximum height 15.24 m across a local nalla that meets Beddi nalla, a tributary of Bhima.	N.A.	Construction of headwork is in progress.
19.	Krishna Irrigation	Satara	Construction of earth dam across Krishna river near Dhom and Borkhal villages and on the Venna river near Kanhertogether with the canal systems.	1968-69	The work on main items not yet started. Survey works for canals and cross drainage works are in progress.
20.	Kukadi—Stage I	Poona	Construction of a dam at Manikdoh and a weir-cum-	1969-70	The works are mostly in preliminary stage.

6.2—*Contd.*

truction	Cost					
Date of likely comple-tion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
1973	22.00	1.65 (Up to Mar. '69)	7.28	5.83	3.16	
IV Plan	4.35	2.98 (Up to Mar. '69)	N.A.	N.A.	1.10	
IV Plan	2.15	0.47 (Up to Mar. '69)	N.A.	N.A.	0.83	
V Plan	276.56	0.95 (Up to Mar. '68)	139.01	122.46	106.29	
V Plan	179.00	0.02 (Up to Mar. '69)	72.85	52.49	42.79	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons-	
				Date of com-mence-ment	Important items of works completed
1	2	3	4	5	6
			storage at Yedgaon both on Kukadi river. A dam across river AI at Pimpel-gaon-Toga together with a left bank canal from Yedgaondam.		Construction work has not yet been started.
Mysore					
21.	Tungabhadra (Jointly with Andhra Pradesh)	Bellary	Construction of a masonry dam about 49.39m high and 2,441m long across river Tungabhadra, left bank canal 226.87 km long with power house on left side, a low level canal 349.15 km long with two power houses on right side.	1945	Construction of dam and right bank canal completed. Work on left bank Main canal is in progress.
22.	Rajolibunda Diversion Scheme (Jointly with Andhra Pradesh)	Raichur	Construction of an anicut 820 m long and 9.4 m high across Tungabhadra river and left bank canal 143.0 km long of which 43 km will be in Mysore and rest in Andhra Pradesh.	1944	Work more or less completed.
23.	Bhadra	Shimoga	Construction of a masonry dam 440.5 m long and 71.6 m	1947	Construction of the dam, allied works and some

6.2—*Contd.*

truction	Cost					
Date of likely comple-tion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
V Plan	919.41	252.59 (Up to May '70)	712.07 For Mysore only	623.24	272.10	
IV Plan	38.30	38.51 (Up to Mar. '70)	3.24 For Mysore only	2.47	2.38	
IV Plan	350.00	310.67	152.69	121.41	99.02	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons- Date of com-mence-ment	Important items of works completed
1	2	3	4	5	6
			above the deepest foundation and 59.13 above the river bed with 1,267.96 m long earth embankment across river Bhadra and two canals one on either flank.		of the canals completed.
24.	Ghataprabha —Stage II	Belgaum	Construction of a 8,841 m long 50 m high composite dam across the river Ghataprabha near Hidkal village about 19 km upstream of the Dhupdal weir. Extension of Stage I main canal by 43.45 km.	1956	Work on the Hidkal dam is in progress. A major portion of the main canal and branches completed. Two-thirds distributaries completed.
25.	Tungabhadra High Level Canal—Stage I (Jointly with Andhra Pradesh)	Bellary	Construction of Tungabhadra Right Bank High Level Canal and Mid-Penner North and South Canals.	1957-58	Control Board Area Main Canal 0 to 111 km completed.
26.	Hathikoni	Gulbarga	Construction of an earthen dam 923.54 m long and 22.1 m high across Gajarkot stream of Hathikoni river and a canal on left flank.	1959-60	Except for the distribution system all other works have nearly been completed.

6.2—*Contd.*

truction	Cost					
Date of likely comple-tion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
V Plan	485.30	191.05 (Up to June '70)	180.41	144.32	46.54	
IV Plan	62.34	Mysore 20.15 (Up to Mar. '70) Board 99.23 (Up to Jan. '70)	53.82	45.00 For Mysore only	40.47	
	Total	119.38				
1970-71	8.30	8.32 (Up to Mar. '70)	2.87	2.51	2.14	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons- Date of commencement	Important items of works completed
1	2	3	4	5	6
27.	Malaprabha	Belgaum	Construction of a masonry dam 44.19 m high across river Malaprabha and a canal 193.12 km long	1960	Construction of the dam head regulator and the canal system is in progress.
28.	Hagaribommanahalli	Bellary	Irrigation scheme. Earthen dam 15.24 m high and 1,935.48 m long. Two canals on either side of dam.	1960	Construction of head works, canal and distributaries is in advanced stage. Nearly 1/5th of field channels completed.
29.	Kanakanala	Raichur	Construction of an earthen dam 803.15 m long and 15.54 m high across Kanakanala and a canal 16 km long taking off from right flank of the dam.	1960	Construction of the head works completed. Work on canal system and field channels is in progress.
30.	Jambadahalla	Chickmagalur	Construction of an earthen dam 31.70 m high and 838.20 m long across Jambada stream and two canals on either side of the dam.	1961	Construction of head works and canal system is nearly completed. Surplusing works are in progress.
31.	Harinala	Belgaum	Construction of an earthen dam 2,270.76 m long and 21.03 m high across Harinala	1961-62	The project has been deferred for the present.

6.2—*Contd.*

truction	Cost					
Date of likely completion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
V Plan	676.50	124.54 (Up to June '70)	202.35	161.88	121.40	
1970	26.70	18.76 (Up to Mar. '70)	4.73	4.04	2.97	
IV Plan	10.00	8.48 (Up to Mar. '70)	3.24	2.59	2.06	
1972	12.00	9.73 (Up to Mar. '70)	4.04	3.24	2.43	
V Plan	16.52	—	6.07	5.18	4.35	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of Scheme	Time schedule of cons- Date of commencement	Important items of works completed
1	2	3	4	5	6
32.	Upper Krishna —Stage I	Raichur, Gulbarga	Construction of two dams one at Almatti and other at Siddapur across river Krishna and Narayanpur left bank canal.	1963-64	The construction of the two dams and left bank canal is in the initial stages of construction.
33.	Chandramapally	Gulbarga	Construction of an earthen dam 777.24 m long, 26.21 m high across river Sarnatha and two canals one on each bank.	1966	Construction work on the dam and surplusing work is in progress.
34.	Tungabhadra High Level Canal—Stage II (Jointly with Andhra Pradesh)	Bellary	Widening of 1st stage canal and lining both bed and sides throughout the length of the canal	1967	Board area (up to July '70) Earth work —102.25% Backing 104·13% Lining 100.15%

Source: (i) Report of the Krishna. Godavari Commission, Annexures VIII, IX, X and XI.
(ii) Irrigation Statistics of India (1960-61)—Central Water & Power Commission.

6.2—*Contd.*

truction	Cost					
Date of likely comple-tion	Total Cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
1982-83	750.00	30.89 (Up to Mar. '69)	344.80	284.91	242.82	
1972	17.61	7.40 (Up to Mar. '69)	7.08	5.30	5.06	
IV Plan	36.82	41.25 (Up to July '70)	47.99	39.94	40.47	
		For Mysore only				

(iii) India, Irrigation & Power Projects (Five Year Plans)—Central Water & Power Commission, April, 1970.

(iv) Note Volumes of Irrigation Chapter for Andhra Pradesh, Maharashtra and Mysore, Central Water & Power Commission (Unpublished).

APPENDIX 6.3

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by the Planning Commission

Sl. No.	Name of the Project	Name of State	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks if any
1	2	3	4	5	6
1.	Pulivendala	Andhra Pradesh	19.40	22.26	
2.	Dudhganga	Maharashtra	193.74	67.17	
3.	Khadakwasla—Stage II	-do-	170.00	40.21	
4.	Pangaon Hingani	-do-	18.53	10.10	
5.	Nazare	-do-	13.98	3.37	
6.	Ulup	-do-	3.29	0.88	

Source: Report of the Working Group on Irrigation & Flood Control, Fourth Five Year Plan (1969-74) and Annual Plan (1969-70) for Andhra Pradesh, Maharashtra and Mysore States.

APPENDIX 6.4

Salient Features of New Major and Medium Projects Proposed by the State Governments in the Krishna Basin

Sl. No.	Name of the Project	Source of supply	Type (Storage/ Flow/ Lift)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6
Andhra Pradesh					
1.	Upper Krishna Project (Extension to Andhra Pradesh)	Krishna	Flow-cum-storage	72.84	
2.	Sangameshwaram Canal Scheme	-do-	-do-	145.08	
3.	Sangameshwaram Canal Scheme—Stage II	-do-	-do-	291.37	
4.	Nagarjunasagar—Stage II	-do-	-do-	496.14	
5.	Pulichintala Project	-do-	-do-	158.23	
6.	Nagarjunasagar—Stage III	-do-	-do-	814.62	
7.	Bhima Project	Bhima	-do-	161.87	
8.	Tungabhadra Project Left Bank Low Level Canal Extension (into Andhra Pradesh)	Tungabhadra	-do-	48.56	
9.	Varadarajaswamy Project	Munimadgulavagu	-do-	2.19	
10.	Vaikuntapuram Pumping Scheme	Krishna	Lift	6.88	
11.	Akheru Project	Akheru	Flow-cum-storage	2.63	
12.	Rajolibanda Right Canal Scheme	Tungabhadra	Flow	16.19	
13.	Muneru Project	Muneru	Flow-cum-storage	3.04	
14.	Kalikota Project	Wyra	-do-	6.88	
Maharashtra					
15.	Koyna Irrigation Scheme—Stage I	Koyna and Krishna	Flow-cum-storage	42.17	
16.	Bhima Lift Irrigation Project—Stage I	Pavna	Storage-cum-lift	40.47	
17.	Urmodi Project	Urmodi	Flow-cum-storage	9.79	
18.	Koyna Irrigation—Stage II	Koyna and Krishna	-do-	58.52	

Appendix 6.4—*Contd.*

Sl. No.	Name of the Project	Source of supply	Type (Storage/ Flow/ Lift)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6
19.	Wang Project	Wang	-do-	28.13	
20.	Yeralwadi Project	Yerala	-do-	5.06	
21.	Patharpunj Project	Warna	-do-	2.43	
22.	Gothana Project	Nalla joining Warna near Gothana	-do-	0.81	
23.	Kadvi Project	Kadvi and Shali	Storage-cum-lift	4.05	
24.	Kasari Project	Kasari	Flow-cum-storage	1.62	
25.	Phonda Project	Bhogavati and Radhanagari	-do-	25.90	
26.	Kumbhi Project	Khumbi and Dhamni	Storage	2.02	
27.	Vedganga Project	Vedganga	Flow-cum-storage	6.88	
28.	Ajra Project	Hiranyakeshi	-do-	3.24	
29.	Chaskaman Project	Bhima	-do-	46.54	
30.	Bhima Lift Irrigation Project—Stage II	Pavna, Indrayani, Bhama & Bhima	Lift	101.98	
31.	Kukdi Project—Stage II	Ghod, Mina, Arand Kukdi	Storage	74.70	
32.	Nira Valley Project	Nira	Flow-cum-storage	101.05	
33.	Nimgaon-Ganguard Tank	Sina	-do-	7.69	
34.	Sina Project	Sina	-do-	18.21	
	Mysore				
35.	Bijapur Lift Irrigation Scheme	Krishna	-do-	343.98	
36.	Upper Krishna Project—Stage II	-do-	-do-	269.92	
37.	Ghataprabha Project—Stage III	Ghataprabha	-do-	120.59	
38.	Ghataprabha Project—Stage IV	Hiranyakeshi, Markandeya & Ghataprabha	-do-	67.18	

Appendix 6.4—*Contd.*

Sl. No.	Name of the Project	Source of supply	Type (Storage/ Flow/ Lift)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5	6
39.	Markandeya Project	Markandeya	-do-	4.73	
40.	Bhutevadi Storage Scheme	Malaprabha	-do-	18.21	
41.	Sattinala Project	Sattinala	-do-	2.35	
42.	Don River Project	Don	-do-	10.12	
43.	Bhima Lift Irrigation Scheme	Bhima	Storage-cum-Lift	40.47	
44.	Bhima Irrigation Scheme	-do-	Flow-cum-storage	40.47	
45.	Diksanga Scheme	Bori	-do-	2.75	
46.	Amarja Project	Amarja	-do-	6.68	
47.	Kagna Project	Kagna	-do-	16.19	
48.	Mullamari Project	Mullamari	-do-	9.79	
49.	Benithora Project	Gondori, Benithora and Kansur	Flow-cum-storage	24.28	
50.	Upper Tungabhadra Project	Tungabhadra	Flow	84.98	
51.	Tunga Reservoir Project	Tunga	Flow-cum-storage	101.17	
52.	Extension & remodelling of Bhadra Anicut Channels	Bhadra	Flow	5.50	
53.	Madag Masur Scheme	Kumadavati	Flow-cum-storage	9.75	
54.	Varada Scheme	Headgoanhalla and Varada	-do-	8.09	
55.	Dandavathi Reservoir Project	Dandavathi	-do-	3.24	

Source: Report of the Krishna-Godavari Commission (July, 1962).

APPENDIX 7.1

Monthly and Annual Normals of Rainfall in the Basin of East-flowing Rivers Between the Krishna and the Penner

Sl. No.	State/ District	Monthwise Normal Rainfall in mm.												Annual Normal Rainfall in mm.
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Andhra Pradesh													
1.	Guntur	5.8	10.6	9.4	16.0	44.3	78.8	121.0	122.0	147.7	158.3	102.9	14.9	831.7
2.	Kurnool	3.2	6.2	6.1	18.4	37.6	67.2	100.9	99.7	142.4	91.7	44.8	6.7	624.9
3.	Nellore	29.3	9.7	10.3	15.0	39.7	42.3	72.6	74.0	106.2	229.4	250.9	72.8	952.2

Source : Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX 7.2

Salient Features of Existing Major and Medium Projects in the Basin of East-flowing Rivers Between the Krishna and the Penner

Sl. No.	Name of the Project	Zone/District	Cost/Total expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion	Type (Flow/ Storage/ Lift)	Ultimate Irrigation ('000 hectares)	Remarks
1	2	3	4	5	6	7	8	9
1.	Mopad reservoir	Nellore	2.44	Manneru	1921	Storage	5.06	One seasonal paddy crop
2.	Markapur Tank	Kurnool	0.13	Gundlakamma	N.A.	-do-	1.62	
3.	Cumbum Tank	-do-	N.A.	-do-	N.A.	-do-	4.86	
4.	Karedu anicut	Nellore	N.A.	Manneru	N.A.	Flow	N.A.	
5.	Veeraraghavuni Kota Anicut	-do-	N.A.	-do-	N.A.	-do-	2.27	
6.	Upputeru Upper Anicut	-do-	N.A.	-do-	N.A.	-do-	N.A.	
7.	Rallapadu—Stage I	-do-	N.A.	-do-	N.A.	Storage	N.A.	
8.	Romperu Drainage Scheme	Guntur	12.80	N.A.	1956	Drainage	4.17	
9.	Upputeru Lower Anicut	Nellore	1.39	Manneru	1956	Flow	0.77	
10.	Nakkalagandi Reservoir	-do-	0.73	Manneru	1956	Storage	0.40	
11.	Paleru Reservoir	-do-	0.70	Paleru	1956	-do-	0.61	
12.	Rallapadu—Stage II	-do-	10.58	Manneru	1959	-do-	4.45	One seasonal paddy crop
13.	Paleru Bitragunta Supply Channel Scheme	-do-	2.62	Paleru	1962	Flow	2.22	-do-

Source : (*i*) Irrigation Statistics of India (1960-61),
(*ii*) Irrigation Map of India.
(*iii*) Note Volume of Irrigation Chapter for Andhra Pradesh, Central Water & Power Commission (1970)—Unpublished.

APPENDIX 7.3

Salient Features of Major and Medium Projects Under Construction in the Basin of East-flowing Rivers Between the Krishna and the Penner

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of construction		Total cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
				Important items of works completed	Date of likely completion			
1	2	3	4	5	6	7	8	9
1.	Gandipalam	Nellore	Construction of a reservoir across river Pillaperu, 0.8 km south-west of Gandipalam village in Nellore district and canal system.	The scheme is under detailed investigation	IV Plan	13.3	4.05	

Source : Note Volume of Irrigation Chapter for Andhra Pradesh, Central Water & Power Commission, 1970—Unpublished.

APPENDIX

Salient Features of Existing Major

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expenditure incurred (Rs. million)	Source of water supply (River)	Year of completion	Type (Flow/ Storage/ Lift)	G.C.A. ('000 hectares)
1	2	3	4	5	6	7	8
Andhra Pradesh							
1.	Nellore Anicut	Nellore	70.7	Penner	1825	Flow	N.A.
2.	Sangam Anicut	,,		,,	1886	,,	,,
3.	Kurnool-Cuddapah Canal System	Kurnol-Cuddapah	764.74	Tungabhadra	1866	,,	187.38
4.	Thambalepalli Anicut (Upper Sagileru)	Cuddapah	3.737	Sagileru	N.A.	,,	N.A.
5.	Vidyaranyaswamigudi	Anantapur	0.259	Chitravati	1956	Storage	,,
6.	Upper Penner	Anantapur	15.862	Penner	1958	,,	,,
7.	Pincha Project	Cuddapah	6.226	Pincha Nadi	1959	,,	,,
8.	Lower Sagileru Project	Cuddapah	5.726	Sagileru	1959	,,	,,
9.	Siddalagandi Project	Chittoor	0.614	Local stream	1959	,,	,,
10.	Chennarayaswamigudi Project	Chittoor	3.255	Papagni	1960	,,	,,
11.	Zurreru	Kurnool	3.033	Zurreru	1963	,,	0.81

Source: (1) Note Volume of Irrigation Chapter, Andhra Pradesh.
(2) Irrigation Statistics of India, 1960-61.
(3) Volume I—Penner Basin Report, Central Water & Power Commission.

8.1

and Medium Projects in Penner Basin

C.C.A. ('000 hectares)	Ultimate Irrigation ('000 hectares)	Length of main canal & branches (Kms.)	Whether perennial, two seasonal or one seasonal	Cropping Pattern	Remarks
9	10	11	12	13	14
N.A.	43.40	303.36	One seasonal crop	Paddy	
,,	57.38				
178.07	104.02*	672.11	Perennial for first 27 km and then two-seasonal	Sugarcane, Paddy and others	*The project utilises, the Krishna basin waters for irrigation. Of the total irrigated area of 122.2 thousand hectares, 18.2 thousand hectares lie in Krishna basin.
N.A.	1.8	N.A.	N.A.	N.A.	
,,	0.08	,,	,,	,,	
,,	3.93	28.97	One seasonal	Paddy	
,,	1.58	10.47	N.A.	N.A.	
4.33	3.24	23.35	,,	,,	
N.A.	0.16	N.A.	,,	,,	
,,	0.46	10.50	,,	,,	
0.73	0.93	5.64	One seasonal	Paddy	

APPENDIX

Salient Features of Major and Medium Projects

Sl. No.	Name of the Project	Zone/ District	Description of the Scheme	Time schedule of construc-	
				Date of commence-ment	Important items of work completed
1	2	3	4	5	6
Andhra Pradesh					
1.	Kanupur Canal	Nellore	Diversion of flood waters of Penner river to feed the existing tanks. It is proposed to take off two canals 39.00 km long above the Sangam anicut, west of head sluice of Nellore tank supply channel.	1960	Earthwork of canal and construction of cross drainage work is in progress.
2.	Tungabhadra High Level Canal-Stage I (Jointly with Mysore)	Anantapur	Construction of main high level canal from the high level sluice of the Tungabhadra Dam, Mid Penner North and South Canals and Tadipatri Branch	1958	The work is in an advanced stage of construction.
3.	Bahuda Reservoir	Chittoor	Construction of a dam across Bahuda river near village Nimanapalli and 2 pick-up anicuts at Mugalamari and Chintaparthi villages. Irrigation is proposed to be carried out by letting out waters into river to be picked up lower down by the pick up anicut and partly by the channels taking off at flanks.	1960	Job works completed up to M-2 F7 out of M4 F-6 on left side. Mangalam anicut is completed, Chintapathy anicut nearing completion, sluices and regulators completed except erection of shutters.

Under Construction in Penner Basin

tion	Cost					
Date of likely comple- tion	Total cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
Fourth Plan	32.593	10.328 (Up to Mar. '69)	N.A.	N.A.	6.88	
,,	190.00	126.03 (Up to Apr. '70)	163.46	136.14	48.21* (For Andhra Pradesh only)	*Of the total area irrigated by the project, only 34.04 thousand hectares lie in Penner basin. The project is fed by, mostly, Krishna basin waters.
,,	4.100	0.891 (Up to June '69)	N.A.	N.A.	1.17	

Appendix

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of construc-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
4.	Tungabhadra High Level Canal-Stage II (Jointly with Mysore)	Cuddapah Ananta-pur Kurnool	Construction of Mylavaram dam across river Penner, widening and lining of Tungabhadra High Level main canal, construction of Guntakal branch, Cuddaph North and South Canals, fixing crest gates to Mid-Penner dam and widening and extension of Mid-Penner South Canal.	1968	Work on widening of canal and Guntakal Branch is in progress. Work of Mylavaram dam is in initial stages.

Source: Note Volume of Irrigation Chapter, Andhra Pradesh.

8.2—*Contd.*

tion	Cost					
Date of likely comple-tion.	Total cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
Fifth Plan	112.6	14.35 (Up to Apr. '70 Andhra Pradesh)	181.38	129.88	†55.62 (For Andhra Pradesh only)	†Of the total area irrigated by the project, only 37.00 thousand hectares lie in Penner basin. The project gets most of its supplies from Krishna basin waters.

APPENDIX 8.3

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by The Planning Commission

Sl. No.	Name of the State/Project	Estimated Cost (Rs. million)	Area proposed to be irrigated ('000 hectares)	Remarks
1	2	3	4	5
1.	Somasila	335.2	166.73	

Source: Project Report on the Somasila Project, Government of Andhra Pradesh, August, 1971.

APPENDIX 9.1

Monthly and Annual Rainfall of River Basins Between Penner and Cauvery

Sl. No.	State/ District	Month-wise Normal Rainfall in mm.												Annual Normal rainfall in mm.
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Andhra Pradesh													
1.	Chittoor	19.1	7.5	11.0	24.1	62.5	57.7	79.3	104.0	128.3	145.1	139.2	45.1	822.9
2.	Cuddapah	9.5	3.5	6.0	15.4	44.9	58.3	84.8	97.0	132.9	114.4	95.3	23.5	685.5
3.	Nellore	29.3	9.7	10.3	15.0	39.7	42.3	72.6	74.0	106.2	229.4	250.9	72.8	952.2
	Mysore													
4.	Bangalore	4.7	7.1	10.0	42.7	106.4	63.1	82.1	114.1	148.2	143.9	59.7	11.6	793.6
5.	Kolar	8.0	6.3	9.5	33.9	79.9	59.4	78.1	102.5	143.7	121.5	73.3	14.4	730.5
	Tamil Nadu													
6.	Chingleput	42.0	11.8	13.3	17.3	37.9	49.1	88.9	124.4	135.3	260.5	304.9	125.6	1211.0
7.	North Arcot	30.0	8.9	11.5	24.3	70.8	59.1	87.6	132.9	160.5	166.2	158.4	60.9	971.1
8.	South Arcot	53.7	14.6	15.3	29.3	56.4	43.9	73.6	132.5	141.8	215.9	277.3	134.6	1188.9
9.	Salem	14.5	8.8	11.9	43.3	107.3	52.5	65.5	111.2	131.6	160.1	102.8	33.6	843.1
10.	Tiruchchirappalli	32.0	13.9	15.0	44.5	71.1	38.1	48.5	105.0	119.0	171.9	149.0	69.1	877.1

Source : Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX

Salient Features of Existing Major and Medium Projects

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expen-diture incurred (Rs. million)	Source of supply (Name of river)	Year of comple-tion	Type (Flow/ Storage Lift)
1	2	3	4	5	6	7
Andhra Pradesh						
1.	Swarnamukhi	Chittoor	N.A.	Swarnamukhi	N.A.	Flow
2.	Aranier	,,	10.59	Araniar	1958	Storage
3.	Malliamadugu	,,	3.19	Malliama-dugu	1959	,,
4.	Kalangi	,,	3.52	Kalangi	1960	,,
5.	Swarnamukhi Left Bank Canal	,,	2.92	Swarnamukhi	N.A.	Flow
Tamil Nadu						
6.	Chembarambakkam Tank	Chingleput	0.76	Cooum, Palar & Kortalaiyar	N.A.	Storage
7.	Shatiatope regulator	South Arcot	1.09	Vellar	1848	Flow
8.	Palar anicut	North Arcot	2.61	Palar	1858	,,
9.	Vriddhachalam anicut	South Arcot	0.11	Manimuk-thanadi	1869	,,
10.	Mehamathur anicut	,,	0.09	,,	1870	,,
11.	Vallur anicut	Chingleput	0.08	Kortalaiyar	1872	,,
12.	Pelandurai regulator	South Arcot	0.69	Vellar	1876	,,
13.	Madras Water Supply and Irrigation System	Chingleput	1.87	Kortalaiyar	N.A.	Storage Lift
14.	Barur Tank and Nedungal Anicut	Salem	0.46	Ponnaiyar	1888	Flow-cum-storage
15.	Tirukkoyilur anicut	South Arcot	0.42	,,	N.A.	Flow
16.	Poini anicut	North Arcot	0.30	Poini	1897	,,
17.	Cheyyar anicut	,,	1.04	Cheyyar	1905	,,

9.2

in River Basins Between the Penner and the Cauvery

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches (Km.)	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
N.A.	N.A.	4.20	N.A.	N.A.	N.A.	
2.05	—	2.45	26	One seasonal	Rice	
N.A.	N.A.	1.62	N.A.	N.A.	N.A.	
N.A.	N.A.	1.89	N.A.	N.A.	N.A.	
N.A.	N.A.	2.25	N.A.	N.A.	N.A.	
N.A.	N.A.	6.05	N.A.	N.A.	N.A.	
43.73	17.79	13.72	66	Two seasonal	Rice, other kharif and other rabi	
57.04	42.51	33.60	253	Two seasonal	Rice, other kharif and other rabi	
N.A.	6.62	4.05	20	Two seasonal	N.A.	
N.A.	N.A.	2.02	12	Two seasonal	N.A.	
4.10	2.75	2.02	5	Two seasonal	N.A.	
N.A.	N.A.	6.45	63	Two seasonal	N.A.	
N.A.	N.A.	3.23	N.A.	Two seasonal	N.A.	
N.A.	N.A.	3.23	N.A.	Two seasonal	N.A.	
N.A.	18.61	11.30	75	Two seasonal	N.A.	
N.A.	N.A.	9.69	N.A.	Two seasonal	N.A.	
11.92	11.92	9.69	98	Two seasonal	Rice, other kharif and other rabi	

Appendix

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expen- diture incurred (Rs. million)	Source of supply (Name of river)	Year of comple- tion	Type (Flow/ Storage Lift)
1	2	3	4	5	6	7
18.	Tholudur regulator and Willingdon reservoir	South Arcot	2.62	Vellar	1925	Storage
19.	Krishnagiri	Salem	20.24	Ponniayar	1959	,,
20.	Vidur	South Arcot	8.89	Varahanadi	1959	,,
21.	Sathanur—Stage I	North Arcot	25.80	Ponnaiyar	1958	,,
22.	Sathanur—Stage II	South Arcot	6.00	,,	1966	,,
23.	Improvement to Palar Anicut	North Arcot	6.30	Palar	1966	Flow
24.	Gomukhinadi	South Arcot	12.11	Gomukhi	1969	Storage

Sources: (1) Descriptive booklet on the important irrigation projects in Madras (now Tamil Nadu) State, Govt. of Madras, 1952.
(2) Irrigation Statistics of India (1960-61), Central Water & Power Commission.
(3) Note volumes of Irrigation Chapters of Andhra Pradesh and Tamil Nadu, Central Water & Power Commission, 1970—Unpublished.
(4) Replies of Tamil Nadu State to the questionnaire issued by the Irrigation Commission.

9.2—*Contd.*

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches (Km.)	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
15.54	11.68	10.12	51	Two seasonal	Rice, other kharif crops and other rabi crops	
4.55	3.64	3.64	32	One seasonal	Rice	
5.36	3.93	1.30	18	One seasonal	Rice	
13.97	8.51	8.50	35	One seasonal	Rice	
			(Madras Portion)			
N.A.	N.A.	2.02	N.A.	N.A.	N.A.	
N.A.	N.A.	1.38	N.A.	N.A.	N.A.	
N.A.	N.A.	2.02	N.A.	N.A.	N.A.	

APPENDIX

Salient Features of Major and Medium Projects Under Construction in

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of construc-	
				Date of com-mence-ment	Important items of works completed
1	2	3	4	5	6
Tamil Nadu					
1.	Manimuk-thanadi	South Arcot	Construction of a storage dam across the Manimukthanadi, tributary to Vellar about 0.8 km above the existing Pallagachery anicut and a right bank canal 11 km long.	1966	Headworks 60.3% completed and canal system 25% completed.

Source: Note Volume of Irrigation Chapter of Tamil Nadu State, Central Water & Power Commission, 1970 (Unpublished).

9.3

the River Basins Between the Penner and the Cauvery

tion	Cost					
Date of likely completion	Total cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
IV Plan	11.76	9.96 (Up to Mar. '69)	N.A.	N.A.	1.72	

APPENDIX 9.4

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by The Planning Commission

Sl. No.	Name of Project	Estimated cost (Rs. million)	Ultimate Irrigation ('000 hectares)	Remarks
1	2	3	4	5
Tamil Nadu				
1.	Thandarai Anicut	4.70	0.57	
2.	Restoration of Nandan Channel	3.20	0.11	

Source: Fourth Five Year Plan 1969-74 and Annual Plan 1969-70 'Reports of the Working Group on Irrigation and Flood Control'.

APPENDIX 10.1

Salient Features of Existing Major and Medium Projects in the Cauvery Basin

Sl. No.	Scheme	River or tributary	Irrigation benefits (hectares)	Remarks
(1)	(2)	(3)	(4)	(5)
I.	**PREPLAN SCHEMES**			
	Mysore			
1.	Krishnarajasagara	Cauvery	50,600	Irrigated area taken from "Irrigation Potential of Cauvery River Basin" and corrected according to Note Volumes of Irrigation Chapters of respective States wherever available.
2.	Chamaraja Anicut	,,	10,400	
3.	Mirle Anicut	,,	2,050	
4.	Ramsamudram Anicut	,,	3,460	
5.	Tippur Anicut	,,	409	
6.	Rajaparameswari Anicut	,,	1,525	
7.	Ramaswamy Anicut	,,	4,860	
8.	Mahadeva Mantry Anicut	,,	1,820	
9.	Chikkadevaraja Sagara Anicut	,,	8,657	
10.	Deveraya Anicut	,,	960	
11.	Virajnadi Anicut	,,	3,670	
12.	Bangardoddi Anicut	,,	308	
13.	Bandikere	,,	92	
14.	Kattepur Anicut	,,	1,720	
15.	Ramanathapur Anicut	,,	664	
16.	Hanagod Anicut	Laxmantirtha	4,500	
17.	Kattemalavadi	,,	243	
18.	Husanpur Anicut	,,	329	
19.	Sirur Anicut	,,	486	
20.	Marchalli Anicut	,,	124	
21.	Anandur Anicut	,,	601	
22.	Ayar Halli	,,	60	
23.	Junige Halla	,,	810	
24.	Ambigola	,,	2,834	
25.	Kariyalar	,,	810	
26.	Mandagere Anicut	Hemavathi	4,610	
27.	Hemagiri Anicut	,,	900	
28.	Akkihebbal Anicut	,,	154	
29.	Kalhalli Anicut	,,	482	
30.	Kannamabadi Anicut	,,	468	
31.	Sriramadevaru Anicut	,,	3,898	
32.	Rampur Anicut	Kabbani	2,551	
33.	Hulhalli Anicut	,,	2,040	

Appendix 10.1—*Contd.*

(1)	(2)	(3)	(4)	(5)
34.	Laxmanapura Anicut	Nugu	190	
35.	Hongelvadi Anicut	Suvarnavathi	855	
36.	Sargur Anicut	,,	92	
37.	Muralahalli Anicut	,,	124	
38.	Alur (new) Anicut	,,	63	
39.	Horahalli Anicut	,,	59	
40.	Hemma Anicut	,,	166	
41.	Kudhir Anicut	,,	40	
42.	Alur (old) Anicut	,,	52	
43.	Honaganur Anicut	,,	728	
44.	Maddur Anicut	Shimsha	2,498	
45.	Kananu Anicut	,,	388	
46.	Vaidyanathapur Anicut	,,	100	
47.	Bairan Anicut	,,	113	
48.	Chananahalli Moralvadi tank	,,	246	
49.	Moti Talav taam	Lokapavani	293	
50.	Marconhally Dam	Shimsha	4,115	
51.	Kanva Dam	Kanva	1,630	
52.	Byramangla	Vrishabhavati	1,418	
	Tamil Nadu			
1.	Kodiveri Anicut	Bhavani	9,610	
2.	Kalingrayan Anicut	,,	5,450	
3.	Nandyar Channel	Cauvery	3,225	
4.	Cauvery Delta System including Upper Anicut, Grand Anicut, Lower Anicut and Grand Anicut Canal.	,,	546,920	

II. PROJECTS COMPLETED DURING PLANS:

(1)	(2)	(3)	(4)	(5)
	Mysore			
1.	Nugu reservoir	Nugu (Kabbani)	8,070	
2.	Hebbahalla	Hebbahalla (Kabbani)	1,210	
3.	Chikkahole	Chikkahole (Cauvery)	1,600	

Appendix 10.1—*Contd.*

(1)	(2)	(3)	(4)	(5)
	Tamil Nadu			
1.	Lower Bhavani	Bhavani	78,920	
2.	Amaravathi	Amaravathi	21,660	
3.	Mettur Canal	Cauvery	18,210	
4.	Kattalai High Level Canal	,,	8,340	
5.	Pullambadi Canal	,,	8,950	
			842,440	

Source: (1) Irrigation Potential of Cauvery River Basin (CW&PC).
(2) Note Volume of Irrigation Chapter Mysore—March, 1970 (CW&PC).
(3) Note Volume of Irrigation Chapter Tamil Nadu—March, 1970 (CW&PC).

APPENDIX

Salient Features of Major and Medium Projects Under

Sl. No.	Name of Project	Zone/ District	Description of the scheme	Cost: Total cost (Rupees million)	Cost: Expenditure incurred (Rupees million)
(1)	(2)	(3)	(4)	(5)	(6)
Mysore					
1.	Kabbani	Mysore	Construction of a composite dam 59.45 m high and 2,701 m long across river Kabbani near village Bidarahalli and two canals one on either bank.	248.00	45.09 (Up to Mar. '69)
2.	Lakshmanathirtha	Coorg	Construction of a 430 m long composite dam with spillway in central portion 26 m long across river Lakshmanathirtha near village Harihar.	16.06	N.A.
3.	Arkavathi	Bangalore	Construction of a composite dam 701 m long, 23.8 m high with central spillway 75 m long across river Arkavathi near village Arabole and two canals one on either side.	19.85	N.A.

10.2

Construction in the Cauvery Basin

Time schedule of construction			G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)
Date of commencement	Important items of work completed	Date of likely completion			
(7)	(8)	(9)	(10)	(11)	(12)
1959	Work on the dam is in progress. Survey work of canals completed	V Plan	N.A.	N.A.	50.992
1962	N.A.	V Plan	4.05	3.24	2.83
1970-71	N.A.	V Plan	N.A.	N.A.	2.83

Source: Note Volume of Irrigation Chapter for Mysore, C.W. & P.C. (Unpublished).

APPENDIX 10.3

New Projects Proposed by the Various States
in the Cauvery Basin

Sl. No.	Name of Project	Name of river	Estimated Cost (Rs. million)	Ultimate irrigation ('000 hectares)
(1)	(2)	(3)	(4)	(5)
Mysore				
1.	Hemavathi	Hemavathi	163.00	40.50
2.	Harangi	Harangi	110.00	30.40
3.	Cauvery Reservoir Project	Cauvery	50.00	8.10
4.	Yagachi Reservoir Project	Yagachi	54.20	13.00
5.	Suvarnavathi	Suvarnavathi	18.70	6.90
6.	Manchanabele	Arkavathi	23.74*	2.80
7.	Gundal Reservoir	Gundal	18.50	6.10
8.	Sagare doddakere	Bandiganda	4.43	0.80
9.	Taraka	Taraka	17.00	7.30
10.	Votehole	Votehole	19.90	5.30
Tamil Nadu				
11.	Modernisation of the Cauvery Delta Scheme	Cauvery	490.00	142.00
12.	Parappalar	Nanganji	3.56	1.00
13.	Palar Porandalkar Palar	Porandalkar	25.60	6.10
14.	Chinar (Dharmapuri)	Chinar	10.75	1.80
15.	Ponnaniar	Ariyarvur	4.61	0.85
16.	Dodahalla	Dodahalla	9.18	0.77

*Including flood component of Rs. 8.8 million.

APPENDIX 11.1

Monthly and Annual Normals of Rainfall of East-flowing River Basins From Cauvery to Kanniyakumari (Excluding Cauvery)

Sl. No.	State/ District	Monthwise Normal Rainfall in mm.												Annual Normal Rainfall in mm.
		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Tamil Nadu													
1.	Madurai	32.1	16.6	23.9	67.2	72.8	31.5	34.6	74.7	92.4	190.9	159.5	58.6	854.8
2.	Ramanathapuram	45.2	20.5	26.1	57.6	49.2	21.8	31.4	62.3	69.9	181.5	186.5	87.5	839.5
3.	Tanjavur	64.6	19.1	20.5	39.5	54.6	33.9	47.2	96.6	108.3	200.5	299.6	163.4	1,147.8
4.	Tiruchchirappalli	32.0	13.9	15.0	44.5	71.1	38.1	48.5	105.0	119.0	171.9	149.0	69.1	877.1
5.	Tirunelveli	50.2	30.2	41.3	59.8	38.0	29.6	26.4	23.3	30.2	166.0	208.2	111.6	814.8

Source : Memoirs of the India Meteorological Department, Vol. XXXI, Part III.

APPENDIX

Salient Features of Existing Major and Medium Projects in the Basin of

Sl. No.	Name of the Project	Zone/ District	Cost/ Total expenditure incurred in Rs. million	Source of supply (Name of river)	Year of completion	Type (Flow/ Storage/ Lift)
1	2	3	4	5	6	7
Tamil Nadu						
1.	Marudur Anicut System	Tirunelveli	0.06	Tambraparni	N.A.	Flow
2.	Srivaikuntam Anicut System	,,	1.76	,,	1873	,,
3.	Periyar System	Madurai	10.84	Periyar	1897	Storage
4.	Manimuthar	Tirunelveli	50.50	Manimuthar	1958	,,
5.	Vaigai Reservoir	Madurai	33.00	Vaigai	1959	,,

Sources: (1) Descriptive booklet on the important irrigation projects in Madras State, Part I, Govt. of Madras (now Tamil Nadu) 1955.

(2) Irrigation Statistics of India, 1960-61, Central Water & Power Commission.

11.2

East-flowing Rivers Between Cauvery and Kanniyakumari

G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Length of main canal and branches (km)	Whether perennial, two seasonal or one seasonal	Cropping pattern	Remarks
8	9	10	11	12	13	14
N.A.	N.A.	8.48	37	N.A.	N.A.	
32.38	13.56	10.50	87	Two seasonal	Rice, other kharif, other rabi	
310.81	57.87	57.70	245	Two seasonal	Rice, other kharif, other rabi	
N.A.	N.A.	41.68	46	One seasonal	Rice	
19.36	9.23	8.83	29	One seasonal	Rice	

(3) Note Volume of Irrigation Chapter of Tamil Nadu, March 1970—Central Water & Power Commission (Unpublished).

(4) Replies of Tamil Nadu to the questionnaire issued by the Irrigation Commission.

APPENDIX

Salient Features of Major and Medium Projects Under Construction in

Sl. No.	Name of the Project	Zone/ District	Description of the scheme	Time schedule of construc-	
				Date of commencement	Important items of works completed
1	2	3	4	5	6
Tamil Nadu					
1.	Gatana Reservoir	Tirunelveli	Construction of a storage reservoir on the Gatananadi, tributary of the Tambraparni river, 3.2 km from Sambankulam village in Ambasamudram taluk of the Tirunelveli district.	1966-67	The construction of the dam and the spillway is in progress
2.	Ramanadhi	,,	Construction of an earthen dam 788 m long across the Ramanadhi river, a sub-tributary of the Tambraparni river near Malakadayam village, an anicut across Thankan branch of the river about 0.6 km below the dam and a canal system taking off from it.	1967	The work on construction of the dam and spillway is in progress.
3.	Modernising Vaigai Channels	Madurai and Ramanathapuram	Construction of two regulators across the Vaigai, one at Virahanur and another at Parthibanur with common channels on either side of these regulators to feed several existing tanks and channels.	1968-69	Earth work excavation for left and right main canals of Parthibanur regulator is in progress. Earth work excavation for foundation for the drops in both the main canals is also in progress.

Source: Note volume of Irrigation Chapter of Tamil Nadu State, Central Water & Power Commission, 1970 (Unpublished).

11.3

the Basin of East-flowing Rivers Between Cauvery and Kanniyakumari

tion	Cost					
Date of likely comple-tion	Total cost (Rs. million)	Expenditure incurred (Rs. million)	G.C.A. ('000 hectares)	C.C.A. ('000 hectares)	Ultimate irrigation ('000 hectares)	Remarks
7	8	9	10	11	12	13
IV Plan	20.00	4.00 (Up to 1970-71)	N.A.	N.A.	3.29	
IV Plan	11.50	3.00 (Up to 1970-71)	N.A.	N.A.	1.42	
IV Plan	39.40	0.11 (Up to Mar. '69)	N.A.	N.A.	44.43	

APPENDIX 11.4

New Schemes Included in the Fourth Five Year Plan Subject to Clearance by The Planning Commission

Sl. No.	Name of Project	Estimated cost (Rs. million)	Ultimate irrigation ('000 hectares)	Remarks
1	2	3	4	5
Tamil Nadu				
1.	Improvement to Periyar Channels	42.50	8.70	
2.	Marudhanadhi Scheme	6.20	0.94	
3.	Karuppanadhi Scheme	14.00	1.16	
4.	Anicut across Vaippar Athankarai	2.30	0.42	
5.	Pilavaikkal Scheme	7.60	1.07	

Source: Fourth Five Year Plan 1969-74 and Annual Plan 1969-70. 'Reports of the Working Group on Irrigation and Flood Control.'